Crop Diversity, Its Conservation and Use for Better Food Systems

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1 The Loss of Agrobiodiversity and Its Risks

Climate change, biodiversity loss and the food system crisis are among the major challenges of the twenty-first century, and they are closely interrelated. Climate change is threatening the survival of species and affecting crop yields, for example, and the destruction, degradation and fragmentation of ecosystems is accelerating climate change, driving biodiversity loss and affecting food security.

Biodiversity loss includes the depletion of ecosystem diversity, of species diversity and of genetic diversity within species. One of the strongest drivers of biodiversity loss is agriculture, for example, the conversion of forests and peatlands into arable land. However, there is also a loss of biodiversity within agriculture, for example:

- Loss of species diversity on agricultural land, both the number of crop and livestock species themselves and those of associated biota (e.g., weeds, soil microorganisms, pollinators) due to the use of fertilizers, herbicides and pesticides.
- Loss of genetic diversity within crop and livestock species, or genetic erosion, as the result of modern agricultural practices.

Agriculture is thus both the culprit and the victim.[1]

This loss of crop diversity poses a considerable risk to global food security. This is because the genetic diversity of cultivated plant species, and their wild relatives, is the raw material of crop improvement. It has been thousands of years since the

[1] After these introductory remarks on the entire range of agricultural genetic resources, i.e., plant, animal, etc., only the partial aspect of plant genetic resources will be pursued in the following.

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J. von Braun et al. (eds.), *Science and Innovations for Food Systems Transformation*,
https://doi.org/10.1007/978-3-031-15703-5_29

advent of agriculture, and the need for it will only grow. The pressures on agriculture will increase in the future. The world population continues to grow, and grows richer and more demanding in the process. The climate is changing and, with it comes the likelihood of crop failure, including due to the emergence of new pests and diseases.

Meeting these challenges will only be possible if the genetic diversity contained in crops and their wild relatives remains available for use. This genetic diversity is the foundation of tomorrow's agriculture, allowing farmers and professional breeders to develop the new crop varieties that agriculture needs to adapt to changing conditions. The development of new varieties will be necessary for successful adaptation to climate change, and thus to secure the world's food supply in the future (Hawtin and Fowler 2012).

The maintenance of agrobiodiversity in situ, i.e., in nature and agricultural practice, remains indispensable, and is a task for protected areas and on-farm conservation efforts (Vincent et al. 2019). However, given the risks associated with this strategy, a second approach must be pursued consistently in parallel: the conservation of agrobiodiversity *ex situ* in genebanks.

2 Why *Ex-Situ* Conservation?

In view of the dramatic risk of loss of plant genetic diversity in nature and agricultural practice, its rescue before it is irretrievably lost is imperative. However, *ex-situ* conservation would make sense from a use point of view, even if there were no genetic erosion going on in the field at all.

This is because it would be tremendously complicated and expensive if, every time a plant breeder needed new genetic diversity, new material had to be collected from the wild or from farmers' fields, often in distant countries. It is true that there are many breeders who maintain their own working collections of germplasm, for short-term purposes. But there are clearly considerable efficiencies to be gained from collective efforts to build more comprehensive collections for long-term use in centralized genebanks at the national, regional and international levels. Such efforts are being made around the world, usually with the support of governments, and sometimes the international community. The values of conserving collections of plant genetic resources in genebanks are diverse and considerable (Hawtin and Fowler 2012):

- Having invested in collecting plant material from the wild or from farmers' fields – an expensive exercise – the cost of maintaining it in a genebank is often small by comparison.
- Samples are available from genebanks throughout the year, unlike plants growing in the wild or on farmers' fields that can generally only be collected in certain periods of the year, such as at harvest time.

- Genebanks are generally able to supply adequate quantities of good quality seed for research and breeding purposes. It is often difficult to collect adequate numbers of seeds of good quality from plants growing in the wild.
- Genebanks are generally able to supply samples that are free from pests and diseases. It is much harder to guarantee the health of material collected in the wild.
- Collections maintained in well-run genebanks remain genetically stable over time, unlike varieties maintained by farmers or populations under in situ conditions. This facilitates research and the generation of reliable information about samples, which, in turn, encourages their use in breeding programs.
- Genebanks offer a "one-stop" shop. Breeders are able to access a large range of diversity, often from many different countries, with a single request.
- Well-run genebanks have the facilities, administrative systems and experience not only to maintain samples, but also to distribute them nationally and internationally.
- Well-run *ex-situ* collections have reliable and readily available passport, characterization and evaluation data on samples, and, increasingly, data at the molecular level. Such data are critical to the ability of users to make informed choices about which materials to request, and how to use them.
- Over time, collections become ever more valuable as the data on the material in them become more comprehensive. Useful comparative data can be built up and made available for sets of samples grown across multiple environments.
- *Ex-situ* collections provide a "safety net" – a last resort – that enables locally adapted varieties and/or specific traits to be reintroduced into farming systems after they have been lost due to natural or human-induced disasters.

3 Status of *Ex-Situ* Conservation

The latest available data suggest that there are more than 1750 genebanks worldwide, of which about 130 hold more than 10,000 accessions each (FAO 2010). They are located on all continents barring Antarctica, though there are relatively few in Africa compared to the rest of the world. While it is estimated that about 7.4 million accessions are maintained globally, it is probable that, at most, only between 25% and 30% of these are unique, with the remainder being duplicates held either in the same or a different genebank. Clearly, there is a need for a measure of rationalization within and among collections (Hawtin and Fowler 2012).

While the majority of large collections are maintained at the national level, international collections are critically important because of their size and coverage, the availability of information on their contents and the ease of obtaining samples. Eleven of the CGIAR centers manage germplasm collections on behalf of the world community under Article 15 of the Plant Treaty, and, of these, the collections maintained by CIMMYT, ICARDA, ICRISAT and IRRI each comprises more than 100,000 accessions. Collectively, the CGIAR centers maintain more than

730,000 accessions of 3,000 species from 500 different genera. National genebanks managing more than 100,000 samples include those of Brazil, Canada, China, Germany, Japan, India, Russia, South Korea and the USA.

4 What Remains to Be Done

Unfortunately, many genebanks, especially in the Global South, are unable to guarantee the safety of the material they are responsible for, and valuable collections may be in jeopardy because their storage conditions and management are suboptimal. Further, the purpose of genebanks is clearly not just to conserve diversity, but also to create opportunities for plant breeding and more sustainable agriculture, i.e., for said diversity to be used. Much remains to be done. We focus here on three key interventions:

1. Strengthening the global system of *ex-situ* conservation
2. Making the global system fit for the purpose of caring for hard-to-conserve materials
3. Innovative funding of the global system

4.1 Towards a Stronger Global System of **Ex-Situ** *Conservation*

International and national genebanks operate within a worldwide community, or global system, that is made up not only of the institutes managing genetic resources, but also of a global plan of action, various technical standards, regional and crop networks and other instruments, all underpinned by the policy framework provided by the Plant Treaty, the Convention on Biological Diversity, the International Plant Protection Convention and the FAO Commission on Genetic Resources for Food and Agriculture.

The Crop Trust works with all parts of this community and has a unique role in helping to strengthen the global system so that it may become more effective, rationalized and collaborative. There are four main ingredients to strengthening the global system:

- A critical component in making the global system work is the availability of good quality data. It is only through good data that we know what is conserved, where and whether it is alive and available for use. Genesys, the online portal for accession-level data, provides a means for genebanks worldwide to share passport and characterization data on their collections, as part of the Plant Treaty's Global Information System. For such systems to reach their potential, genebanks require support to manage and share their data. For that reason, GRIN-Global

Community Edition is being developed for adoption by any genebank to help manage their data and their collections, and to build linkages with diverse data resources and systems that can enrich data holdings and help promote the use of diversity.

- Good quality data is intimately related to good operational practices and quality management. The Crop Trust, with CGIAR, has been developing a genebank quality management system (QMS) framework. Based on FAO genebank standards, the genebank QMS supports the documentation, review, improvement and sharing of genebank operations and practices. It provides a supportive tool for training and staff succession and an excellent vehicle for strengthening risk management and staff health and safety. Through QMS, new principles, protocols and research findings can be introduced into genebanks and spread among the global system as a whole.
- Armed with new data management tools and QMS, the Crop Trust has introduced new ways of building capacity through Genebank Operations and Advance Learning (GOAL) workshops, QMS Intensives, Genetic Resources on the Web (GROW) webinars, and communities of practice, each tailored for different levels of learning. The Crop Trust has also introduced performance targets to complement the FAO genebank standards, monitoring tools, audits and reviews, which are key to managing its long-term grants, but which can also apply to any genebank with an ambition to reach high standards of operation and fully participate in the global system.
- Finally, the global system has been growing and developing over several decades, and there is an opportunity now for different institutes to specialize and complement each other more coherently. The Svalbard Global Seed Vault, just over ten years old now, has already proven its worth in providing a unique mechanism for genebanks to deposit accessions for safe back-up. More institutions may be able to take up specialist roles on behalf of the community as a whole, whether it is conserving difficult crops and wild species, cryopreservation, or disease testing and cleaning for international germplasm movement. The Crop Trust would like to expand its work to help build capacity and partnerships to allow institutes to specialize and provide services for others.

4.2 Making the Global System Fit for the Purpose of Caring for Hard-to-Conserve Materials: Cryopreservation

The vast majority of crops have so-called orthodox seeds, which can be conserved relatively easily in cold stores if adequately dried. However, there are also other important crops – like bananas, cassava, cacao and coffee – that are propagated vegetatively, do not produce seeds or have seeds that are not orthodox. Their *ex-situ* conservation is therefore not possible through the typical drying and storage of seeds at −18 °C. Instead, these crops are usually conserved in field genebanks or in vitro, i.e., in tissue culture. Both of these require constant vigilance and are labor- and cost-intensive. Furthermore, as growing plants or plantlets, they are exposed to greater risks from contamination and disease, and safety duplication is also a major challenge. These factors all make collections of such crops particularly challenging to safeguard, especially when access to them is significantly reduced, e.g., because of social distancing during the Covid-19 pandemic.

Cryopreservation is the optimal method for safely maintaining genetic resources of such crops in the long-term. It is a process whereby organic material is conserved by cooling it to very low temperatures, typically −196 °C, using liquid nitrogen. It is a form of conservation that is technically challenging and requires high upfront investment. However, it is the most effective, long-term complement to the labor-intensive methods of conservation in field genebanks and *in vitro*.

Unfortunately, while there are abundant studies on how to cryopreserve plant genetic resources, only a handful of institutes have succeeded in cryopreserving collections on a large scale. This is due to the lack of investment in transforming research into routine application. Protocols need to be highly refined to work on the range of diversity in global collections and adequately tested to ensure that materials going into cryopreservation can come out of it and grow into healthy, whole plants. The organization required to build a successful cryo-pipeline is considerable, demanding both substantial investment and a donor who is not afraid to wait to see good results.

CGIAR genebanks have now established cryopreservation pipelines in Peru, Belgium, Nigeria and Colombia. More than 4,000 accessions of banana, cassava and potato are maintained in CGIAR cryobanks. The Centre for Pacific Crops and Trees (CePaCT) in Fiji is also in the process of setting up a cryopreservation pipeline for taro and coconut. However, more than 100,000 accessions are believed to be conserved in *in vitro* and field collections worldwide. Consequently, CGIAR is working with the Crop Trust and the Plant Treaty to engage national partners and cryopreservation experts in collaborating on a global initiative to secure this diversity in long-term conservation. Through setting up regional specialist hubs, CGIAR and partners hope to offer capacity-building and backstopping to support national programs bringing their own collections into cryopreservation and safely duplicating them.

4.3 *Innovative Funding for the Global System of* Ex-Situ *Conservation*

The Crop Trust was founded in 2004 and is recognized as an essential element of the funding strategy of the Plant Treaty. It provides sustainable, long-term funding for a rational, effective and efficient global system that can secure crop diversity forever.

The core activities of the Crop Trust are funded through sustainable investment income generated from an endowment fund. To strengthen the global system of *ex-situ* conservation as described above, an additional US$500 million need to be raised to achieve its total endowment target of US$850 million that will ultimately support implementation of SGD 2 by securing the world's crop diversity in perpetuity.

Unrestricted grant contributions to this endowment fund will always be the preferred means of funding the global system of *ex-situ* conservation. However, due to the slow growth of official development assistance and declining grants from governments, it is necessary and urgent for the Crop Trust to tap additional sources of funding.

The Crop Trust is exploring the issuance of a 30-year bond ("Food Security Bond" or "FSB") to private sector investors, which would be supported by (1) a government guarantee that commits the government to provide for any shortfall upon redemption in Year 30, and (2) government grants to pay the bond coupon in order to reduce the cost to the Crop Trust to zero. All bond proceeds would be invested in the existing endowment fund, with net investment returns to be used to fund the conservation of crop diversity in genebanks. In order for the FSB to be a success, it is absolutely critical that it has government support from one or more donor countries.

Overall, the advantages of issuing such a bond, combined with firm support from governments by way of guarantees and grants, include the following:

- Public/private engagement – The FSB has the potential to engage private market investors and government donors in a combined effort to support the global system and the conservation of crop diversity in perpetuity.
- The rating of the issuer – the higher the credit rating, the better the pricing in terms of the cost of funds. A highly rated government guarantee will mean lower coupons to be paid by the Crop Trust.
- The market environment – low interest rate market environments create the demand for yield up to and above current short-term issuances. Lack of alternatives to satisfy the needs of a section of investors, particularly pension funds and insurance companies, creates a demand profile for long/ultra-long maturity bonds.
- The guarantee provided by governments – a bond profile enhanced by a guarantee provides a layer of comfort for the investor and an attractive proposition to the market on behalf of the issuer, resulting in potential demand enhancement. For no money upfront, governments can help unlock substantial private capital for food security.
- The profile of the issuer – environmental, social and governance (ESG) issues are now one of the foremost attributes of investors and the need for them to gain exposure to ESG-related asset classes. In addition, as investors focus on the implementation of the Sustainable Development Goals, a Crop Trust bond supporting SGD 2 would be highly attractive to investors. The Crop Trust is also a signatory to the UN Principles of Responsible Investment and all endowment fund assets are invested in line with its responsible investment policy.

- Scalability – the bond could be issued in a number of tranches to raise vital funding, not just for the Crop Trust, but for other international organizations implementing SDG 2.
- Risk – as there is no recourse to donor contributions within the endowment fund, the risk of a shortfall upon redemption of the bond lies with the governments who have provided the guarantee, and not with the Crop Trust.

With this funding, the Crop Trust aims to scale up the endowment fund to provide critical support to national and regional genebanks around the world; continue support for routine budgets of the 11 CGIAR genebanks; and fund information system development, the Svalbard Global Seed Vault and the Crop Trust Secretariat with the aim of securing the foundation of global food security.

In addition, discussions are underway with the Secretariat of the Plant Treaty to explore whether a share of the annual income earned from this additional funding could be made available to the Plant Treaty for complementary activities to safeguard crop diversity in the field and in the wild.

References

FAO – Food and Agriculture Organization of the United Nations, Commission on Genetic Resources for Food and Agriculture (2010) The second report on the state of the world's plant genetic resources for food and agriculture. FAO, Rome

Hawtin G, Fowler C (2012) The global crop diversity trust. An essential element of the treaty's funding strategy. In: Frison C, Lopez F, Esquinas-Alcazar J (eds) Plant genetic resources and food security: stakeholder perspectives on the on the international treaty on plant genetic resources

Vincent H, Amri A, Castañeda-Álvarez NP, Dempewolf H, Dulloo E, Guarino L, Hole D, Mba C, Toledo A, Maxted N (2019) Modeling of crop wild relative species identifies areas globally for in situ conservation. Commun Biol 2(1):136–143