CGIAR-Crop Trust System Level Review of Genebank Costs and Operations (GCO)

Report

October 2020

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Executive Summary

In early 2020 the Crop Trust and CGIAR set up a Panel to review the operations and costs of CGIAR genebanks and to propose priorities for future resource allocation. The Panel started by asking the question: given the expectation of rapid and major global change, and evolving technology, what should a genebank of the future look like? What genetic resources and information will be needed, by whom and how should they be provided? To address such issues, three online discussions were held, involving 33 experts, under the title: *The Chatham House Dialogue on Crop Diversity for Challenging Times: The Role of Genebanks in Sustainable Development*[1].

The Dialogue participants agreed that in a future that will continue to be turbulent and uncertain, crop genetic diversity can only increase in importance. New technologies are opening up opportunities for improving conservation as well as novel ways to genetically enhance crops. There are thus expanding opportunities for CGIAR genebanks to play a more proactive, strategic and catalytic role, not only within CGIAR but also the wider global genebank community. CGIAR cannot – and should not – do everything and partnerships will become ever more important. In order to play a stronger leadership role, there must be a clear vision, strong and effective leadership, and adequate funding.

Building on the Dialogue, the Panel recognised that the collections are not CGIAR assets but are held in trust for the global community. While the Centres are major users of the collections, all *bone fide* users worldwide have a legitimate expectation to be able to access them. Given that most accessions were provided for the international common good, there is both a strong moral as well as legal obligation for CGIAR to maintain them securely and make them widely available. This obligation is recognised in the agreements signed by the Centres with FAO in 1994 and with the Plant Treaty[2] in 2006. Given their special status, the Panel considered it important that a *sui generis* system-level approach is taken for the management of the CGIAR genebanks, policy unit and germplasm health units (GHUs). It will be important to maintain and, if possible, expand the work on policy to help promote a supportive international policy environment and ensure CGIAR compliance.

The move to "One CGIAR" provides exciting opportunities for doing things more efficiently and effectively. Consideration should be given to creating a unified, CGIAR-wide genebank system with a single programme head appointed at a very senior level. System-wide leadership responsibilities should be assigned for key areas of the program, e.g. for particular crops or crop groups, major technical areas etc. There may also be opportunities for physically consolidating certain collections, especially of the same crops. However, any such move needs to be carefully planned and only implemented after a thorough assessment of political, physical and reputational risks.

Stronger links should be forged between the genebanks and CGIAR's work at the regional level. Regional or sub-regional multi-crop hubs for the two-way movement of germplasm and information should be considered. Such hubs, which could be established progressively,

[1] https://www.genebanks.org/news-activities/news/chatham-house-dialogue/

[2] International Treaty on Plant Genetic Resources for Food and Agriculture

could serve the breeding programmes as well as the genebanks and could be set up in partnership with other institutions. Such hubs would logically also serve as locations for a uniform CGIAR-wide phytosanitary system.

The Panel stressed the importance of monitoring and reporting (e.g. to the Plant Treaty) all movement of germplasm from CGIAR, whether by the genebanks or breeding programs, and to ensure it occurs under common CGIAR phytosanitary and policy control.

In considering the future structure and funding, the Panel found it useful to think of three, inter-related components:

1) *Guaranteeing diversity in perpetuity*: the minimum activities required for fulfilling the legal and moral obligations to conserve the collections and make them available.
2) *Futureproofing collections and exchange*: comprising
    a. Conservation innovation: research in areas such as cryopreservation, germplasm health, seed longevity and conserving forages, multipurpose trees and crop wild relatives, improved data management and enhancing operations through automation, etc.
    b. Moves to consolidate and align management and expertise at CGIAR level, and
    c. Genetic resources policy and germplasm health services.
3) *Increasing value*: activities designed to make the collections more valuable to users, whether plant breeders or others, (e.g. pre-breeding, genotyping, phenotyping etc.) and thereby increase their actual use and contribution to sustainable development.

CGIAR, with support from the Crop Trust, should put in place system-level mechanisms to ensure adequate, ring-fenced funding for at least the first two components, recognising that these activities are not accommodated in a typical CGIAR research project framework nor as a shared service. *Increasing value*, while also a critically important and worthwhile investment, could be considered for support by other CGIAR mechanisms. If this schema is adopted, it will be necessary to assign specific activities to each category and the Panel has recommended where the boundaries should lie. The need to standardize accounting, especially regarding cost recovery, is also stressed.

CGIAR should consider playing a greater international leadership role in the conservation and distribution of additional crops, especially those important for nutrition. This does not necessarily imply taking on responsibilities akin to those for the current 'mandate' crops, but carrying out, in partnership with appropriate institutions, activities such as training, coordination, making facilities available, etc.

Partnerships will continue to be critical to the genebanks' success. It is vital that the strong partnership with the Plant Treaty be maintained. CGIAR is at the heart of the global system[3] and continued efforts are needed to help strengthen the system, and in particular to ensure

[3] "Global system" refers to the worldwide community of genebanks and institutes, which are working together and individually to conserve and use plant genetic resources for food and agriculture, and the policy instruments and global action plans that bind them together and support their work. CGIAR genebanks, given the size and diversity of their collections, their global mandate, and extensiveness of their partnerships form the central pillar to this system.

that low- and middle- income countries are able to fully participate and benefit from their participation in a global system contributing to increased food security.

Given the nature of CGIAR genebanks' global responsibilities, the Panel considered it important to establish a standing panel, or other mechanism consistent with CGIAR's structures and processes that would bring together key actors both from within CGIAR and external experts from the world at large to provide appropriate guidance for the management of the genebank system.

1. Background

The 11 CGIAR genebanks (see Annex 1) conserve and make available crop and tree genetic diversity on a long-term basis under the management and coordination of CGIAR Genebank Platform. They are responsible for a large proportion of annual germplasm distribution occurring under the auspices of the Plant Treaty. The continued conservation of, and access to, these unique public resources is of global concern. Changing demand, technologies and knowledge have a fundamental influence on the operation and impact of the genebanks. Assessing the current status of the collections and their future operation is a critically important exercise for CGIAR and also the Global Crop Diversity Trust (Crop Trust), which is a long-term funder[4].

Current budgets for "routine operations"[5] of individual genebanks were determined in an in-depth costing study that was commissioned by CGIAR and Crop Trust in 2009. After more than 10 years of operation and two phases of technical reviews plus a costing exercise, the Crop Trust decided to review the allocations of funding to, and the costs of, genebanks operations. In partnership with CGIAR and the Plant Treaty Secretariat, this review aims to look at costs and operations from a system level perspective in order to feed into the reform towards "One CGIAR".

The specific objectives of the review are to:

- Consider the overall scope and objectives of CGIAR genebanks within the context of evolving CGIAR priorities and global system for conservation and use – encompassing the relationship between CGIAR genebanks and other international genebanks, national genebanks and other partners, as well as future CGIAR research programs;
- Prioritize genebank operations with a special focus on consolidating the "essential operations" that should be targeted for endowment or ring-fenced funding;
- Recommend specific actions for improving efficiency, collaboration and rationalization within the System;
- Agree general principles to facilitate the fair allocation of resources to CGIAR genebanks.

[4] Crop Trust also, since 2012 (until 2021), has had the role of coordinating CGIAR Genebank Platform, and so has a unique technical oversight of the 11 genebanks.

[5] "Routine operations" are the critical daily activities required to ensure that germplasm is monitored, conserved and made available for the long term. Sixteen defined operations and sub-activities are included.

GCO Panel members (Annex 2 provides brief biographies):

- Geoff Hawtin (Independent consultant, Panel Chair)
- Mellissa Wood (Independent consultant)
- Sonja Vermeulen (CGIAR System Organization)[6]
- Ruaraidh Sackville Hamilton (Independent consultant)
- Kent Nnadozie/Alvaro Toledo (Plant Treaty Secretariat but acting in their personal capacity)
- Janet Muir (Crop Trust Finances)
- Charlotte Lusty (Genebank Platform/Crop Trust, Panel Secretary)
- Luigi Guarino (Crop Trust)

The GCO Panel was constituted early in 2020 and had its first call on 24 April. A series of seven calls took place over the following months. The Panel members input to the development of four background papers (Annex 3), which were prepared by the Crop Trust, CGIAR genebank managers and Management Team members, and were involved in the consultations and Panel discussions. Early on the Panel decided to reach out beyond CGIAR to seek views from a diverse group of thinkers in order to consider the global context in which CGIAR genebanks function and to stimulate more objective, ambitious thought towards future scenarios. In pursuing this objective, the Panel partnered with Chatham House and commissioned two stimulus papers (Annex 4) for presentation and discussion among a group of 33 invited experts (Annex 5), including Panel members, as part of a the "Chatham House Dialogue: Crop Diversity for Challenging Times - The Role of Genebanks in Sustainable Development", which took place in three virtual sessions over three consecutive days. Following the Chatham House Dialogue the Panel members undertook three further sessions of in-depth discussion and two consultations with relevant CGIAR Centre Directors General, Science Leaders and genebank managers (Annex 6).

This is the resulting report of GCO Panel's review. It includes a summary of the key messages from the Chatham House Dialogue, the findings of the Panel and recommendations directed specifically at the Crop Trust and CGIAR System for consideration in the funding and formulation of the program of work undertaken by CGIAR genebanks from 2022 when the current CGIAR Genebank Platform ends. It is hoped that the report will also be useful and that relevant findings and recommendations will be considered by the Governing Body of the Plant Treaty.

2. Summary points from Chatham House Dialogue

- Crop genetic diversity – both inter and intraspecific – will continue to be critically important in whatever scenario might be envisaged lying on the spectra of shifting diets and changing global interconnectivity (Figure 1).
- Genebanks - both international and national – will continue to have a vital, and probably increasing role in conserving crop genetic diversity, adding value to it, and supplying it to users. They have a major role as a source of specific traits to improve crops. Given the availability of new technologies and adequate investment, CGIAR and

[6] Jamie Craig of CGIAR System Organization was involved in Panel calls until and including 8 September

other genebanks should be supported to play this role more effectively across multiple spheres, including efforts to:

  - adapt to and mitigate climate change,
  - support more diverse, resilient farming systems,
  - promote more nutritious agriculture,
  - conserve varieties and species that are rapidly going extinct.

- CGIAR genebanks should play a more proactive, strategic and catalytic role in supporting the sustainable transformation of food, land and water systems through providing or sourcing crop genetic diversity on a wide scale, including staples, forages, underutilized crops, vegetables, roots, tubers, fruits and crop wild relatives and even non-food crops that are important for generating income and employment in smallholder agricultural systems, such as fibre, fuel, medicinal, beverage, decorative, aromatic or green manure crops.
- CGIAR cannot do everything; it doesn't have the capacity, nor should it. National and other genebanks have a complementary role to play and one that needs to be strengthened and supported. Partnerships, federated systems and a clear division of responsibilities are necessary for a truly effective and efficient global system in the future.
- For partnership to work, governance and the policy framework must be functioning, effective and well supported.
- For the CGIAR genebanks to think and act more strategically, there must be effective leadership, clear vision, adequate funding, trust and a realistic theory of change. These are only possible based on improved information and ways of quantifying, analysing and communicating demand and the current and option values of genebank materials.

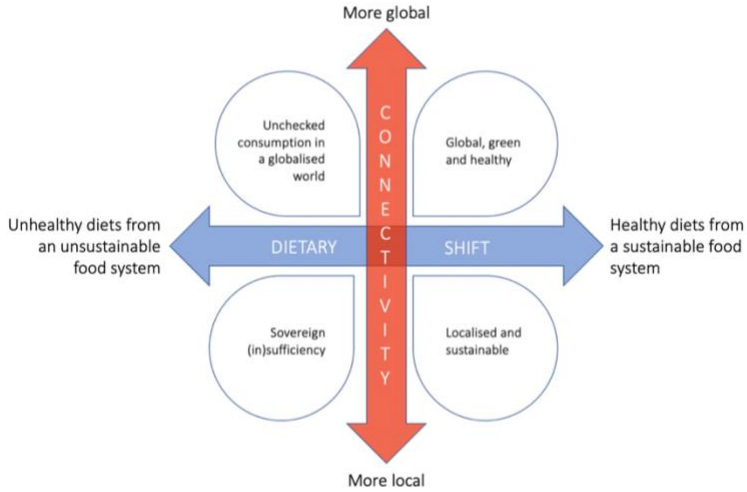


Figure 1. Four plausible alternative futures for food systems, based on axes of global-local connectivity, and degree of dietary shifts. Source: *How may food systems evolve: looking ahead in an uncertain world* by Tim Benton.

3. GCO Panel Findings and Recommendations

Prof. Tim Benton's presentation during the Chatham House Dialogue described the future as being TUNA – turbulent, uncertain, novel and ambiguous. In all of the potential scenarios that were considered, however, genebanks continue to have a critical role to play in responding to future needs. It is quite clear that these needs and the community that CGIAR genebanks

serve, go much further than CGIAR breeding programs. What's more, participants to the discussions reiterated that CGIAR genebanks could play a more catalytic role in supporting the transformation of agriculture and food systems. The Panel considered that there are two very different dimensions to this:

- collaborating with upstream researchers to make the most of newly available tools and information to provide specific alleles and traits with more precision than has been possible in the past and thus support genetic gains in breeding programmes
- promoting the use of diversity of different species of crops, forages and trees or different varieties within species in order to create options to deal with multiple challenges and change in any target geography, including nutrition security and disease and climate resilience.

The first dimension explores the depth of diversity on a genetic scale and the second its vast breadth across species; together they provide the possibility for genebanks to seek excellence and exploit opportunity. To make the genebanks adequately responsive and flexible to contribute meaningfully to these somewhat perpendicular worlds is probably one of CGIAR's most interesting opportunities, which has been alluded to in the 2019 Multilateral Organisation Performance Assessment Network (MOPAN) report[7].

The GCO Panel's perspective is that there is a possibility here for CGIAR to seriously consider the bold step of reconfiguring its genebanks at the same time as it modernizes its breeding programs and focuses resources on addressing priority regional challenges and needs. If CGIAR's genebank system were to be built from scratch today, there would be a strong argument to concentrate long-term conservation efforts in a small number of specialised sites – catering separately for (1) orthodox seed, (2) wild species and trees, and (3) clonal crops, and perhaps for further biological differences within these categories - and to expand the scope of the active collections so that all target geographical regions can have much readier access to the knowledge and germplasm of a range of relevant crops, forages and tree species. This expansion could involve the evolution of existing locations into hubs that actively facilitate the two-way exchange of crop genetic diversity and knowledge on a regional basis and ensure that everything CGIAR disseminates and acquires complies with both international policy and phytosanitary standards.

Such a division of roles, not only between CGIAR genebanks but between genebanks in the global system, would not bring about cost savings compared to the current system, but it would improve efficiency. Its main objective would be to improve users' access to crop, forage and tree diversity and to ensure that efforts, internal and external to CGIAR, to tackle the multitude of challenges in regional food and agriculture systems are underpinned by all of the possible options that are represented by agricultural biodiversity. Partnership with national programs is key in this vision; all geographical regions are served by national genebanks of varying capacity and the specific role played by CGIAR in different regions should take this into account.

There are serious considerations in taking such a step – not least the legal and political obstacles in reconfiguring the current collections. The concentration of conservation activities

[7] http://www.mopanonline.org/assessments/cgiar2019/CGIAR%20report%20Web.pdf

would depend heavily on being able to move germplasm easily across international borders. If the current lockdown conditions and crisis are any indication of future dysfunctionality in international collaboration and movement of goods, then building a system based on fewer locations for long-term conservation would need careful risk assessment. However, there are significant steps that can be taken now that do not commit CGIAR to any one future pathway. These are described in the following findings and recommendations.

3.1 Structure and content of the genebank system

3.1.1 Program structure

To develop a shared understanding of genebank operations it is essential to appreciate the distinct objectives of genebanking and, most particularly, the long-term conservation objective versus the immediate objective of providing information, advice and clean germplasm in response to requests. Requests to genebanks are rarely specific; users require help in identifying accessions with the characteristics they need. There are distinct constituencies from which requests come. Some users seek diversity *per se* potentially even in the form of multiple crops or species; some seek subsets, genotypes or varieties that have been the subject of published research; others seek very specific traits. Genebank managers and staff take considerable time and effort in responding to a wide range of demands that are continuously changing over time.

Meanwhile, sustaining conservation activities remains critical, especially to avoid the build-up of backlogs of accessions that require monitoring or regenerating. Large parts of any collection may remain obscure and underutilized; they tend to be the least well known and the most difficult to manage parts of the collection and yet they have unique genes and traits that may serve a purpose for as yet unknown future needs. Applying disciplined processes and optimizing protocols, especially for difficult-to-conserve species, are the least glamorous parts of the job of a genebank. And yet, without adequate focus on the long-term health and viability of conserved germplasm, a genebank will become inefficient and ultimately fail its legal and moral obligations. Similarly, without adequate focus on current needs and demands, a genebank becomes the archetypal “museum”.

In seeking a way to balance these equally important but often competing objectives, it becomes evident that they need to be somewhat firewalled from one another both in terms of management and funding. The GCO Panel identified three distinct components of the work of genebanks. They are described and presented in more detail as follows:

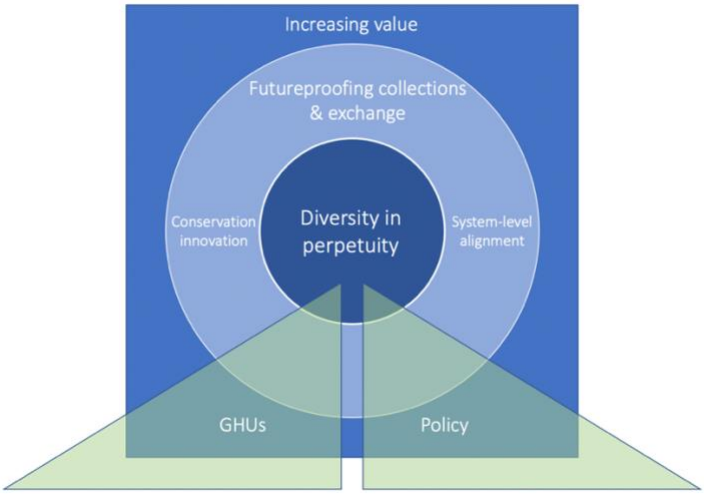


Figure 2. Components of the future genebank system

Components of genebank work:
A. Guaranteeing diversity in perpetuity
B. Futureproofing collections & exchange
C. Increasing value of collections

A. Guaranteeing diversity in perpetuity

These are the *In perpetuity* operations that are required to meet CGIAR's legal, moral and technical obligations to maintain and make available designated collections under Article 15 of the Plant Treaty. Every actively curated accession in the collection must be viable, healthy, true-to-type and protected against the risk of loss. To achieve this, it must pass through processes that are documented, audited and reviewed to meet scientific standards as described in the FAO Genebank Standards. *In perpetuity* activities comprise those essential duties that sustain a steady state of operation (without backlogs), which if not carried out effectively and in a timely fashion will ultimately lead to loss of accessions. These tasks correspond to what have been previously referred to as "routine" or "essential" operations.

B. Futureproofing collections & exchange

This component of the work of the genebank system is necessary for CGIAR genebanks to maintain and improve efficiency and effectiveness. Specific priority activities take the form of time-bound responses to new needs and opportunities as they emerge, and thus change with time. Current priorities include the need to function more coherently as a system and, even more fundamentally, to comply with all appropriate policy and phytosanitary measures. The three main priorities under *Futureproofing* are summarised as follows:

(1) Conservation innovation: While *In perpetuity* processes are well defined by the CGIAR Genebank Platform, new technologies, approaches and circumstances impose the need for regular review and improvement of methods and processes. In addition, significant backlogs of accessions that require regeneration, testing, cleaning or other active processes may exist or be created in the event of major acquisition, ageing of the collection and deterioration of seed viability, and the arrival of new pests or diseases of quarantine concern. Research to improve efficiency and effectiveness of processes, and

efforts to deal with backlogs are considered to be part of *Futureproofing* the genebanks. They comprise such topics as:

- Research into, and large-scale implementation of, cryopreservation for clonal crops and potentially for recalcitrant seeds
- Research into complementary conservation protocols for clonal crops and for recalcitrant seed and wild species
- Research into seed quality management and optimization of relevant processes
- Dealing with major backlogs if the genebank has not reached performance targets
- Optimization of the composition of collections
- Piloting and implementation of automation of selected processes
- Development, customization and implementation of unified data management software and analytics

Of particular note here is the need to stabilise the clonal crop collections. While there exist hundreds of seed collections in conservation in genebanks large and small around the world, the number of tissue culture collections that are successfully conserving clonal crops long term are extremely few (perhaps less than a dozen). CGIAR stands out in this regard also because of its high phytosanitary standards. In many instances, it remains the only available source of clean germplasm of crops such as banana, cassava, yam, etc. To tackle the expense, complexity and vulnerability of conserving and making available clonal crops, CGIAR must upscale its work on cryopreservation as the chosen technology for long-term conservation and of advanced phytonsanitary tools such as use of sRNA. Under the Genebank Platform, both technologies have passed through proof of concept phases, CGIAR should now invest further in their large-scale application.

(2) System level alignment and expertise: The GCO Panel considers that the opportunity of transitioning to One CGIAR and establishing a new program for the genebank work should facilitate and benefit from a greater centralization of genebank expertise and management at a system level. These ideas are explained in more detail in Section 3.2. Under more centralized management, subprograms of work on the thematic areas above may be led and implemented across multiple collections. Also, general standards, processes and data management across the collections may be more closely aligned, especially where the same crop is conserved in multiple Centres. Finally, cost-benefit analysis should be at the basis of investments of time and funding to ensure that approaches are strategic, and specifically the investment in long-term conservation of specific crops by specific genebanks.

(3) Genetic Resources Policy and Germplasm Health: CGIAR genebanks depend fundamentally on specialist engagement in international plant genetic resources policy fora and on the efficient and effective functioning of CGIAR germplasm health units (GHUs). Application of policy work and health testing is relevant to all three components of the genebank system, as well as to all CGIAR programs that work with or disseminate plant genetic resources. GHUs and the CGIAR Genebank Platform Policy Unit perform a service for CGIAR as a whole and share many of the same needs for management, oversight and resourcing as the genebanks do. The Management Team of the Genebank Platform have made convincing arguments for why the genebanks, GHUs and Policy Unit

function better together[8] and the Panel agrees that their continued close cooperation presents a stronger, more coherent program.

As part of the *Futureproofing* component, the Policy Unit is able to continue building system-wide capacity to comply with and engage with relevant international policy instruments and the GHUs are able to invest in reaching and maintaining common, high standards of operation, as well as engage with national, regional and international phytosanitary bodies.

C. Increasing value of collections

CGIAR genebanks perform a widely acknowledged global role in the international provision and exchange of plant genetic resources underpinning agriculture development worldwide. It is, however, the opinion of the GCO Panel, reinforced by the Chatham House Dialogue, that CGIAR should be more proactive in increasing the value of the collections managed by the international genebanks and: (1) support the active participation of genebanks in projects to discover and mine the wealth of traits in the collections and (2) make full use of the diversity options presented in collections to address the needs of agriculture systems the world over to adapt to climate change and to increase nutrition and food security.

The scope of activities under this component of work is vast. Leadership, analysis, and dialogue with partners are needed to determine where CGIAR genebanks have the comparative advantage to play a more active role. The future genebank system must work hand-in-hand with CGIAR's breeding initiatives to ensure that the traits prioritised in crop product profiles are researched and supplied. However, resources also need to be dedicated to endeavours that may not be an obvious or immediate priority for CGIAR research; these include actively exploring the value of less well known diversity of crop wild relatives, traditional varieties, minor crops, agroforestry trees and species/variety combinations, that may contribute to the resilience and nutritional offer of specific agriculture systems, as well as respond to the ever-growing and changing demand for partnership and germplasm from a wide range of users outside CGIAR. It is absolutely critical CGIAR fully recognize and embrace the evidence that more than half of the germplasm distributed by genebanks goes to public sector users in middle- and low-income countries. This is an important constituency that is likely to increase in both size and importance.

3.1.2 Program operations

The genebank "essential operations" are well defined and remain largely unchanged from the 2011 study. However, experience has revealed a need to clarify more precisely the boundaries between these operations and other essential or desirable genebank activities. The GCO Panel reviewed in detail a number of identified ambiguous boundary areas, and provides recommendations on each one in Table 1.

[8] See Background paper 2b (Annex 3)

Table 1. GCO Panel recommended resolution of boundary areas concerning genebank in perpetuity operations and the relevance of these recommendations to the different Findings/Recommendations listed following the Table

Boundary area	GCO Panel recommendations	Relevant to
Seed collections		
Acquiring breeding materials & genetic stocks - increasing collection size but not necessarily overall diversity. Should genebanks be doing more to manage breeders' materials on their behalf?	*The acquisition & curation policy for each collection should be developed by the curator based on the principal aim of ensuring long-term conservation of a balanced coverage of diversity of the crop genepool – both cultivated and wild – and also on the cost-benefit analysis of keeping more of specific parts of the genepool versus the biological limitations of their* ex situ conservation*. Requests to conserve, process or make available materials that do not meet the long-term conservation objective should be at the full expense of the requester.*	Recommendations 1 & 5
Multiplication & distribution of larger amounts of germplasm. Should users pay to obtain larger germplasm quantities?	*There may be a strategic need to multiply larger than normal amounts of germplasm for distribution of certain crops in specific situations. Distributing larger quantities of germplasm is not an* in perpetuity *need but should be considered as a strategic way of increasing use of diversity*	Recommendation 1: *Increasing value* component & Recommendation 7.
Distribution of germplasm beyond genebank materials. How should appropriate phytosanitary and policy measures be applied to the distribution of all CGIAR materials, including nurseries, other outputs of research, breeding programs, seed system work etc.?	*To comply with legal obligations under the Plant Treaty and for many other reasons, monitoring and reporting of the distribution of all germplasm from all CGIAR programs should be coordinated, fulfil common standards, and come under common phytosanitary and policy controls. All distributions are an important way of showing how CGIAR is contributing to non-monetary benefits. However, this function, while essential, should not necessarily be the responsibility of the future genebank system, though it will need to contribute to it.*	Recommendation 8
Genebank information management is limited and focussed on collection management. How should CGIAR genebanks invest in information management and resources?	*More investment is needed in information and data management at all levels of operation including in perpetuity operations. There are differences between what is required to support genebank processes and collection management on the one hand and the broader range of data needs to facilitate the use of the collections on the other. The genebanks are best placed to address the former but partnerships will be needed for the latter, which fits into Increasing Value. Unified information management is a key enabler for the consolidation of collections.*	Recommendation 2: All 3 components - *In perpetuity, Futureproofing collections* & *Increasing Value.*
Conservation research (seed longevity, dormancy) is not currently considered an essential operation but it is funded as a one-off activity under the Genebank Platform. It is the key means of improving efficiency	*Conservation research activities to improve the longevity of seed in storage, reduce rates of regeneration, increase viability monitoring intervals, improve the germination rate of seed exhibiting dormancy, address the recalcitrance of some species to conventional storage, production of seed of wild species, increase subculture period in tissue culture, etc. should be supported primarily at a collective level so that all genebanks can benefit from joint efforts to address similar problems and implementation of best*	Recommendation 2: *Futureproofing collections* (Conservation Innovation) & Recommendation 5.

Boundary area	GCO Panel recommendations	Relevant to
and addressing the difficulty of managing many seed collections, especially of crop wild relatives. How should CGIAR support the costs of conservation research to improve the efficiency of genebank processes and conservation activities?	*practice while being able to customize experiments and implementation to local conditions.*	
Rate, cost and success rate of regeneration varies widely among crops and genebanks. How should CGIAR set parameters for covering costs of regeneration?	*There should be an active effort to reduce the rate of regeneration. Regeneration should be based on clearly defined triggers (such as reduction of viability below an accepted threshold). From 2022, regeneration rates should be reduced to 5% or less for those genebanks that have reached performance targets. Regeneration is part of* in perpetuity *operations, but to the extent that backlogs remain or reappear in some genebanks they should be addressed by increasing regeneration through funding from other sources (Futureproofing Collections (Conservation innovation)).*	Recommendations 2, 4, 6
Maintaining genetic integrity of collections. How should CGIAR set parameters for covering costs of genotyping of genebank collections?	*There are two aspects of collection management that would be substantially improved using modern technologies to genotype accessions. Firstly, maintaining genetic integrity of accessions would be assisted with the use of low density genotyping to control quality during genebank processes. This would be a relatively low-cost application of genotyping, targeted only at accessions undergoing active processing. This should be part of in perpetuity operations, although to optimize procedures additional upfront investment may be required. Secondly, where cost-benefit analysis is supportive (e.g. it is very expensive to conserve accessions of clonal crops) it may be worth investing in more high-density genotyping to identify duplicate accessions and to assess new acquisitions to ensure that redundancy in the collection is minimized.*	Recommendation 2: *In perpetuity & Futureproofing collections* (Conservation innovation) & Recommendation 6
Evaluation of genebank collections. How should CGIAR set parameters for covering costs of genotyping and phenotyping collections to promote their use?	*This area of activity is critical to increasing the value and use of collections. However, it is neither possible nor desirable to evaluate all accessions for all traits, nor is it essential to guarantee diversity in perpetuity. Evaluation should be strategically targeted by crop and objective and designed to reveal the genes and available variants that determine current priority traits. As such, the work must be driven by demand and integrated with genotyping and genetic analysis. The specific roles of each genebank must be tailored according to the capacities and comparative advantages of the genebank and its partners in evaluation and genetic analysis.*	Recommendation 2: Increasing value
Automation may be appropriate where throughput is high and diversity is manageable. How could more be done to innovate in automation?	*Different types of automation may be relevant, and useful, especially to large, centralized collections. Large-scale facilities may be suited to automated seed counting, packing, storage and retrieval. Other forms of automation or remote management may be relevant on a wider scale. All forms should be considered only through careful cost-benefit analysis and piloting. Piloting and adopting*	Recommendation 2: *In perpetuity & Futureproofing collections* (Conservation innovation)

Boundary area	GCO Panel recommendations	Relevant to
	automation should be considered part of Conservation Innovation and maintained as an in Perpetuity operation.	
Clonal crop collections		
Genotyping for incoming materials to ensure new acquisitions add diversity and are not duplicates. How should CGIAR set parameters for covering costs of genotyping of clonal crop collections?	*Conforming with the recommendation above on genetic integrity, for expensive-to-conserve collections, genotyping new acquisitions should be a in perpetuity operation.*	Recommendation 2: *In perpetuity*
Medium term storage of specific crop species should be improved through protocol optimization & research (e.g. sweetpotato, yam). How should CGIAR support the costs of conservation research to improve the efficiency of genebank processes and conservation activities?	*It is recognised that support is needed particularly in improving protocols to conserve clonal crop collections and recalcitrant seed and trees. This is an essential activity to improve security, efficiency and to futureproof the collections.*	Recommendation 2: *Futureproofing collections* (Conservation innovation)
With time all cultures are susceptible to **declining viability and/or somaclonal variation.** What is the most cost-effective way of addressing declining viability and somaclonal variation?	*Periodic rejuvenation of accessions from tissue culture on a standard basis (based on risk assessment) should be part of routine operations.*	Recommendation 2: *In perpetuity*
Research on cryopreservation protocols from proof of concept to development of protocols for large-scale implementation (for crops beyond potato and banana). How should CGIAR support the costs of cryopreservation research?	*Research into, and improvement of, cryopreservation protocols are seen as priorities to improve the conservation status of clonal crop collections and potentially also of recalcitrant seed. Protocol research and refinement is a critical activity for the security and improved cost-efficiency of conserving clonal crops and recalcitrant species.*	Recommendation 2: *Futureproofing collections* (Conservation innovation) & Recommendation 5
Large-scale implementation of cryopreservation for large clonal crop collections. How should CGIAR support the costs of implementing cryopreservation?	*Large-scale implementation of cryopreservation follows the successful development of a cryopreservation protocol for a specific crop. While the introduction of a collection into cryopreservation is a major long-term investment and part of Conservation innovation, the ongoing maintenance of the cryobank and introduction of newly acquired accessions are considered to be part of Diversity in Perpetuity operations.*	Recommendation 2: *Futureproofing collections* (Conservation innovation) & Recommendation 5

Boundary area	GCO Panel recommendations	Relevant to
Freeze dried leaves provide an alternative to live germplasm when only DNA is required or when diseased germplasm cannot be distributed. They can also act as reference material. How should CGIAR support the costs of conserving lyophilised leaves?	*It would be worthwhile to measure the cost-benefits of preparing and distributing lyophilised leaves for research purposes instead of germplasm, based on the example provided by Alliance-Bioversity for Musa. Preliminary indications suggest that freeze drying leaves in the process of rejuvenating accessions would present a low cost alternative to providing living accessions for some research purposes.*	Recommendation 2: *In perpetuity*
Managing RTB crop wild relatives (CWR) in tissue culture is not ideal. Protocols to produce and conserve crop wild relatives are needed to improve coverage of crop genetic diversity. To what extent should CGIAR be conserving CWR of difficult-to- conserve crop species?	*The costs of producing and conserving long-term CWR of roots, tubers and bananas are considerable. This is an area where it would be worth investigating costs-benefits in more detail to determine to what level and which priority species should be conserved ex situ and where in situ or other methods may be preferable. The most obvious priority is to ensure that threatened CWR species are conserved. In the same vein, trees species for ex situ conservation should be prioritized according to the same kind of cost-benefit analysis. These activities are part of Futureproofing Collections.*	Recommendation 2: *Futureproofing collections* (Conservation innovation) & Recommendation 5
Permanent live plant collections (i.e. in field, greenhouse) are justifiable when accessions cannot be held in other forms. Can they be justified for other reasons (e.g. CIP potato, IITA cassava)? How should the costs of supporting live collections be covered?	*Diversity in Perpetuity operations should include only one primary active conservation method unless other methods are clearly explicitly justified*. If the only realistic, cost-effective long-term conservation method is in the form of a living plant, then this should be funded as a in perpetuity activity. Otherwise they may find space in *Futureproofing Collection*.	Recommendation 2: *In perpetuity &* Recommendation 6
Various **clonal crop collections or parts of collections** (e.g. yam, banana, Andean roots & tubers) remain unavailable because of quarantinable pathogens and processes are encumbered by phytosanitary bottlenecks. How can CGIAR make a significant difference to the phytosanitation specifically of clonal crop collections?	*It is apparent that phytosanitary bottlenecks are restricting not only the availability of some collections but also extending the time it takes for materials to be accessioned and made available, thus being a major factor in the cost-efficiency of long-term conservation. This is a major hurdle especially for less well-resourced crop collections. CGIAR should invest more in disease diagnostics research and cleaning to make real headway in removing bottlenecks and making accessions available. This should not be left to a cost-recovery mechanism. The costs of research, protocol optimization and large-scale implementation should be shared with other programs that use the GHUs. For genebanks, this activity would be part of Conservation Innovation, whereas routine testing and cleaning are properly in perpetuity operations.*	Recommendation 2: *Futureproofing collections* (Conservation innovation) & Recommendation 5

3.1.3 Recommendations on the structure and content of the genebank system

Recommendation 1. The activities of the genebanks, GHUs and associated enabling policy work is a unique global domain of CGIAR. The GCO Panel recommends that a sui generis, system-level approach is taken to the oversight, funding and management of the future genebank system, including policy and GHUs. The legal and moral obligations for long-term conservation of collections held in trust and the need to make them available to users worldwide, in particular, require that the program is considered on its own merits, rather than alongside, or as part of, CGIAR breeding and research activities.

Recommendation 2. CGIAR should recognise the significance of and need for distinguishing between three inter-related components of CGIAR's genebank system:

- **Guaranteeing diversity in perpetuity operations are the minimum activities required for CGIAR to fulfil its legal, moral and technical obligations to the international community and require clearly defined, protected, in perpetuity funding. Such activities are currently the main target for support from the endowment managed by the Crop Trust.**
- **Futureproofing collections & exchange includes three areas of work: (1) Conservation innovation, (2) System level alignment and expertise, and (3) Genetic Resources Policy and Germplasm Health, that contribute to the current and future effectiveness of CGIAR genebank system as a whole and likewise require protected funding.**
- **Increasing value activities have a wide-ranging scope and should be supported from multiple sources.**

Recommendation 3. The careful delineation of In perpetuity operations is an important aspect of supporting and managing the genebanks because it underpins the base funding of individual genebanks. The GCO Panel has reviewed what constitutes In perpetuity, Futureproofing and Increasing value operations and recommends a number of changes to take into consideration in determining future workplans and budgets for individual genebanks (Table 1). This is of particular relevance to the Crop Trust in targeting endowment funding and negotiating long-term partnership agreements.

3.2 Consolidation of collections and pursuit of cost-efficiencies

There are opportunities for pursuing greater efficiency both within individual genebanks and across the system. In individual genebanks, the recent technical reviews have considered such objectives in some depth in validating genebanks quality management systems. The Panel, therefore, considers that important gains can be made by fully responding to technical reviewers' recommendations.

In the current Genebank Platform, internationally recruited managers and specialists focus on the genebanks in which they are based. With greater cohesion in the management of the Centres under One CGIAR and one Executive Management Team, there is a tremendous opportunity to develop a yet stronger CGIAR genebank system in which specialist oversight and direction are provided at a system level so that practices and curation approaches may be aligned across multiple Centres. The existing efforts to bring multiple genebank data management systems onto the same software platform should be built upon and prioritized to ensure the effectiveness and applicability of one common data system and its role in

facilitating the consolidation of collections. The preliminary achievements in aligning the two CGIAR tropical forages collections, one at ILRI and the other Alliance in Colombia, are also indicative of the greater efforts that could be made in sharing approaches to managing and rationalizing collections of shared crops and even similar crops.

3.2.1 Recommendations on the consolidation of collections and pursuit of cost-efficiencies:

Recommendation 4. Individual genebanks should implement the recommendations of the genebank technical reviews as expeditiously as possible. Where required activities go beyond 2021, these costs should be included in the new genebank system as part of the Conservation Innovation activities in *Futureproofing collections & exchange*.

Recommendation 5. The Panel recommends that CGIAR's genebank system is brought under the responsibility of a single Director, who reports to the highest level within CGIAR (i.e. Executive Management Team). Expertise in specific areas (Figure 3) should be maintained or built at a system level rather than at a Centre level to provide leadership and alignment below the level of Director. A conscientious effort will be needed to ensure that leadership positions are implemented effectively at a system level and not in favour of any one Centre or crop, involving mechanisms to help build trust and learn from past experiences.

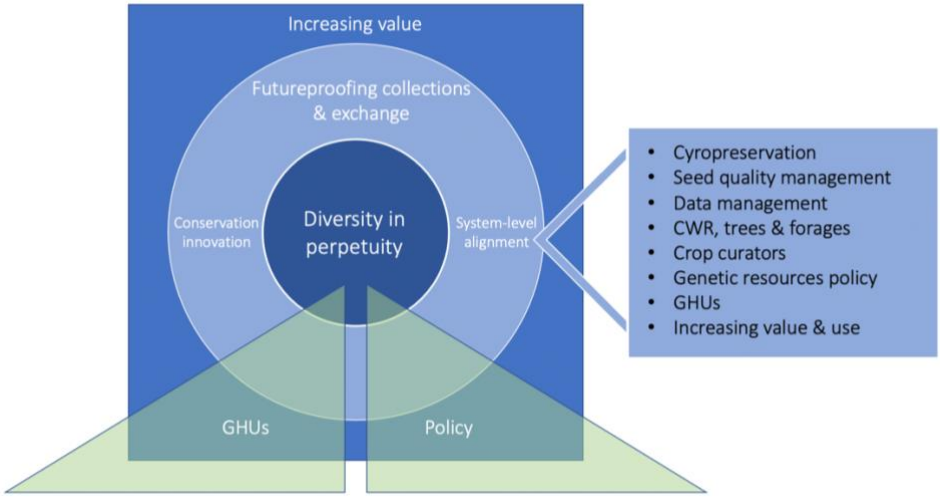


Figure 3. Components of the future genebank system with system level expertise

Recommendation 6. Collections should be strategically rationalized through reducing unnecessary duplication of accessions within collections, or of conservation forms or seed lots, and of accessions between collections. Logically this should focus, at least initially, on the crops with high per-accession conservation costs, where the potential for cost savings merit greater investment. The work should be in line with the framework currently being established to strategically curate collections and should be coordinated with activities to fill gaps in collections, with the broader objective of optimising the genetic composition of the collections as a whole. A single genebank should take responsibility for the long-term conservation of specific mandate crops or crop groups (even if the collection is physically held across more than one locations), involving carrying out conservation research, protocol optimization and balancing the composition

of CGIAR collection as a whole. Accession data on shared crops should be available and searchable by curators under a shared data management system.

3.3 Enabling CGIAR genebanks to play a catalytic role

Clearly there are numerous opportunities that CGIAR could take to enable the genebanks to have a stronger role in research and development programs within CGIAR and with partners outside CGIAR. One of the most obvious steps is to improve the information relating to the collections. More effort can be made to improve and make use of accession level data on geographic and environmental origins. However, the greatest gains are to be made in genotyping the collections on a large scale, starting with strategically selected subsets. There can be little justification for CGIAR to hold back on doing this given current costs and opportunities. Phenotyping of the genotyped subsets should be carried out in a more strategic way in partnership with upstream researchers and breeders.

Following this thinking, the proposed component of work on *Increasing value* of collections should support the generation and management of data to improve information on the collections and the genotyping of subsets and whole collections where possible. It should also provide seed money to the genebanks to be able to collaborate with researchers. However, success here will depend on strong collaboration and integration with other CGIAR programs.

The external face of the genebanks must not be forgotten. Currently more germplasm leaves CGIAR genebanks for users outside CGIAR than inside, and the scope for growth and impact in these external interactions is considerable. However, the current locations of CGIAR genebanks corresponds more closely to centres of diversity than to hotspots for use. For instance, there is increasing potential demand of diversity of Latin American origin (e.g. potatoes, cassava, sweetpotato, maize, etc) in Sub-Saharan Africa and Asia, and for other crops (e.g. forages, banana, yam, etc.) in the reverse direction. Some interesting opportunities open up, if CGIAR genebanks were to move towards a more multi-crop, regionalized modus operandi. Closer cooperation between hubs and national programs and CGIAR projects could potentially lead to a more dynamic exchange of genetic resources and information and improved responsiveness to specific needs. The technicalities of putting into operation such an approach are, however, complex – with the necessity to take into account existing capacities and the movement of germplasm across continents. There is a significant risk of only duplicating efforts rather than genuinely improving outreach. The Panel considers that more focussed analysis is needed to study different options, identify target areas, analyse risks and to pilot the approach. There are also some obvious steps that can be taken now.

3.3.1 Recommendations on enabling CGIAR genebanks to play a catalytic role:

Recommendation 7. The GCO Panel recommends that a detailed analysis is undertaken to examine the options for CGIAR to develop a network of regional hubs, either in existing facilities or in partnership with national or other programs, to support the exchange of crop genetic diversity, implementation of capacity building, and to undertake seed multiplication, health testing, policy compliance and other tasks on behalf of CGIAR programs and genebanks on a regionalized basis. In the interim, and as part of this exercise, in collaboration with CGIAR breeding and research programs, each target geographical region should be linked to a specific CGIAR genebank and/or partner institute, which should

be supported to engage with regional stakeholders to identify and address crop genetic diversity needs on behalf of the CGIAR genebank system.

Recommendation 8. Monitoring and reporting of the distribution (and acquisition) of all germplasm from all CGIAR programs should be coordinated, comply with common standards, and come under common phytosanitary and policy controls.

Recommendation 9. An assessment should be made of the need and possible modalities for expanding the plant genetic resources work beyond current mandate crops, including a study of how CGIAR should cooperate with other international and regional genebanks such as WorldVeg, CePaCT, CATIE, ICBA, SPGRC and possibly others.

3.4 Genebank system costs and funding

CGIAR genebanks operate relatively cost-effectively compared with benchmark institutes. The current rate of operation is high while genebanks are reaching performance targets but is expected to reduce for nearly all seed banks for the next programmatic phase. In contrast, clonal crop collections still have significant backlogs to tackle. Given the sizes, locations and histories of the genebanks and their management, there are justifications as to why each genebank costs what it does and operates the way it does. There are opportunities for gaining efficiency and implementing more standardized approaches but the largest potential gains, as conveyed above, are to be made across the system rather than within individual genebanks.

Post 2021, if CGIAR were to continue supporting the current 11 genebanks, GHUs and Policy Unit as one program, but focus management and expertise at a system level and rebalance priorities to support upscaled initiatives on cryobanking, GHUs, *Increasing Value*, the overall ringfenced funding required to support the future genebank system will remain roughly comparable with the current level of funding provided to the CGIAR Genebank Platform (Figure 4). However, carrying out a bolder transformation of the genebank system to centralize conservation activities and expand regionalized hubs would require more funding and detailed planning.

Figure 4a. Average allocation of annual funding to Genebank Platform activities in the Genebank Platform 2017-2019 (USD x 1,000; total USD 28 million)

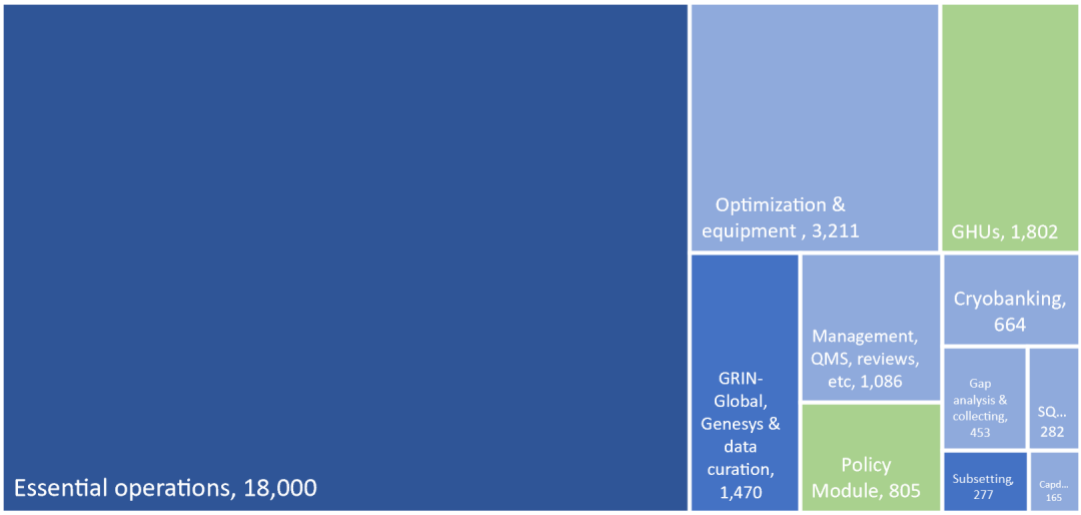
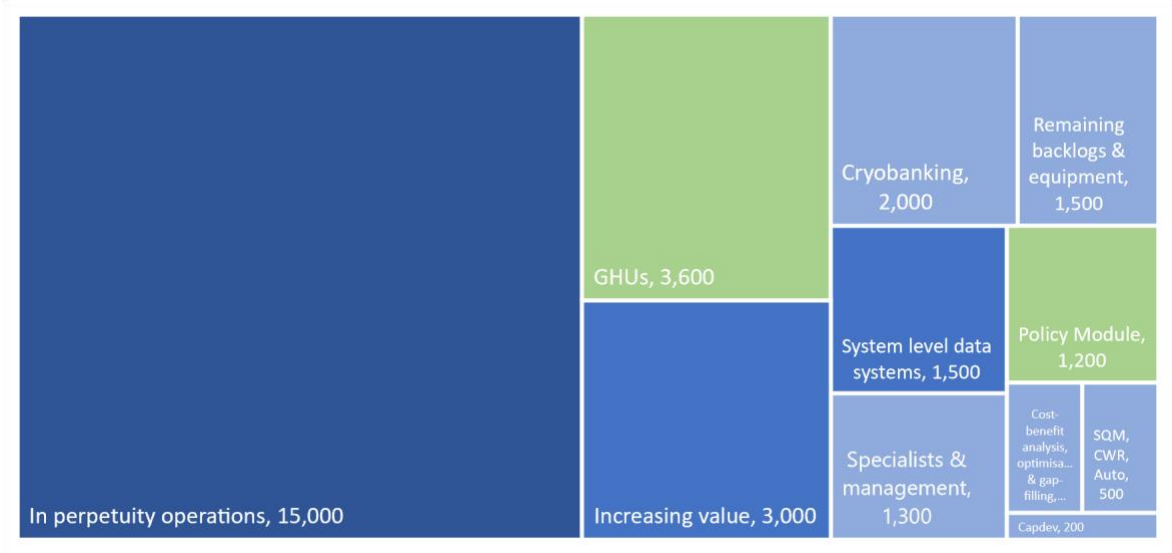


Figure 4b. Suggested rebalancing of allocations (USD x1,000: total USD 30 million)



The Panel was informed that the Crop Trust will remain an important donor, committed to continue funding the existing nine long-term grants (LTG) and one long-term partnership agreement (LPA) with CGIAR Centres after 2021, currently totalling USD 3.7 million. However, this amount will increase over the next few years as new LPAs are negotiated upon individual genebanks reaching target performance standards. Furthermore, the Crop Trust will continue its role of monitoring performance standards, managing Genesys, and other activities that contribute to CGIAR's genebank system. It will also continue to support projects and seek funding for new projects that involve CGIAR genebanks and research partners.

Table 2 provides a more detailed breakdown of the annual costs of the current CGIAR Genebank Platform compared to future indicative costs and potential funding sources.

Table 2. Breakdown of current and future indicative costs of CGIAR's genebank system and their potential funding sources

	Component	Breakdown	Indicative annual cost (US '000s)		Potential funding source	Assumptions
			2017-2019 average	2022+		
A	Diversity in perpetuity	11 genebanks	18,000	15,000	• Crop Trust: pending individual genebanks reaching performance targets approx USD 5 million from endowment from 2022 and increasing over time • CGIAR: pooled funding to cover remaining amount	• Standardized implementation of financial guidelines • Centralization of management & specialist staff • Rationalization of activities & rate of operation in some genebanks • Additional costs in some genebanks
		SUBTOTAL	18,000	15,000		

	Component	Breakdown	Indicative annual cost (US '000s)		Potential funding source	Assumptions
			2017-2019 average	2022+		
B	Futureproofing: Conservation Innovation	Backlogs & equip Cryobanking Seed quality mngt Collecting SUBTOTAL	3,200 700 300 450 4,650	1,500 2,000 500 500 4,500	• Traditional window 2 donors • Crop Trust projects • CGIAR: pooled funding to cover remaining amount	• Less need to support processing of backlogs • Implementation of system-level projects
	Futureproofing: System consolidation	Specialists & mngt SUBTOTAL	1,100 1,100	1,300 1,300	• Traditional window 2 donors • CGIAR: pooled funding to cover remaining amount	• Centralization of management & specialist staff • Any costs of movement of collections, refurbishing facilities, building capacity is covered from additional funding.
	Futureproofing: GHUs & Policy	GHUs Policy Unit SUBTOTAL	1,800 800 2,600	3,600 1,200 4,800	• Traditional window 2 donors • CGIAR: pooled funding to cover remaining amount	• Per unit cost of processing samples in GHU is covered from relevant budgets (genebanks & breeding programs)
C	Increasing value	Data mngt SUBTOTAL	1,500 1,500	1,500 1,500	• Full range of donors • Crop Trust projects • CGIAR: pooled funding to cover remaining amount	• Crop Trust covers the costs of maintaining Genesys web portal • Shared data management system is fully adopted
		Increasing value SUBTOTAL	300 300	3,000 3,000	• Full range of donors • Crop Trust projects • CGIAR projects	• USD 3 m is suggested minimum amount required but scope could be much greater depending on collaboration & project development • Does not include the potential costs of implementing or sustaining a transformed system with regionalized hubs
		Capacity dev	150	200	• Full range of donors • Crop Trust projects • CGIAR projects	• USD 200K is suggested minimum amount required

	Component	Breakdown	Indicative annual cost (US '000s)		Potential funding source	Assumptions
			2017-2019 average	2022+		
		SUBTOTAL	150	200		but scope could be much greater.
	Grand total		**28,300**	**30,300**		

3.4.1 Recommendations on Genebank Platform costs and funding:

Recommendation 10. A mechanism is required to ensure that individual Centres' accounting methods do not impinge differentially on the genebank operating budgets as they do at present. Strong system-level financial guidelines and standardization, particularly of the application of cost recoveries, is critical to the future pursuit of cost-efficiencies and to genebank operations generally.

Recommendation 11. The level of funding required by the new genebank system will depend on the detailed objectives and activities, the point of interface with other CGIAR programs and on decisions on the development of regional hubs, expanding mandates and concentration of resources at the system-level. Whatever decisions are made, the GCO Panel recommends that the overall funding for the three components described in this report is not less than current levels provided to the Genebank Platform.

3.5 Role of CGIAR in the global system

CGIAR genebanks are a keystone within the global system, working under a shared policy framework, the Global Plan of Action, shared scientific standards (e.g. FAO Genebank Standards) and the Plant Treaty's Global Information System (GLIS). In other words, CGIAR genebanks are far from isolated in their endeavours and many other participants in the global system rely heavily on them. They are very much in the public eye. While the CGIAR Genebank Platform Policy Unit ensures that CGIAR as a whole engages positively within this system and complies with policy obligations, much more could be done to strengthen the global system and build on potential synergies.

3.5.1 Recommendations on the role of CGIAR in the global system:

Recommendation 12. CGIAR should continue to work closely with the Crop Trust, and the Secretariat and Governing Body of the Plant Treaty to refine institutional roles and responsibilities within the evolving global system. As a first step, this report should be formally brought to the attention of the Governing Body. In its planning and implementation, CGIAR should take into account the need to:

i. **Contribute to and strengthen the Plant Treaty's Global Information System;**
ii. **Communicate and support the concepts of multilateral access and benefit sharing and farmers' rights in all aspects of CGIAR work;**
iii. **Convene dialogues and studies to further strengthen the global system;**
iv. **Maintain agreed performance targets and the obligations of Article 15 agreements with the Plant Treaty and long-term grants and partnership agreements with the Crop Trust;**
v. **Strengthen subsidiarity and devolve functions that are most appropriately the responsibility of national genebanks or others.**

Recommendation 13. A standing oversight panel[9] should be established by CGIAR with representation from the EMT, CGIAR Board, Crop Trust, Plant Treaty Secretariat, funders and two, or preferably more, external experts. Such a panel would provide guidance on CGIAR's continuing role, future direction, collaboration and policy compliance and engagement within the global system.

Recommendation 14. There is a compelling need to ensure low income countries can benefit from CGIAR's genebank system and be supported to make use of the crop genetic diversity and information that CGIAR makes available. This involves building the capacity of scientists and breeders as well as national genebanks and facilities. This should be seen as a moral imperative and key element of benefit sharing under the Plant Treaty and should be highlighted as such.

Recommendation 15. An effort needs to be made to scale up awareness raising, communications and publicising facts and stories to convey impact in support of the genebanks. This effort should cater to multiple target audiences across geographical regions and be developed in coordination with other relevant CGIAR communications. Genebanks and GHUs need direct support in communicating their role and value to both potential users and to collaborators and donors.

Conclusions

There is little doubt that the contribution of crop genetic diversity to helping solve current and future challenges can only increase. The current CGIAR collections represent a major global asset that has been entrusted to CGIAR for safekeeping, both for its own use and as an international public good. There is thus both a moral and legal obligation to maintain the materials in these collections securely for the long term and to make them readily available.

Technological advances are opening up new and exciting possibilities both for increasing the efficiency and effectiveness of conservation as well as for enhancing the value and potential use of the collections. It is important that CGIAR stay at the forefront in both areas and this will require continued investment in research and in the application of new technologies to genebank operations. One CGIAR also offers substantial opportunities for ensuring the work of the genebanks delivers greater impact. The creation of a unified CGIAR genebank system under a single leader would contribute to tackling current inefficiencies, a significant number of which are due to fragmentation, duplication and a diversity of approaches. Under such a programme it would become feasible to think of combining certain collections and even creating regional multi-crop distribution hubs.

The proposed categorization of genebank operations into three areas, *Guaranteeing diversity in perpetuity*, *Futureproofing of collections and exchange* and *Increasing value*, provides a template for allocating funds to essential operations. While implementing the recommendations contained in this report is not going to result in reduced costs overall,

[9] A model is provided in a previously established Genetic Resources Policy Committee under the Systemwide Genetic Resources Program

taking the direction proposed will increase efficiencies and effectiveness in the long term and should result in a significantly greater impact per dollar invested.

CGIAR genebanks do not work in isolation but are a key element of the global system. Through working in partnership with other international and national institutions, public and private, and especially the Plant Treaty, the impact of CGIAR's work can be greatly multiplied. Helping strengthen the international policy environment, building national capacity and even possibly extending the range of crops in which CGIAR is directly or indirectly involved, are all ways in which CGIAR can contribute to making sure the full range of plant genetic resources that underpin both current and future agriculture and food security are fully safeguarded and remain available for use long into the future.

The Panel would like to thank all those who have contributed time and ideas to our work and we hope the report will prove useful in helping steer future developments in this critically important area.

Annex 1 CGIAR genebanks and holdings

Centre	Crops	Total accessions
AfricaRice	Rice	21,300
Alliance-Banana	Banana	1,617
Alliance-CIAT	Beans, cassava, tropical forages	66,787
CIMMYT	Maize, wheat	184,071
CIP	Potato, sweetpotato, Andean roots and tubers	17,830
ICARDA	Dryland cereals, grain legumes, temperate forages	140,111
ICRAF	Trees	14,702
ICRISAT	Sorghum, millets, grain legumes	128,446
IITA	Cowpea, maize, legumes, banana, cassava, yam	34,775
ILRI	Tropical forages	18,662
IRRI	Rice	132,166
Grand total		**760,467**

Annex 2 Panel members of the System Level Review of Genebank Costs and Operations (GCO)

Geoffrey (Geoff) Hawtin

Geoff is an expert in agricultural biodiversity and the conservation and use of plant genetic resources. He was founding Director of the Crop Trust and has been Director General of both Bioversity International and CIAT, as well as Deputy DG of ICARDA. He has served on the CGIAR System Management Board and chaired or co-chaired the Boards of Trustees of CIAT, the Bioversity-CIAT Alliance and CATIE. He has served on the Board of Kew Royal Botanical Gardens and in 2017 was awarded Officer of the Order of the British Empire (OBE) for services to Global Agrobiodiversity Conservation, Subsistence Livelihood Enhancement and Sustainable Food Programmes.

Sonja Vermeulen

Sonja is Director of Programs at the CGIAR System Organization, leading on coordination of the delivery, performance and results of the shared CGIAR research portfolio, plus future strategies for effective agricultural research for development.

She previously served as Global Food Lead Scientist at WWF International, Head of Research at CGIAR's Research Program on Climate Change Agriculture and Food Security (CCAFS), Director of Business and Sustainable Development at the International Institute for Environment and Development (IIED), and Research Fellow at the University of Zimbabwe. She is also an Associate Fellow at the Hoffmann Centre for Sustainable Resource Economy at Chatham House, and was a Commissioner on the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems.

Kent Nnadozie

Kent is the Secretary of the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture. Prior to his appointment as Secretary, he was the Senior Officer at the Secretariat, overseeing various technical areas of the Programme of Work. Over the last decade, he has worked on legal and policy matters and intergovernmental processes, with both the Plant Treaty and FAO's Commission for Genetic Resources for Food and Agriculture. Before joining FAO, Mr Nnadozie was in private legal practice and academic research. He has extensive practical experience in related international processes and legal instruments.

Álvaro Toledo

Álvaro is an agricultural engineer with a specialization in crop sciences and plant genetic resources. He has worked for FAO since 2002 in the area of agricultural biodiversity for sustainable development. In the Plant Treaty Secretariat, he provides technical and policy leadership to the processes to enhance the functioning of the Multilateral System on Access and Benefit-sharing and the Plant Treaty's Funding Strategy. He is also responsible for overseeing the operations of the Benefit-sharing Fund. Prior to joining the Plant Treaty Secretariat, he worked within the Secretariat of the Commission on Genetic Resources for Food and Agriculture where he helped develop its first multi-year programme of work covering not only plant and animal genetic resources, but also forest and aquatic genetic resources, as well as micro-organisms and invertebrates for food and agriculture.

Mellissa Wood

Mellissa has 30 years' experience leading and funding rural research and representing the Australian Government through leadership roles in international agricultural research and development sectors, including the CGIAR.

Recently retired as ACIAR's General Manager, Global Programs, she was previously the Director of the Australian International Food Security Centre (AIFSC). She led ACIAR's engagement with global and multilateral fora as well as co-investments alliances in Africa, including 'Cultivate Africa's Future'. She was Alternate Member for Australia on the CGIAR System Council for five years, System Council representative on the CGIAR System Management Board and Chair of Asia Pacific Association of Agricultural Research Institutes (APAARI). Prior to joining ACIAR, Mellissa was a Director at the Global Crop Diversity Trust, working with FAO and CGIAR on the conservation and access of plant genetic resources. Her background includes 15 years at the Bureau of Rural Sciences providing scientific advice on natural resource management to Federal Department of Agriculture, Fisheries and Forestry and Landcare.

Luigi Guarino

As Director of Science, Luigi oversees the Crop Trust's Science Team. Luigi co-authors one of the most eminent Twitter accounts and blogs on crop diversity conservation in the world.

He previously worked at the Secretariat of the Pacific Community in Fiji, where he coordinated and managed a regional network for the Pacific Island countries and territories. He coordinated Bioversity International's global research agenda on measuring, locating and monitoring genetic diversity, with responsibility for the application of GIS at the Bioversity Regional Office for the Americas in Colombia. He also managed Bioversity's work on germplasm use in the region, including research on patterns of use of *ex-situ* collections. He had responsibility for national and regional programme development in the Caribbean sub-region. He has worked on diverse genetic diversity issues at Bioversity International's Sub-Saharan Africa Group in Nairobi, Kenya and as a consultant for FAO and IBPGR, working in the South Pacific and Middle East.

Charlotte Lusty

Charlotte is the Head of Programs and CGIAR Genebank Platform Coordinator, coordinating the Crop Trust's work to oversee the technical and financial management of the CGIAR genebanks. Between 2008 and 2012, she worked on a Bill and Melinda Gates Foundation project, managing projects with more than 40 countries to implement a massive rescue effort for the conservation and availability of crop diversity.

Before joining the Crop Trust, Charlotte was Scientist, at Bioversity International where she developed and coordinated projects and strategies and carried out impact assessment work on banana, cacao and coconut. Key roles include developing the Global Conservation Strategy for Musa (banana) and a HarvestPlus Challenge Programme initiative to address micronutrient-deficiencies with high-provitamin A banana cultivars.

Ruaraidh Sackville Hamilton

Ruaraidh Sackville Hamilton is retired principal scientist at the International Rice Research Institute, where he headed the T.T. Chang Genetic Resources Centre team for 17 years. His expertise in the hands-on management and use of plant genetic resources is matched with an acute knowledge of international plant genetic resources policy and law, and he represented IRRI and CGIAR in various international arena such as the International Treaty on Plant Genetic Resources for Food and Agriculture. In 2018, Ruaraidh was awarded the Crop Trust Legacy Award.

Janet Muir

As the Director of Finance at the Crop Trust, Janet manages the financial operations of the Crop Trust, which includes financial reporting, management reporting, strategic financial planning and investment management, supervision of income, treasury functions, operational expenses and grant awards. She has more than 15 years of management experience in the Irish university and international public sectors. She has held financial positions with the University of Dublin (Trinity College), Interactive Services Limited, Lidl GmbH and Ernst & Young.

Annex 3 Background papers to the GCO review

Available at: https://www.genebanks.org/news-activities/news/chatham-house-dialogue/

Paper 1. Summary of the findings of CGIAR genebank financial reviews and reported expenditures (prepared by Crop Trust)

Paper 2a. CGIAR genebank profiles 2020 (prepared by CGIAR genebank managers)

Paper 2b. CGIAR Genebank Platform (prepared by CGIAR Management Team)

Paper 3. Germplasm health units (prepared by GHU leaders)

Paper 4[10]. Scope and roles of the CGIAR genebanks: 2030 vision (prepared by Dr Ruaraidh Sackville Hamilton)

Paper 5. Genebank essential operations (prepared by Crop Trust)

[10] *N.B. Paper 4 is the same as Stimulus paper 2*

Annex 4 Stimulus papers to the Chatham House Dialogue

Available at: https://www.genebanks.org/news-activities/news/chatham-house-dialogue

Stimulus paper 1. How may food systems evolve: looking ahead in an uncertain world (prepared by Prof Tim Benton)

Stimulus paper 2. Scope and roles of the CGIAR genebanks: 2030 vision (prepared by Dr Ruaraidh Sackville Hamilton)

Annex 5 Chatham House Dialogue participants

Alexander Schöning	Advisor, Deutsche Gesellschaft für Internationale Zusammenarbeit
Aly Abousabaa	Director General, ICARDA
Andrew Jarvis	Associate Director General for Research, Strategy and innovation, The Alliance of Bioversity International and CIAT
Anke van den Hurk	Deputy Director, Plantum
David Jordan	Professor in Crop Breeding and Genetics, University of Queensland
Douglas Gollin	Professor of Development Economics, University of Oxford
George Bigirwa	Deputy Vice President for Programme Innovation and Delivery, Alliance for a Green Revolution in Africa (AGRA)
Gigi Manicad	Senior Consultant, Manicad Development Consultancy
Jessica Fanzo	Bloomberg Distinguished Professor of Global Food & Agricultural Policy and Ethics, Johns Hopkins University
Jonathan Drori	Ravensbourne University
Kuldeep Singh	Director, Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources
Michael Abberton	Head of the Genetic Resources Center, International Institute of Tropical Agriculture (IITA)
Pierre du Plessis	Technical Advisor to the African Union Continental Coordinating Committee on Matters Related to Biodiversity, Biosafety and ABS
René Castro-Salazar	Assistant Director General, Food and Agriculture Organization of the United Nations (FAO)
Robert Bertram	Chief Scientist, United States Agency for International Development's Bureau for Resilience and Food Security
Rodomiro Ortiz	Professor of Genetics & Plant Breeding, Swedish University of Agriculture Sciences (SLU)
Stefan Schmitz	Executive Director, Crop Trust
Steffen Entenmann	Advisor, Deutsche Gesellschaft für Internationale Zusammenarbeit
Susan McCouch	Professor of Plant Breeding and Genetics, Cornell University & Chair DivSeek International
Tim G. Benton	Research Director-Emerging Risks & Director-Energy, Environment and Resources Programme, Chatham House
Tony Cavalieri	Senior Program Officer, Bill and Melinda Gates Foundation
Tony Simons	Director General, ICRAF & Executive Director, CIFOR-ICRAF
Wanjiru Kamau-Rutenberg	Director, African Women in Agricultural Research & Development (AWARD)
Yasmina El Bahloul	Head of Breeding and Genetic Resources Conservation, National Institute for Agricultural Research (INRA) Morocco & Chair, Governing Body International Plant Treaty
Panel members - System level review of CGIAR genebank costs and operations (GCO Review)	
Alvaro Toledo	Deputy Secretary, Plant Treaty
Charlotte Lusty	Head of Programs Crop Trust & Coordinator, CGIAR Genebank Platform
Geoffrey Hawtin	Independent Consultant
Janet Muir	Director of Finance, Crop Trust
Kent Nnadozie	Secretary, Plant Treaty
Luigi Guarino	Director of Science, Crop Trust
Mellissa Wood	Independent Consultant, Mellissa Wood Consulting
Ruaraidh S. Hamilton	Independent Consultant
Sonja Vermeulen	Director of Programs, CGIAR System Management Organization

Annex 6 Timeline of review discussions

Date of Call	Agenda	In attendance
24 April	• Feedback on the objectives and contents of the shared paper • What's missing? Additional panel members, consultations or papers? • Coordinate timeline with One CGIAR discussions	Geoff Hawtin, Charlotte Lusty, Janet Muir, Luigi Guarino, Jamie Craig, Alvaro Toledo, Kent Nnadozie, Mellissa Wood, Sonja Vermeulen and Ruaraidh S. Hamilton
9 June	• Informing those who need to know about the review • Feedback from call with Chatham House • Proposed background papers for review	Geoff Hawtin, Charlotte Lusty, Janet Muir, Luigi Guarino, Jamie Craig, Alvaro Toledo, Mellissa Wood, Sonja Vermeulen and Ruaraidh S. Hamilton
1 July	• Feedback on Vision paper by Ruaraidh Sackville Hamilton • Timeline, planning of consultations and paper 2 template • Feedback on Chatham House and One CGIAR process	Geoff Hawtin, Charlotte Lusty, Janet Muir, Luigi Guarino, Jamie Craig, Alvaro Toledo, Kent Nnadozie, Mellissa Wood, Sonja Vermeulen and Ruaraidh S. Hamilton
15 July	Focus on the planning for the Chatham House sessions: • Update on discussions with Jon Drori and Chatham House • Overall objective and desired outcome, Key outputs • Target audience, Participants, Timing • Format and foci of discussions • Facilitation and Involvement of Chatham House	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Mellissa Wood, Janet Muir, Ruaraidh S. Hamilton and Kent Nnadozie
30 July	• Feedback on discussion with Chatham House – confirm sessions, papers and outputs • Proposed Chatham House Dialogue participants • Change of dates for Chatham House sessions and GCO Panel consultations and discussions • GCO Panel – proposed consultations	Geoff Hawtin, Charlotte Lusty, Jamie Craig, Alvaro Toledo, Mellissa Wood, Ruaraidh S. Hamilton and Kent Nnadozie
25 Aug	• Update on Chatham House Plans and dates • Draft Background papers • GCO Panel draft agenda and dates	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Alvaro Toledo, Mellissa Wood, Sonja Vermeulen, Ruaraidh S. Hamilton
8 Sept	• Share Papers 1, 2, 2a, 2b, 3, 4 and 5 with the Panel • Present Papers 1 and 5 in order to prepare for the Panel consultations later in the month. • More details on the Chatham House Sessions, key questions for breakout groups and the draft Stimulus Paper on Future Scenarios for Session 1 to be presented by Tim Benton.	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Jamie Craig, Alvaro Toledo, Mellissa Wood, Sonja Vermeulen, Ruaraidh S. Hamilton and Kent Nnadozie

Date of Call	Agenda	In attendance
21 Sept	Chatham House Session 1	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo, Kent Nnadozie, Sonja Vermeulen, Mellissa Wood and Ruaraidh S. Hamilton
22 Sept	Chatham House Session 2	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo, Kent Nnadozie, Mellissa Wood and Ruaraidh S. Hamilton
23 Sept	Chatham House Session 3	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo, Kent Nnadozie, Mellissa Wood and Ruaraidh S. Hamilton
24 Sept	GCO Panel Discussions	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo, Mellissa Wood and Ruaraidh S. Hamilton
28 Sept (AM)	• GCO Panel discussions • Consultations with Policy and GHU	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo, Mellissa Wood and Ruaraidh S. Hamilton
28 Sept (PM)	• GCO Panel discussions • Consultations with DGs & Research DDGs, Genebank Managers, Clonal CoP	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo and Ruaraidh S. Hamilton
29 Sept	• GCO Panel discussions • Drafting recommendations	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Alvaro Toledo, Mellissa Wood, Sonja Vermeulen and Ruaraidh S. Hamilton
16 Oct	Discussions on: • first draft of the GCO report • finalization of the report and next steps	Geoff Hawtin, Luigi Guarino, Charlotte Lusty, Janet Muir, Kent Nnadozie, Alvaro Toledo, Mellissa Wood, Sonja Vermeulen and Ruaraidh S. Hamilton

List of abbreviations and acronyms

Alliance-Bioversity/CIAT	The Alliance of Bioversity International and CIAT, Italy & Colombia
BMZ	The Federal Ministry of Economic Cooperation and Development, Germany
CATIE	Tropical Agricultural Research and Higher Education Center, Costa Rica
CePaCT	Centre for Pacific Crops and Trees, The Pacific Community, Fiji
CIMMYT	The International Maize and Wheat Improvement Center, Mexico
CIP	The International Potato Center, Peru
CoP	Community of Practice
Crop Trust	Global Crop Diversity Trust, Germany
CWR	Crop Wild Relatives
DDG	Deputy Director General
DG	Director General
DNA	Deoxyribonucleic acid
EMT	CGIAR Executive Management Team
FAO	Food and Agriculture Organization of the United Nations, Italy
GCO	System Level Review of Genebank Costs and Operations
GHU	Germplasm Health Unit
GLIS	Global Information System of the Plant Treaty
GRIN-Global	Germplasm Resource Information Network Global
ICARDA	International Center for Agricultural Research in the Dry Areas, Lebanon
ICBA	International Center for Biosaline Agriculture, United Arab Emirates
ICRAF	World Agroforestry, Kenya
ICRISAT	The International Crops Research Institute for the Semi-Arid Tropics, India
IITA	International Institute of Tropical Agriculture, Nigeria
ILRI	International Livestock Research Institute, Ethiopia
IRRI	International Rice Research Institute, Philippines
LPA	Long-term partnership agreement
LTG	Long-term grants
MOPAN	Multilateral Organisation Performance Assessment Network
Plant Treaty	International Treaty on Plant Genetic Resources for Food and Agriculture
QMS	Quality Management Systems
RTB	CGIAR Research Program on Roots, Tubers and Bananas
SPGRC	SADC Plant Genetic Resources Center, Zambia
SQM	Seed Quality Management
sRNA	small RNA
WorldVeg	World Vegetable Center

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