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CGIAR Genebanks Options Paper for FC13

Submitted by:
Consortium Office

CGIAR Genebanks Options Paper for FC13

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RESEARCH PROGRAM FOR Managing and Sustaining Crop Collections

CGIAR

CROP TRUST

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1. INTRODUCTION

Executive summary

The CGIAR genebanks are a global resource of vital importance to humanity. Assessing, identifying and nurturing new sources of genetic variation is a critical component of a long term strategy to enhance the productivity, sustainability and resilience of global food systems in the presence of climate change. As such the CGIAR genebanks are pivotal to the delivery of the system wide goals and outcomes described in the Strategy and Results Framework (SRF). The large size, specialism, diversity and strategic locations of the CGIAR genebanks place them in the wholly unique position of being able to provide diversity for screening, characterization and research on a large scale at the point of need. Present-day opportunities provided by big data and high-throughput technology make this potential all the more poignant.

The need to continue financing the genebanks appropriately beyond 2016 and into the indefinite future is considered essential to achieving and maintaining international standards of operation. The meeting of agreed performance targets by the genebanks and the growth of the endowment fund, which is managed by the Global Crop Diversity Trust (Crop Trust), to a target level of USD 500 million in 2020 are both key to establishing a sustainable system of genebank operation in perpetuity. However, continued investment of funds is required from 2017 to 2021 to support this process. We present three funding options, which represent different levels of activities; the first allows the CGIAR to fulfill its minimum international and legal obligations, the second provides some support to collecting, outreach and partnership, and the third presents a potentially "game changing" concept for a more ambitious proposal for transforming the genebanks and their use. The latter would need to be developed in wider consultation with CGIAR breeders, researchers and external partners.

Projections are made, both for the endowment growth and for the improvement of genebanks' performance. In approaching 2021, the endowment will cover an increasing proportion of costs in Funding Option 1 and overall costs will decline as efficiencies are made. The need for funds from the CGIAR will diminish, as follows:

	2017	2018	2019	2020	2021	Total
OPTION 1: Total funding needs for core operations and collective needs	29.69	28.33	26.52	24.27	23.30	132.10
Contribution from endowment	6.75	9.06	11.53	13.35	15.03	55.72
Funds requested from CGIAR Fund	22.94	19.27	14.99	10.92	8.27	76.38
OPTION 2: Total funding needs for core operations, collective needs, collecting, outreach and partnership activities	30.54	29.84	28.03	25.56	23.75	137.71
Contribution from endowment	6.75	9.06	11.53	13.35	15.03	55.72
Funds requested from CGIAR Fund	23.79	20.78	16.50	12.21	8.72	81.99

Table 1. Summary of total funding needs and contributions from the endowment and CGIAR fund for Funding Options 1 and 2 (see page 9)

In conclusion, the Centers, Consortium Office and Crop Trust recommend that the Fund Council ensures the continued funding of essential operations and considers the possibility of widening opportunities to invest in strategic actions to explore the depths of the collections and transform the ways genetic resources are conserved and promoted globally for use.

Purpose of document

This document responds to a request from the Fund Council for an analysis of the "*funding for and management of the CGIAR genebanks, including identifying potential implications in the event of a short fall in the Crop Trust's target endowment and proposing a plan for submission to the Peer Review Team for its review and input*". It lays out the need for continued funding from the CGIAR Fund to the genebanks beyond 2016 to complement funds provided by the endowment managed by the Crop Trust, and describes what the group of genebanks, together with the Consortium Office and Crop Trust, consider to be the most essential and highest priority activities. However, it goes one step further by describing opportunities to stimulate much greater use of genetic resources by taking advantage of a rapidly evolving technology landscape.

Responsibilities to the CGIAR and wider community

CGIAR genebanks safeguard some of the largest and most widely used collections of crop diversity, critical to attaining global development goals to end hunger and improve food and nutrition security, which arguably gives their stewardship an imperative and global prominence unsurpassed by any other single undertaking in CGIAR. The genebanks are at the center of CGIAR core business, fundamental to delivering CGIARs' SRF. In addition, they contribute probably more than any other community directly to achieving Targets 2.5 and 2.a of the draft Sustainable Development Goals[1]:

GOAL 2 "End hunger, achieve food security and improve nutrition and promote sustainable agriculture"

Target 2.5: *by 2020 maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge as internationally agreed*

Target 2.a: *increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development, and plant and livestock gene banks to enhance agricultural productive capacity in developing countries, in particular in least developed countries.*

Open Working Group finalized draft 19 Jul 2014

[1] https://sustainabledevelopment.un.org/content/documents/1579SDGs%20Proposal.pdf

It is important to stress the significance of CGIAR's legal obligations with regard to the international collections. Through agreements[2] signed in 2006 between each Center and the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty), Centers are obliged to make collections and associated data under their management available under the Multilateral System of Access and Benefit Sharing of the Treaty. Under the same agreements, the genebanks are bound to "*manage and administer these ex situ collections in accordance with internationally accepted standards, in particular the Genebank Standards*[3]*, as endorsed by the FAO Commission on Genetic Resources for Food and Agriculture*". The Centers' agreements with the Governing Body create downstream legal obligations for CGIAR breeders who incorporate materials from the genebanks in improved germplasm they distribute. Implicit also in these obligations under Article 15, is the CGIAR genebanks' role in leading the global community in terms of both conservation and use of crop genetic resources. This role was borne out in a recent Bill & Melinda Gates Foundation/UN Foundation-funded project, implemented by the Crop Trust, in which the vast majority of the national partners (more than 70 institutes) chose to safety duplicate their materials in CGIAR genebanks rather than other genebanks.

Changing landscape and expectations

The landscape surrounding plant genetic resources (PGR) has changed dramatically over recent years, not only in aspects of technology but also in terms of expectations to balance productivity, nutritional benefits and sustainability. These changes have increased both the urgency and the opportunities to utilize genebank collections. The changes have also created new opportunities and needs for global strategic alliances and standardization of methodologies across crops.

The large-scale genetic and phenotypic characterization of collections, already underway in some genebanks within and outside the CGIAR, has the potential to trigger an explosion in our scientific understanding which could enable true step changes in the productivity, sustainability and resilience of improved crop varieties in the medium term. This raises new opportunities for pre-breeding within and outside the CGIAR where support for such activities has been inconsistent across many food crops and often non-existent for under utilized crops in developing countries.

From a policy perspective, the day-to-day operations of genebanks and their downstream users (including CGIAR breeders and partners) are subject to an increasingly complex range of international and national laws concerning access and benefit-sharing, intellectual property, and biosafety. New scientific and technical capacities, such as those described above, are provoking new policy-related questions and challenges. The CGIAR genebanks are expected to adhere to the highest standards of compliance and transparency; non-compliance (and alleged non-compliance) carry heavy risks. That said, the CGIAR genebanks, as central nodes in the evolving global system, can make important

[2] http://planttreaty.org/content/agreements-concluded-under-article-15
[3] FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rev. ed. Rome.

contributions to international processes and proactive engagement in genetic resources policy issues will be increasingly important for the CGIAR in pursuit of its mission.

Vision

CGIAR genebanks will be state-of-the-art, trusted service-providers, supplying unique diversity and knowledge to requestors and working in partnership to provide a platform to catalyze the greater use of crop genetic diversity for more productive and sustainable agrifood systems into the future.

Current status of genebanks

Since the Genebank CGIAR Research Program (CRP) was set up in 2012, the genebanks have distributed more than 300,000 accessions to users in 120 countries, regenerated more than 200,000 accessions, sub-cultured more than 100,000 tissue-culture samples and acquired more than 30,000 new accessions. These figures do not convey the value of these accessions or the unique knowledge and expertise associated with every transaction, especially the expert guidance provided by the collection curators to germplasm requestors. Aside from the individual achievements of the Centers, the collaboration between the CGIAR genebanks over several decades have brought about a number of globally significant outcomes:

- The early work of the CGIAR genebank community contributed critically to the negotiation of the Treaty and particularly to Article 15.
- The success of the Svalbard Global Seed Vault would have been impossible without the wholesale buy-in and commitment of the CGIAR genebanks.
- The development of Genesys (www.genesys-pgr.org), the global portal by which the general public may access information and order accessions, is built upon years of sharing accession data. It now provides data on 2.7 million accessions worldwide.
- The community drives stronger cohesion in data standards and quality; both in developing and sharing data-management tools, such as GRIN-Global.
- The ongoing construction of a quality management system tailored specifically to genebanks is also a remarkable and unique community effort, based on a history of sharing a multitude of best practices, protocols and guidelines.

The CRP Managing and Sustaining Crop Collections (Genebank CRP, 2012-2016), which is managed by the Crop Trust, provides a centralized mechanism by which the activities of 11 Centers in managing 35 crop and tree collections is financed and monitored through the use of common performance targets (see Table 2), online reporting and external review processes. In the past, genebanks competed poorly for funding within research programs, and numerous routine genebank activities were chronically under-resourced. Likewise the facilities of several genebanks have been built over the past three decades in an opportunistic and ad-hoc fashion. The Genebank CRP has not only secured adequate funding for the essential operations of the genebanks, but is also allowing the Centers to make strategic investments in staff, facilities and optimizing operations. In addition, the CRP has invested in collective efforts to build and strengthen quality management, evaluate and pilot test new barcoding and data management tools and initiate a large-scale study of

historical seed viability data in order to seek efficiencies by pushing current limits of seed longevity.

Through the CRP reporting, performance targets have been consolidated (Table 2) and a much clearer picture of the status of collections has been revealed. Most notably, of the 725,000 accessions held by the CGIAR in 2013, 480,000 were available for distribution and 378,000 were safety duplicated. The genebanks are now regenerating increased numbers of accessions to improve these figures.

	Indicators	Targets
1	**Availability**: % collection which is clean of pathogens of quarantine risk, viable, and in sufficient quantity to be immediately available for international distribution from medium term storage	90% accessions
2	**Security**: % collection held in long-term storage in two locations and also in the Svalbard Global Seed Vault. For clonal crops, % of the collection held in cryopreservation at two locations; % of the collection held in slow growth conditions *in vitro* at two locations	90% accessions in seed collections, long-term target 50% accessions in cryopreservation; intermediate target 90% accessions in *in vitro* collections
3	**Data availability**: % collection with minimum passport and/or characterization data available online	90% accessions in the collection
4	**Quality Management System**	Minimum elements of QMS/ISO are in place.

Table 2. Performance targets determining eligibility for long-term funding from the endowment

By the end of 2016, CIMMYT's wheat collection and IRRI and Bioversity genebanks will likely meet the performance targets, which render them eligible for long-term funding from the endowment. Given continued funding, remaining genebanks are expected to meet targets between now and 2021, also becoming eligible for endowment funding (Figure 1).

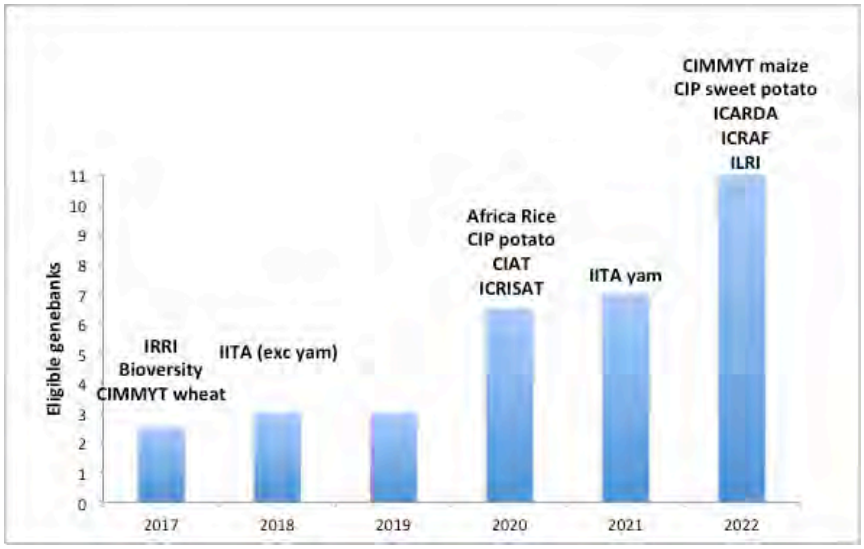

Figure 1. Timeline for genebanks to reach performance targets given continued funding (Funding Option 1)

System-wide analyses and review recommendations have indicated where efficiencies can be made in staffing and resources both in individual Centers and across the system (see Annex 1 for a more detailed summary on each genebank). As an example of possible efficiencies, approximately 10% of the accessions in the seed collections are being regenerated and processed annually. This incurs a large part of the annual running costs of the genebanks. Through research and optimization of equipment and procedures, the genebanks can reach a significantly higher state of efficiency whereby accessions remain viable for longer in storage and considerably fewer accessions are planted annually in the field. For high throughput collections, automation of germination and seed sorting and handling processes also has the potential to bring about significant efficiencies.

The collections of clonal crops, wild species and trees require special mention because they incur almost 50% of the total routine costs while representing less than 10% of the total number of accessions. After years of research into cryopreservation, the CGIAR genebanks are now establishing large-scale cryobanks. At present, less than 10% of the clonal crop collections are secured in cryopreservation, and significant investment is needed now to secure these collections. Similarly, the conservation of wild species, trees and genetic stocks demand more strategic approaches to conservation, curation and management to ensure sustainability and keep costs under control. Adequate funding to meet standards, invest in facilities and equipment, and develop efficiencies through research and optimization will provide returns by reducing or stabilizing running costs within an estimated 3 to 5 years. Through the CRP, the Centers are initiating much of this work and continued funding beyond 2016 to achieve and maintain standards as well as support core genebank requirements is key to allowing them to realize these goals.

Role of the Global Crop Diversity Trust

The Global Crop Diversity Trust has a mission to ensure the conservation and availability of crop diversity for food security worldwide. The Crop Trust's primary roles continue to be building and funding a global system for crop diversity conservation and use through projects with national partners and long-term funding to international genebanks. Leading the Genebank CRP, the Crop Trust has provided independent management that has guided the CGIAR genebanks towards much stronger monitoring processes and performance targets, introducing also for the first time external reviews of genebanks by relevant experts. The Crop Trust also reinforces the importance of crop genetic resources and the profile and leadership role of the CGIAR genebanks through independent initiatives; including global projects on the use of crop wild relatives in pre-breeding and rescuing threatened crop diversity, development of the global portal for accession information, Genesys, and ongoing support to the Svalbard Global Seed Vault. The Crop Trust will continue to provide long-term funding to and monitor the performance of the CGIAR genebanks receiving grants irrespective of the program arrangements of the CGIAR.

2. RECOMMENDATIONS AND FUNDING OPTIONS

Continuous support for the core activities of the genebanks is nothing less than essential. Any lapse of the current commitment from 2017 would result in the rapid decline of the

status, availability and security of collections. Relying solely on the projected endowment income of USD 6.75 million in 2017, would not only mean a decline in status but would cause severe staff and operation cuts, a complete halt to routine viability testing and regeneration, and a very harmful decline in the distribution of materials.

The genebanks, Consortium Office and Crop Trust recommend that core activities be supported as the highest of priorities. However, in addition to ensuring the minimum operation of the genebanks, we consider it inadvisable to ignore the activities and roles of the genebanks to reach out to partners, contribute to the development of a strong global system, and collect threatened wild and cultivated accessions, nor to miss the increasingly important opportunities to promote the use of the collections. Hence, we make the following three recommendations to the Fund Council, which build one upon the other:

1) The core genebank operations and collective needs are financed through a combination of endowment and CGIAR funds until 2021. Thereafter, the endowment will cover core operations of eligible genebanks. CGIAR will remain responsible for ongoing funding of any collections that fail to reach standards and identified core collective needs;
2) The collecting, outreach and partnership activities of the genebanks are fully supported by the CGIAR;
3) A "Genebanks plus" is established as a game changer that would exploit the cross-species synergies and scale of operation of the genebank platform, and attract new resources to accelerate utilization of variation within CGIAR genebanks.

The following funding options relate to these recommendations.

	Total funds required from the CGIAR Fund between 2017-2021	Activities covered
1	USD 76.38 million	• Core genebank and collective requirements (Recommendation 1)
2	USD 81.99 million	• Core genebank and collective requirements • Collecting, outreach and partnership activities (Recommendations 1 & 2)
3	USD 150+ million	• Core genebank and collective requirements • Collecting, outreach and partnership activities • "Genebank Plus" (Recommendations 1, 2 & 3)

Governance and management options are dependent on the scope and content of the genebank program or platform and the portfolio of CRPs as a whole. Clearly, the operations and the research activities of the genebanks should be integrated seamlessly into the overall research and breeding activities of the CGIAR and incorporated into the numerous impact pathways that depend on the use of genetic resources. The current Genebank CRP has specific arrangements, allowing it to function as a support program; it reports against unique performance indicators and benefits from stable funding. These measures have been instrumental in developing core capacity in a highly structured manner at a system level. Given the strategic importance of genebanks and the system wide nature of their

operation, we petition strongly for these measures to be sustained for the core requirements of the genebanks.

3. CORE ACTIVITIES

Previous costing analyses of the CGIAR genebanks (Koo et al 2002[4], Shands et al 2010[5]) have provided a basis to define the essential activities for the routine management and use of crop collections. For the purpose of this document we further distinguish these essential activities as follows:

- Core genebank operations: the minimum non-research activities that must be undertaken by a genebank, and without which the fundamental security of the collection or its use is at serious risk. These operations will eventually be funded entirely by the endowment;
- Core collective needs: the minimum activities that are needed to upgrade and empower the CGIAR genebanks to fulfill their international obligations and achieve expected standards. These activities will generally not be funded by the endowment in the long-term. The needs for support to achieve standards will reduce significantly once standards are met.

Beyond these two categories, exist numerous activities to enhance the way genebanks manage and deliver crop diversity to users. We have categorized these activities as follows:

- Collecting, outreach and partnership activities: are activities that make an immediate and critical contribution to the collections and to the global system of conservation and use within which the CGIAR plays a pivotal, leadership role. Such activities include targeted collecting, capacity building and partnership projects, and monitoring and communication of impact.
- Opportunities: correspond to the possibilities open to the CGIAR to take advantage of developing trends and technologies and carry out large-scale initiatives to genotype and phenotype the collections. These *Opportunities* are outlined in Section 5.

Core genebank operations

The following activities are identified as core routine operations:

[4] Koo B, Pardey PG, Wright BD. 2002. Endowing Future Harvests: the long-term costs of conserving genetic resources at the CGIAR Centers. International Plant Genetic Resources Institute, Rome, Italy. http://www.bioversityinternational.org/e-library/publications/detail/endowing-future-harvests-the-long-term-costs-of-conserving-genetic-resources-at-the-cgiar-Centers/

[5] Shands H, Hawtin, G, MacNeil, G. 2010. The Cost to the CGIAR Centres of maintaining and distributing germplasm http://library.cgiar.org/bitstream/handle/10947/2566/fc4_funding_proposal_CGIAR_Genebanks.pdf

Activity	Implications for genebanks	Main benefits to users
a) Acquisition: maintaining the basic capacity to process new material for inclusion in the collection (initiatives to acquire new material should be prioritized and funded through special projects)	Able to respond effectively to conservation needs without rebuilding capacity each time	Users gain access to a wider range of diversity
b) Characterization: gathering essential passport and basic descriptor data for purposes of identifying accessions. Some molecular and biochemical characterization may be included, where possible, to avoid introduction of duplicates.	Genebanks have the minimal level of descriptive information required to manage the collections	Descriptive information helps users make minimally informed choices on the identify and origin of accessions
c) Safety duplication, including the deposit of materials in the Svalbard Global Seed Vault	Genebanks are insured against the loss of accessions	CGIAR meets its commitment to conserve crop diversity safely
d) Preservation of vegetatively-propagated crops: in vitro conservation, cryopreservation, field genebanks, DNA banks, collections of lyophilized leaves and true seed, as appropriate	Mandated genebanks can preserve accessions of clonal crops	The CGIAR meets its commitment to preserve the diversity of clonal crops
e) Medium (5°C) and long-term (-20°C) seed storage	Mandated genebanks can preserve accessions of seed crops	The CGIAR meets its commitment to preserve the diversity of seed crops
f) Regeneration, including both the rejuvenation of aging stocks and the replacement of dwindling stocks after distribution	Accessions in the collections are viable and in sufficient amounts for distribution	The CGIAR meets its commitment to make available the diversity of crops
g) Germination testing, seed processing and germplasm health testing (including disease cleaning where needed)	Genebanks have the information required to ensure timely regeneration of accessions	Information is available to enable the CGIAR to meet its commitment to sustainably conserve the diversity of crops
h) Distribution, including compliance with international agreements and regulations	Genebanks deliver accessions and information to users	Users have assured access to crop diversity; the CGIAR meets its commitment to provide crop diversity to users;
i) Information management for genebank operations and for making information about the collections widely available electronically	Genebanks have the information they need to maintain the collections, and enable potential users to identify and select accessions	Users are able to search directly for the accessions that they need

Table 3. Core activities of the genebanks

Core collective needs

The process of monitoring and reviewing performance of the genebanks has highlighted the challenges that urgently need to be addressed. In essence, the CGIAR must get its house in order; genebanks must achieve and maintain international standards before efficiencies

can be achieved, running costs stabilized and the full use of diversity explored and promoted. All of these objectives can be achieved faster and more effectively by working collectively: by sharing procedures, practices and data management tools, and by presenting a consolidated, well-researched front.

Core collective needs are grouped in three categories:

Achieving minimum standards: In order to meet performance targets, it is a priority for CGIAR genebanks to regenerate and clean accessions that are currently not safe to distribute. Added to this, special attention is needed to improve the status of collections of clonal crops, wild species and trees. This involves elements of research to develop effective phytosanitary diagnostics, optimize cryopreservation and storage protocols, eliminate redundancies in collections and determine more strategic methods of conservation and curation of costly-to-conserve taxa. In addition, external reviews have identified needs for increased staff capacity, facilities and equipment. A careful review of the age of key equipment and facilities has revealed that a large number of items are likely to be functioning at suboptimal performance; some need urgent replacement. While there is a perpetual need for funding optimization to ensure the maintenance of standards, the funds required for these activities will tail off significantly as genebanks reach standards (see Table 7).

Data management: existing data management systems are woefully inadequate to meet the increasing expectation of users who rightfully demand more integrated, detailed and standardized information. At least three Centers are adopting GRIN-Global, which provides a not-to-be-missed opportunity for increased harmonization and standardization of data across the system. The CGIAR also has an important role to play in the continued development of Genesys.

Policy: It is critically important for the Centers to be represented at intergovernmental fora where rules affecting their operation are being developed and monitored. While there has been a commitment since 1974 to CGIAR system-wide coordination and representation of genetic resources policy issues, no such mechanism is in place at present. Already a resolution of the fifth session of the Treaty's Governing Body (constituting 132 countries) has called on the CGIAR to prepare a report on its implementation of Article 15 agreements, (paragraphs 34-37) and an investigation of the CGIAR's compliance with the Treaty vis-à-vis plant genetic resources for food and agriculture under development is under way (paragraph 43). Continued failure to engage in policy at the system level exposes the CGIAR to a significant risk of liability claims; it also means the CGIAR will miss opportunities to positively influence policy development and implementation processes. It is essential to set up a high-level policy unit, preferably in 2015, with appropriate capacity, authority and expertise to coordinate system-wide consideration of policy developments, developing technical contributions to international policy fora, and strengthening capacity within the system for compliance and full engagement. This unit will need to call on the contribution of a wider stakeholder group than the genebanks; an independent structure

may, therefore, be appropriate. However, to ensure this need does not fall between the cracks, it is included among essential core genebank needs.

Activity	Implications for the genebanks	Benefits for the System
Achieving minimum standards as pre-requisite to long-term agreements with the Crop Trust		
a) Replace aging equipment (but not major building infrastructure, which will require separate funding) and plan for continuing replacement as needs arise	Equipment is replaced as necessary and genebanks function efficiently	Improved efficiency reduces costs for utilities and services
b) Clear backlogs in processing activities for most genebanks and reach standards	Genebanks enabled to operate at steady state	More diversity will be securely conserved and available
c) Establish and implement strategic approaches to managing difficult-to-conserve taxa and increase availability, security and efficiency: cryobanking, optimization of seed processing & storage according to seed longevity studies, developing and implementing improved phytosanitary controls.	Genebanks are empowered to operate at the highest international standards	Confidence through assurance of high management standards and efficiency
d) Quality and risk management improvement, validation and review	Genebanks quality of operation is assured	Increased confidence in the quality and efficiency of the genebanks
Data management		
e) Upgrade data management capacity to enable increased mobile genebanking, improve the management of workflows, support implementation of automated processes	Quality, efficiency and security of genebank operations increases	Users requests will be managed with increased efficiency
f) Ensure data safety and security, capture legacy data and develop an open access repository, building on existing initiatives	Quality, efficiency and security of genebank operations increases	Users will have better access to good quality data
g) Improve the quality and quantity of data available in Genesys and contribute to the development and implementation of wider data standards.	Genebanks publish accurate and reliable data under one global portal	Users have easy access to data of increasing quality and quantity
Policy: the new high-level policy unit must have the authority and expertise to:		
h) Represent the CGIAR at international fora such as the Treaty, the FAO Commission on Genetic Resources for Food and Agriculture, Convention on Biological Diversity, the Nagoya Protocol, the International Plant Protection Convention, UPOV, WIPO, etc.	Genebanks' interests will be properly represented	CGIAR's interests will be properly represented; the CGIAR will perform the functions required

Activity	Implications for the genebanks	Benefits for the System
i) Engage with CGIAR management to raise awareness and build capacity to ensure that internal policy and practices are compliant from the acquisition of accessions through to the release of improved varieties	Genebanks will be aware of and compliant with international obligations	CGIAR will be trusted player in a stronger global system
j) Work with the CRPs and Centers to produce reports or other technical contributions to relevant international fora as required	Genebanks will be empowered to contribute to international fora	CGIAR will contribute to international fora
k) Multistakeholder 'eyes-on-the-horizon' policy advisory committee provides feedback and perspectives to CGIAR on policy developments, options for engagement, CGIAR policies and best practices	Genebanks will benefit from inputs of wider stakeholder community	CGIAR will be trusted player in a stronger global system

Table 4. Core collective activities of the genebanks

Collecting, outreach and partnership activities

The following activities are identified to support the outreach, partnership and capacity building activities of the CGIAR genebanks, and to address ever-threatening erosion of crop genetic diversity and gaps in collections through collecting in partnership with national programs:

Collecting, outreach and partnership activities	Implications for the genebanks	Benefits for the System
a) National partners, with special emphasis on Africa, are provided targeted support, backstopping and partnership to help fulfill their roles in conserving and promoting the use of crop diversity at local and national levels.	Genebanks function within a strengthened national and local environment for conservation and use of crop diversity	Increased use of the CGIAR collections
b) The genebanks' activities, outputs and achievements and their impact are strategically monitored and communicated to ensure continued interest in and use of the collections.	Interest in and support to the genebanks is increased.	Interest in and support to the CGIAR is increased
c) Targeted collecting, in partnership with national programs, is carried out to improve the representation of the collection.	Increased conservation and availability of unique diversity	CGIAR contributes to Target 2.5 of SDGs

Table 5. Outreach and partnership activities of the genebanks

Phytosanitary needs

An important point concerning the management of phytosanitary controls in the Centers has arisen in several external reviews. The distribution of germplasm from the genebanks is wholly dependent on the adherence to rigorous phytosanitary controls. It is evident that all CGIAR Germplasm Health Units (GHUs) adhere to high standards of operation; most notably two of the GHUs have pursued ISO accreditation/certification. However, the coordination between Center GHUs and the sharing of standards and protocols is limited. In addition, the

capacity of national phytosanitary agencies is varied and vastly inadequate, providing little means by which CGIAR GHU controls may be independently checked. The situation continues to arise where countries refuse entry to materials from CGIAR Centers. This is not acceptable and we strongly endorse the need for support to CGIAR GHUs for upgrading, research and strengthening of quality management systems. It is debatable to what extent such a program should be linked with the genebanks program. However, a full costing and itemization of needs for the GHUs has not been attempted for this paper.

4. FINANCING

Projection of endowment funding

The Crop Trust endowment is projected to increase from its current level of approximately USD 170 million to reach USD 500 million in 2020 in order to fund sustainable, long-term grants for the benefit of the crop collections protected under Article 15 of the Treaty on Plant Genetic Resources for Food and Agriculture. The current fundraising strategy targets some 50 governments, complemented by private donors such as foundations, corporations, industry associations, wealthy individuals and also private households. An international donors' pledging conference in April 2016 is expected to generate the required financing commitments from government donors. After this event, projections of the available endowment income can be made with more certainty than at present.

There are additional assumptions that add uncertainty to the meeting of the endowment target of USD 500 million in 2020. While many of the donor countries targeted for grant contributions will provide firm, legislatively approved financing commitments, some donors may opt to pay their contributions over a number of years, which would delay the build-up of the endowment and reduce the investment income available to support crop collections.

The actual income provided by the target endowment will also be influenced by two main factors. Firstly, the long-term, average investment return assumption for the endowment is 4.0% per year plus the rate of US dollar inflation. Such a return may, however, not be achievable over the next 5 years, given historically low capital market interest rates on bonds and largely overvalued world equity markets. Therefore, should the Crop Trust experience sustained investment returns well below its average long-term target, a restriction in income distributions from the endowment to the CGIAR crop collections may have to be considered so as to protect the capital value of the endowment fund. Secondly, the Crop Trust's withdrawals from the endowment are based on the average endowment value over the preceding 12 quarters. Therefore, as the endowment is growing, the associated investment income available for withdrawal rises with a considerable time lag.

With these substantial caveats in mind, the total annual investment income projected to become available for withdrawal from the Crop Trust endowment would be as follows: USD 9.2 million for 2017; USD 11.8 million for 2018; USD 14.4 million for 2019; USD 16.3 million for 2020; and USD 18.0 million for 2021. While we could scale projections to arbitrary numbers of donors committing funds, we prefer to provide an estimate of the endowment income that the Crop Trust has the most confidence to stand behind at this point in time. A

very positive and immediate response from donors at the 2016 pledging conference would allow the Crop Trust to present a more optimistic scenario. The Fund Council's support in generating such a response would be mutually beneficial.

The endowment income will go towards existing and new grants to support the Svalbard Global Seed Vault, non-CGIAR collections, CGIAR collections and will also fund half of the running costs of the Crop Trust Secretariat in Bonn, with the other half to be financed through donor grants. The Secretariat costs are assumed to remain at a level of USD 2.6 million per year, with adjustment for inflation, to 2018. This is needed in view of the substantial outreach to current and potential donors to build up the endowment fund. From 2019 onwards, the projection is for the Secretariat's running costs to fall by about 15% per year, over three years, reflecting the reduction in the partnerships and communications outreach effort. Secretariat costs may stabilize at slightly more than 50% of their current level by the year 2021, adjusted for inflation. The expected use of investment income for 2017 is broken down in Table 6.

Expenditure item	Projected use of the endowment income in 2017 (USD millions)
Svalbard Global Seed Vault	0.15
Non-CGIAR collections	0.92
Crop Trust Secretariat	1.33
Existing grants to CGIAR Genebanks	2.65
Additional funds available to CGIAR Genebanks eligible for long-term funding	4.15
Total	9.20

Table 6. Use of the projected income from the endowment in 2017

It should be noted that the above estimated future funding amounts from the Crop Trust for CGIAR genebanks are projections. They do not constitute a commitment. The actual financial capabilities of the Crop Trust will depend critically on the future donor support. It may be informative to add that once the USD 500 million is raised, the Crop Trust aims to raise a further USD 350 million for the support of key national collections of the 25 crops on Annex 1 of the Treaty.

Indicative Budget for Core Requirements

The indicative budget is provided in Table 7. The core genebank requirements are based on the costs determined in the 2010 Costing Study, which are used as the basis of the current budget for the Genebanks CRP. These costs will be carefully revised over the course of the next few months as the Crop Trust puts in place a "Parity model" and achieves better convergence in funding allocations across the system. The use of incentive and contingency funding is also built into this model (see Annex 2). The funding of core genebank requirements will ultimately be taken over entirely by the endowment.

USD millions							
	2016	2017	2018	2019	2020	2021	Total
Core genebank requirements							
AfricaRice	0.39	0.40	0.40	0.40	0.40	0.40	2.00
Bioversity	1.10	1.12	1.14	1.16	1.17	1.19	5.78
CIAT	2.70	2.75	2.76	2.72	2.68	2.63	13.54
CIMMYT	1.32	1.35	1.35	1.34	1.32	1.30	6.65
CIP	3.65	3.72	3.79	3.83	3.87	3.90	19.10
ICARDA	1.63	1.66	1.66	1.65	1.64	1.62	8.23
ICRAF	1.09	1.11	1.13	1.13	1.13	1.12	5.62
ICRISAT	2.78	2.84	2.81	2.77	2.73	2.68	13.84
IITA	1.28	1.31	1.32	1.31	1.31	1.30	6.54
ILRI	0.95	0.97	0.97	0.95	0.92	0.90	4.70
IRRI	1.57	1.60	1.60	1.57	1.54	1.51	7.83
Subtotal	18.46	18.83	18.93	18.82	18.70	18.56	93.83
Collective requirements							
Achieving & maintaining standards	0.87	5.67	3.48	3.19	1.98	1.59	15.91
Data management (inc. Genesys)	0.73	1.46	2.52	1.51	0.97	0.76	7.22
Policy	-	0.57	0.58	0.59	0.61	0.62	2.97
Subtotal	1.60	7.70	6.58	5.29	3.56	2.97	26.10
Program management							
Management and direct costs (inc. review, meetings, travel)	0.90	0.55	0.56	0.57	0.59	0.60	2.87
Total Direct Costs		27.08	26.07	24.68	22.84	22.13	122.80
10% Overhead (CGIAR funds only) & 2% CSP		2.62	2.26	1.84	1.43	1.17	9.30
Grand total (Option 1)		29.69	28.33	26.52	24.27	23.30	132.10
Contribution from endowment		6.75	9.06	11.53	13.35	15.03	55.72
Funds required from CGIAR Fund		22.94	19.27	14.99	10.92	8.27	76.38
Collecting, outreach and partnership							
Collecting, outreach and partnership activities	1.09	0.75	1.35	1.35	1.15	0.40	5.00
Total Direct Costs		27.83	27.42	26.03	23.99	22.53	127.80
10% Overhead (CGIAR funds only) & 2% CSP		2.71	2.42	2.00	1.57	1.22	9.91
Grand total (Option 2)		30.54	29.84	28.03	25.56	23.75	137.71
Contribution from endowment		6.75	9.06	11.53	13.35	15.03	55.72
Funds required from CGIAR Fund		23.79	20.78	16.50	12.21	8.72	81.99

Table 7. Indicative budget for core requirements

In the transition to a long-term funding mechanism, the following principles will apply:

1. Collections become eligible for long-term funding when they have reached performance targets.
2. Indirect costs will conform to the Crop Trust's Board-approved institutional overhead policy.
3. Allocation of direct costs will be determined on an activity-based costing model, which is in line with the revised CGIAR FG5 Guidelines.
4. Long-term agreements will be based on a 10-year business plan to be submitted by the genebank, outlining expected growth and use of the collections, any extraordinary staffing, facility or equipment needs, sources of funding and plans for controlling or reducing costs.
5. Long-term agreements will require co-funding to be provided by the Center, which may be deployed to support activities that contribute to the increased use or improvement of the collections.

The budget figures show a gradual reduction in costs from 2018 as efficiencies are built into the system and expected reductions occur in the rate of regeneration, testing and processing of seed accessions, but such efficiencies will be entirely dependent funding being provided for collective requirements.

Collective requirements are considered to be core to essential operations and are included in Funding Option 1. These indicative costs are based on a relatively detailed genebank needs survey, as well as known costs of ongoing activities in the CRP; plus estimates for the proposed Policy Unit and activities are provided by the Treaty policy expert, Michael Halewood (Bioversity International). Collecting, outreach and partnership activities are included in Funding Option 2. The costs included here are estimated from ongoing related activities. A breakdown of all these costs is provided in Annex 3.

Figure 2 shows the expected investment income from the endowment that would be available for the CGIAR genebanks against the costs of those collections that are expected to have reached performance targets. These projections indicate that the endowment income may be adequate to cover the full costs of essential operations of those genebanks that have reached performance targets (Table 8). Additional funding may be available also from the endowment to support individual collections to achieve standards.

The genebanks have received highly variable amounts of bilateral funding in the past three years, which has been used for activities that are not funded by the Genebank CRP but which are complementary to routine genebank operations (e.g. ISO certification, evaluation, identity verification, virology research, etc.). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) continue to be highly supportive of the international genebanks and may be envisaged to continue providing funding on an annual basis. Such funding might be used to scale up upgrading, outreach activities, or for activities described in Section 5.

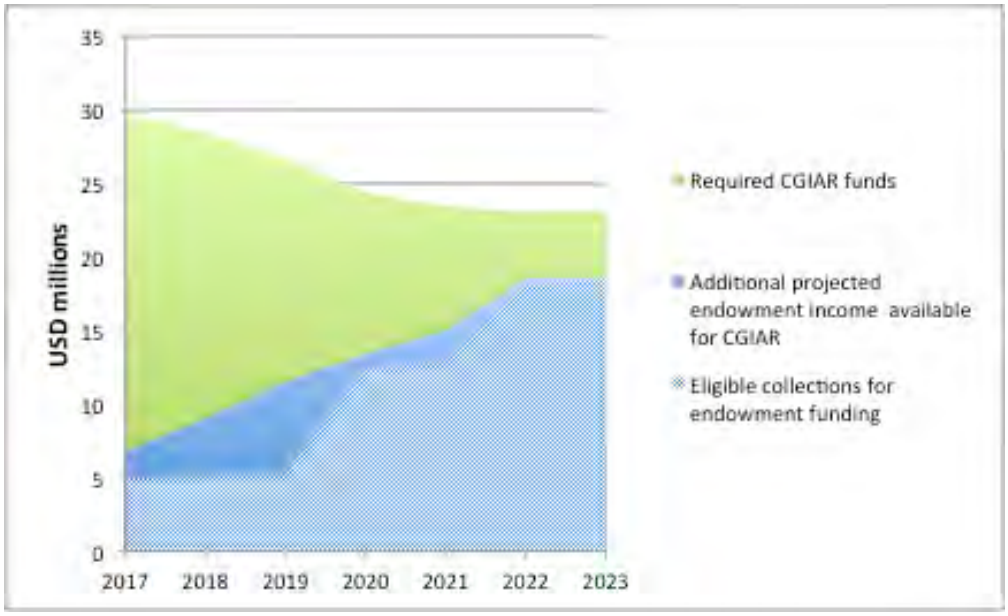

Figure 2. Projected contribution of endowment income and required CGIAR funds (Funding Option 1)

	2017	2018	2019	2020	2021	Total
Core genebank requirements						
AfricaRice	0.00	0.00	0.00	0.40	0.40	0.80
Bioversity	1.12	1.14	1.16	1.17	1.19	5.78
CIAT	0.32	0.33	0.33	2.68	2.63	6.29
CIMMYT	0.62	0.63	0.63	0.65	0.65	3.18
CIP	0.23	0.23	0.23	2.10	2.11	4.90
ICARDA	0.36	0.37	0.37	0.38	0.38	1.86
ICRAF	0.00	0.00	0.00	0.00	0.00	0.00
ICRISAT	0.36	0.36	0.36	2.73	2.68	6.49
IITA	0.24	0.24	0.58	0.59	1.30	2.95
ILRI	0.10	0.10	0.10	0.10	0.10	0.50
IRRI	1.60	1.60	1.57	1.54	1.51	7.83
Subtotal	4.95	5.00	5.33	12.34	12.95	40.59
Collective requirements						
Achieving & maintaining standards	1.79	4.02	6.20	1.01	2.08	15.10
Data management (inc. Genesys)	-	-	-	-	-	-
Policy	-	-	-	-	-	-
Management and direct costs (inc. review, meetings, travel)	-	-	-	-	-	-
Contribution from endowment	6.75	9.06	11.53	13.35	15.03	55.72

Table 8. Proposed contribution of projected endowment to core genebank and collective requirements

5. OPPORTUNITIES

All CGIAR genebanks carry out research that contributes to the outputs of other CRPs. In most cases, very restricted or opportunistic funding is provided to support these activities. Funding Options 1 and 2 would help genebanks reach accepted standards of operation and perform their international role. However, the activities described and costed so far do not allow the genebanks to carry out research to support the structuring, characterization and use of the collections or to make innovative use of available technology or carry out research to improve conservation methods.

We are in the midst of a data revolution triggered by high-throughput genotyping and phenotyping and 'big data' processing platforms, which are adding a rapidly growing informational and knowledge component to the physical accessions held in genebanks and tested in researchers' fields. The implications are going to be profound, both in terms of the way genebanks will operate in the future (including aspects covered in Section 3) and the value they can offer to their clients[6]. Over the next several years, all genomes of major food crops will be sequenced. Next-generation DNA-sequencing platforms make it possible to genotype entire genebanks at high marker densities, and automated phenotyping technologies are enabling the evaluation of phenotypes at an increasing spatial and temporal resolution. 'Big data' platforms are being developed to extract biologically relevant knowledge from exponentially growing data streams.

The likely consequences of this data revolution are beyond the scope of this paper and require separate, dedicated examination. Yet to put the paper into context, it seems pertinent to at least include a highlight of the opportunities that have arisen during the last several years. In line with a "form-follows-function" approach, no attempt is made here to explore options for operationalizing any of these opportunities (e.g., how to best liaise with commodity-crop CRPs, the relative benefits of cross-cutting vs. crop-specific approaches, etc.). It should be emphasized, however, that at whatever scale such activities might take place, it would be important to ensure that this research is included wherever in the CRP portfolio is ultimately most appropriate and that the full involvement of the genebanks is financially supported.

In describing opportunities, we envision three main areas of impact, illustrated in Figure 3, without implying any particular prioritization: (a) transforming the way genebanks operate, (a) promoting effective, data-driven use of genetic resources to broaden the genetic base of crops, and (c) enhancing how genetic resources are conserved globally.

[6] Initial examples include the *Seeds of Discovery* (SeeD) project has used genotyping-by-sequencing (GbS) platforms to genotype CIMMYT's entire maize genebank (27,000 accessions) and about a third of the wheat-genebank accessions (40,000 accessions). IRRI's 3,*000 Genomes Project* has re-sequenced the whole genome of 3,000 rice accessions. In a similar vein, ICRISAT is whole-genome re-sequencing 3,000 chickpea accessions while evaluating them across different environments. All these projects combine the genetic data generated with field-based evaluation of key agricultural traits.

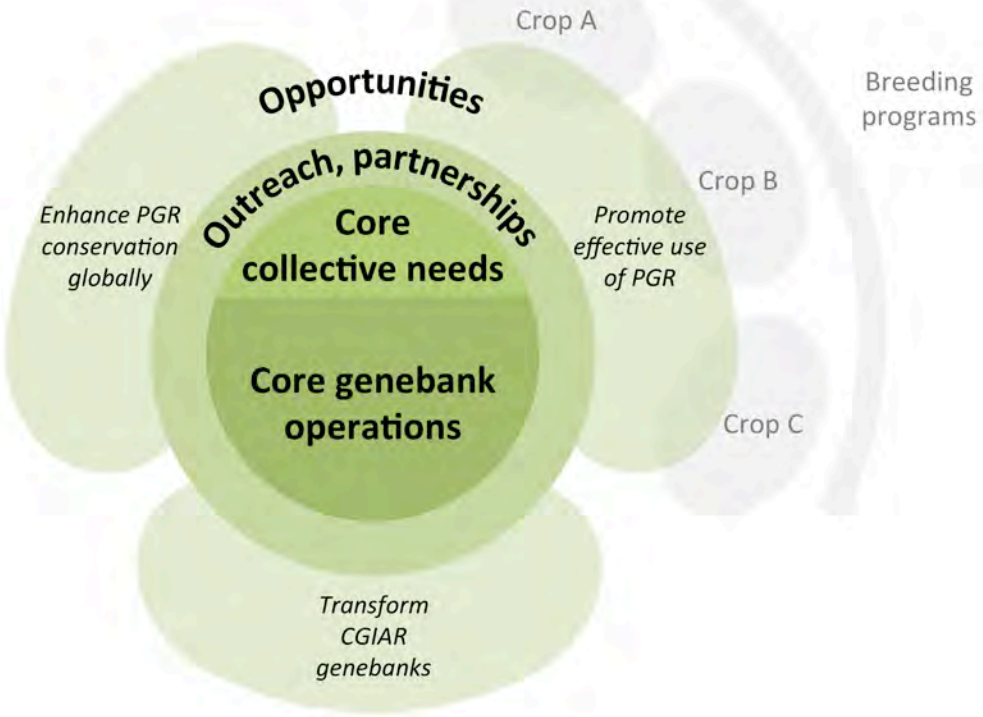

Figure 3 Domains of genebank activities

Transforming the way genebanks operate

Opportunities

- For the first time, genebanks will be able to organize accessions based on their inherent genetic constitution rather than on more circumstantial criteria. This will create further opportunities to reduce redundancies and rationalize collections.
- Cost-effective genotyping assays for quality control and monitoring will enable genebanks to reduce the chance of human error when manipulating accessions and to detect changes in allele frequency during regeneration. In this way, the genetic integrity of accessions can be maintained in a way that has not been possible before now.
- Adoption of modern diagnostic methods will increase the sensitivity and broaden their scope of phytosanitary tests, while reducing the time and costs of routine assays.
- Improvements in cryopreservation will expand the range of species and subspecies that can be safely cryopreserved in the long term beyond clonal crops.
- Optimization of conditions to maximize seed germination and longevity will allow genebanks to reduce regeneration needs and enable parts of the collection that are infrequently used or particularly difficult to manage to be confidently archived.

- The adoption of more automated and mechanized procedures for accession-handling, characterization and retrieval will increase efficiency and allow investment of time and resources in other activities.

Researchable topics

- *What is an efficient way to rationally structure a genebank if the genetic relationships amongst all accessions are known with precision? Would it be useful to define nested subsets, each representing the total diversity available, but with smaller subsets having increasing amounts of associated data ('onion' model)?*
- *To what extent should genetic stocks, introgression lines, etc. be conserved in genebanks?*
- *How should existing information systems for managing genebank operations adapt to a genetics-driven genebank design, integration of genebank-information systems with breeding-information systems, and flow back of information from breeders and researchers?*
- *What are the costs/benefits of incorporating routine genotyping assays for quality control purposes at different genebank workflow steps, and by how much could human-error levels be reduced?*
- *What role could rapid-turnaround next-generation sequencing platforms play in routine phytosanitary tests?*
- *How well have open-pollinated accessions maintained their genetic integrity over multiple cycles of regeneration in the past?*

Promoting effective use of genetic resources to broaden the genetic base of crops

Opportunities

- For the first time, genebanks will be in a position to enable their clients to select accessions in a targeted manner from a global pool of collections based on a combination of passport, genotypic, phenotypic and environmental data. This will add tremendous value to the collections, particularly if information can be accessed through simple, user-oriented interfaces (a 'Google for genetic resources').
- Knowledge generated by combining genotypic and phenotypic data will enable researchers to estimate and catalog allele/haplotype effects across and between crop genomes, thus triggering a gradual transition from accession-centric to gene-centric approaches to mining genebanks. 'Seed banks' will become true 'gene banks'.
- Genome profiles will allow the detection of rare recombinants, for example in peri-centromeric regions that only seem to recombine very rarely, thus enabling researchers to use genebanks as "recombination libraries".
- Researchers will be in a position to systematically introgress untapped variation from genebank accessions into elite breeding pools to *proactively* broaden the genetic base of crops by developing 'bridging genepools' for mining novel diversity in elite

genetic backgrounds (Figure 4, right half). Such efforts will complement ongoing 'case-by-case' approaches to rapidly capture novel variation for specific traits to *respond* to specific challenges (Figure 4, left half).

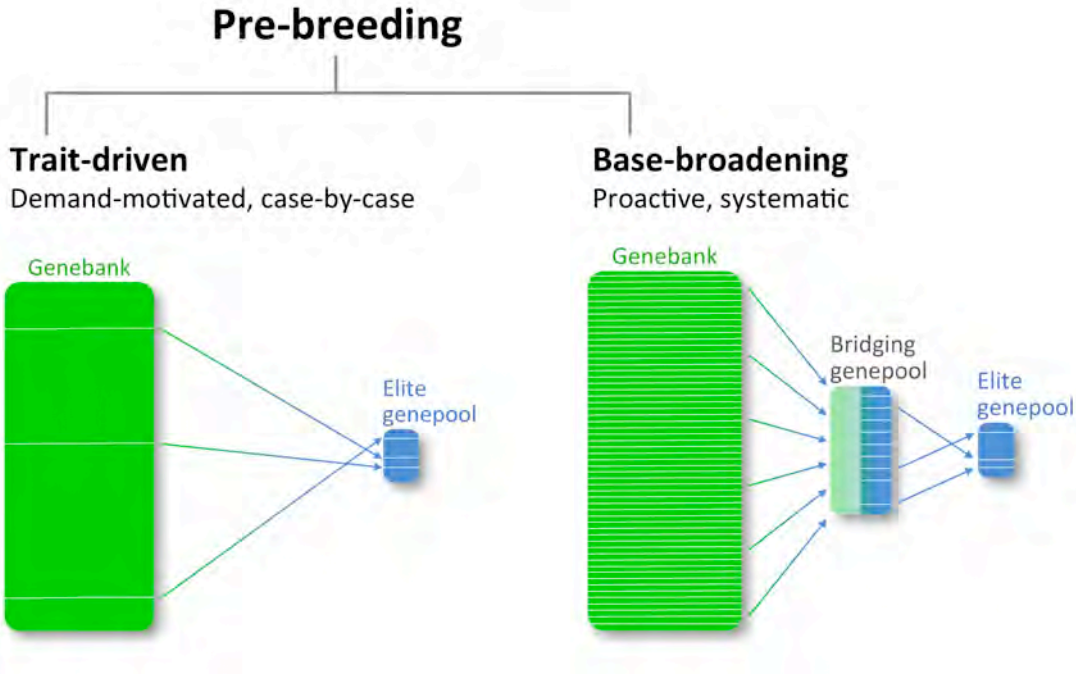

Figure 4. Two complementary approaches to pre-breeding

Researchable topics

- *What kind of (meta)data standards and best practices are required to enable a 'big data' revolution in the domain of plant genetic resources? Can the PGR community learn from others?*
- *What are the key requirements for information platforms to efficiently manage the growing avalanche of germplasm-associated data (e.g., scalability, interoperability, etc.)?*
- *How to best visualize, analyze and mine large genomics/phenomics data sets for targeted queries at a resolution that is relevant, and in a manner that is intuitive to breeders?*
- *How to best predict phenotypes and population performance from genotypic (and ecogeographic) data? How to identify rare alleles in genebank collections?*
- *How to reduce linkage drag during introgression efforts?*
- *What are the relative merits of dissecting complex aggregate traits by dissecting them into physiological component traits to identify large-effect alleles, compared to manipulating such traits via genomic selection?*
- *What are effective approaches to introgress novel variation for traits with complex genetic architecture: should beneficial alleles first be accumulated in a native (non-elite) genetic background using recurrent selection, before mobilization into elite genetic backgrounds?*
- *What are the relative benefits of investing in pre-breeding of major vs. minor crops? In minor crops, more substantial benefits and step changes in performance*

Researchable topics

may be expected. In major crops, incremental improvements have larger impacts.

- *Domestication of novel species may be an effective strategy to produce plants with traits such as perenniality: How could available technologies be deployed for 'accelerated domestication' purposes?*

Enhancing how genetic resources are conserved globally

Opportunities

- Integration across information systems at different institutions will enable the identification of overlaps among collections and will, for the first time, allow the community to get a truly global picture of the total diversity available for a particular crop genepool. This will be a strong starting point for efforts to restructure and improve the representivity of collections across the CGIAR and the global system.
- Gap analyses informed by molecular data followed by targeted collecting efforts will ensure that landraces, in addition to the primary, secondary and tertiary genepools, are properly represented in genebank collections.
- Integration of information resources among partners inside and outside the CGIAR will be a critical trigger to strengthen global genetic-resource communities, develop more effective partnerships and exchange of services, and promote broad-based capacity-building efforts.

Researchable topics

- *Which standardized and generically applicable genotyping platform(s) are best suited for inter-genebank comparisons of accessions?*
- *How much genetic redundancy has been accumulated across genebanks for different crops? How much redundancy is desirable for back-up purposes?*
- *What are the gaps in genetic diversity that are not sufficiently represented in genebanks? What is the urgency and what are the costs of filling such gaps?*
- *What is the relative importance of primary, secondary, and tertiary genepools for different types of crops (grains, legumes, clonal crops, etc.)*

Where from here?

CGIAR genebanks are the 'backbone' of international efforts to conserve crop diversity. As such, they stand very much at the center of the opportunities provided by a rapidly evolving technological landscape. This has already led to projects harnessing the genetic resources of specific crops (CIMMYT, IRRI, ICRISAT). It is also the reason why CGIAR genebanks are

represented prominently in an emerging global initiative dubbed Diversity Seek that aims at building synergies among and adding value to such projects.[7]

Because of their competitive advantage, the CGIAR genebanks have an opportunity to assume a global leadership role in efforts to unlock genetic resources for food security and climate adaptation. New types of partnership with technology providers, 'big data' experts and a new generation of statistical and quantitative geneticists will be required to address the researchable topics outlined above. Such partnerships have the potential to attract external funds to promote a broader use of CGIAR collections.

Clearly, prioritization and costing of the research opportunities listed above will be necessary. It is relevant to mention here, that the results of a recent email survey of CRPs leaders and breeders by the Consortium Office (Annex 4 provides more details) suggests that the perceived top priority needs in the domain of pre-breeding are:

1) Evaluation of accession subsets for multiple priority traits and development of trait-specific subsets
2) Genome-wide genetic profiles and comparison between genebank material and breeding pools
3) Validation and transfer of beneficial alleles into elite genetic backgrounds
4) Development and optimization of double-haploid protocols.

Many of these activities are scalable, but we believe that to achieve the intended impact, a budget in the range of USD 100-200 million would be needed over five years.[8] It goes without saying that the research targeted by DivSeek presents a prime opportunity to attract talent and train a new generation of scientists capable of applying game-changing genomics and 'big data' technologies to demand-driven agricultural research for development.

[7] DivSeek (www.divseek.org); Gewin V (2015) 'DivSeek' aims to mine the genetic treasure in seed bank vaults. *Science* 347; McCouch et al. (2013) Agriculture: feeding the future. *Nature* 499:23; Editorial (2015) Growing access to phenotype data. *Nature Genetics* 47:99

[8] USD 28M: high-throughput genotyping of 700,000 accessions in CGIAR genebanks, including DNA extraction and data analysis; USD 5M: development of 'big data' repositories and data-query, analysis & visualization tools; USD 5M: ongoing management, validation and analysis of data; USD 3.5M: implement routine genotyping for QC of genebank operations; USD 4M: gap analyses, targeted collecting efforts and re-structuring of genebank holdings; USD 14-42M: phenotypic evaluation of 10% of the accessions for a set of key traits across sites/years at USD 200-600 per accession; USD 52.5-105M: pre-breeding programs to broaden the genetic base of elite genepools (USD 0.3-0.6M per pre-breeding program and year for 35 crop collections); USD 3M: outreach and capacity-building

Annex 1 – CGIAR Genebanks: summary

The following summary aims to highlight the uniqueness of each genebank and illustrate some of the challenges that they face. It is not an exhaustive account of issues and needs and several points (such as collecting, improving data quality, management and availability, characterizing and evaluating collections and specifically genotyping, which is underway at varying levels for most collections) are not mentioned because they are ubiquitous and continuous needs.

1. Africa Rice	
Collections	19,983 accessions of rice, most of which originate from Africa, including the world's largest collection of *Oryza glabberima*. Africa Rice is unique in representing an association of 25 African countries, on whose behalf it conserves and makes available the collection.
Status	78% of the collection is available; 41% is safety duplicated. Africa Rice established the collection under difficult conditions when it was forced to relocate from Cote D'Ivoire in 2005. It has succeeded in building core facilities but these require improvement. Long-term storage (LTS) and much of the field capacity is provided by IITA. Less than half of the collection is held in LTS and the focus of the current workplan is to regenerate accessions from medium term storage (MTS) for characterization, safety duplication and storage in LTS.
Expected to reach performance targets	Given the relatively small size of the collection and the current focus on optimizing procedures and reaching targets, Africa Rice should reach performance targets in 2019
External review - selected quotes	*"Particularly noteworthy was the obviously strong integration of the genebank activities into the overall institutional programme of work, especially with the crop breeding, plant pathology and molecular biology activities".* *"There is an urgent need for adequate facilities for the processing of the new materials arising from collecting, regeneration or from any other activity that produces seeds that will be stored. Such facilities should, at a minimum, include a temporary storage room that is rodent- and insect-proof and provide for adequate air circulation to allow for further drying. Also, a covered threshing space with the essential equipment, benches and shelves, is urgently needed to replace the current open air threshing concrete slab behind the genebank building."* *"The successful evaluation of germplasm would dovetail with pre-breeding. The promising, but non-adapted, materials so identified from evaluations and used in hybridizations to generate intermediate materials with novel allele combinations could enhance the adaptive capacities of rice cropping systems to climate change. This would result in tangible products that demonstrate the utility of genebanking. A more assertive role of the GRU in the procedures that facilitate use as well as annual planning meetings between genebank and plant breeders/researchers to plan activities related to the characterization, evaluation and screening of germplasm will further facilitate the use of a broader genetic diversity in Africa's rice breeding programs."*
Main challenges	• Develop and consolidate the data management system

and needs	• Consolidate seed health testing capacity and procedures • Implement barcoding and optimize procedures, especially relating to the monitoring of the off-site collection held at IITA • Ensure all of the collection is held in long-term storage conditions • Improve drying and storage conditions and facilities
2. Bioversity	
Collections	1479 accessions of banana and plantain held in tissue culture and 910 in cryopreservation. Bioversity collaborates closely with national genebanks through its MusaNet network, including specialist working groups that provide expert guidance and data and the Musa Germplasm Information System which provides accession data from multiple national collections as well as the Bioversity genebank.
Status	60% available and 61% safety duplicated in cryopreservation (meets target). The % availability is expected to increase once the quarantine status of the Banana Streak Virus (BSV) complex is resolved. In the meantime, affected accessions are made available for research in the form of lyophilized leaves. Bioversity is well known and appreciated for its stringent phytosanitary controls. It outsources virus-indexing and cleaning to the University of Gembloux.
Expected to reach performance targets	Bioversity should reach performance targets in 2016 assuming a positive outcome to efforts to confirm which forms of BSV are quarantine risks.
External review – selected quotes	*"One of the strengths of the genebank is its decentralization and interactions and interdependence with a wide range of local genebanks and other types of users…we believe that this key characteristic can be further strengthened to add value to services offered and to result in greater use of the accessions and greater benefits from their traits…We discuss the need to encourage greater proactiveness in the areas of acquisition and distribution. This will require better tools to obtain feedback from the partners about their specific demands, in order to make the work of distribution more effective."* *"The review notes that there have been several calls to address gaps in the collection, which have so far met limited response, especially in the case of wild species."* *"With solid foundations in the scientific reputation of the university and in close association with the scientific milieu there, the genebank has maintained a high level of conservation management and research…the staff of the genebank has built a highly collegiate and dynamic network of partnerships with research, conservation and crop improvement organizations throughout the tropical world."*
Main challenges and needs	• Conservation of wild species • Maintaining expert capacity in cryopreservation, virus indexing and disease cleaning • Ensuring availability of good quality characterization and evaluation data on accessions in the collection • European costs
3. CIAT	
Collections	6,643 cassava in tissue culture with 10% core in cryopreservation and a growing proportion held as bonsai plants, 37,987 beans and 23,140 forages, of which 1,200 accessions are conserved as trees or live plants.

Status	Cassava: 18% available and 35% safety duplicated Beans: 58% available and 68% safety duplicated Forages: 55% available and 63% safety duplicated CIAT maintains accessions only in long-term storage conditions, as part of a rationalized strategy. The genebank has unique expertise in the conservation of diverse species of bean and forages, which involves the management of 3 exceptional field sites to provide specific growing conditions. CIAT distributes at least twice as much germplasm outside the CGIAR as it does inside. For forages in particular, CIAT is frequently the sole source of germplasm and planting materials for producers and other users.
Expected to reach performance targets	CIAT is expected to reach targets in 2019. It is currently undertaking a project to multiply 3000 forage and bean accessions in addition to its routine regeneration of approximately 3000 accessions.
External review – selected quotes	*"the respected US scientist Paul Gepts called the GRP "... one of the best organised units in the world..." and stated that "... operations of the collection, in terms of seed increase, viability and disease testing, etc., are a model for other PGR Units as to systematic conservation, rigour of operations ...".* *"The Review Panel believes that the current GRP is operating at high technical and scientific standards, relative to most other genebanks in the world. The users of the CIAT genebank notice this and appreciate it very much. However, given the history of the GRP and the lack of a proper technical review in the past, there is some space to further improve the quality of the operations."* *"A genebank, especially those in the CGIAR system, must be a reliable repository of germplasm for conservation and access, i.e., all germplasm should be conserved in a sustainable way and be accessible for use....approximately one third of the material is currently not available, even though it is presented as genebank material on the GRP's website. This situation is highly undesirable and has the potential to generate damage in terms of public relations for both the CIAT genebank and the entire CGIAR. The lack of sufficient material for distribution is caused by a continuing backlog in regeneration stretching back a decade, caused by a lack of capacity and the high standards set in terms of minimally required seed quantities."*
Main challenges and needs	• Facilities are old and ill suited for a genebank. Efforts are under way to raise funds for a purpose-built facility • Safety duplication of the cassava collection is carried out through regular shipping of tissue culture samples to Peru (which is frequently hampered by national phytosanitary controls). Cryopreservation and bonsai plants will provide more secure and less costly alternatives. • Continued research to optimize the implementation of existing cryopreservation protocols and for production of botanical seed • Capturing legacy evaluation information from breeders • Collaboration with national programs especially Brazil for the conservation of cassava wild relatives
4. CIMMYT	
Collections	149,764 wheat accessions, 28,067 maize accessions, including a collection of 161 *Tripsacum* maintained as a field collection
Status	Wheat: 86% availability, 61% safety duplication Maize: 63% availability, 87% safety duplication

	The CIMMYT genebank is a well-equipped, purpose-built facility. The genebank functions at high levels of efficiency, distributing sometimes up to 50,000 samples annually.
Expected to reach performance targets	The wheat collection is expected to reach targets in 2016 The maize collection is expected to reach targets in 2021. Maize is a challenging crop to regenerate, not only because it requires controlled pollination and exhibits high levels of within accession diversity, but there are also specific types in the collection, such as tropical highland maize, which are difficult to regenerate in Mexico. Trials in new high-altitude sites started in 2014 and appear to be showing positive results. CIMMYT is also setting up a new collaboration with ICARDA to regenerate wheat wild relatives in Lebanon.
External review – selected quotes	*"The CIMMYT genebanks have a long history of being relatively well-supported, and an outstanding record of providing germplasm and information which has supported international crop development and global food security."* *"A clear, strong, technically based curatorial policy should be developed with rational support in place. Different policies should be created for managing accessions that are actually confirmed to be unique and of long-term importance versus pre-breeding or other materials, some of which may be of interest for a relatively short term duration. They should not be treated as a single collection of inventories. Policies and protocols that define the criteria for acquisition, classification as to collection type, purpose, and status, and their periodic review should be established. The main goal for the long-term collection held in trust should be to ensure regeneration while maintaining genetic integrity and availability, and prolonging the time between successive regenerations. Increasing availability of these valuable global resources is very important."* *"Great differences in seed storage behavior are recognized between plant species. In addition, huge within-species variation exists. However, there is a deficit in understanding the biology behind long and short seed life. Institutions that have held large collections over a long period of time are clearly in a unique position to contribute to this much-needed research."*
Main challenges and needs	• Improving the regeneration rate of the full range of maize genotypes in different field sites • Controlling high-risk phytosanitary and biocontrol threats for both wheat and maize • Developing strategic approaches to acquisition, especially genetic stocks • Completing the implementation of GRIN-Global and integration with breeders' data
5. CIP	
Collections	6991 accessions of potato maintained as tissue culture and in the field. 2402 accessions, mainly wild species, are also maintained as seed. 7593 accessions of sweetpotato maintained as tissue culture, in the field and in the screenhouse. 3817 held as seed. 1172 accessions of 9 species of Andean root and tuber crop (ARTC) accessions held as tissue culture, in the field and screenhouse. Large-scale cryobanks for sweetpotato and potato are also in the process of being developed
Status	Potato: 30% availability, 70% safety duplication

	Sweetpotato: 10% availability, 49% safety duplication ARTC: 0% availability, 89% safety duplication A highly complex and diverse collection and the largest tissue culture collection in the CGIAR by far. Field and screenhouse collections are managed in 3 sites in addition to the main Lima campus. The collections include a large number of crop wild relatives.
Expected to reach performance targets	CIP will reach targets in 2021. It is possible that the potato collection will reach targets earlier in 2019. Already some achievements have been made to rationalize the collections. Ongoing efforts are focused on identity verification of field, screenhouse and tissue culture collections, improving the health status of accessions, and optimizing protocols for tissue culture and cryopreservation. No funding has been available to develop phytosanitary diagnostics for ARTC, rendering them mostly unavailable for international distribution. CIP initiated in 2013 a large-scale project to cryopreserve at least 2000 accessions of potato and sweetpotato
Main challenges and needs	• Ensuring the security of the clonal collections; Safety duplicating tissue culture samples essentially demands the management of two entire tissue culture collections – developing a cryobank is a slow process but a much more effective and secure alternative in the long term • Improving the health status and hence the availability of accessions in the collection • Completing the work to verify identity of the accessions will allow CIP to rationalize the field and screenhouse collections and remove duplicates • Upgrading aging and outdated infrastructure
6. ICARDA	
Collections	148,059 accessions of barley, wheat, chickpea, faba bean, grasspea, lentil, pea and temperate forages. Highly diverse collections, characterized by traditional landraces and wild species from the Fertile Crescent. ICARDA's FIGS subsets (subsets enriched for specific characteristics inferred from environmental modeling) are popular with requesters. The DG of ICARDA has recently been recognized by the Gregor Mendel Foundation for the institute's extraordinary commitment to ensure the safety of the collection in the face of the deepening crisis and violence in Syria.
Status	78% safety duplicated. While the collections are still intact in Syria, the lack of easy access to the large part of the collection for distribution is forcing ICARDA to initiate plans to rebuild the active collection in its new facilities in Morocco and in Lebanon. Decentratlization funds are supporting the construction and equipping of field and genebank facilities and CRP funds will support the initiation of regeneration activities to reconstitute the active collection.
Expected to reach performance targets	Given continued support, ICARDA will be able to reconstruct its genebank and re-establish routine operations and services in 2021.
Main challenges and needs	• Reconstruction of facilities and collections • Regenerating numerous accessions requiring controlled pollination and wild species in an appropriate environment • Developing strategic approaches to acquisition, especially breeding materials
7. ICRAF	
Collections	4577 accessions of tree species are held as seed and 3,600 accessions are held in field collections in multiple sites mostly in Africa, but also in South

	America and Asia. ICRAF has the task of conserving *ex situ* domesticated, partially domesticated and wild tree species. These include species of value for their fruit, timber, medicinal properties or other products. As such, different international conventions or treaties determine their availability.
Status	Status of availability and safety duplication is under review. Accessions available for distribution under SMTA[9] are being identified. ICRAF does not have faciltiies to provide long-term storage conditions. Existing facilities are currently being upgraded to improve conditions for medium-term storage. Field sites are managed by national partners and seeds are made available locally
Expected to reach performance targets	Given appropriate focus, ICRAF will be able to establish a manageable collection for long-term conservation and reach performance targets in 2021.
Main challenges and needs	• Developing strategic priorities and conserving representative diversity given such a wide scope of activities and species • Safety duplication and regeneration of long-generation species • Caring for accessions in numerous, dispersed field sites under the management of national partners • Upgrading facilities and operations to meet international standards
8. ICRISAT	
Collections	123,023 accessions of sorghum, pearl millet, pigeon pea, small millets, groundnut and chickpea. ICRISAT also carries out conservation activities in 3 regional stations in Africa, which have limited facilities but represent important portals for collecting and distributing germplasm and interacting with key users regionally.
Status	88% availability, 3% safety duplication. ICRISAT has duplicated most of the collection at the Svalbard Global Seed Vault, but first level safety duplication is required to reach performance targets. ICRISAT has a well-established and efficient genebank. The numerous mini-core collections, developed to represent the diversity of different collections, have stimulated wide interest, for which the genebank director has received multiple awards.
Expected to reach performance targets	ICRISAT has already initiated a program of seed increase to enable adequate levels of safety duplication and expects to reach targets in 2019.
External review – selected quotes	*"The RP had an impression of a well-organised and effective operation with dedicated staff. The management procedures, which are very well documented, are of a high standard, and the facilities are in general of high quality. Also the agronomy at the regeneration sites was of high quality."* *"The value of PGR is determined by the information available. The RP noted that the current genebank documentation system and web interface meet the most basic requirements, they allow storage of the basic genebank information….evaluation data cannot be stored, no metadata about the phenotypes are given, data cannot be downloaded, it is not possible to show what accessions are represented in the mini-cores, nor does it allow on-line ordering or click-wrap SMTA's. The website appearance is not up to date and the information about the collection and how to select or obtain the material is hard to find."* *"much information is generated about the collections (e.g. the tremendous*

[9] standard material transfer agreement

	success of the mini-core collections). The RP considers it a missed opportunity that so little of this information is made available for genebank users….If the distribution of material would be actively followed up, much precious information could be compiled adding to the value of the Genebank collections…Besides collecting and making available phenotypic data (including appropriate metadata) also links to external -omics data relating to genebank material should be provided."
Main challenges and needs	• Expanding cold room capacity • Strengthening data management and availability • Developing and strengthening strategic operations for conservation and distribution in Africa
9. IITA	
Collections	23,317 accessions of cowpea, maize and diverse legume species 7376 accessions of banana, cassava, yam and cocoyam held in tissue culture and in field collections. IITA also hosts part of Africa Rice's collection in long-term storage.
Status	Seed collections: 30% availability, 50% safety duplication Clonal collections: 22% availability, 37% safety duplication IITA manages a range of African crops requiring very different conservation methods and demanding particular attention to prevalent phytosanitary threats. IITA, through bilateral funding, is strengthening its cryopreservation capacity.
Expected to reach performance targets	IITA will reach targets in 2017 for all crops except yam. Yam is difficult to establish in meristem culture, which continues to be an area of research and optimization.
External review – selected quotes	*"Visits to the genebank indicated a well-organised, clean and effective operation. The gene bank documentation is handled with precision, using inventory software. The data are published on the web in an accessible web-site, which is being upgraded."* *"Significant base broadening of the parental lines is called for. The IITA genebank is a unique repository of an imposing array of heritable diversity that can be leveraged towards the enhancement of the allelic diversity of crop varieties being released in countries. But, the harnessing of these latent potentials in the genebank goes beyond the remit of the conservation, characterization – and even, the evaluation – of the genebank accessions. It requires the identification of putative parents that contain desirable traits and crossing those with elite lines to generate intermediate materials that may be subsequently introduced into plant breeding. This is pre-breeding, the interface between germplasm conservation and plant breeding. These intermediate materials are notoriously unattractive to plant breeders on account of the required additional investments in time and resources to break linkage drags associated with unintended deleterious alleles. This gap between germplasm conservation and plant breeding must be bridged."* *"The significant efforts that have been invested in the management of the gene bank have resulted in the near complete characterization of all germplasm accessions at IITA. Considering IITA's leadership role, one germplasm accession that has not been characterized is one too many. IITA is therefore encouraged to complete, as a matter of utmost urgency, the characterization of all its germplasm accessions and the provision of the data online. IITA gene bank must remain a de facto model, a status that the non-availability of the totality of this body of information detracts from."*

Main challenges and needs	• Managing phytosanitary challenges • Developing more effective methods for yam tissue culture • Developing a cryobank • Increasing levels of distribution and use of the clonal collections
10. ILRI	
Collections	18,640 accessions of tropical forages including 1526 accessions in 4 field sites. Although not included in the Genebank CRP, the ILRI genebank oversees the dissemination of seed for sale to producers in Ethiopia from its Herbage Seed Unit – a unique service.
Status	43% availability, 19% safety duplication The extremely wide taxonomic diversity of the collection and the fact that it is mainly composed of wild species demands quite a different management approach to most other CGIAR genebanks. ILRI is in the process of building new facilities to replace the old pre-fabricated structure that currently houses the genebank.
Expected to reach performance targets	ILRI will not meet targets before 2021. Current rates of regeneration are limited to around 800-900 accessions per year because of the demands for space and equipment to deal with cross-pollinating wild species. With improved knowledge of seed storage behavior and longevity for the diversity of species involved ILRI will be able to develop customized strategies for the conservation of individual species.
External review – selected quotes	*"The ILRI genebank rightly has a strongly positive international reputation for the conservation of forage germplasm…it has helped to develop crop genetic resource protocols used by the international community and has trained a significant number of scientists. The bank appears to stand at a cross-road. A successful future depends on it being used to its maximum potential. The continued support of the Genebank CRP is essential if this globally important facility is to thrive."* *"A key factor for effectively developing a germplasm collection that serves a dual purpose (i.e. meeting the needs of a broad range of users, and conserving germplasm for the future) yet remains manageable in size, is having a curator that understands the gene pools of the crops in question, who is actively engaged with users and other PGR institutes conserving the same or similar material."* *"The ILRI genebank has a number of challenges over the coming few years. The very first task of a genebank is to secure the germplasm that it has been entrusted with. Consequently, it must ensure that the collections (or at least samples of all of them) are stored under the best conditions to make sure that they are available for future generations. One of the greatest benefits of genebanks is that a large amount of diversity is located in one convenient place. This is also their biggest potential downfall. Consequently, it is essential that the material is adequately duplicated and that risk assessments are comprehensive. The material must also be monitored for viability and the documentation must be objective and as complete as possible. With this in place, it is essential that the germplasm is made to work and in order for this to happen there needs to be good connection to the potential user community."*
Main challenges and needs	• Increasing seed quantity of wild species with long generation times • Developing a strategic approach to conserving diverse perennial species • Increasing the use of the collection

	• Upgrading aging facilities
11. IRRI	
Collections	126,593 accessions of rice
Status	92% availability (meets target), 91% safety duplication (meets target) IRRI operates at high-levels of efficiency and throughput and has been able to meet increasing demands for germplasm while maintaining high standards of conservation.
Expected to reach performance targets	IRRI has consistently maintained operations at target levels. Furthermore IRRI has a strong focus on conservation research, which has allowed it to make significant inroads into improving operations and increasing the longevity of seeds in long-term storage. IRRI is currently building an automated seed phenotype sorting capacity, which will allow seed processing to take place overnight and free staff for other operations.
External review – selected quotes	*"The review team acknowledged the efforts of IRRI management to forge a strong integration between conservation and use of genetic resources and the product-focussed breeding programmes in the context of GRiSP. Such thrust is apparent in the gene discovery research and in the enhanced collaboration between breeders and genebank staff in the use of genebank materials. A further strengthening of such integration and linkages is expected with the availability of genomic data and the tools to manage and analyse such genomic data. The review team shared IRRI's views on the need of such integration to achieve best use of the IRRI rice collection."* *"The wealth of knowledge and skills accumulated by the staff over the years regarding seed handling in the genebank, the management of the wild rice germplasm, and the field operations is very impressive. Such knowledge and skills are invaluable for the continuity of operations of GRC in the years to come."* *"The GRC applies very high standards in its operations. It would, therefore, create a "Gold Standard" if the GRC completes and consolidates a fully documented quality management system for its basic genebank operations. The review team notes that attempts have been made in the past to establish this QMS but that the effort has not been completed. It is recognized that this will require additional investment of time and effort by the staff and external process documenters in preparing and implementing the QMS, but this process will be essential to capture the unique experience of the long-serving staff."*
Main challenges and needs	• Upgrading aging facilities • Strengthening data management capacity and tools • Replacing key staff with unique expertise

Annex 2 – Long-term financing of the International Genebanks

Excerpt from the Paper to the Executive Board meeting, March 2015

Purpose

This paper describes in detail how funding allocations for the routine operations of global system genebanks might be determined and proposes features to amend and strengthen the long-term grant agreements.

Background

A two-tier system has been proposed to manage agreements with global system genebanks (figure 1). Those genebanks that fulfill eligibility principles and criteria, and have reached performance targets may enter into a long-term agreement with the Crop Trust. Those that are still working towards achieving targets, will, in contrast, enter into a short-term upgrading agreement, which may or may not cover the full costs of routine operations (depending on the availability of funds from the partner institute and from the endowment). The Crop Trust is in the process of developing this system further by creating a solid, standardized basis for allocating long-term funds, and strengthening the contract language of the long-term agreements.

The 2010 Costing Study was a major step towards understanding the costs of specific operations of the international collections, from acquisition to distribution. Costs for personnel, operations, other variable costs, capital and indirect costs were entered into an Excel-based Decision Support Tool. However, the Centers, which were transitioning from a period where they received substantial core, or unrestricted, funding to one of exclusively project funding, were only able to make estimates of the costs of utilities and services (e.g. use of fields, health testing, etc) incurred by the genebanks. Since then, most of the Centers have been applying full cost recovery to various services provided to the genebanks. However, the methods of attributing these costs still vary markedly from one Center to another, despite the existence of system-wide financial guidelines. Together with the varying levels of genebank performance and operation, this variation is a significant factor affecting the lack of parity in funding allocations. Given the need to protect the endowment and ensure that long-term agreements are sustainable, a solid basis for allocating appropriate levels of funding is required.

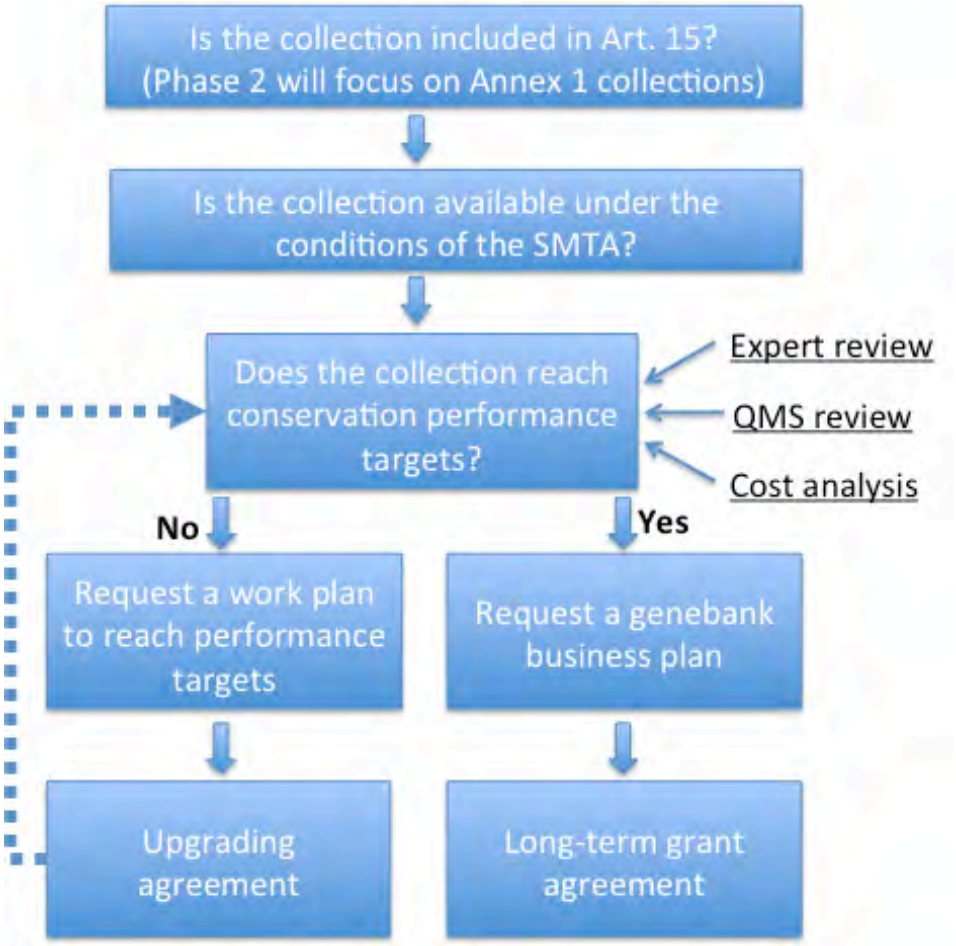

Figure 1. Two-tiered system for managing grants provided by the endowment

Funding allocations

The Crop Trust has hired Simon Linington, previously of the Millennium Seed Bank, to develop model specifications for a genebank managing different categories of crop (e.g. self-pollinating cereal, cross-pollinating cereal, etc). More than half of the accessions managed by the CGIAR are of relatively easy-to-manage, self pollinating cultivated species. The model specifications will determine an acceptable complement of essential staff, facilities, equipment and operating costs for the routine management of collections according to their size. Local costing structures can then be applied to this model to derive "routine" budgets for all genebanks. For those genebanks with more-difficult-to-manage species, especially clonal and cross-pollinating crops, wild crop relatives and forages, additional funding will then be provided for identified additional needs. Further to these two layers of funding, we would like to implement forms of contingency funding and incentive funding using the income from the endowment. We also continue to respect the need, identified since the first long-term agreements were put in place, for matching funding or co-funding from partner institutes as a means of showing commitment to the partnership and the long-term sustainability of the collections.

Funding layers	Estimated funds (USD million)	Use of funds
Fixed basic funding	12	To cover the essential needs of the genebanks.
Additional needs funding	4.5	To cover additional needs (e.g. screenhouses, pollination cages, special field sites) for difficult-to-conserve species
Incentive funding	0.7	One-off funds awarded annually to genebanks that have achieved significant improvements or cost-efficiency or exceptional levels of distribution
Contingency	0.8	To cover unplanned needs or variations in costs (e.g. currency fluctuations)
Co-funding	4	Provided by the partner institute to promote distribution and use of diversity from supported collections
Total	22	

Table 1. Funding layers relating to long-term agreements with genebanks

The precise figures for the different layers of funding will be available once the Linington model has been piloted and tested in consultation with the Center finance units. We are expecting this work to be completed in the course of the next 6 months. The overall total cost is expected not to differ substantially from the current budget of the Genebanks CRP, under which the genebanks have been functioning for the past three years. The administration of these funding layers will need to be resolved. For instance we foresee the need for an advisory body to support decisions taken by Crop Trust staff.

The long-term grants

The current contracts for long-term grants are inadequate to support the system described above. There is little obligation on the part of partners to ensure that performance standards are maintained, that accessions are made available or appropriately safety duplicated, that an appropriate acquisition or curation policy is in place, that recommendations of external reviews are addressed or that costs are controlled. As the endowment increases to cover the full costs of routine genebank operations, it will be increasingly important that the associated agreements are adequate, and mechanisms are in place to ensure appropriate management of collections. We therefore propose to modify the contractual language and format of the existing agreements to include the following elements:

1. A business plan for the next 10 years, including:
    a. plans for growth and curation of the collections, including data management;
    b. detailed analysis of facilities and major equipment needs and how they will be addressed;
    c. expected sources of complementary funding;

   d. activities and use of the genebank, including research and pre-breeding, which are financed through co-funding;
   e. partnership activities and interaction with users;
   f. actions to encourage efficiencies and to optimize the costs of routine genebank operations;
   g. contingency plan to outline how the Center will deal with a rise in costs or unexpected events.
2. Baseline information describing the status of the collections with regards to eligibility criteria, performance targets and the minimum elements of the Quality Management System (Standard Operating Procedures, Evacuation plan, Risk management plan, Staff succession).
3. A mechanism that allows either party to withdraw from the agreement should the performance of either fall below agreed standards for an extended period of time without attempted redress.
4. Clear statement of the management and communication responsibilities of both parties to the agreement. In particular, the Crop Trust should be party to major management decisions concerning the genebank.

Annex 3 – Breakdown of the costs of collective requirements, collecting, outreach and partnership

Budget in USD	2017	2018	2019	2020	2021	Total
Achieving & maintaining standards	5.67	3.48	3.19	1.98	1.59	15.91
A. Replacing aging equipment	2,787,393	581,073	428,350	96,668	0	3,893,484
B. Meeting performance targets	1,372,215	1,379,114	1,343,090	774,605	517,944	5,386,968
C. Difficult-to-conserve crops	1,312,721	1,314,739	1,214,740	894,741	854,742	5,591,683
D. QMS	200,000	204,000	208,080	212,242	216,486	1,040,808
Subtotal	5,672,329	3,478,926	3,194,260	1,978,256	1,589,172	15,912,943
Data quality and management	1.46	2.52	1.51	0.97	0.76	7.22
Mobile genebanking, workflow management, automated processes	1,051,600	1,881,000	869,000	325,380	331,887	4,458,867
Data safety & security, legacy data, open access repository	22,000	242,520	235,844	240,561	11,907	752,832
Improving data quality & quantity & Genesys	385,000	392,700	400,554	408,565	416,736	2,003,555
Subtotal	1,458,600	2,516,220	1,505,398	974,506	760,530	7,215,254
Policy	0.57	0.58	0.59	0.61	0.62	2.97
A. Representation at meetings, research	82,000	83,640	85,313	87,019	88,759	426,731
B. Capacity building & compliance within CGIAR	104,500	106,590	108,722	110,896	113,114	543,822
C. 'Eyes-on-horizon' consultation group (10 member committee)	53,000	54,060	55,141	56,244	57,369	275,814
D. Partnership & capacity building of NARS	45,500	46,410	47,338	48,285	49,251	236,784
E. Coordination unit: staff & management	285,960	291,679	297,513	303,463	309,532	1,488,147
Subtotal	570,960	582,379	594,027	605,907	618,025	2,971,299
Collecting, outreach and partnership activities	0.75	1.35	1.35	1.15	0.40	5.00
A. Capacity building NARs (regional training workshops & follow-up partnership projects)	250,000	255,000	260,100	265,302	0	1,030,402
B. Impact communication (staff, research & travel)	200,000	204,000	208,080	212,242	216,486	1,040,808
C. Targeted collecting (gap analysis & joint collecting missions)	300,000	890,000	885,000	670,000	180,000	2,925,000
Subtotal	750,000	1,349,000	1,353,180	1,147,544	396,486	4,996,210

Annex 4 – Report of inter-commodity CRPs survey on breeders' views on priorities in pre-breeding

No.	Pre-breeding tasks	Positive responses
1	Evaluating subsets of accessions for individual breeders' priority traits	100%
2	Genome-wide sequencing & genetic diversity analysis of breeders' elite lines	89%
3	Gene validation for breeders' priority traits	89%
4	Preliminary breeding to transfer high value alleles from inferior genetic backgrounds into elite lines	89%
5	Combined analysis of sequence data on breeders' and gene bank materials	80%
6	Developing trait-specific subsets e.g. by FIGS (Focused Identification of Germplasm Strategy for breeders' priority traits	78%
7	Evaluating subsets of accessions for multiple agronomic traits	78%
8	Development and optimization of DH (Doubled Haploid) protocols cost effective and non-variety dependent	78%
9	Establishing networks for the multi-environment evaluation of accessions	67%
10	GWAS on genebank materials and its use for preliminary identification of candidate genes and candidate parents	67%
11	GS & genomic estimation of breeding value of breeders' elite lines	67%
12	Convert sequence data on validated genes into markers	67%
13	Genome-wide sequencing and genetic diversity analysis of accessions	56%
14	New approaches for dealing with heterosis, apomixis, etc	56%
15	Genomic estimation of breeding value of gene bank accessions	44%
16	Developing cores / mini-cores etc	33%
17	Analysis of sequence data on accessions and/or elite lines for validated, or almost validated genes for breeders' priority traits	33%
18	Finding the function of all genes in the genome regardless of relevance to current breeders' priorities	33%
19	Development of populations (MAGIC, NAM etc) to expose the hidden variation among accessions	33%
20	Development of populations (MAGIC, NAM etc) between accessions and breeders' elite lines to explore the hidden potential of accessions to improve elite lines	33%
21	Development of populations (MAGIC, NAM etc) to expose the hidden variation among breeders' elite lines	33%
22	Development of mutant populations for classical TILLING & TILLING by sequencing	30%
23	Increase variability by induced mutagenesis	22%
24	Development of Chromosome Substitution Lines by classical & reverse breeding approaches	22%

(Kindly provided by Sivakumar Sukumaran and Victor Kommerell/CIMMYT Wheat CRP