Food and Agriculture Organization of the United Nations

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

International Treaty on Plant Genetic Resources for Food and Agriculture

CROP TRUST

PROCEEDINGS
of the

First International Multi-Stakeholder Symposium on Plant Genetic Resources for Food and Agriculture:

Technical consultation on *in situ* conservation and on-farm management of plant genetic resources for food and agriculture

29–30 March 2021, Rome, Italy

Virtual zoom event

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Wheat landrace, Morocco © FAO/B. Furman

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Foreword

Feeding the world's ever-increasing population will require substantial improvements to global agrifood systems. We are seeing negative trends reverberate around the world. Global hunger and malnutrition continue to rise, natural resources – which undergird food and agricultural systems – are increasingly depleted and scarcer, and erratic and extreme weather events and the incidence of novel biotypes and strains of pests and diseases are causing strife in many parts of the world.

There is an urgent need to increase the resilience and productivity of agrifood production systems, of which at least 80 percent are plant-based. The world currently relies on a few varieties of a narrow set of staple crops for food, which is clearly unsustainable. Embedded in the FAO Strategic Framework 2022–2031, better production requires harnessing the broadest possible crop diversity to produce more diverse and nutritious food with fewer external inputs – to produce more with less.

One way to achieve better production is to increase intra- and inter-specific diversity on the farm. Farmers' varieties and landraces provide livelihoods for millions of people around the world and contain traits that are valued by farmers, such as agronomic and culinary qualities and locally important cultural values. But we must also tap into the traits of crop wild relatives, which are found in nature – where they continue to evolve to adapt to their environments and can be a key resource to counteract the effects of climate change. Safeguarding this rich reservoir of novel traits and genes is key to developing nutritious and resilient crop varieties.

The *First International Multi-stakeholder Symposium on Plant Genetic Resources for Food and Agriculture: Technical Consultation on* in situ *conservation and on-farm management of PGRFA* underscored the important contributions that the conservation and sustainable use of crop diversity can make to our collective efforts to eliminate hunger and malnutrition and in achieving the Sustainable Development Goals. The proceedings of this symposium are an important record of the information disseminated during the event and can be useful to build on to harness crop diversity for sustainable food and agricultural systems that can meet the needs of current and future generations.

Beth Bechdol
Deputy Director-General,
Food and Agriculture Organization
of the United Nations

Acknowledgements

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First and foremost we thank the members of the Organizing Committee: Luigi Guarino and Benjamin Kilian of the Crop Trust; Mario Marino and Mary Jane Ramos de la Cruz of the Treaty Secretariat; Dan Leskien of the Commission Secretariat; Bonnie Furman, FAO, and Arshiya Noorani, FAO. The Committee members were instrumental in developing the agenda and overall structure of the Symposium, identifying session chairs and approving the speakers and panellists.

Some of the technical and plenary sessions were chaired and/or moderated by Organizing Committee members; the remainder were kindly facilitated by: Jingyuan Xia, FAO; Chikelu Mba, FAO; Mariana Yazbek, ICARDA; Devra Jarvis, Platform for Agrobiodiversity Research; Mario Pagnotta, University of Tuscia, Italy and Alvaro Toledo, Treaty Secretariat. A special recognition goes to Stefano Diulgheroff, FAO, for moderating the Symposium as a whole and for providing the closing remarks.

The FAO Plant Production and Protection Division (NSP) provided the core technical and organization support for the Symposium, which was coordinated by Bonnie Furman and Arshiya Noorani. NSP was also responsible for the organizational and administrative aspects of the Symposium, and the contributions of Elena Rotondo and Juliet Upton are gratefully acknowledged. Many thanks also to Maria Soledad Fernandez Gonzalez, Shane Harnett, Ginevra Virgili and Mahnoor Malik for their support to the communications aspects, including social media contributions and logo design.

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Abbreviations and acronyms

BOLD	Biodiversity for Opportunities, Livelihoods and Development
CAAS	Chinese Academy of Agricultural Sciences
CacaoNet	Global Network for Cacao Genetic Resources
CBD	Convention on Biological Diversity
Cenargen	Brazilian Agricultural Research Corporation National Centre for Genetic Resources and Biotechnology
CENESTA	Centre for Sustainable Development and Environment
CIAT	International Center for International Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
Commission	Commission on Genetic Resources for Food and Agriculture
CONABIO	Comisión Nacional para el Conocimiento y Uso de la Biodiversidad
Crop Trust	Global Crop Diversity Trust
CSBs	community seed banks
CWR	crop wild relatives
Embrapa	Brazilian Agricultural Research Corporation
FAO	Food and Agriculture Organization of the United Nations
FFS	farmer field schools
GEF	Global Environment Facility
GRC	genetic resource centres
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IL	introgression line
LI-BIRD	Local Initiatives for Biodiversity, Research and Development, Nepal
LR	landrace
MDI–CTU	Mekong Delta Development Research, Institute of Can The University, Philippines

NORAD	Norwegian Agency for Development Cooperation
NSAP	National Strategic Action Plan
NSP	FAO Plant Production and Protection Division
NUS	neglected and underutilized species
PGRFA	plant genetic resources for food and agriculture
PPB	participatory plant breeding
PPV&FRA	Protection of Plant Varieties and Farmers Rights Act, India
PVS	participatory variety selection
QTL	quantitative trait loci
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
SEARICE	Southeast Asia Regional Initiatives for Community Empowerment
Second GPA	Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture
Treaty	International Treaty on Plant Genetic Resources for Food and Agriculture
UN	United Nations
UNEP	United Nations Environment Programme
ZARI	Zambia Agricultural Research Institute

1. INTRODUCTION

Terrace farming, China
© FAO/A. Noorani

1.1 Background

The efficient conservation and sustainable use of the broadest possible diversity of plant genetic resources for food and agricultural (PGRFA) are key elements in addressing the challenge of producing more food with fewer inputs. Currently, drivers of genetic erosion, such as changes in agricultural practices, the overreliance on a narrow set of modern crop varieties, changes to land use, destruction or fragmentation of habitats and climate change are increasingly threatening the continued existence, and hence availability, of these resources.

A significant amount of crop diversity can only be preserved effectively in natural and semi-natural environments, including protected areas, where evolution and adaptation continue to occur, and in farmers' fields. Crop wild relatives (CWR) represent a rich and largely unexplored reservoir of traits and genes that can be used to develop improved crop varieties with novel traits, such as pest and disease resistance and adaptation to abiotic stresses. Wild food plants can play important roles for food security and nutrition as sources of vitamins, minerals and other nutrients and may complement staple crops, especially during times of food scarcity. PGRFA found on-farm, including farmers' varieties/landraces, are often the mainstay of families' livelihoods, and are adapted to specific ecological conditions and/or farming practices. Failure to manage this critically important diversity may result in its permanent loss.

Recognizing the importance of *in situ* conservation and on-farm management of PGRFA, the Commission on Genetic Resources for Food and Agriculture (Commission), at its Seventeenth Regular Session, requested FAO to hold, in cooperation with the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty), two symposia on: (i) *in situ* conservation of CWR and wild food plants; and (ii) on-farm management of farmers' varieties/landraces. It requested FAO to make the outcomes available to the Commission's Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture (Working Group), the Commission and the Governing Body of the Treaty (FAO, 2019, paragraph 62).

Upon consultation with the Bureau of the Commission, it was agreed that a single symposium would be organized due to thematic synergies, the need to optimize the use of resources and time, and to sustain interest and momentum. The event, originally scheduled to be held on 15 and 16 June 2020 in Rome, Italy, was delayed due to the COVID-19 pandemic and was subsequently held on 29 and 30 March 2021 as a virtual event. It was co-organized with the Treaty and the Global Crop Diversity Trust (Crop Trust).

The Symposium highlighted the current state of knowledge and the enabling environment for *in situ* conservation and on-farm management of PGRFA. It provided a forum for the exchange of information and experiences among experts, practitioners and other stakeholders. The Symposium also contributed to an increased understanding of the role and importance of *in situ* conservation of CWR and wild food plants, and on-farm management of farmers' varieties/landraces.

1.2 Main themes and organization of the Symposium

The Symposium was structured around four broad themes (see Annex 1: Agenda):

a. The challenges and opportunities for sustainably managing crop diversity.
b. In situ conservation of crop wild relatives and wild food plants.
c. On-farm management of farmers' varieties/landraces.
d. The way forward: creating communities of practice.

In order to increase the outreach of the Symposium, a webpage was made available in all official United Nations (UN) languages (FAO, 2022). Technical presentations were pre-recorded to allow global audiences to view them at their convenience in their respective time zones. The presentations were made available online in all official UN languages on the Symposium webpage well in advance of the event. The event was advertised through partner websites for PGRFA, the FAO Members Gateway, relevant networks and through social media.

The Symposium held on 29 and 30 March 2021 saw over 800 people participating online. For those participants that did not register, the event was streamed live; an additional 256 people watched via FAO's media website. The recordings are accessible on the Symposium webpage (FAO, 2022).

References

FAO. 2019. *Report of the Seventeenth Regular Session of the Commission on Genetic Resources for Food and Agriculture*, Rome, 18–22 February 2019. Rome. https://www.fao.org/3/mz618en/mz618en.pdf

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2. OPENING AND WELCOME

Vegetable market, India

2.1 Session summary

The Opening and Welcome Session was chaired by Jingyuan Xia, Director, Plant Production and Protection Division, FAO. In his introductory remarks, Mr Xia explained that the Symposium is part of ongoing efforts of the FAO Commission on Genetic Resources for Food and Agriculture to facilitate collaboration among practitioners involved in the conservation and sustainable use of PGRFA. In that vein, he mentioned that the event was being held together with FAO's Plant Production and Protection Division, the Secretariat of the Treaty and the Crop Trust.

Mr Xia reminded participants of the present Decade of Action to achieve the Sustainable Development Goals (SDGs), which calls for accelerating sustainable crop production and protection solutions. He stressed that a systems approach must be adopted based around two key strategies: optimization[1] and minimization,[2] which must be strengthened. As such, he emphasized the importance of optimizing the sustainable use of plant genetic resources while minimizing their loss, requiring a holistic approach and comprehensive solutions that imply increased collaboration among all stakeholders. Mr Xia commended the virtual format of the Symposium as contributing to this approach, allowing stakeholders to gather from all corners of the globe to discuss the conservation and use of these important genetic resources.

Organizers of the Symposium were then invited to deliver their welcome remarks at the Opening Session. During this Session, the speakers stressed the importance of resilient agricultural and food systems for achieving the SDGs. Enhancing crop diversity on-farm and *in situ* was highlighted as a key strategy to improving both the resilience of crop production systems and the nutritional status of people.

Beth Bechdol, Deputy Director-General, FAO, emphasized that the challenge of sustainably producing more food with fewer inputs could be met only if the broadest possible diversity of plant genetic resources were accessed easily and used as sources of new traits. As such, the outputs of the Symposium would contribute towards maintaining diverse crops and varieties in farmers' fields, thus buffering against unforeseen threats. In this context, she drew attention to the role of the Symposium and its outputs to FAO's new Strategic Framework: more sustainable, inclusive and resilient food systems for better production, better nutrition, a better environment and a better life, leaving no one behind.

1 Optimization of system structure, functionality and service; combination of key components; adoption of major technologies.

2 Minimization of crop losses from pest damage; residual risk from inappropriate use of chemical pesticides; environmental contamination from overuse of chemical fertilizers.

Irene Hoffmann, Secretary of the Commission, in welcoming participants, reminded them of the past attempts to better coordinate and strengthen global cooperation on *in situ* conservation and on-farm management of PGRFA. As such, participants and stakeholders were invited to articulate how FAO could use its facilitating and convening power to strengthen *in situ* conservation and on-farm management of PGRFA, and consider platforms for information exchange.

The importance of recognizing the critical role of crop diversity in achieving food and nutrition security was also stressed by Kent Nnadozie, Secretary of the Treaty. He further highlighted the need to advocate and raise awareness on the importance of PGRFA to promote better cooperation and partnerships, including between public and private sectors, for the benefit of the conservation and sustainable use of crop diversity.

The final welcome address was provided by Stefan Schmitz, Executive Director of the Crop Trust. He emphasized that *in situ*/on-farm conservation and use of both landraces and CWR are mutually supportive to *ex situ* conservation. In this context, he described a number of initiatives in synergy with FAO's work to enhance farmers' access to crop diversity, thus contributing to the resilience of food systems in partner countries.

2.2 Opening address

Beth Bechdol, Deputy Director-General, FAO

Thank you for the opportunity to be with you this morning.

I think it is important at the opening of this important Session to assert something we all know and regularly discuss – that we are off track to achieve the Sustainable Development Goals and more work is needed to eradicate hunger and malnutrition.

The most recent edition of the report on the *State of Food Security and Nutrition in the World* contains very worrying statistics: nearly 690 million people are hungry – 9 percent of the world's population

This represents an increase of 10 million people in a single year and nearly 60 million in five years. In fact, about one in ten people in the world have been exposed to severe levels of food insecurity.

This Symposium has been organized to engage all actors – all of us – in a systemic approach to the SDGs. More specifically, around SDG 2 *End hunger, achieve food security and improved nutrition and promote sustainable agriculture* and SDG 15 *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.*

The transition to a sustainable future requires that food consumption and production systems must achieve more with less. It is urgent to do things differently and act holistically to transform our agrifood systems.

Broadening the range of crop and genetic diversity, and increasing the quality of cultivated crops, can contribute significantly to this aspiration.

These resources are also essential for improving the resilience of production systems to environmental shocks, especially the stresses attributed to climate change.

The current food system relies on only nine crops to provide two-thirds of crop production worldwide and over half of the global average daily calories consumed, although globally around 6 000 plant species have been cultivated for food.

Plant genetic resources for food and agriculture found on-farm, including farmers' varieties and landraces, provide livelihoods for millions of farmers throughout the world.

Farmers cultivate these for preferred agronomic, culinary quality and locally important cultural values.

The challenge of sustainably producing more food with fewer inputs may be met only if the broadest possible diversity of plant genetic resources can be easily accessed and used as sources of new traits.

And, the importance of crop wild relatives and wild food plants cannot be minimized.

Crop wild relatives are a rich reservoir of novel traits and genes that can be used to develop crop varieties that are adapted to climate change, and there is ample evidence of their successful use in crop improvement. For example, genes from crop wild relatives for pest and disease resistance have contributed directly to increased crop yields and to reduced use of pesticides and fungicides.

Wild food plants, on the other hand, constitute important components of the diets of many people across the globe. They are rich sources of very important micronutrients and could play critically important roles in combatting malnutrition.

Unfortunately, this wide spectrum of crop diversity is threatened today by changes in land use, together with high rates of urbanization and emigration, displacement of traditional crops in favour of a few starchy staples, and abandonment of marginal agricultural areas.

Losing this genetic diversity reduces our options for sustainably managing resilient agriculture in the face of adverse environments and rapidly fluctuating meteorological conditions.

And, so it is essential to strengthen their conservation *in situ* and management on-farm.

For crop diversity to be useful in addressing malnutrition and climate change, their characteristics need to be measured, evaluated and recorded in information systems that are available to all relevant stakeholders.

While *in situ* conservation is important, the complementary conservation *ex situ* in genebanks to safeguard these valuable resources is vital.

FAO's ongoing support to countries on the conservation and sustainable use of these resources is in accord with several international instruments and agreements – the Convention on Biological Diversity, the International Treaty on Plant Genetic Resources for Food and Agriculture, the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture and, most recently, the Sustainable Development Goals.

This very Symposium is another contribution to FAO's new proposed framework with the Director-General's vision of leaving no one behind through more sustainable, inclusive and resilient food systems for better production, better nutrition, a better environment and a better life.

Increasing and evolving patterns of human food consumption, together with high rates of urbanization, pollution, unsustainable use of natural resources, spread of invasive species, and the displacement of local crop varieties and environmental changes are all threats to the world's rich and highly adapted plant genetic resources.

Despite the increased public, political and scientific interest in conserving plant genetic resources, there is still much to do to protect crop wild relatives and wild food plants. There is especially an urgent need to ensure their appropriate conservation and sustainable use at the global, regional, national and local levels.

I am confident that the outputs of this Symposium will be vital contributions to devising the means to maintain the widest diversity of crops and varieties in farmers' fields. And, this will provide us with the necessary insurance against unforeseen threats, contribute to the alleviation of poverty and ultimately increase food security and nutrition.

Thank you again for the opportunity to be with you for this important gathering.

2.3 Welcome address

Irene Hoffmann, Secretary, Commission on Genetic Resources for Food and Agriculture, FAO

Dear colleagues and friends,

A very warm welcome from the side of the Commission Secretariat to this First International Multi-stakeholder Symposium on Plant Genetic Resources for Food and Agriculture. I am pleased that the Commission's request, back in 2019, has met with such a great response from so many participants from all over the world.

This Symposium, which embraces both *in situ* and on-farm conservation, has been organized at the request of the Commission on Genetic Resources for Food and Agriculture and we are happy that the Treaty and the Global Trust joined us in this event.

There seems to be widespread interest in *in situ* conservation and on-farm management of plant genetic resources for food and agriculture (PGRFA) and, at the same time, a widespread sentiment that for much too long not enough attention has been paid to them.

Ten years ago, I repeat: ten years ago, the Commission, and I quote: "recognized the importance of establishing a global network for *in situ* conservation and on-farm management of plant genetic resources for food and agriculture in coordination with the International Treaty, the Global Strategy for Plant Conservation of the Convention on Biological Diversity and other relevant stakeholders, and to avoid duplication of efforts. The Commission requested FAO to elaborate on the means and opportunities for such a global network for its consideration."

In fact, early attempts to better coordinate and strengthen global cooperation on *in situ* conservation and on-farm management of PGRFA reach back more than 20 years in the Commission's history.

What has happened since with regard to the establishment of a global network or networks for *in situ* conservation and on-farm management? I could give you a detailed reply. I could list all the meetings, documents, special events and seminars organized at the Commission's request, and, of course, the many meeting reports, many calling for another meeting and another meeting.

But I assume you prefer the short answer, which is: with the exception of all the meetings, very, very little has happened.

The Commission, I am sure, would not have requested the convening of this Symposium, if there had not been the motive to get something out of it, and by that I mean something very practical, some action, some initiative, some first steps towards a global network or several regional networks, or the regularization of this kind of symposium or whatever organizational form, if any, you believe is preferable.

This is my first request: Exchange of scientific information, knowledge and experience is important; in fact, it is essential. But please start thinking, in very concrete terms, about what is needed from your point of view and what can a UN organization like FAO and a body like the Commission, in collaboration with its partners, do to strengthen *in situ* conservation and on-farm management, to improve the flow and exchange of information to assist you, stakeholders, farmers, communities of practice and scientists in your work. Please start thinking about this.

This Symposium offers the place to voice proposals and requests, to come up with very concrete ideas as to how cooperation can be improved to strengthen *in situ* conservation and on-farm management of PGRFA.

One of the most frequent proposals: FAO should provide financial support. Very simple to ask, and direct action to another party. However, providing financial support is not FAO's unique selling point – FAO is not a funding agency as you all know - and there are other donors with much deeper pockets. But FAO can assist countries, at their request, to raise funds.

FAO and its Commission play a perhaps more important and rather unique role in that they provide a platform that can facilitate the building of trust and consensus and generate intergovernmental, global support for new initiatives. FAO has a facilitating and convening power.

This is my second request: Please start thinking, in very concrete terms, as to how you want FAO, its Commission and our partners to use this facilitating and convening power to strengthen *in situ* conservation and on-farm management of PGRFA.

The Commission endorsed in the recent past two important guidelines: one on the conservation and sustainable use of farmers' varieties/landraces and another one on the conservation and sustainable use of crop wild relatives and wild food plants. Both guidelines reflect important features of the type of work the Commission can bring to the table. What other work could the Commission and its Working Group do to contribute to assist in on-farm management and *in situ* conservation?

Over the last few decades, considerable progress has been made in safeguarding and providing access to crop genetic diversity in *ex situ* germplasm collections. But, despite progress made in the *ex situ* conservation of these resources, crop wild relatives and landraces, especially those of minor crops, remain under-represented in genebanks. It is therefore crucial to build the linkages between the crop genetic resources conserved *ex situ* in genebanks, and those conserved *in situ* in farmers' fields and in the wild.

The importance of these resources is that their continuous evolution, both on farm and in the wild, has the potential to generate adaptive characteristics thus enabling them to cope with changing environmental conditions.

The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture has highlighted the loss of crop genetic diversity both *in situ* and on-farm. The genetic erosion, caused by land-use practices, climate change and the loss or degradation of natural habitats, is of major concern.

This is my third request: This Symposium brings together all the different stakeholders, who all play their very distinct and important roles. Can they agree on a strategy to better link *in situ*, on-farm and *ex situ*? Explore how the private sector can play a more important role in this regard and shoulder some of the conservation burden?

Finally: This Symposium and the fact that you all attend seem to demonstrate that there is a need for exchange of information. This is my fourth request: Please start thinking about how information exchange between the different stakeholders may be improved. Does it have to be improved? It seems yes. But then, how should it be done? Through a network like the Domestic Animal Diversity Network (DAD-Net), which is an email-based network, with about 3 000 multi-stakeholder subscribers worldwide? It provides a free, moderated forum for the discussion of issues relevant to the management of animal genetic resources. Or what other options are there to improve information exchange?

The Commission welcomes the development of concrete steps forward in order to conserve and utilize crop diversity in a sustainable manner for current and future generations. We look forward to your suggestions.

2.4 Welcome address

Kent Nnadozie, Secretary, International Treaty on Plant Genetic Resources for Food and Agriculture, FAO

Good day to all the participants and colleagues from all over the world.

Welcome to the First International Multi-Stakeholder Symposium on Plant Genetic Resources for Food and Agriculture: Technical Consultation on *in situ* conservation and on-farm management of PGFRA.

I would like to particularly welcome the representatives of indigenous, local and farming communities from all regions. Local and indigenous farmers and communities have played a crucial role in managing the wide range of crops and genetic diversity, *in situ* and on-farm. These guardians of the world's food crops will continue to play a crucial role in conserving the diversity of the world's PGRFA, which in turn is crucial for achieving food security, improved food nutrition and sustainable rural livelihoods.

We are delighted to have all of you here with us online today. Thanks to technology, we are still able to gather, albeit virtually, in the midst of the worst pandemic of our lifetimes. Thank you all for joining what promises to be a lively and important discussion.

One of the objectives of this Symposium is to provide a platform for the exchange of information and experiences among technical experts, practitioners and other stakeholders, and to enhance understanding of and the importance of *in situ* conservation of crop wild relatives and wild food plants and on-farm management of farmers' varieties or landraces.

I would like to echo what my colleagues have said in stressing the importance of recognizing the critical role of crop diversity in the achievement of food and nutrition security. All of us have a role to play in conserving and sustainably utilizing plant genetic resources. It is not the task of only the Commission, the Crop Trust and the International Treaty

Plant genetic resources for food and agriculture are important, both at the global level and at the local level. Agricultural research and plant breeding depend on access to a broad range of plant genetic diversity.

They are the basis of and the "life insurance for our food production". They are critical to food security because they are the basic building blocks for providing crops with resistance to diseases, pests and environmental stresses, and to improving yields and nutritional quality. They are also important in the rehabilitation of degraded ecosystems and strengthening different farming systems.

Without a wide range of crops and their genetic resources, we cannot have quality food nutrition for healthy living, adapt our crops to climate change, or cope with environmental challenges, or sustain healthy food systems, or achieve the Sustainable Development Goals established by the United Nations.

A brief note about the role of the Treaty on PGRFA:

The Treaty is the only international treaty whose primary purpose is to ensure the conservation and sustainable use of crop genetic diversity, which form the basis of global food security. It makes sure the plants that feed the world continue to exist and remain available for the common good of all. It does so in many ways.

It establishes a global system to provide farmers, plant breeders and scientists with access to plant genetic materials and the data pertaining to PGRFA – through its Multilateral System of Access and Benefit-sharing and its Global Information System.

The Treaty ensures that benefits derived from the use of these genetic materials are shared widely and equitably, especially with farmers in developing countries; and it recognizes the enormous contribution of indigenous and local communities and farmers to the diversity of crops that feed the world.

Indeed, the Treaty is the first legally-binding international agreement to explicitly acknowledge their huge contribution and to encourage the protection of farmers' rights.

In plain language, the fundamental purpose of the Treaty is to save, share and take care of the plant genetic material upon which we rely for our food and nutrition, and it strives to protect the rights of indigenous and farming communities who have been the guardians of this biodiversity for millennia.

We collaborate with governments, farming communities, the private sector, civil society and other stakeholders to promote the conservation and sustainable use of PGRFA, and to ensure that their diversity remains available for generations to come – and as a public good that benefits the global community.

Through its various work tracks, the Treaty is supporting the conservation of genetic diversity, both *in situ* and *ex situ*. For example, through its Benefit-sharing Fund, the

Treaty has invested USD 26 million in 81 projects in 67 developing countries that focus on supporting on-farm management and improvement of PGRFA and promoting the development of primarily farmers' varieties/landraces and underutilized crops.

Projects funded through the Benefit-sharing Fund support on-farm and *in situ* conservation, farmer-to-farmer exchanges, local seed value chains and a better flow of PGRFA from *ex situ* collections to farmers and back. These projects transcend the divide that is often seen between *in situ*/on-farm and *ex situ* conservation, and epitomizes how initiatives from farming communities through national and international genebanks are linked together through the Treaty.

I am happy to note that quite a few of the panelists at this Symposium represent institutions that the Treaty's Benefit-sharing Fund has worked with over the years and which we continue to support through projects (for example: SEARICE, LIBIRD, the International Potato Center, Embrapa, ICRISTAT, CENESTA, ICARDA, Asociación ANDES, Zambia Agriculture Research Institute).

Through its work on the Global Information System, the Treaty recently developed *Descriptors for Crop Wild Relatives* in situ data, which will enable countries to compile and exchange data held by different national and international organizations, advanced research institutes and other bodies, and to bring their information into an accessible standardized format for consistent data compilation and management.

These are just some of the fundamental initiatives that we are involved in by way of supporting governments and other stakeholders in the conservation and sustainable use of PGRFA.

There is an increasing awareness and acknowledgment of the importance of crop diversity – in achieving food security and improving nutrition, livelihoods, health and well-being for people, especially for the most vulnerable communities, through conservation and sustainable use, *in situ* and on-farm management of farmers' varieties or landraces, crop wild relatives and wild food plants.

It is fortuitous that this Symposium and technical consultation are coinciding with the celebration of the International Year of Fruits and Vegetables. Let us seize this opportunity to advocate more and raise awareness about the importance of PGRFA, to promote better cooperation and partnerships between public and private sectors for the benefit of the conservation and sustainable use of crop diversity.

I am looking forward to our discussions over these two days. We look forward to learning from our speakers about their experiences with science-led innovations for *in situ* PGRFA conservation and management on-farm, and about the traditional, yet sustainable and evolving, knowledge and techniques used to address climate change, making crops more resistant to diseases and pests, while producing quantity and quality crop production.

In closing, I would like to thank you all for participating in this important journey to conserve and sustainably use our common heritage of plant genetic resources for food and agriculture. And I wish to particularly thank our partners, the Commission on Genetic Resources for Food and Agriculture, the NSP and the Crop Trust, as well as the speakers, and all the participants for joining us.

Thank you.

2.5 Welcome address

Stefan Schmitz, Executive Director, Global Crop Diversity Trust

Distinguished participants, ladies and gentlemen, dear colleagues,

I thank the FAO Commission on Genetic Resources for Food and Agriculture and the Treaty for the opportunity to collaborate in this important event, at this critical moment in time.

And I very much welcome the continued collaboration with the Commission and all other partners in this event. We are indeed stronger together. I could hardly think of any area in which cross-border, international cooperation is as important for the survival of humankind as the conservation and use of genetic resources for food and agriculture.

2020 was my first year as Executive Director at the Crop Trust. At once a great honour, and, given the significant global challenges we currently facing, a role I do not take lightly.

We are aware that our planet is at a breaking point. We all face exceptional environmental challenges. The newest among these is the COVID-19 pandemic, which forces us to triage our efforts, pushing healing the planet aside to heal ourselves.

These combined crises have shone a stark light into dark corners of our societies – global, regional and national. And our fragile interdependence has become painfully apparent.

The vulnerability of our food systems was one such corner, which brought renewed global attention to the importance of seeds, and their conservation and use.

And, while *in situ* conservation and on-farm management are not part of the Crop Trust mandate, we recognize their importance as mutually supportive to *ex situ* and use of both landraces and crop wild relatives.

We support the need for complementary approaches and look forward to tangible examples of such mutual support in the coming presentations and discussions, particularly those that centre on marginalized and diverse voices.

At the Crop Trust, we work with many dedicated partners around the world, not least in the Crop Wild Relatives Project. We will be hearing from some of these partners during the Symposium. They have been collecting and conserving crop wild relatives in 25 countries, and pre-breeding them in support of climate change adaptation in 50 countries. Funded by the Norwegian Government, this global project wraps up this year after 11 years of impressive work.

Among others, this year we also look forward to launching a major new project BOLD (Biodiversity for Opportunities, Livelihoods and Development). This project aims to capitalize on the success of the NORAD-funded Crop Wild Relatives Project by enlarging its pre-breeding and evaluation partnerships to include national genebanks, and by supporting the participation of genebanks in seed systems interventions.

BOLD will enhance farmers' access to crop diversity, and thus contribute to the resilience of food systems in partner countries. In addition, BOLD is increasing awareness and use of the Svalbard Global Seed Vault and facilitating new deposits from genebanks eligible for official development assistance.

BOLD is one important element in a larger growth strategy for the Crop Trust: more partnerships, even greater practical relevance and, hopefully, of course, continued growth in financial resources. Because only these financial resources will enable us to fulfil our mission and put our work at the service of an international community that combats and resists the loss of agrobiodiversity.

This difficult time is also a time that makes it very clear how important science is. Only with reason, applied research and evidence-based decision-making can humankind address the survival issues of the twenty-first century.

FAO and its organs and bodies are the global agora where this spirit of reason, monitoring and analysis, information dissemination and evidence-based decision-making for food and agriculture is nurtured and developed. FAO's leadership in this area is immensely important!

In our efforts to secure and invest in the future of our food systems, we must not underestimate this new digital age, thrust upon us by the pandemic. It is estimated that 70 percent of the world will be online in this decade.

It provides us with an opportunity to be heard like never before – and it is our responsibility to work together to ensure our message reaches the right ears.

Our world is on an environmental red alert. We must continue to sound the alarm, louder than ever because seeds have never been more important.

Thank you very much for your attention.

3. SESSION 1:
SETTING THE SCENE: THE CHALLENGES AND OPPORTUNITIES FOR SUSTAINABLY MANAGING CROP DIVERSITY

Quinoa farmer, Bolivia (Plurinational State of)
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3.1 Session summary

Keynote addresses were delivered by: Kuldeep Singh, National Bureau of Plant Genetic Resources, India; Maria Andrade, International Potato Center, Mozambique; and Johan Robinson, United Nations Environment Programme. The presentations highlighted current approaches to *in situ* conservation and on-farm management of PGRFA. The importance of linkages between *in situ* and *ex situ* conservation was stressed as crucial for successful and integrated conservation, and use of PGRFA was also highlighted. The experiences reported from India, for instance, included a number of approaches to promote such linkages; these included diversity assessments, prioritization, map-based collecting to increase PGRFA diversity in genebanks, and value addition to farmers' varieties. Speakers stressed the importance of: (i) genetic diversity for developing improved crop varieties; and (ii) smallholder farmers' involvement in participatory varietal selection, assessing the potential of farmers' varieties/landraces for market development, seed production, distribution networks and setting research priorities.

Speakers also highlighted the need for sustainable approaches and practices for the use of crop diversity, such as accelerated breeding programmes to develop new and diverse varieties, and investments in technologies that promote diversity in crop production and strong research collaboration and synergy. In this context, a case study from southern Africa focusing on sweet potato diversity and its contribution to breeding of improved varieties was presented; collaboration among different stakeholders resulted in the release of 104 varieties of nutrient-rich orange-fleshed sweet potato in 16 countries. During the discussions, it was emphasized that integrating work across the agriculture, forestry, health and resource management sectors is crucial for the effective conservation and sustainable use of crop diversity. Lessons from public–private partnerships underscored the importance of including diverse stakeholders for successful conservation of PGRFA *in situ*. At the same time, it was stressed that the needs of different stakeholders should to be balanced against each other to ensure the success and long-term sustainability of these initiatives. Discussions identified the overall need for good governance, sustainable financing and multi-stakeholder cooperation as critical to success.

3.2 Crop diversity for sustainable development: bridging the gaps between *in situ* and *ex situ* conservation

Kuldeep Singh, National Bureau of Plant Genetic Resources, India

Sustainable agriculture calls for an integrated system of plant and animal production practices that would over the long run enhance environmental quality and the natural resource base on which the entire agricultural economy depends. It also satisfies four essential goals: satisfying human food, feed, fibre needs and contributing to addressing biofuel needs; enhancing environmental quality and the natural resource base; sustaining economic viability of agriculture; and enhancing quality of life of farmers, farm workers and society as a whole. Nature has provided a large diversity of crops to fulfil all the requirements of human beings. However, anthropogenic activities are causing huge losses to diversity and their adaptive and evolutionary processes. Loss of crop diversity, for example, in hill agriculture cropping patterns has shifted from multi-crop cultivation to cultivation of a single or few crops of commercial value due to reduction in family size, declining income from traditional crops, etc. The negative impact of this has been observed in the form of an increased anaemic and malnourished population.

Over more than 820 million people across the world are undernourished, two billion suffer from micronutrient deficiencies and two billion are overweight or obese. Globally, the diversity of food crops is decreasing. FAO estimates that 75 percent of crop diversity was lost in the twentieth century and only 12 plant species provide more than 75 percent of all human food. This clearly shows that today's global food system is not sustainable and fails to enable healthy food choices for a large part of the population. To feed the 1.66 billion people in India, we need to increase our food grain production by approximately 70 percent (from 2015 base year) and PGRFA would be key to achieve it.

Plant genetic resources for food and agriculture (PGRFA) are the genetic material of plant origin of actual or potential value. PGRFA provide the biological basis for agricultural production and world food security. These resources serve as the most important raw material for farmers, who are their custodians, and for plant breeders. The genetic diversity in these resources allows crops and varieties to adapt to ever-changing conditions and to overcome the constraints caused by pests, diseases and abiotic stresses. PGRFA are essential for sustainable agricultural production. There is no inherent incompatibility between the conservation and the use of these resources. In fact, it is critically important to ensure that the two activities are fully complementary. The conservation, sustainable use and fair and equitable sharing of benefits from the use of genetic resources are international concerns and imperatives. These are the objectives of the International Treaty on Plant Genetic Resources for Food and Agriculture, which is in harmony with the Convention on Biological Diversity (CBD). Conservation of plant genetic diversity plays a crucial role for attaining food security, as is recognized by the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture and the Sustainable Development Goal 2 on Zero Hunger, under Aichi Target 13.

India has four of the 35 biodiversity hotspots with 18 048 flowering plants (29 percent are endemic). It is one of 12 mega-diversity centres and about 168 crop taxa have originated and/or been developed in India. About 1 000 wild edible plant species and 817 species of wild relatives of crop plants occur in India. Rice, sugar cane, pigeon pea, yam, taro, eggplant, banana, cucumber, cardamom, pepper, mango, citrus and many other crops originated in India.

There are various agencies in India responsible for conserving and utilizing PGRFA. For *in situ* conservation, Ministries/ Departments of Central /State Governments in forests, protected areas (national parks, wild life sanctuaries, biosphere reserves and reserve forests) are responsible for conserving mostly crop wild relatives (CWR) and wild plants (edible, ornamental, medicinal and aromatic plants, economic and industrial use). During recent years, conservation of CWR has been given priority and 100 CWR species are prioritized. Georeferenced maps have been generated for most of the conserved genetic resources. New initiatives has been taken by creating 21 biodiversity heritage sites for long-term *in situ* conservation of wild habitats. On-farm conservation is mainly undertaken by farmers, although several NGOs provide support. Establishment of 19 community seed banks, such as Richariya Kishani Sambardhan Samiti-Dhamtari (Rice 268), Dharohar Samiti-Kondagaon (Rice 257), Sangta Sahbhagi Gramin Vikash Sansthan- Amibikapur (Rice 150) has helped in maintaining over 2 000 traditional varieties of different crops at farmers' community level.

Institutions responsible for *ex situ* conservation include the National Bureau of Plant Genetic Resources with its national genebank, field genebanks, tissue culture and cryobank facilities, crop-based institutes, State agricultural universities and institutes (medium-term storage modules and field genebanks), the Botanical Survey of India and CSIR institutes (genebanks, botanical gardens). The Indian national genebank holds 4.5 lakh accessions comprising wild relatives and landraces of about 2 000 crop species. The share of the major crop group germplasm is as follows: cereals (164 402); legumes (66 763); millets (59 270); oilseeds (59 200); vegetables (26 483). In cryobanking facilities, 13 678 samples are preserved while *in vitro* (tissue culture) facilities conserve

1 874 accessions of tropical and temperate fruits, tuber crops, bulbous crops, medicinal and aromatic plants. In field genebanks with various national active germplasm sites (horticultural crops) germplasm of major fruit crops is conserved: mango, banana, citrus, guava, jackfruit, grapes, papaya and spices and industrial crops. Also, vegetatively propagated germplasm such as cassava, sweet potato, yams, aroids, potato, yam bean, greater yam and Chinese potato are conserved at various National Active Germplasm Sites.

There is a strong need for bridging the gap between *in situ* and *ex situ* conservation. Economic incentivization to benefit farmer communities would get a boost through various strategies, such as the identification and recognition of custodian farmers, protection of farmers' varieties/clone and geographical indication (GI). Multiple strategies are required to further bridge the gap, including piloting good farming practices that reduce risk and increase productivity, improving access of information and materials, identifying and increasing demand for the best materials, and creating markets. Policies should be framed for recognition of custodian farmers. Also, local institutions may be strengthened and farmers may be empowered. Further, seed availability at community level will be promoted through the traditional concept of "Char Jhaniya", where seeds are shared with four people at each multiplication step.

Agricultural diversity would also help minimize the risks associated with climate change. For that, farmers should be exposed to more crop varieties and increase their first-hand knowledge about different traits and options available. Strengthening of their seed systems and seed-saving capacities are required to have access to planting material according to changing needs. Also, broadening the genetic base of crops or deployment of crop diversity on-farm are required to empower farmers for climate change adaptation. Crop diversity is essential to respond to the challenges of change as growing more diversity on-farm would lead to sustainable production. Thus, there is a need for mainstreaming diversity on-farm or genetic base broadening of the farming system – both at inter- and intra-specific levels.

Under the National Agricultural Innovation Project, agrobiodiversity was linked with farmers' livelihoods during 2010–15 when 26 community seed banks with a capacity to store about 15–20 quinitals of seed were established in three districts for seed storage and supply of good quality seed of local landraces at community level. In addition, accessions with desired unique traits were identified and about 30 landraces were developed for registration under the Protection of Plant Varieties and Farmers Rights Act (PPV&FRA). Also, proposals of 15 farmer varieties of maize (5), rice (2), sorghum (2), pigeon pea (2), red kidney bean (1), green gram (1), black gram (1) and Indian bean (sem) (1) were submitted to the PPV&FR Authority for registration.

Genetic diversity with good practices and high-quality seeds should be targeted for value addition and novel food products, with recipes marketed in efficient ways for livelihood purposes. Thus our approach to mainstream agrobiodiversity should be enhancing crops/varietal diversity, repatriating *ex situ* collections to the farm; enhancing access and availability of diversity (seed)/ development of community seed banks; enhancing livelihood options and incomes through added value options, entrepreneurship development and market linkages; capacity building, awareness and dialogues on conservation and use of agrobiodiversity and benefits thereof. Further, engaging farmers in participatory varietal selection enriches variety recommendations, improves on-farm testing, engages and empowers farmers, supports scaling of on-farm agricultural produce, contributes to a diversification of seed, enables farmers to do their own variety selection and women empowerment is also encouraged.

Presently, a project funded by the Global Environment Facility is being implemented in four agroecological regions: western Himalayas including the cold arid tract (Ladakh, Himachal Pradesh and Uttarakhand), north eastern region of Eastern Himalayas (Assam), central tribal region (Madhya Pradesh, Chhattisgarh and Bundelkhand region of Uttar Pradesh) and western arid/semi-arid region (Rajasthan). The main focus area of the project is mainstreaming 20 crops for agrobiodiversity conservation and utilization in the agricultural sector to ensure ecosystem services and reduce vulnerability, adaptive management of crop diversity for resilient agriculture and improved livelihoods, strategies and policies for sustainable conservation and use of crop diversity including access and benefit-sharing and improved agricultural support systems, institutional frameworks and partnerships that support crop diversity on-farm. To promote on-farm conservation, recognition of custodian farmers is required as these are the key stakeholders for on-farm conservation. These farmers are highly motivated and self-driven by conservation ideology, maintain rich diversity and get recognition from the community. Considering their role as conservers, dynamic innovators and promoters of diversity, we need to publicly support these farmers and compensate them. Biodiversity may be linked with livelihood security. For example, a custodian farmer from Karnataka cultivates the Siddu jackfruit, a farmer's variety with a high nutritive value and attractive coppery red flakes, which fetches high prices for the planting material.

Geographical Indication is used on products that have a specific geographical origin and possess qualities or a reputation that are due to that origin. GI are part of the intellectual property rights that come under the Paris Convention for the Protection of Industrial Property. In India, GI registration is administered by the Geographical Indications of Goods (Registration and Protection) Act of 1999. Geographical indications are typically used for agricultural products, foodstuffs, wine and spirit drinks, handicrafts and industrial products. Out of 370 GI tags issued, 106 belong to the agricultural sector. Establishment of market linkages between unique agricultural diversity producers and consumers would drive their production and conservation by the farmers. Some examples are Jeeraphool, a short grain aromatic rice of Chhattisgarh. Establishing the value chain on millets has been done through intervention at various steps: on-farm production through technology backstopping with ITC Ltd for nutritional evaluation, processing diversification, creating awareness in target groups, commercialization and entrepreneurship development.

PPV&FRA is instrumental in protecting farmers' rights. The National Gene Fund constituted by the Government of India in 2007 supports the conservation and sustainable use of genetic resources including *in situ* and *ex situ* collections. Under PPV&FRA, 1 807 certificates were issued for protection of farmers' varieties. In addition, Plant Genome Saviour Farmers' Reward and Recognition was implemented by PPV&FRA for rewarding farmers or communities who are engaged in the conservation and utilization of PGR. These awards are: Plant Genome Saviour Farmer Reward, Plant Genome Saviour Farmer Recognition (20) and Plant Genome Community awards (5).

One of the major challenges of sustainable use of agrobiodiversity and bridging the gaps between *in situ* and *ex situ* conservation is a lack of long-term economic viability. Thus, to promote agrobiodiversity conservation in an economically viable and sustainable manner, approaches such as the promotion of seed fairs, community seed banks, farmers' awareness programmes, quality seed distribution, participatory variety selection, local producer's markets, procurement systems, denomination of origin labelling and e-commerce schemes and an appropriate enabling environment and reward system are essentially required.

3.3 Successful approaches and practices for the sustainable use of crop diversity

Maria Andrade, International Potato Center (CIP), Mozambique

Crop diversity in agriculture is used to ensure food security, adapt to climate change, reduce environmental degradation, protect nutritional security and increase incomes for the rural people, with minimal environmental impacts. Crop diversity is the variance in genetic and phenotypic characteristics of plants used in agriculture, within each crop as well as the number of species commonly grown.

The diversity of our crop genetic resources is rapidly disappearing, and conservation is crucial for the present and future of world food security. Little to no genetic diversity makes crops susceptible to widespread disease, as happened during the Irish Potato Famine, when the late blight pathogen wiped out entire crops of the dominant potato variety, and one million people starved to death.

Crop diversity provides communities with varied diets, stability of production, minimization of risk and reduction in pests and disease. For the highly variable environments, higher total production was achieved by planting a wide variety of crops specifically adapted to the micro-environments in which they evolved. Farmers value not only crop yield, but other attributes such as taste, cooking ability, marketability, early maturity, the ability to utilize residual soil moisture and storability.

Sustainable approaches to ensure crop diversity include:

- speeding up breeding processes substantially: accelerated breeding programmes to develop new and diverse varieties with ability to co-exist with other crop species;
- investing in technologies that promote diversity in crop production: conservation agriculture, intercropping systems, conservation of the genetic diversity of crops including their wild relatives and other valuable plant species; and
- strong research collaboration and research synergy among the CGIAR centres to identify crops that can complement each other to promote crop diversity at farm level.

The International Potato Center (known by its Spanish acronym CIP) works to study, protect and utilize the diversity of potato, sweet potato and other Andean root and tuber crops in sustainable agriculture systems, ensuring food security and increasing incomes for the rural people. While the genetic diversity is in the large range of shapes, colours and taste, this diversity also contains a hidden treasure: unseen characteristics, such as resistance to disease and drought, providing a valuable repository of traits that breeders and farmers can use.

The CIP genebank conserves *in vitro* germplasm and seeds of these genetic resources, which the scientific community, upon request, can use in a sustainable way. This collection is used in breeding programmes in over 100 countries around the world. CIP works with other genebanks to ensure that clean material from its collections is backed up. Scientists at CIP work to identify traits that help meet farmer needs and preferences, particularly in the face of climate change pressures. Traits have been identified for: resistance to potato tuber moth and the Andean potato weevil; tolerance to frost, drought, heat and soil salinity; higher iron content and bioavailability in potato and sweet potato; and higher beta-carotene content in sweet potato, as well as traits associated with cooking quality.

CIP also works closely with Andean communities on the *in situ* conservation of potato diversity and has repatriated thousands of accessions previously lost to them. Scientists, together with Andean farmers and community organizations, are working to restore disease-free potato germplasm to its place of origin. They have also contributed actively to establishing community seed banks in the field, discovering and incorporating new varieties in the collections.

More than 1 000 sweet potato varieties are grown by smallholders in Papua New Guinea. Researchers from CIRAD showed that most of the varieties were bred locally from plants resulting from sexual recombination that appeared spontaneously in plots. This is a dynamic process that enables production to adapt to change, and constitutes an asset for the future.

Orange-fleshed sweet potato (OFSP), now colloquially known as a “supercrop”, is a model for biofortified crops with a visible trait – that of being orange in colour. Worldwide, sweet potato is the sixth most important food crop after rice, wheat, potato, maize and cassava, with over 105 million tonnes produced annually, of which 95 percent in developing countries. The crop is a storage root, different from the tubers, such as potato. It is a resilient species, cultivated from sea level to 2 500 m above sea level. Sweet potato is diverse in colour, from yellow to orange to purple or white. Just 125 g of the orange variety’s root contains enough beta carotene to provide the daily vitamin A needs of a preschool-aged child. The crop is also a valuable source of vitamins B, C and E. In addition, the vines of the sweet potato are used as feed for livestock, with studies suggesting that the animals fed on this crop produce less methane.

Through the accelerated breeding scheme, varieties are being produced in 4–5 years instead of 8–10 years. Since 2009, there have been major advances in the development of sweet potato, including: 162 varieties released in 16 countries, with 104 being orange-fleshed; 112 varieties bred by 12 African programmes; 16 varieties released in more than one country; and, 14 sub-Saharan African countries have committed to mainstreaming OFSP.

In order to promote nutrient-rich crops, such as OFSP, there is a need for research priorities to shift focusing on individual crops to encompassing complex farming systems. Additionally, plant breeding should be integrated into other disciplines, such that it becomes a more widely accepted approach to climate change adaptation and improved nutrition.

The importance of the contribution of communities cannot be underestimated. Integrating community seed banks and home gardens promotes the conserving of seed resources for locally-adapted material and engages local communities to recognize and promote the conservation and sustainable use of resilient, nutritious crops. Governmental policies are crucial in conserving the plant genetic resources upon which the food system depends.

3.4 Conserving crop diversity *in situ* and on-farm: balancing the needs of diverse stakeholders

Johan Robinson, United Nations Environment Programme, Kenya

The world relies on three crops – maize, rice and wheat – for more than 50 percent of its plant-derived calories. Hunger is increasing every year, globally. It is estimated that there will be more hungry people in the year 2030 than there were in 2005. Malnutrition in all its forms impacts one in every three people. Over two billion people are overweight or obese: adult obesity is increasing in almost every country in the world. It is projected that adult obesity will double between 2012 and 2030. The production of fruits, vegetables, seeds and nuts falls short by 22 percent of the global population's needs.

The food system also has an impact on nature. Eighty percent of all deforestation can directly be attributed to the food system and so can 29 percent of all greenhouse gas emissions.

Agriculture uses 34 percent of the land surface of the planet. It consumes 70 percent of freshwater and is directly responsible for 68 percent of total biodiversity lost. The hidden environmental and economic health costs are estimated at USD 12 trillion/year, and projected to increase to USD 16 trillion/year by the year 2050. This commodity-driven super system produces more calories for growing populations albeit at this huge cost. It is for this reason that the UN Secretary-General will be convening the Food Systems Summit later in 2021 as part of Agenda 2030 in the Decade of Action in achieving the Sustainable Development Goals (SDGs) by 2030. The aim of the Food Systems Summit is to change the way we think about food, how we consume food and how we produce food. It is guided by five Action Tracks, of which Action Track 3: Boost nature-positive production clearly states that it is critical to have biodiversity/agricultural diversity for sustainable and resilient food systems.

Nature has provided us a way forward – tens of thousands of alternative crops can substitute and/or complement the three main crops. For example, sorghum, millet and quinoa, grow in difficult conditions, have high nutritious value and their yields can be potentially increased. Wild and indigenous fruit trees, in many cases, have higher nutritious values than their exotic counterparts. By using biodiversity-based approaches across the vast area of the Earth under agriculture, we can reduce runoff, we can reduce emissions, we can reduce the need for synthetic inputs, while increasing soil quality and conserving varieties and species.

Agricultural diversity is also a source of species and varieties that are tolerant to climate extremes, from floods to drought to extreme temperatures. These are very important traits that are/can be taken forward in future climate adaptation. Therefore, agricultural biodiversity is a critical component of a sustainable food system, without which a food system cannot be sustainable. The conservation of crop wild relatives (CWR) and wild food plants is an overlap with the conservation of overall biodiversity, in the fields of biodiversity, agricultural and forestry.

The focus of this presentation is on CWR and wild food plants with some mention of landraces. CWR thrive in natural areas without human intervention. Wild food plants constitute an important component of the diets of many people. Studies have shown that CWR are well represented in protected areas but are not actively managed. This lack of information, or lack of capacity on the part of protected area managers, can be overcome very easily.

The United Nations Environment Programme (UNEP), through funding from the Global Environment Facility (GEF), worked in Cuba with the project being executed by the Alliance of Bioversity International & CIAT. The project focused on building capacity for protected area managers and farmers in conserving and managing CWR and associated agrobiodiversity in two “Man and Biosphere” reserves. The first step was to create an inventory of all the agrobiodiversity that was present in these areas. This information contributed to the development of conservation action plans and integrated these into the five-year management plans of these two reserves. Capacity building was provided for 800 people, including the farmers and protected area managers, for the conservation of agrobiodiversity. This is a very simple example of how easy it is to overcome this barrier of lack of capacity or lack of information, in this case, the management of CWR in protected areas. We have to acknowledge, however, that there are significant numbers of CWR and wild food plants that have no legal protection in protected areas.

With regard to landraces, which are mainly conserved in farmers’ fields, orchards and home gardens, these are one of the most severely threatened components of agrobiodiversity. It is extremely challenging to know how many landraces exist globally. Exacerbating this, the landrace “maintainers” are almost always older people, and their numbers are dwindling every year.

The stakeholders involved in these efforts are diverse and range from governments to civil society organizations to research institutions and more. The governmental stakeholders entail ministries from different sectors such as agriculture, environment and natural resource management and forestry. Local authorities play a key role and are major stakeholders, as are farmers and local communities. National research institutions, university and other education institutions are also important. Civil society organizations, including farmers' organizations, are very relevant, as are non-governmental organizations (e.g. conservation organizations). Private sector entities, mainly from the agricultural sector, can contribute significantly through knowledge sharing of technologies and approaches. Finally, regional and international organizations, including research centres and networks, are key in providing platforms for technology transfer and sharing of best practices.

These diverse stakeholders, while contributing to the conservation of agrobiodiversity as a whole, also have different needs. Balancing these needs is a complex issue and there is no one-size-fits-all. However, there are three areas where the needs of the diverse stakeholders can be balanced, especially coming from the protected area management sector: (i) harmonized governance; (ii) creating or improving sustainable financing of the area or the crop; and (iii) cross-sectoral collaboration.

i) Governance

This focuses on the structure and process of determining how responsibilities and power are exercized, how decisions are taken and how and who is involved. The governance structure must be context-specific and effective in delivering lasting conservation results, livelihood benefits and the respect of rights. An example of an innovative governance system that was used to balance the needs of stakeholders was seen in the Bangweulu wetlands in northern Zambia. This is a rich and diverse ecosystem, with over 400 birds, including the shoebill stork. It is also the only place in the world where an endemic species of antelope, the black lechwe, is found. Directly relevant to the topic of the Symposium, also present in these wetlands are a number of species of ground orchids. The tubers of these orchids are harvested by the local people to make a local savoury dish known as chikanda. Years of human pressure on these resources had depleted the wildlife of Bangweulu wetlands. In 2008, the community resources boards, who represent the communities that owned the land, invited a non-governmental organization, African Parks, to partner in managing the wetlands. The Bangweulu Wetlands Management Board was established, consisting of representatives of the six chiefdoms that own the land, representatives of African Parks and government representatives from the Department of National Parks and Wildlife. The success of this governance system can be seen in numbers. In 2008, there were 35 000 black lechwes on the plains while today there are over 50 000. Human development successes have also been achieved with a number of community-based enterprises that have been established, ranging from beekeeping to fish management to community-run ecotourism enterprises. The result of voices being heard and people being represented in the governance system will allow the needs of stakeholders to be addressed more effectively.

ii) Sustainable financing

This is a prevalent approach in protected area management and as CWR occur in these areas, it is important to address this topic here. Sustainable financing can be increased by adding value to products, through increased demand and through public support leading to policy and legislative changes. Value addition is undertaken in value chain and product development. In 2005, 20 women from six villages from Surguja district, India, became concerned about the disappearance of an indigenous, super-fine aromatic rice variety, Jeeraphool. The women created a self-help group and set out to conserve and promote this variety. The varietal promotion resulted in an increased market demand as well as increased demand for group membership. The group registered Jeeraphool with the Plant Varieties and Farmers' Rights Authority of India and applied for a geographical indication tag in March 2019. Once again, the success of this approach can be seen in numbers. In 2005, 120 hectares were planted with this variety and 180 tonnes harvested, which has now increased to over 400 hectares planted and over 1 000 tonnes harvested in this district. This initiative was recognized and adopted by a UNEP GEF project and scaled up and out to different parts of India.

Another example of value addition is seen in Armenia, where an alcoholic beverage was developed from wild sea buckthorn and is now sold locally. Other areas where value can be added are through ecotourism and providing resources to the private sector.

Consumer demand is normally increased by greater public awareness. By creating public awareness, a broad support base for the products or for the area is created. This can be achieved through personal contacts, group exchanges, diversity fairs and even through poetry, music and drama festivals. The international and local media also play an important role. Publicizing cookbooks and recipes specially linked to the nutritious values of local crops is an innovative approach to mainstreaming crop diversity.

Public support is often needed to drive changes in policies and practice. Increased public awareness can be the catalyst for necessary changes in policies and legislation. Economic studies can significantly influence how decision-makers channel financing. There are a limited number of economic studies to this effect. For example, 30 percent of increases in production are linked to CWR, with an estimated annual value of USD 115 billion. Another study looked at the wild relatives of 29 crops and attributed the value of USD 42 billion to them. These are important figures and can change the course of financing decisions.

iii) Collaboration

Collaboration happens if communities have a common cause, such as in a community of practice. The exchange of information may be subtle, and often not obvious, but provides a drive and direction while supporting other community members in working towards a common goal. Collaboration also contributes to problem-solving at the community level, interactive and iterative learning and communication, increasing efficiency and driving innovation.

In moving ahead with developing communities of practice in the conservation of crop diversity on-farm and *in situ*, platforms for communication are needed at the local, national, regional and global levels. At the local level, such structures may be very easy to develop. For example, in Uzbekistan, local farmers created a social network over their mobile phones for sharing information on markets, plants, weather, etc. At the global level, the Global Environment Facility has a number of programmes, such as the global wildlife programme, to which a number of country projects contribute, and an overarching programme on knowledge management and capacity building, creating an effective community of practice. Overall, based on personal observation, it is felt that projects under a programme deliver more effectively than stand-alone projects.

In conclusion, in order to balance the needs of diverse stakeholders that contribute to *in situ* conservation and on-farm management of crop diversity, there is a need to: (i) create and support innovative governance structures; (ii) improve financial sustainability of the conservation of crops and their environments; and (iii) collaborate effectively.

4. SESSION 2: *IN SITU* CONSERVATION OF CROP WILD RELATIVES AND WILD FOOD PLANTS

Wild artichoke (*Cynara cardunculus* L. subsp. *sylvestris*), Italy

4.1 Session summary

Three key themes were addressed in Session 2: securing wild PGRFA diversity *in situ* and in complementary *ex situ* programmes; *in situ* conservation and its integration with plant breeding; and the conservation and use of wild food plants. Speakers presented context-specific best practices for conservation management of PGRFA in natural habitats and in complementary *ex situ* programmes, and the use of CWR in pre-breeding. Speakers presented conservation efforts and constraints in centres of origin and diversity, such as threats to *in situ* populations (from invasive species, habitat destruction, fragmentation, overcollecting, etc.) and the lack of sufficient resources for *ex situ* conservation. Participants considered multiple ways to overcome these constraints: e.g. by supporting policies, collaborative fundraising, developing technical capacities in *in situ* and *ex situ* conservation and bridging gaps in the conservation continuum.

A CWR conservation strategy from southern Africa exemplified the linkage between *in situ* and *ex situ* conservation of CWR in the field. Key elements of this strategy included access to genetic materials for breeders to use them in pre-breeding, which is enabled by a number of policies. For example, the establishment of genetic reserves requires appropriate legislation, laws, regulations and policies to ensure long-term land tenure for the purpose of *in situ* conservation. It was also highlighted that policies are needed to support the development of an evidence base for *in situ* and *ex situ* conservation linkages, including demographic studies, genetic diversity studies, seed biology, characterization and evaluation of genetic materials, among others.

The Session included the presentation of a survey of the native flora of Brazil, the results of which were published in 2020 and revealed 46 975 native species of plants, algae and fungi. In order to safeguard these species effectively, it was considered essential to map the locations of wild and cultivated PGRFA, use comparative threat assessments to prioritize conservation activities for species and populations, and develop capacities in taxonomy to increase identification, collection, conservation and characterization of CWR and wild food plants. Key enabling factors highlighted were: multi-institutional collaboration; the need to restrict human encroachment into protected areas; financial incentives for valorizing ecosystem services; the leveraging of conservation sites to improve livelihoods of local communities; and building of capacities and awareness raising to encourage farmers to actively participate in conserving CWR.

A study conducted in Yunnan Province, China, demonstrated different methods of physical isolation, and approaches that combine conservation activities with farmers' agricultural production systems. The isolation methods included brick walls, solid fences and plant fences in protected areas containing wild rice species. The study also highlighted the impacts of *in situ* conservation on the livelihoods of farmers with decreased dependence on CWR habitats. Improved polices and financial incentives encouraged local farmers to adapt to a market-oriented economy and to participate actively in the conservation of CWR. In addition, farmers' income per capita was found to have increased significantly over a ten-year period, which increased the quality of education of young people in villages.

Speakers stressed the importance of CWR and underscored their importance in pre-breeding and the mining of their alleles for biotic and abiotic resistance, as well as for yield improvement. The case of pigeon pea (*Cajanus cajan*) was presented, in which a number of pre-breeding populations were developed from its secondary (*Cajanus acutifolius* and *Cajanus scarabaeoides*) and tertiary (*Cajanus platycarpus*) genepools. A number of trait-specific introgression lines for enriching the variability in the primary genepool were identified for use in breeding, including for salinity tolerance, and resistance to pod borer and Phytophthora blight. Similar work on chickpea, groundnut and pearl millet had also been conducted. These examples illustrated the importance of conserving CWR and developing adequate strategies to enhance their utilization in crop improvement programmes.

Wild food plant species, important for the diets and livelihoods of local communities, especially during times of food scarcity, were also discussed. Participatory approaches, including through demand-driven value chains, were presented as successful methods for promoting the conservation and sustainable use of nutritious wild food plants. It was emphasized that these species have multiple uses beyond just consumption, including for medicinal, material or environmental purposes. The MGU-Useful Plants Project, developed under the Millennium Seed Bank Partnership and with an important component on the development of capacities in local communities to conserve and use wild edible plants, was presented, and its successes highlighted. Overall, the speakers in this Session described ten priority species, indicating their uses and products as well as their potential for commercialization. The case of the morama bean (*Tylosema esculentum*) was described as one of the species prioritized by local communities in Botswana for its high oil and protein content. During the project, community gardens were established as nurseries and for capacity development in seed collecting and conservation, cultivation, value addition and marketing of these climate-smart emerging crops.

4.2 Theme 1: Securing wild PGRFA diversity *in situ* and in complementary *ex situ* programmes

Collecting crop wild relatives in Central America
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4.2.1 Bridging *in situ* and *ex situ* conservation in the field

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For millennia, humans have been actively collecting wild species for food and agriculture, domesticating them, and moving them across countries. However, it has been only in the last century that the plant genetic resource for food and agriculture (PGRFA) conservation movement started. Pioneers such as Nicolai Vavilov and others recognized that the genetic diversity of crops and their wild relatives is rapidly being lost from the field. This loss was further exacerbated by the Green Revolution in the 1960s and 1970s, which boosted productivity with high-yielding cultivars at the expense of genetic diversity in the field. In the 1970s, the world community recognized this loss and established the International Board for Plant Genetic Resources to support collection and conservation of threatened PGRFA predominantly in genebanks. Nevertheless, large-scale cultivation of high-yielding cultivars and environmental mismanagement continue to erode basic *in situ* and on-farm resources. It was only in the 1980s and 1990s when the negotiations of the Convention on Biological Diversity (CBD) and the FAO International Undertaking on PGRFA were taking place that *in situ* conservation gained more attention. It was argued that conservation allowed biological evolution to continue and that this fact was critical for adaptation of PGR and creation of new genes and traits to cope with present and future challenges for food production.

Dichotomy between *in situ* and *ex situ* conservation

In situ and *ex situ* conservation are two recognized approaches to the conservation of biodiversity, which includes PGRFA. *In situ* conservation is widely recognized as the conservation of natural habitats and ecosystems. It also entails the conservation and maintenance of viable populations of species in their natural habitats. In the case of domesticated or cultivated crop species and varieties, these populations are conserved on-farm, where they have developed their distinctive properties. Conversely, *ex situ* conservation refers to the conservation outside of natural habitats, for example in genebanks. Over the past decade, the scientific community debated that conservation (of biodiversity) should be done predominantly *in situ*, with *ex situ* playing a backup role. The CBD recommends that countries, to the extent possible, undertake complementary *in situ* measures and adopt measures for the *ex situ* conservation of components of biological diversity, including crop diversity, ideally in the country of origin. As such, the establishment and maintenance of specialized *ex situ* facilities is also recommended.

Recognition of the complementarities between *in situ* and *ex situ*

The complementarity between *in situ* and *ex situ* conservation has now been globally recognized in the major international fora, although they have not been explicitly stated. However, the International Treaty on PGRFA, in its Article 5, calls on its parties to promote an integrated approach to the exploration, conservation and sustainable use of PGRFA, including *in situ* and *ex situ* conservation. The CBD has separate articles on *in situ* (Art. 8) and *ex situ* conservation (Art. 9), but there is no mention of complementarities between them except, as mentioned above, that CBD recognized *in situ* as being a priority over *ex situ*. The FAO Second Global Plan of Action (Second GPA) for PGRFA also emphasizes that the conservation strategies are most effective when they are complementary and are well coordinated. *In situ* and *ex situ* conservation and sustainable use need to be fully integrated at all levels.

Complementarities between *in situ* and *ex situ* conservation

In situ and *ex situ* complement each other in three main ways. First, *in situ* conservation is seen as dynamic conservation where genetic material continues to evolve and the allelic composition at the level of the population is changing over time. While some alleles are being lost, others are appearing as a result of natural selection. On the other hand, *ex situ* conservation freezes the genetic diversity at the time of collection and conserves that diversity for long-term use and prevents it from being lost. In that sense, both these approaches are fully complementary to each other. A second important complementarity is that *in situ* conservation allows the conservation of a greater diversity of the taxa, but the genetic diversity of each taxon can be very scattered over a large area and difficult to access, while with *ex situ* a greater diversity of target species can be conserved in a limited space and is easily accessible to breeders. A third important complementarity is that *in situ* conservation is amenable to all types of PGRFA. But *ex situ* is limited to some types only, for example those having orthodox seeds or for which techniques have been developed and been refined and require less efforts for their long-term conservation.

Bridging the gap between *in situ* with *ex situ* conservation and with use

The process for integrating *in situ* and *ex situ* conservation and use of PGRFA including crop wild relatives (CWR) follows the different stages of conservation planning, which starts with the identification and prioritization of the diversity, developing conservation and use strategies that bring together all the different components of *in situ* and *ex situ* and how they are used. This leads into the implementation of *in situ* and *ex situ* conservation activities in a complementary way and enhancing its use. The question of the availability and access to the genetic material is also an important issue to consider so that users of genetic resources (breeders, farmers, etc.) can characterize and evaluate their potential use in pre-breeding/breeding programmes. For these steps to happen it is necessary that enabling policies and strategies are in place to enhance the conservation and use of PGRFA.

The first step is to develop a National Strategic Action Plan (NSAP), which involves making a detailed assessment of the diversity and developing strategies and concrete action plans to ensure the conservation of the resources in a coordinated and complementary manner. For example, in the Southern African Development Community (SADC) region, a number of countries have developed NSAPs for the conservation and use of CWR funded by African, Caribbean and Pacific-EU Cooperation Programme in Science and Technology (FED 2013/330-210) and the United Kingdom Department for Environment Food & Rural Affairs/Darwin Initiative SADC-CWR project (project 26-023), in which participating countries (Malawi, Mauritius, South Africa, the United Republic of Tanzania and Zambia) have prepared NSAPs, in which all the key stakeholders from environment and agriculture sectors are involved. This was done by establishing a multi-stakeholder committee that brought these key stakeholders to develop these NSAPs in a fully participatory way so that the key actors have a sense of ownership and are able collaborate to ensure that the diversity of PGRFA is conserved in the most cost-effective and efficient and complementary manner. In each country, the NSAP is then implemented by multi-disciplinary scientific teams involving protected area managers, landowners including farmers, taxonomists, genebank curators and breeders. Working together in this way is critical to strengthen the links between *in situ*, *ex situ* conservation and use of the genetic resources that will open a series of activities in the field, in genebanks and in use in breeding programmes.

Enabling policies

A key element of complementary conservation of PGRFA is having the right enabling policy environment in place to overcome the major constraints that face complementary conservation actions. For example:

- having legal long-term land tenure in place for *in situ* conservation sites;
- *ex situ* facilities are adequately supported both in terms of human resources and funding;
- access and benefit-sharing mechanisms need to be in place to ensure access to *in situ* and *ex situ* materials by bona fide users and ensuring that benefits arising from their use are equitably shared;

- policies in place to address various management and technical constraints – threats to *in situ* populations (for example invasive species, habitat destruction, fragmentation, overcollecting, etc.); and
- policies to support research on *in situ* and *ex situ* conservation, characterization and evaluation of genetic materials.

In conclusion, there is a need to dispel the dichotomy and promote the integration of the conservation (*in situ* and *ex situ*) approaches and their use, which must be seen as being fully complementary and be part of one conservation strategy. Countries should be encouraged to develop NSAPs for CWR and other PGRFA, bringing together all relevant stakeholders and establish the right enabling policy environment at the national level for ensuring the most effective and efficient conservation and facilitating the use of PGRFA.

4.2.2 Complementary conservation strategies: experiences from the Crop Trust

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Crop diversity is an important part of the solution to feed a growing world population under climate change, but it is at risk. *Ex situ* and *in situ* conservation strategies need to work hand in hand to secure this diversity for future generations and make it available to those at the frontlines of combating climate change.

Genebanks collect and preserve crop diversity and make it available to breeders, scientists and farmers for use. Breeders, for example, are able to introgress traits from crop wild relatives (CWR) into the domesticated genepool to create more climate-ready varieties for farmers to use. The Crop Trust's mandate is focused on *ex situ* conservation, but we clearly recognize the importance of *in situ* conservation too. *In situ* conservation allows continued evolutionary dynamics on farm and in the wild, and the preservation of traditional knowledge and expertise. *Ex situ* conservation facilities offer a useful backup and complement to *in situ* conservation efforts through their focus on long-term preservation and easier use by scientists and breeders around the world. The Crop Trust encourages all of its partners to take note of the benefits of both conservation methods and subscribes to the view that they are best considered as part of an overall "conservation continuum", rather than two independent methods.

In the Crop Trust's work to develop global conservation strategies for different crops and groups of crops, although the main focus is on *ex situ* conservation, *in situ* is also considered whenever possible. For example, for the recent development of conservation strategies on yam, groundnut, millets and potato, specific sections of the strategies were prepared by relevant experts that specifically considered *in situ* conservation methods.

For the past decade, the Crop Trust has coordinated a project called, "Adapting Agriculture to Climate Change: Collecting, Protecting, and Preparing Crop Wild Relatives", funded by the Government of Norway. The first step of this project was mapping the distribution of CWR around the world, which revealed that genebank collections of these species are generally inadequate. This information was then also used by researchers to assess where *in situ* conservation sites could be established to most effectively protect these important genetic resources. Only a small number of *in situ* conservation efforts for CWR exist at the moment, although about two-thirds of the 150 sites identified in the study can be found in areas that are protected to some extent. Therefore, significant progress could already be achieved if existing protected area management plans would more explicitly take into consideration CWR as an important and valuable resource to be conserved.

Another example of strengthening linkages between *ex situ* and *in situ* conservation comes from the Crop Trust-CGIAR Genebank Platform, under which the International Maize and Wheat Improvement Center (CIMMYT) has run the *Jala Rematriation Project* to work together with national, regional and local partners in Mexico to return seeds that have been stored *ex situ* for over 60 years back to the communities from where they were originally collected. The project developed strategies for a dynamic conservation approach of maize genetic resources at the prominent example of the Jala maize landrace from the Jala valley of Mexico, which notably produces the largest ear of any known landrace around the world. These strategies could serve as a model for other such efforts around the world.

Furthermore, the Crop Trust is also implementing the Seeds for Resilience project, which is a partnership with five national genebanks in sub-Saharan Africa (Ethiopia, Ghana, Nigeria, Kenya, Zimbabwe) that focuses on upgrading facilities and building the capacity of these important collections. The project also includes a component on linking genebanks better with users through participatory evaluation of materials. A similar approach is also a focus of a new project the Crop Trust has just initiated with support from the Government of Norway, called "Biodiversity for Opportunities, Livelihoods and Development (BOLD)", which includes a work stream to strengthen linkages between genebanks and farmers.

The Crop Trust is also aiming to develop further a project concept, tentatively called Foundations of Our Food (FOOD), in collaboration with Asociación ANDES and the Alliance of Bioversity International & CIAT, which aims to strengthen the conservation continuum. FOOD would document and analyse the state of crop diversity in regions of crop origins, and establish networks of diverse "food neighbourhoods" following the model of the Parque de la Papa in Peru. Such neighbourhoods would link local communities with each other as well as with national or international *ex situ* collections.

Viewing *in situ* and *ex situ* conservation of crop diversity as a continuum not only allows diverse stakeholders to work together and cooperate, but it also helps use limited resources for more effective conservation action.

4.2.3 Identification of promising species, collecting plant germplasm and in situ conservation in Brazil

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The identification of promising species (in addition to those already recognized as primary food species) is discussed from a point of view that implies social and political responsibility for any possibility of success. Further, the uncertainties of plant germplasm collection activities, and the prospects of *in situ* conservation of plant genetic resources for food and agriculture (PGRFA) should also involve formal decision-makers.

At the time of the European discoveries, what is now Brazil had a large human population, which was capable of meeting the nutritional needs for survival and growth. In addition to hunting and fishing and plants simply gathered by nomadic consumers, there were the familiar American food plants, many of which have become essential agricultural items across the globe.

This primary agricultural matrix, available until 1500, made up of local food plants used in pre-Columbian times, was gradually replaced by an expanded matrix, continuously transformed from 1500 to the present. New food plants were constantly imported from the Old World, throughout the discoveries, colonization and increase in maritime trade. Again, many of these plants are now neglected as this is a dynamic process, with the international flow of species for agricultural purposes continuing.

More recent discoveries, from the 1960s to the present, have affected the regional search for PGRFA. The world is witnessing a shift from the "need to feed" to a "need to nourish", based on a growing scientific understanding of food biochemistry and human physiology, and including concerns about population expansion and the potential impacts of climate change. New food plants with varied nutritional attributes and wild relatives of crops to expand the genetic basis for crop improvement, have become new targets.

The current Brazilian food matrix brings together a multitude of species, varieties, landraces and commercial varieties. Many of these are neglected or locally extinct, while others are growing in importance in modern diets. The matrix includes crops with no local relatives, exotic crops with local wild relatives, American crops with landraces, South American crops with local wild relatives, and even some crops domesticated in Brazil, with many wild relatives. There is also an increasingly well-documented component of wild relatives of global crops. Foreign, regional and national germplasm of typical crop plants must be conserved on-farm and *ex situ*, while wild Brazilian relatives of regional or Brazilian crops need to be conserved *in situ* and *ex situ*. The same is true for wild species with a potential for use as crops, which are not wild relatives of crops, but also need to be conserved both *in situ* and *ex situ*.

The Brazilian Flora 2020 project published a catalogue of 32 696 species of angiosperms, of which 55 percent of the Brazilian land plant species are found only from Brazil. This means that the project recognizes thousands of promising species for food and agriculture. The question is, how many are safely conserved?

While the conservation of biodiversity itself can be achieved largely through initiatives to preserve plant communities in nature, the conservation of PGRFA will not be effective if their germplasm is not made available for characterization. This is a first step for the recognition of utility, and this is only possible when samples are obtained from nature or from remote communities.

Much has been discussed about the conservation and sustainable use of PGRFA and the fair and equitable sharing of the benefits arising from their use, but the evidence is that sharing of germplasm is challenging. The international exchange of plant genetic resources faces limitations, and even domestically, in many countries, the collection of plant genetic resources is more difficult in modern days than it has been in the past. Despite strong restrictions on distribution abroad, as well as internal barriers to institutional sharing, germplasm sampling of the diversity of crops and their wild relatives continues in Brazil, although not as fast and comprehensive as it should be, in order to compensate for the pace of environmental disturbance.

The need for trained germplasm collectors is also a major concern. Sampling the local diversity of exotic or regional crops requires a typical agronomic profile and targets farmers' fields and local markets. However, the rescue of wild food plants and crop wild relatives (CWR) requires additional botanical training. Success as a wild plant germplasm collector depends on synergistic agronomic/botanical training, which will also be useful in seeking to integrate *ex situ* and *in situ* conservation efforts.

For many of the crops at stake, wild relatives have peculiarities that are rare or absent in landraces and cultivars, referring to plant morphology, life cycle, ecological preferences, distinct modes of reproduction and many other characteristics. Crop specialists often do not recognize wild relatives in nature, but the Brazilian Academy of Sciences (Academy) is working to mitigate this problem, and Brazil currently has three well-structured postgraduate courses in plant genetic resources, at the doctoral level. Efforts are currently seeking to integrate these courses and institutions responsible for genetic resources with the postgraduate courses in botany, so that well-trained plant germplasm collectors can be available as needed in the long term.

Collaborative efforts to collect wild relatives of crops have already helped to emphasize the importance of living plants available *ex situ* for taxonomic and phylogenetic characterization. As new species are brought to light, plant germplasm collectors and genebank curators end up sharing the authorship of plant names, which in the past was traditionally reserved for herbarium botanists who dealt preferentially with pressed specimens. Collection for increase and availability of live plants *ex situ* has grown as a practical and scientific activity in Brazil since the 1960s, with mutual benefits for the agronomic and botanical communities.

Comparing the geographic distribution of native PGRFA with that of expanded mechanized agriculture in Brazil, it is obvious that the prospects for successful *in situ* conservation of wild relatives are very limited outside officially protected areas. However, on the positive side, the number of Official Conservation Units with federal, state or municipal mandate is 2 201, totalling 250 million hectares. But expectations are not homogeneous for different groups of plants. For example, the natural distribution of wild Brazilian species of *Arachis*, the wild relatives of the groundnut, is concentrated in the geographic area with the greatest livestock and agricultural activity. Due to the peculiar underground seed production of this genus, this concentrated distribution was not a serious problem for the *in situ* survival of wild *Arachis* species until the 1980s, when the use of herbicides was intensified. The same can be said of wild relatives of cassava, the wild species of *Manihot*, also densely concentrated in West-Central Brazil.

Detecting the presence of CWR in Conservation Units has become a priority. However, the highly heterogeneous academic background, rarely including any agronomic or botanical training, of the local conservation teams, is generally insufficient for the simple maintenance and security inspection of areas under their assigned control.

After many decades in which germplasm collection was not allowed in Conservation Units, the documentation of the presence of PGRFA in these areas is now seen from a more constructive point of view. Success, in this regard, depends on collaborative association between government agencies and at an institutional level, in addition to personal initiatives that improve knowledge about what is where, and permission to collect germplasm, to create real possibilities for characterization and subsequent use.

The main challenges for the *in situ* conservation of wild crop relatives in Brazil are: (i) the lack of knowledge about CWR in the Academy, in the farming communities and among conservation agents; (ii) the scarcity of trained professionals to carry out the necessary research and *in situ* management of wild food species and CWR, in addition to their interface with *ex situ* protocols; and (iii) potential effects of climate change in Official Conservation Units and other protected areas.

Farmers and conservation agents will only act positively to conserve PGRFA *in situ* if and when they are aware of their presence, and able to recognize them in the diverse Brazilian vegetation. Only the effective characterization of the reproductive behaviour, genetic relationships and the potential for hybridization with the related species will validate the wild relatives of crops as potential sources of new genes. This must necessarily be done *ex situ*. If done effectively, then documenting the relevant qualities will provide additional justification for the expensive and difficult *in situ* conservation work.

4.3 Theme 2: *In situ* conservation and integration with plant breeding

Crop wild relative drought evaluations, CIP
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4.3.1 Pre-breeding using crop wild relatives

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The genetic improvement of crops in modern agriculture is hindered mainly due to the narrow genetic base of the cultivars. Further, several biotic and abiotic stresses, specifically those emerging due to climate change, cause major yield losses. Often, high levels of resistance and tolerance to these stresses are not available in the cultivated gene pool. Crop wild relatives (CWR) continue to grow in nature and have evolved mechanisms, including the traits for better adaptation to withstand the climatic extremities. They are known to carry several novel alleles for the genetic improvement of present-day crop cultivars.

Low utilization of CWR in crop improvement

Though the importance of CWRs in improving the modern crop cultivars is well known, these resources are not utilized adequately and efficiently in crop improvement programmes. Major factors responsible for their low utilization includes lack of reliable characterization and evaluation data on traits of breeders' interest, phenological differences between cultivated and wild accessions, cross-incompatibility barriers and linkage drag, etc. Further, there is a fear among breeders that involving CWR in breeding programmes may lead to deteriorating performance of their working collection due to linkage drag. Owing to these constraints, coupled with varying degrees of success rates, utilization of CWR in breeding programmes has become a time-consuming and resource-demanding research endeavour.

Pre-breeding: a link between genebanks and breeding programmes

Efficient utilization of these important but underexploited resources in crop improvement programmes requires an intermediate step, i.e. pre-breeding. Pre-breeding involves all the activities associated with identification of desirable traits and/or alleles from un-adapted germplasm (exotic landraces, CWR) that cannot be used directly in breeding programmes. It also involves the transfer of these traits into well-adapted genetic backgrounds, resulting in the development of an intermediate set of material that can be used readily by the plant breeders in specific breeding programmes to develop new varieties with a broad genetic base. Focused and systematic pre-breeding programmes will assist in accessing novel alleles from the untapped secondary and tertiary gene pools for enriching variability in the primary gene pool.

Pre-breeding for pigeon pea improvement at ICRISAT

Pigeon pea (*Cajanus cajan* (L.) Millsp.), the sixth most important grain legume crop, is cultivated for its protein-rich seeds mainly in Asia (India and Myanmar) and eastern and southern Africa (Kenya, Malawi, Mozambique, Uganda and the United Republic of Tanzania). It is an often cross-pollinated diploid (2n = 2x = 22) crop that is grown for its multiple uses such as food, feed, medicine, fuel, fencing, roofing, basket making, etc., and as a soil enricher and soil binder. Despite enormous breeding efforts in India and elsewhere, genetic enhancement in this crop is not adequate due to its narrow genetic base. Wild *Cajanus* species provide novel genetic variations for important traits such as resistance to sterility mosaic disease, Fusarium wilt, Phytophthora blight, pod borer (*Helicoverpa armigera*), pod fly, root-knot nematodes and tolerance to abiotic stresses such as salinity, drought and photoperiod insensitivity.

The RS Paroda genebank at ICRISAT conserves about 13 787 accessions including 555 accessions of wild species from 60 countries. In the theme "Pre-breeding at ICRISAT", efforts have been made to introgress useful genes/alleles for important traits such as tolerance to salinity, and resistance to pod borer and Phytophthora blight from wild *Cajanus* species into cultivated pigeon pea. Using cross-compatible secondary gene pool species, *C. cajanifolius, C. acutifolius, C. scarabaeoides* and cross incompatible tertiary gene pool species, *C. platycarpus*, and *C. volubilis* as donors and popular pigeon pea cultivars, ICPL 87119 (also known as 'Asha') and ICPL 85010 as recipients, advanced backcross populations were developed at ICRISAT. Efforts were also made to introgress pod borer resistance from wild *Cajanus* species into cultivated pigeon pea following simple- and complex-cross approaches. In wild *Cajanus* species, different mechanisms confer pod borer resistance such as antixenosis (oviposition non-preference) and antibiosis. Using the *C. acutifolius* having high levels of antixenosis for oviposition and antibiosis and the *C. scarabaeoides* accession, ICPW 281, having a high density of C-type trichomes as donors and the two popular pigeon pea varieties, ICPL 87119 and ICP 8863 as recipients, two advanced backcross populations were developed. Besides this, with a view to combine different components governing pod borer tolerance into a common genetic background, two backcross populations derived from complex four-way F1 crosses were developed in two different genetic backgrounds. These populations were evaluated under controlled environmental conditions and/or natural field conditions at ICRISAT to identify trait-specific gene pools.

Identification of trait-specific gene pools

Evaluation of an advanced backcross population consisting of 138 introgression lines (ILs) derived from salinity tolerant *C. platycarpus* accession ICPW 68 in the pot experiments resulted in the identification of 20 salinity-tolerant ILs. Further, three advanced backcross populations consisting of 138, 149 and 183 ILs derived from *C. platycarpus*, *C. acutifolius* and *C. cajanifolius*, respectively were screened for Phytophthora blight resistance under controlled environmental conditions at ICRISAT. Eighteen ILs derived from *C. acutifolius* and five ILs derived from *C. platycarpus* were found moderately resistant to Phytophthora blight. For pod borer, evaluations of four pre-breeding populations were derived from simple- and complex-cross approaches under unsprayed field conditions. This was undertaken over diverse years and locations as well as using laboratory bioassays, resulting in the identification of 39 ILs having improved pod borer resistance.

In pigeon pea, varieties/hybrids in different maturity groups, such as super-early (matures in <100 days), extra-early (mature in 100–120 days), early (121–140 days), mid-early (matures in 141–165 days), medium (166–180 days) and long duration (>180 days) groups, were cultivated in different agroecosystems, which are defined by altitude, temperature, latitude and day length. Most of the pigeon pea cultivation was within the medium maturity duration group, with Asha as the most dominant cultivar grown in these areas.

Breeders are working to develop new higher-yielding varieties as a replacement for Asha. Further, due to short cropping seasons, pigeon pea breeding programmes are now focusing on developing new cultivars with early and mid-early maturity duration. Evaluation of different pre-breeding populations resulted in the identification of 91 high-yielding ILs in the early, mid-early and medium maturity duration groups, 22 bold-seeded ILs, 16 ILs in the extra-early maturity group and with determinate flowering pattern, 15 ILs in the early and mid-early maturity group and with indeterminate flowering pattern, 153 ILs with semi-determinate flowering pattern and several sterility mosaic disease and wilt-resistant ILs.

Multi-location evaluation in collaboration with NARS, farmers and the private sector in India and Myanmar

Multi-location evaluation of selected 91 high-yielding ILs resulted in the identification of 12 ILs: ICPL 15017, ICPL 15019, ICPL 15023, ICPL 15028, ICPL 15042, ICPL 15043, ICPL 15048, ICPL 15061, ICPL 15062, ICPL 15067, ICPL 15072 and ICPL 15075. These ILs had high yields across different locations in India. Besides this, 20 salinity-tolerant ILs and 23 Phytophthora blight-tolerant ILs were also evaluated for yield and component traits across different locations in India to identify promising ILs with good agronomic performance.

Farmers were invited to visit the evaluation trial sites to provide their feedback and select the most promising ILs. Among the 12 high-yielding ILs, six ILs were selected and shared with farmers for further evaluation in participatory trials. Further, the superiority of a few ILs over local and/or national checks has provided an opportunity for breeders to include promising ILs in the Initial Varietal Trial (IVT) of the All India Coordinated Research Project (AICRP) on pigeon pea for potential release as a variety(ies). For example, ICPL 15072 has been nominated for IVT of AICRP during the 2019 rainy season from Gulbarga, Karnataka, India, due to its better performance than the checks ICPL 87119 (Asha), ICPL 8863 (Maruti) and local checks over three consecutive years: 2016, 2017 and 2018.

The high-yielding ILs, as well as salinity- and Phytophthora blight-tolerant ILs, were also shared with breeders in Myanmar to study the adaptability and performance of these ILs for yield-related traits. Evaluation across locations and over years has resulted in the identification of a few promising ILs, such as ICPL 15028, ICPL 15062, ICPL 15072, ICPIL 17116 and ICPIL 17124, which are being used in the national breeding programmes in India and Myanmar. Bold-seeded ILs were shared with a breeder in Nairobi, Kenya. Promising ILs are also being used in the pigeon pea breeding programme of Daftari Seeds Pvt. Ltd, Nagpur, India.

Conclusion

Pre-breeding using CWR has great potential for enriching genetic variability in primary gene pools for ready use by plant breeders when developing new climate-resilient cultivars with a broad genetic base. However, the success of pre-breeding programmes is hindered by several challenges. Due to the involvement of unadapted and incompatible CWR, it takes many years to develop breeding populations, thus making pre-breeding a time-consuming, long-term, resource-demanding and less-attractive research area. Further, specialized expertise is required to deal with several technical challenges, especially for using cross-incompatible wild species. To harness the full potential of CWR conserved in genebanks, systematic and focused pre-breeding programmes should be in place. There is an urgent need for active engagement with stakeholders to strengthen pre-breeding programmes, which will ensure the continuous supply of new genetic variability into the main breeding programmes, with the aim of accelerating genetic gains and improving nutrition and resilience traits of modern crop varieties.

4.3.2 Experiences in crop wild relative conservation and use

Maria Francisca José Acevedo, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Mexico

The COVID-19 pandemic has shown that current globalized agriculture and food systems are failing the task of efficiently, effectively and sustainably feeding the world. While cooperation among all actors continues to be absolutely essential, what we aim for and how we depend on each other, in our efforts and ideals, must be reframed to consider key factors in agricultural and food systems that, until today, have hardly been visualized, valued and supported.

One of the key factors that has been mostly uncared for, undervalued and taken for granted is the traditional farming system, mostly practised by smallholder farmer units around the world, which happen to provide at least two invaluable public goods to society, enabling us all to bet for a future full of diverse and nutritious food. The public goods traditional farming systems provide ”food and evolutionary services”.

The future of agricultural and food production worldwide depends on the conservation of the genetic diversity of the crops that we are familiar with. The genetic diversity that is referred to is primarily conserved in *in situ* conditions, mostly present in those regions of the world where agriculture originated and, most importantly, in those parts of the world where traditional agriculture prevails up until today thanks to the millions of smallholder farmer units worldwide that assure the continued presence of such genetic diversity.

The processes that foster genetic diversity are directly linked to ”evolution under domestication”', where crops have continued to be selected by smallholder farmers. The traditional knowledge, practices and seeds have been maintained, shared and passed from one generation to the next for hundreds or even thousands of years.

These evolutionary services are provided by the natural world, through the presence of thousands of known crop wild relatives present in wild conditions that continue to evolve through natural selection. The services are also provided through the very intricate human-construed traditional practices that promote continued domestication processes and local adaptation.

Conserving these elements is core. It requires achieving a complex balance between farmers, politicians, the private and public sector, as well as society at large, to share and target a necessary pathway towards assuring that the evolutionary processes related to domestication that started thousands of years ago continue into the future. In order for this to be effective, the wild and close relatives of crops must be conserved *ex situ*, but most importantly, *in situ,* so that they continue to evolve in their natural setting.

To be able to effectively and efficiently achieve this, it is necessary to:

- foster research and expertise in these plants through the lens of all related and interconnected disciplines, including the biology, the geographic distribution, the habitats, the ecology, up to the way these are conserved, fostered and managed;
- support the institutions that are behind the research and the expertise in these plants;
- identifythe risk status of these species or subspecies (and within them) as well as the risk drivers, aiming to lower these as much as possible so that the numbers continue to be in the healthy sphere; and
- unveil the hidden values related to these evolutionary services by making visible what is mostly invisible and guiding in making the right choices and decisions to positively impact and strengthen these.

Conservation of the wild crop genetic resources as well as the agricultural practices that foster evolution under domestication up until today are a win–win bet for humanity at large. These provide the genetic combinations at large that we will need into the future. But this needs wilfully treasuring and protecting by all.

To achieve this, we must all contribute to the task by:

- providing funding, including from the private sector involved in agricultural and food systems, which has largely benefited from these processes in the last century or so but managed through a neutral and independent funding mechanism that would reach out and strengthen them;
- building and strengthening education and public awareness at all levels;
- fostering research to build knowledge; and
- identifying, avoiding and lowering prevailing risks.

The aim is to recognize and strengthen the livelihoods of smallholder farmers, who have, over thousands of years, made these processes possible and have provided humanity with the necessary genetic diversity, one of the basics for sustainable production systems.

4.3.3 *In situ* conservation of crop wild relatives in China

Qingwen Yang, Chinese Academy of Agricultural Sciences (CAAS), China

China is recognized as a mega-diverse country, one of the eight centres of origin of crops and one of the three centres origin of agriculture in the world. Therefore, China is abundant in crop wild relatives (CWR) at both the species and genetic levels. Some studies have indicated that there are about 1 300 species of cultivated crops and 1 900 species of wild relatives in China. Since the 1950s, the Chinese Government has collected crop genetic resources and carried out three rounds of field surveys and collection activities at the national level. Up to 2020, China had collected about 520 000 accessions of genetic resources of crops and conserved these *ex situ* in one long-term seed genebank and in 43 field genebanks. The first *in situ* conservation site in China was established in 1985 in an area of less than 500 m^2. However, because of limited funds and techniques, this work was not continued. This was the case until 2001, when the Ministry of Agriculture and Rural Affairs (MARA) organized a project to undertake the *in situ* conservation of wild relatives of crops.

Because too many genetic resources need to be conserved, it was necessary to first make selection criteria for priority species and populations. Three key criteria were used: (i) the species should be listed on the national endangered species list and have commercial or breeding values; (ii) the populations should be present in the genetic diversity centres, or with abundant genetic diversity; and (iii) the populations should be in the most endangered situation, and that local government and residents have strong awareness of conservation. After the priority species and populations were determined, China tried to use physical isolation as well as mainstreaming as the main approaches to undertake *in situ* conservation.

The physical isolation approach includes the isolation with brick walls, solid fences and plant fences. From 2001 to 2020, a total of 205 *in situ* conservation sites were established in 26 provinces, which cover 56 species. Most of the conservation sites were constructed using solid fences, because it had the advantages of delineating clear boundaries with neighbouring lands, no change to the original ecosystem and free exchange of environmental factors within and outside the isolation facilities. However, it had disadvantages as the fences could be destroyed by humans, they rusted due to environmental factors, and the target species could undergo genetic erosion from other species outside the fences. In some cases, local farmers sold the iron material for money or used the materials for their own purposes. To prevent the iron fences from being destroyed, the conservation sites were constructed using brick walls. Since the brick walls were strong and durable, the isolation facilities were not easily destroyed by humans. Therefore, this approach was also used for some special populations, even though it could stop free exchange of environmental factors from outside, and might result in changing the original ecosystem. Another approach used spiny plants as isolation fences. The major advantages were the low cost, and that the original ecosystem could be easily maintained. The main disadvantage was that they were easily destroyed by humans and, therefore, were only used in those areas where local farmers have a relatively high awareness of biological conservation.

Based on the experiences from practice and annual monitoring results, it was found that physical isolation approaches had some critical problems. For instance, it was difficult to get land areas for conservation from farmers. The isolation facilities also had to be repaired and maintained regularly. Further, the target species might lack competitive ability with regard to other species. Moreover, most local farmers in China had no motivation to participate in conservation activities.

The mainstreaming biodiversity approach combines conservation activities with farmers' agricultural production. To solve the problems of the solid isolation approach, a project funded by the Global Environment Facility on the mainstreaming approach was carried out in cooperation with the United Nations Development Programme and MARA-China. In this project, wild rice, wild soybean and wild relatives of wheat were selected as target species, and demonstration sites were set up in eight locations (villages) in eight provinces. After several rounds of investigation at the demonstration sites, it was found that the farmers at the demonstration sites had similar situations such as low income, few options to earn money, bad livelihood conditions and little awareness of conservation and utilization of the wild relatives of crops. The project strategy, named as the threat eradication oriented incentive mechanism, focused on four main themes, i.e. making policies and regulations to restrict human activities; promoting alternative livelihoods to help farmers out of dependence on the habitats of crops wild relatives gradually; trying financial incentives to guide farmers to adapt to a market-oriented economy; and raising awareness to encourage farmers to actively participate in the protection and utilization of CWR. During the project implementation, efforts were made to leverage monetary or non-monetary investments from related stakeholders to carry out all planned activities in the project document. There were two main indicators for the implementation of this project, i.e. promoting farmers' livelihoods and maintaining or improving the original ecosystems of wild relatives of crops. The results, evaluated by international experts, showed that this project achieved success.

As an example, in Yunnan Province, the demonstration site was located in a rural village where there was a population of wild rice but in threatened status. Previous investigation indicated that the habitat of wild rice was gradually being encroached, the water source was used for planting cultivated rice and rubber trees, resulting in less water for the wild rice. So wild rice faced a serious, endangered situation. Moreover, local farmers were rather poor because they mainly depended on rice cultivation. When discussed with farmers, it was found that they understood the importance of conserving wild rice. They also wanted to construct roads to outside, irrigation facilities for crop cultivation and feeding facilities for increasing their incomes. During the project, some key activities of alternative livelihoods and capacity building were implemented within the village, supported by the project office, local government and other stakeholders. After the implementation of this project, there were important achievements both for farmers' livelihoods and wild rice conservation. For instance, farmers' income per capita increased from 1902 RMB in 2007 to 9026 RMB in 2018; the young people in the village had better education, the number of college students, which was zero before 2007, increased to nine in 2018. More importantly, the wild rice was conserved very well, while the distribution area, density and abundance of wild rice were all increased.

For future work on the *in situ* conservation of CWR, the Chinese Government has already made a long-term strategy. The main activities will be focused on continuing to establish more *in situ* conservation sites with both physical isolation and mainstreaming approaches, or the combination of both approaches to make *in situ* conservation sustainable, and strengthening the management of *in situ* conservation sites with more applicable legislation, more criteria and more techniques to ensure *in situ* conservation sustainability.

4.4 Theme 3: Wild food plants: their conservation and use

Alaska wild berries
© USFWS

4.4.1 Wild food plants for a sustainable future

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Although globally there are more than 7 000 edible plant species, mainstream agriculture still relies on a small handful of crops. Among these edible plants, there are the so-called neglected and underutilized species (NUS). Along with the wealth of traditional knowledge on their uses and cultivation practices, these species might bring a solution to support food security at local and global levels, through a more sustainable agriculture.

In this contribution, we present the main results of two publications in which we recently assessed the global status of edible plants. Information was collected on those multipurpose (including edible) species that were most important for some of the local communities in Africa and Latin America.

Recent studies have unveiled the high phylogenetic diversity of edible plants, with *Fabaceae* (e.g. beans and pulses), *Arecaceae* (palms), *Poaceae* (grasses and includes cereals), *Malvaceae* (mallow family, including cacao) and *Asteraceae* (e.g. sunflower and lettuce) being the richest plant families in edible species. These studies have also stressed how human consumption is often not the only traditional use that was reported for these edible species. These species have often additional uses including medicinal, materials, environmental and gene sources (i.e. wild relatives of major crops) and fodder. By considering the different uses, these species provide additional ecosystem services that are important for people's livelihoods and well-being, hence contributing to a more sustainable agriculture.

Among the results of this review there was the identification of a clear latitudinal gradient in the native distribution of edible plants, with species richness decreasing from low to high latitudes. This differs from the main food crop plants whose distribution is mainly driven by centres of diversity identified by Vavilov.

As part of the review, the information available on the conservation status of these edible species and the level of their *ex situ* conservation was also analysed. It was found that there are species-level global conservation assessments for at least 30 percent of these species, and that most of them (over 85 percent) are conserved *ex situ* (as seeds and/or as living plants). Worryingly, around 10 percent of those assessed are considered are threatened, therefore putting at risk their survival as species and as a source of food.

The second part of the paper presents a selection of over 100 NUS that have been recommended in scientific papers or targeted by collaborative projects, networks or international agencies. The authors concluded that for these natural resources to be unlocked, many knowledge gaps need to be filled relating to their biology and ecology to become successful crops of the future

The second publication we presented in this contribution is one of the main dissemination products of the project "The MGU – Useful Plants Project", jointly managed by the Royal Botanic Gardens, Kew, and collaborators in Botswana, Kenya, Mali Mexico and South Africa under Kew's Millennium Seed Bank (MSB) Partnership. The project focused on conserving and sustainably utilizing important native plants for local communities. High-quality seed collections were made, seed lots banked in the five countries and then duplicated and tested at the MSB for long-term conservation. Seed research was carried out to support their conservation and cultivation, and the knowledge generated was transferred to the local communities through workshops and the provision of technical advice. Species were propagated and planted in home and school gardens, while facilities were established or improved at the local level for ensuring their conservation and use. Revenue generation was promoted through the sustainable use of plants and their plant products. For example, communities in Botswana collected the edible seeds of *Tylosema esculentum* (morama bean) for consumption, sale and processing into numerous marketable food products, such as oil, milk and flour.

The book "*Wild plants for a sustainable future*" contains species profiles of a selection of 110 species of great importance for local communities, half of which are reported wild edible plants. Grouped in five chapters (one for each of the countries involved in the project), the book contains information on their taxonomy and nomenclature, plant descriptions, including fruits and seed structures, distribution, habitat, uses, known hazards and safety, conservation status and trade, with practical information on seed conservation, germination, propagation by seeds and vegetative propagation practices, along with key references from the literature. Some other examples of wild edible species included in the book are: *Kigelia africana* (sausage tree) from Botswana and Kenya; *Adansonia digitata* (baobab) from Botswana, Kenya and Mali, whose dried and grained pulp is already sold in some specialized London markets; *Schinziophyton rautenenii* (mongongo nut) from Botswana; *Citrullus lanatus* (Kalahari melon) from Botswana and *Lippia graveolens* (Mexican oregano) and six species of cacti from Mexico.

The book is aimed at practitioners working in those regions to promote the sustainable use of wild multipurpose plant species in agriculture and forestry projects. The information provided in these two publications is key to supporting the conservation and promoting the sustainable use of NUS while helping to support our planet and improve our lives. These species have the potential to "end hunger, achieve food security and improve nutrition and promote sustainable agriculture", as articulated in Goal 2: Zero Hunger, of the United Nations Sustainable Development Agenda.

4.4.2 Wild food plants: increasing dietary diversity

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Wild foods – foods that are co-evolved species and other wild biodiversity in and around farms to supplement foods and earnings – have many roles for communities. They provide the rich local biodiversity, support ecosystem services, strongly connect rural communities and have multiple uses beyond just consumption. It is estimated by FAO that approximately 1 billion people use and depend on wild foods, in various plant and animal forms for their food security. Ethnobotanical surveys of wild plants indicate that more than 7 000 species have been used for human food at different stages of human history. Approximately 1 000 species of edible insects and another 1 000 species of wild fungi are consumed worldwide. In the Northern territories of North America, 200 different wild foods are used by indigenous communities. In India, 600 wild plant species are consumed as food. Last, bushmeat and fish provide 20 percent of protein in at least 60 developing countries. Many of these foods are gathered from natural, wild food environments that consist of forests and jungles, disturbed habitats, open pastures and natural lakes, seas, ponds and rivers.

It is important to consider the centrality of wild foods to the global diet milieu, as dietary patterns are on a detrimental trajectory. First, diets are a significant risk factor for global morbidity and mortality. Dietary patterns around the world are concerning in that most are suboptimal in providing benefits to human health. Across regions, most diets are low in fruits, vegetables, whole grains, nuts and seeds, fibre and legumes, and high in overly processed, packaged refined foods that can contain higher amounts of added sugars, sodium and unhealthy fats. There are subregional exceptions to these trends: in much of Africa, legumes are highly consumed, and in some parts of Asia, vegetable consumption is still considered the mainstay of the diet.

Second, dietary trends show that an increasing proportion of the diet is made up of highly processed packaged foods that have been shown to contribute to obesity and diet-related non-communicable disease (DR-NCDs). Profound dietary changes are occurring in concert with increased movement of people to urban areas, demographic changes among populations, and globalization and trade factors that influence goods and services, particularly in the food sector. The food systems and food environments that engender diets have become more interconnected from global to local levels, with longer, more complex food supply chains and different types of actors beyond just producers and consumers moving food in those chains. With the enhanced interconnectedness of places and people, and the transitions witnessed with globalization and urbanization, there have been shifts in consumer purchases and preferences towards more so-called unhealthy, cheap and convenient diets. This dietary shift has been associated with increasing prevalence of overweight and obesity and DR-NCDs worldwide.

Third, healthy diets – those made up of fresh, nutrient-dense foods – are out of reach and unaffordable for many in the world. Research shows that approximately 3 billion people cannot afford what is considered a healthy diet. That is roughly 40 percent of the world's population with significant constraints for populations in sub-Saharan Africa. Furthermore, 1.6 billion people cannot afford the planetary health diet recommended in the EAT-Lancet Commission report.

The question remains, do wild foods contribute to healthy diets? It depends on where these foods are harvested and a various range of factors including the deepness of poverty of traps, seasonality, cultural changes and other ecosystem forces. Their actual contribution to diets and nutritional status is dependent not only on their availability but also on the number of people using them, frequency of use and quantities consumed relative to other foods. Their contribution to households' diets and overall dietary diversity requires a more nuanced understanding and there is a need for more multi-disciplinary studies on wild foods. If the world is to promote these foods, there is a need to create a sustainable supply and demand of these foods.

That means changing current agriculture policies and public investments towards these foods. One way of doing this is by supporting smallholders and giving them the means to produce more wild foods. Research shows that 53–81 percent of key micronutrients are produced by small and medium farms, which make up 84 percent of all farms and 33 percent of the land areas globally and tend to be more diverse than larger farms. Another way is by promoting both cultivated and wild food environments – the place where people gather, acquire or grow foods. Cultivated food environments make a significant contribution to the diets of subsistence farmers through the production of staple crops, supplemental gardens that produce fruits and vegetables as well as the rearing of livestock, which allows for their consumption as well as that of their by-products (e.g. eggs, milk). They can also contribute to the diets of urban and peri-urban populations. Cultivated food environments are often supplemented with wild food environments, which include forests, jungles, open pastures and bodies of water such as natural lakes, seas, ponds and rivers. These environments are particularly important in terms of increasing access to nutrient-rich foods, including leafy greens, animal source foods, vegetables and fruits, and can increase resilience of households to shocks. Unlike built food environments, wild food environments can act as a food environment and support human well-being in multiple ways, particularly related to improving the diversity and availability of biodiversity. The third way is by promoting the demand for such foods to create market incentives to cultivate and harvest wild foods in sustainable ways.

4.4.3 Indigenous peoples and local communities and the importance of wild food plants in Botswana

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Introduction

Botswana is endowed with over 3 000 indigenous plant species that are resilient to harsh climatic conditions and have great potential to mitigate climate change, reverse plant diversity erosion and combat desertification. They also have great potential for wealth creation, food and nutrition security, combating malnutrition, contributing to economic development and crop diversification. Lives and livelihoods for indigenous communities have been tightly dependent on these (staples and medicines) and they have used them sustainably over time. There is evidence that these indigenous plant resources are threatened by unsustainable extraction for commercial use (outsiders) and encroachment of development projects.

This abstract shares how communities in Botswana selected and prioritized the indigenous plant species to be included in the research and development in response to:

- Botswana Vision 2036 – Prosperity for All by 2036;
- UN Agenda 2030 Goals – Leaving no one behind; Goals 1, 2, 3 and 13;
- International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) Articles 5, 6 and 9;
- New Partnership for Africa's Development (NEPAD) on Traditional Knowledge and Plant Genetic Resources Guidelines; and
- provision of national support to policies and programmes for diversification of food plants based on and including Community Based Natural Resource Management Policy (CBNRM) (2007) and the Forestry Policy (2011).

The National Agricultural and Development Institute has been established with a fully-fledged directorate of natural resources management, including indigenous food value chain development. Curricula of university and technical colleges are set to prepare learners on the importance of wild food plants in Botswana and how they have sustained lives and livelihoods for indigenous people and local communities.

Methodologies

Indigenous and local communities including schools were engaged in the conservation, exploration, collection, characterization, evaluation and documentation of the wild food species. Seeds and herbarium specimens for more than 25 percent flora indigenous to Botswana were collected and banked. Indigenous and local communities identified, selected and prioritized those for research and product development. Geographical distribution of all collections was led by the indigenous and local communities.

Results

Indigenous local communities selected and prioritized largely food and medicinal plants. Community gardens and seed orchards were established. Experiments and training in cultivation and value addition were conducted.

Selected species documentation

Twenty indigenous plants species in the book *Wild plants for a sustainable future* are discussed. These are *Adansonia digitata, Bauhinia macrantha, Cassia abbreviata, Citrullus lanatus, Colophospermum mopane, Cucumis africanus, Grewia flava, Guibourtia coleosperma, Herpagophytum procumbens, Hyphaene petersiana, Kalaharituber pfeilii, Lippia javanica, Myrothamnus flabellifolia. Schinziophyton rautanenii, Sclerocarya birrea, Stomatostemma monteiroae, Strychnos cocculoides, Strychnos pungens*, *Tylosema esculentum* and *Ximenia caffra.*

Product development examples

Research on product development was based on the indigenous knowledge from the local communities. *Tylosema esculentum* bean oil (42 percent) and protein (34.7 percent) content and quality were found to be superior to those for soybean and peanut even though *Tylosema esculentum* still occurs in the wild. The fatty acids profile for the bean are also close or higher than olive. *Tylosema esculentum* bean oil total saturated oil is 25.4 percent compared to 14.3 percent for olive, total polyunsaturated; 27.5 percent compared to 15.2 percent for olive and total monounsaturated; 46.9 percent compared to 56.5 percent for olive oil.

Schinziophyton rautenenii oil (57 percent) and protein (28 percent) contents of the seed are also comparable to those of soybean and peanuts and communities use these for medicinal purposes. The trunks of *Schinziophyton rautenenii* (in older specimens) have a hole called a sip, which stores water. Local communities know where the water is located during dry periods on hunting for wild food expeditions. It is a staple food for the indigenous people who live in northern and southeast Botswana.

Kalaharituber pfeilii (desert truffles) are a common source of food for inhabitants of the desert and other communities. They are sold for income generation. Compared to other mushrooms, they have considerably higher energy, fat, phosphate and potassium content and are a good source of antioxidant properties. As in other parts of the world, they are considered aphrodisiacs. Many animals dig out and eat desert truffles.

Other species include *Citrullus lunatus*, which is abundant in the centre of the country where it is used for water and food, and the seeds used for oil. *Herpagophytum procumbens* and *Cassia abbreviate* are mainly used for their medicinal properties while others are multipurpose.

Geographical distribution: During exploration and collection missions, coordinates for all collections were recorded. However, the distribution of *Tylosema esculentum*, *Schinziophyton rautenenii* and *Citrullus lunatus* were studied and results showed that *Tylosema esculentum* was present mainly in the centre of the country and *Schinziophyton rautenenii* in the north and southeast. *Citrullus lunatus* is also abundant in the centre of the country.

Recommendations

There should be deliberate effort by all concerned to:

- register intellectual property (knowledge, innovations, technologies and products derived from the resources and communities);
- strengthen the capacity of individuals and institutions in research, education and value adding of the species;
- establish inventory on the species distribution and abundance to assure sustainability; and
- develop clear platforms of communication to enhance science-based policy/decision for research and development for scientists, policymakers, implementers and communities (knowledge custodians/custodians).

Conclusions

Strengthening research and development for wild food plants (climate-smart emerging crops) will change lives and livelihoods of indigenous communities if their intellectual property is respected. The Government of Botswana, working with civil society organizations and the private sector, should create a conducive environment for value chain development of these resources aligned to Vision 2036 (Prosperity for All) and Leaving No one Behind aligned to UN-Agenda 2030.

5. SESSION 3: ON-FARM MANAGEMENT OF FARMERS' VARIETIES/LANDRACES

On-farm cultivation, Solomon Islands

5.1 Session summary

The key themes addressed in Session 3 were: measuring and securing on-farm diversity; harnessing on-farm diversity for resilience; and addressing local needs through on-farm management. Strategies and methods for mainstreaming the conservation and sustainable use of famers' varieties/landraces were described, including for measuring on-farm diversity, exploring complementary *ex situ* conservation strategies, utilizing on-farm diversity in crop improvement, as well as for supporting local and regional community-based initiatives that strengthen the on-farm management of PGRFA diversity. Various aspects were identified as being crucial for success: dialogues between genebank managers and farmers; the establishment of community seed banks (CSBs); formal registration of farmers' varieties/landraces; and the development of value chains.

Studies presented on the amount of diversity present at farm, community or landscape levels provided useful information for baseline assessments and for understanding the rates of genetic erosion, as well as the importance of functional diversity in farmers' fields. Richness and evenness assessments were undertaken in the Islamic Republic of Iran to better understand the relationship between the diversity of local varieties of wheat and barley and their responses to biotic and abiotic stresses.

The Session also demonstrated the complementarity of *ex situ* conservation strategies and on-farm management of crop diversity. An examples from projects in the Plurinational State of Bolivia illustrated successful complementary *ex situ* – on-farm activities, including: establishing CSBs; capacity development for local crop conservation and cultivation; inventorying and documenting the diversity of crops managed on-farm; the organization of seed and diversity fairs; and the conservation of farmers' varieties in *ex situ* facilities.

Several presentations also focused on the importance of intraspecific diversity for crop improvement. In this context, 1 300 landrace accessions conserved at the International Institute of Tropical Agriculture were evaluated for specific traits, including drought tolerance, resistance to a number of insects and diseases, and nutritional quality. The study identified a number of landraces useful for cowpea breeding programmes, including 26 accessions that were found to confer drought tolerance. These efforts resulted in the release of improved varieties in Nigeria. The use of landrace diversity in breeding programmes and the associated donor support was consequently stressed.

The Session further considered advances in research and methodologies that facilitate the transfer of traits from accessions conserved in genebanks into elite varieties. Genebank accessions are generally underutilized by breeders due to various reasons such as the time needed to transfer novel genes into adapted germplasm, the linkage drag of undesirable traits and the limitations in phenotyping methodologies. As a result, new technologies, such as sequencing, gene cloning methods, high-throughput phenotyping techniques and speed breeding, are now being employed in public and private research centres to mitigate these constraints. These technologies enable the fast-tracking of the introgression of traits for improved yields and resistance to biotic and abiotic stresses into modern cultivars of different crops, including wheat, canola, chickpea and barley. One of the studies presented described research focusing on the "Vavilov Wheat Diversity Panel", which consists of materials collected by Vavilov and his colleagues. Disease resistance genes are being identified through mapping approaches and then speed bred to fast-track backcrossing and introgression of these genes into improved materials.

During the Session, speakers presented on the development of farmers' varieties/ landraces using participatory plant breeding (PPB). In this context, the improvement of maize landraces in Mexico and barley landraces in the Syrian Arab Republic were highlighted. Speakers then described the use of advanced experimental designs and statistical analyses, undertaken in partnership with farming communities during the process of breeding and selection. Furthermore, the importance of PPB was also highlighted as a mechanism to raise awareness on the use of on-farm PGRFA diversity for increased resilience and nutritional qualities.

Local and regional community-based initiatives from Nepal, Peru and Viet Nam were presented as examples of strengthening on-farm management of PGRFA diversity. Speakers underscored the need for dialogue between genebank managers and farmers on the establishment of CSBs, the formal registration of farmers' varieties/landraces and the development of value chains. The Potato Park initiative, located in the Cusco Valley in Peru, highlighted the role of participatory conservation whereby local potato diversity is cultivated to improve livelihoods. As Peru is one of the centres of origin of potato, the focus on potato as a cultural heritage was demonstrated to be a successful strategy for promoting the conservation and use of the almost 1 400 potato varieties safeguarded by local communities.

Community seed clubs and CSBs were showcased as successful approaches for promoting the conservation, use and dissemination of local crop diversity. In Nepal, the establishment of 23 CSBs in 16 districts contributed to local varieties being registered and released through participatory selection, with quality seeds of these local varieties produced and distributed. In Viet Nam, 365 seed clubs with over 10 000 members undertook activities for seed conservation, exchange and crop improvement. Members of the seed clubs engaged in participatory plant breeding and selection, resulting in approximately 400 locally adapted rice varieties, of which five farmer's varieties were nationally certified. The formal registration of farmers' varieties has been fundamentally important in improving access to quality seeds and for maintaining adapted landraces on-farm, thus positively contributing to national breeding programmes through the linkages established between the formal and informal seed sectors. Experiences from these CSBs and seed clubs demonstrate that they enhanced local seed security and livelihoods, strengthened networks and established strong linkages with supporting institutions.

5.2 Theme 1: Measuring and securing on-farm diversity

Diversity of pumpkin and squash, United States of America
© Crop Trust/L.M. Salazar

5.2.1 Richness and evenness of farmers' variety/landrace diversity maintained by farming communities

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Three key aspects of diversity are richness, evenness and divergence, and calculating those three concepts will help us describe the degree of diversity within a farm, community or landscape, as well as the differences among them. Richness is the number of different types present in the sample, or in the target population, evenness is the similarity in the frequency of types (the lack of dominance of one type) and divergence is the difference between different samples or populations for the types that are present, or their frequency. In other words, divergence is the potential of any two randomly chosen households within the same community to grow different varieties.

Participatory collection of information is one of the effective approaches to measure richness, evenness and divergence at the farmers' and farming community level. The first step is to conduct focus group discussions to identify varieties that farmers are managing and to determine how farmers distinguish them based on descriptions. These descriptors also provide information on the functional traits of each variety. For analysis, the information collected through the focus group discussions is exported into processed tables and presented to farmers. In the second step, a household survey is held to understand how diversity is distributed in the farmer's field and at the community level. In this regard, a household survey on the area planted to each variety is linked to information about household location and household demographic data, such as age, gender and a social-cultural group. The information collected from the household surveys is put together to calculate evenness and divergence at the community level.

Over the last 20 years, the participatory studies of richness, evenness and divergence have been carried out for different crops such as rice, maize, wheat, barley, bean, fava bean, millet, sorghum, cowpea, banana, plantain, mango, chili, apple, apricot, grape, pear, pomegranate, plum cherry, pistachio, walnut, almond, etc., in different countries. The results of diversity measurements show that households' and communities' richness remain high across all crops in countries where these crops were domesticated, or in secondary centres of diversity. The high richness has shown households and communities harboured a large number of varieties. The number of varieties of the same crop that farmers are still managing in their fields and total number of varieties found at village level is quite high. An example is the case of sorghum in Burkina Faso, where the average farm size is 1.2 ha and household richness is 4–5, which means that each household grows on average 4 to 5 varieties that they take from a pool (the community richness) of 23 traditional sorghum varieties. Another example is the case of rice varieties in Nepal, where household richness is low, only 2–3 varieties, but the pool of varieties that are available at the community level (community richness) is high (34), with 25 percent divergence. High evenness suggests no single variety dominates on-farm. The values of the community evenness, with an average of 0.70 across crops, also indicate that the systems are diverse and not dominated by one variety, while the high divergence indicates the high potential that any two randomly chosen households within the same community grow different varieties. With an average value of 0.64, the divergence indicates that if one variety is randomly selected from one household in the village and another variety is randomly selected from another household in the village, these two selected varieties are 64 percent likely to be different.

In the Islamic Republic of Iran, focus group discussions and household surveys were implemented in four locations to better understand the diversity of wheat and barley found in the farmers' fields, and to assess how farmers and farming communities adapt to or cope with changing local climate and biotic and abiotic stresses. During the focus group discussions, farmers listed their cultivated varieties and the traits of each variety, as well as different limitations and stresses they faced. In addition to drought, the main challenges faced included water scarcity, unpredictable rainfall, poor soil, hot wind, freezing stress and soil and water salinity, pests like aphids and *Euregaster integriceps*, and diseases like yellow rust. Farmers also discussed the strategies they are employing to enhance resilience, such as using different varieties, mixtures and evolutionary populations to increase yield and stability, improve resistance to different stresses and produce nutritious food and feed. They also select stress-resistant crops, plant early-maturing varieties, and use fallow and rotation to improve soil fertility and reduce soil salinity.

In four locations in the Islamic Republic of Iran, a participatory assessment of wheat genetic diversity found an average of 6.6 ha of cultivation area, a 1.5 average wheat variety richness per farm, and a 6.0 average variety richness per community. Also, the average Simpson index at the farm level is 0.12, Indicating that most households are dominated by one variety and, at the community, the level is 0.64. Finally, any two randomly chosen households within the same community have an 82 percent chance of being different varieties.

In the Islamic Republic of Iran, 54 percent of the wheat is grown on rainfed land, and the average yield is less than a tonne per hectare. As a result, yields under rainfed conditions are very low and lack of genetic diversity is one of the leading causes. In fact, in half of the area under cultivation of rainfed wheat, only one traditional variety (Sardari) is planted. According to our assessment, there are no traditional varieties in irrigated areas and only the rainfed areas retain them. However in some communities, under this system, if farmers have access to genetic resources, they would try to increase on-farm genetic diversity by using modern varieties, mixtures and evolutionary populations. The high levels of richness within assessed communities have contributed to raising the average yield under rainfed conditions compared to the Islamic Republic of Iran's average. Therefore, we can conclude that globally we can use diversity indices including richness, evenness and divergence as the baseline, not only for estimating future genetic erosion but also for comparing and contrasting the diverse features of farmers' fields to meet their livelihood needs. Farmers must maintain on-farm genetic diversity by growing diverse varieties and implementing diverse varietal management strategies, using the local resources at hand to meet farmers' livelihood requirements.

5.2.2 Complementarity of on-farm management and *ex situ* conservation

Ximena Cadima, Fundación PROINPA, Plurinational State of Bolivia

The Plurinational State of Bolivia is a country located in the Andes of South America. It is a country very rich in diversity. A total of 23 different ecoregions have been reported, as well as more than 20 000 species of higher plants, more than 3 000 species of animals and at least 26 indigenous groups. The Plurinational State of Bolivia is also very rich in agrobiodiversity. Currently more than 50 species of native crops are still part of the diet of Bolivians, especially in rural areas.

Under different contexts, efforts have been made to collect and conserve at least part of this diversity *ex situ*. The *ex situ* collections reported by the Plurinational State of Bolivia in 1995 totalled 9 207 accessions; in 2009, 19 240 accessions; in 2017, 16 225 accessions; and in 2021, 15 522 accessions. Until 2010, the germplasm bank system consisted of a consortium of public and private entities. As of that year, all the collections passed to the administration of the central government of the Plurinational State of Bolivia. The most important collections include cereals and legumes (where maize is the main collection of this group). Oher important groups are the high Andean grains (where quinoa is the main collection) and the Andean tubers (where potato is the main collection).

However, the greatest efforts to maintain the rich agrobiodiversity continue to be in the hands of small farmers, which is evidenced by the importance of family farming in the Plurinational State of Bolivia both in terms of cultivated area (50 percent of the total cultivated area) and quantity of crops (284 different types of crops including: cereals (11), vegetables (46), legumes (9), tubers and roots (12), oil grains (10), fruits and nuts (70), flowers and grasses (87)).

Business agriculture, although it occupies the other 50 percent of the cultivated area in the Plurinational State of Bolivia, only focuses on industrial and export crops (mainly soybean, sugar cane and sunflower), which do not reach the tables of the population. On the other hand, family farming is what effectively brings food to the Bolivian population of a significant diversity of crops. This diversity is managed by small farmers.

On-farm management of agrobiodiversity is conducted under two scenarios: one, autonomously promoted by farmers whose reasons are food security and diversity, income generation, risk avoidance, prestige and social value, among others. The second scenario is promoted by external agents (usually research and development institutions, NGOs, etc.), which carry out various interventions such as in seed systems, in integrated crop management programmes, in value chains or by promoting community seeds banks (CSBs), among others.

The complementary actions between *ex situ–in situ* conservation reported by Bolivian institutions are "classic" such as those described below:

- Support in the formation of CSBs and development of local capacities. Germplasm banks have suggested models or guidelines for community seed banks for the ordering, registration and documentation of varieties and seeds. They have also contributed to training local leaders for the management of CSBs.
- Inventories and documentation (catalogues) of the diversity of crops managed on farmers' farms. Germplasm banks have also contributed to gathering information on local varieties and diversity and documenting them in catalogues.
- Organization and institutionalization of seed and diversity fairs. External agents or germplasm banks have promoted, particularly in municipalities with high agrobiodiversity, the organization and institutionalization of seed fairs. These spread the importance of diversity and conservation and promote the exchange and sale of seeds.
- Deposit of traditional varieties in genebanks and return to farmers as seed with improved phytosanitary quality. As a result of the interaction between farmers and genebanks, farmers usually deposited their varieties in the genebank, and the genebank has on several occasions returned the varieties as seed with improved phytosanitary quality (particularly potato). In this way, the bank contributed to refresh the health of the seeds of native varieties grown by small farmers.
- Farmer participation in genebank management activities (e.g. harvesting, evaluation and selection of promising materials, etc.). In order to encourage greater use and increase the diversity of varieties in farmers' fields, the germplasm banks promoted workshops with farmers to carry out participatory evaluations and selection of varieties.

Some lessons learned from these *ex situ–in situ* interaction actions in past years are briefly described below.

- CSBs come and go because they depend heavily on external agencies for their formation and operation. At the end of the projects, it is very difficult for the CSBs to remain operational.

- The good intentions of governments and favourable policies to promote the complementation of *ex situ–in situ* actions are not enough. Throughout more than 20 years of disseminating and promoting the importance of *in situ* conservation of agrobiodiversity and *ex situ–in situ* complementarity, governments and national authorities have only succeeded in promulgating policies (norms, laws) favourable to the conservation, but these regulations have not resulted in concrete actions.
- Projects end, *in situ* conservation remains weak due to lack of recognition, lack of financial and technical support.
- *In situ* conservation remains in the hands of small "old" farmers. The diversity of traditional varieties ultimately continues in the hands of individual families or guardians of diversity, with little or no support.
- The reactivation of *in situ* management of agrobiodiversity requires innovative actions for new generations of farmers and guardians of diversity. The complementarity should go beyond promoting farmer interaction with genebanks.

Based on the lessons learned in the various years of work of the PROINPA Foundation in promoting *ex situ* and *in situ* conservation, in recent years it has been working with another intervention approach, called "Building a model of socio-ecological resilience to support on-farm management". This is an approach that promotes comprehensive production systems in which on-farm management of agrobiodiversity is the basis of the socio-ecological resilience model. The approach is also designed to promote greater access to the market with products of agricultural biodiversity. The approach includes actions in four areas: ecological, economic-productive, sociocultural and political-institutional.

The ecological approach considers the conservation of environmental functions of the components of the agroecosystem for mainly soil and water. In the case of soils, the improvement of soil fertility and health, and soil conservation, are considered. In the case of water, the use of technology for efficient use of water delivery (for example sprinkler irrigation systems) and forestry for the conservation of water sources are considered. In addition, the strengthening of the conservation of agrobiodiversity is also considered, through the strengthening of custodian farmers and the improvement of local seed systems (for example, increasing the varietal diversity in seed systems, the diversity of seed suppliers and the seed quality in local seed systems).

In the economic-productive, support for agricultural production for more resilient systems with innovations and good farming practices, as well as facilitation of access to market opportunities to enhance economic resilience of families, are considered.

The sociocultural considers the promotion of participation and decision-making by women (empowerment), improving the quality of family nutrition, inclusion of educational centres (schools), documentation and recovery of traditional knowledge.

The political-institutional considers support in the development, rescue and dissemination of regulations for conservation of soils, water and the environment in general, support in the construction of local policies and support in the formation of local capacities (e.g. municipal and community technicians).

Final remarks on strengthening *in situ* or on-farm management and conservation, are:

- Farmers are conscious on the need to use crop diversity to help cope with climate change, but also crop diversity is an opportunity to access new markets, given the new trends and the search for healthier and more nutritious products for human consumption.
- Farmers look for materials with characteristics associated not only with production needs but also with culture and with landscape management. It is known that genetic diversity has different roles in farmers' fields, not only for food purposes, but also for cultural, social and even landscape purposes.
- External agents (research and development institutions, NGOs, genebanks) are key as technology providers, supporting monitoring of changes and maintaining diversity. These actors will continue to be the links for the complementarity of *in situ/ex situ* management of agrobiodiversity.
- External agents are also key to facilitating farmers' links with the market and generating added value for farmers' varieties.

The final comment is that the on-farm management support approach aims to promote conservation through increased use of agrobiodiversity, "the greater the use, the greater conservation".

5.2.3 From the genebank back to the farm

Lee Hickey, The University of Queensland, Australia

This work discusses some of the challenges and opportunities in the transfer of germplasm "from the genebank back to the farm". It is important to note that many staple food crops are ancient crops and have been cultivated for thousands of years. In fact, a study published a few years ago found evidence of ancient breadcrumbs found at a site in north-eastern Jordan that were 14 400 years old. These breadcrumbs contained wild wheats and tubers used to make flat bread.

Modern crops have evolved through a combination of natural and artificial selection, the latter mostly by farmers. Over recent times, modern plant breeding has resulted in highly productive food crops for our farming systems. Unfortunately, this has also resulted in genetic bottlenecks for many staple food crops.

As a result, new genes and new traits are needed for future crops to meet the demands of a rapidly growing human population, expected to reach ten billion people by 2050. There is also a need to address the challenges of climate change, including warmer temperatures, variable rainfall patterns and rapidly evolving and newly emerging pests and diseases. More than ever, the need to improve the productivity of our crops requires scientists to search for new genes and traits that can help us meet this goal.

Inter- and intraspecific diversity of agricultural crops diversity is evident by the vast number of phenotypes of a given crop species. In addition, DNA genotyping or sequencing technologies provide the means to measure genetic diversity directly. The diversity of accessions found in crop species and their varieties provide a potentially large number of traits that are available to plant breeders. The available diversity of many major crops is preserved in genebanks around the world, including crop wild relatives (CWR), landraces, historical cultivars and breeding materials.

While these genetic materials are being preserved, they are often underutilized. This is due to many complex and complicated challenges. For instance, there are limitations regarding phenotyping methods to enable evaluation of large plant populations. In addition, it is often not known if a gene of an accession is "novel" or "new" and whether it appears in modern cultivars. Further, genebank accessions, although very diverse, are often not well adapted to modern farming systems. As a result, plant breeders must make many backcrosses to transfer the genes conferring the desired traits into existing cultivars while effectively separating them from the undesirable genes. This is very time-consuming.

In order to speed up the transfer of traits back to the farm, there are a number of emerging technologies that can help. One of these technologies is called "speed breeding", which has been under development at The University of Queensland with collaborators around the world. Plants are grown under 22 hours of light and at controlled temperatures to trigger early flowering and achieve rapid generation advance. Using this technique, it is possible to grow up to six generations per year, compared to just two or three in a regular glasshouse. This technique can help speed up the transfer of traits from genebank accessions into elite varieties for farmers' field. Speed breeding also works for a range of crop species; it is just a matter of optimizing the protocol.

To illustrate this, take for example a barley accession with four different desirable traits. Traditional methods to transfer these traits into a single modern cultivar would require eight backcrossing generations. If this was done in the field, while growing one generation per year, it would take eight years. If done in a regular glasshouse while growing two generations per year, it would take four years. Using speed breeding, it can be done within 18 months or 2 years for most crop species. This technology is opening up new gene pools available for plant breeding and opportunities to transfer traits from genebanks into farmers' fields.

My team is working on the "Vavilov Wheat Diversity Panel". This panel contains diverse materials collected by Vavilov and his colleagues from around the world. The collected accessions are being screened for disease-resistance traits. While disease-resistance genes are being identified using mapping approaches, speed breeding is being used to fast-track the backcrossing and trait introgression process. Within the scope of a PhD programme, it is possible to identify desirable genes and transfer the trait into elite materials for plant breeders.

At the Commonwealth Scientific and Industrial Research Organization (CISRO) in Australia, the Vavilov Panel is being screened for photosynthesis traits. A high level of variation has been found for traits with potential to increase the efficiency of crop production. Other physiological traits that are a subject of research include root traits, which could help support high yield. One trait of current research focus is root biomass or root proliferation, which could equip the crop with a better root system to explore the soil space. Rare genes for high root biomass were discovered in Chinese wheat landraces. A pipeline to help transfer this gene into elite modern cultivars has been developed, involving screening large populations for both the phenotype as well as marker-assisted selection for the key associated genes. This was all done under speed breeding conditions to accelerate the process. Introgressed lines were developed within just 18 months, and possessed the new root biomass genes, and the result is a much larger the root system.

Field experiments are now underway to evaluate these new genes and traits in a modern variety, in a modern farming system.

In collaboration with Kai Voss-Fels, a colleague at The University of Queensland, diverse barley accessions are being sequenced from the genebank and evaluated for disease traits in different sites of Australia. Using artificial intelligence algorithms, the research is identifying the optimal crossing path to combine many haplotypes associated with resistance within the shortest timeframe possible.

In addition to the examples provided above, desirable genes from CWR may be inserted into modern cultivars via gene cloning, which can bypass the backcrossing process. However, this normally requires years of work to breed new populations required for mapping the genes. Brande Wulff and colleagues at the King Abdullah University of Science and Technology, Saudi Arabia, have developed a new method that enables gene cloning using wild accessions without the need for making a cross. CWR are genotyped using a technique that identifies all the potential resistance genes, combined with phenotyping, using association mapping to identify the casual gene.

The "Open Wild Wheat Consortium", a recent initiative, involves researchers from around the world to sequence 242 genomes of *Aegilops tauschii*, a wild relative of wheat. The researchers employed the new gene cloning technique to identify genes controlling important traits. This highlights the flexibility of the tool and allows for cloning genes directly from the genebank, which can then be inserted into modern varieties.

The above-mentioned novel technologies, such as DNA sequencing, new gene cloning methods, high-throughput phenotyping techniques and speed breeding, can help fast-track trait introgression into modern cultivars, and support the sustainable use of genetic resources for breeding well-adapted varieties.

5.3 Theme 2: Harnessing on-farm diversity for resilience

Participatory selection of improved finger millet
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5.3.1 Harnessing landrace diversity for resilience

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The current rapid human population growth and the frequent challenges associated with climate change have serious impacts on food and nutrition security globally and more critically in the developing countries. From 2.5 billion in 1950, the world population has tripled within 50 years to reach 7.8 billion in 2020 and this is projected to increase by 25 percent to 9.9 billion in 2050. In addition, climate change, which is characterized by hotter and drier conditions in many parts and flooding in other parts of the world, is taking a toll on food production. Unpredictable weather extremes and reduction of arable land and water reserves due to environmental degradation are being recorded. As a consequence of these changes, new variants of pests and pathogens are emerging. In ensuring both food and nutrition security, crop improvement plays an important role. Advances in the sciences related to crop improvement such as molecular genetics (genomics, genetic transformation, genome editing, etc.) are being registered. It is well appreciated that genetic diversity is critical for success in crop improvement leading to sustainable food production, better adaptation and resilience in the face of climate change. Sources of genetic diversity include wild relatives of crops, exotic germplasm accessions, mutants and landraces. Our presentation has shown that landraces are one of the main sources of genetic diversity needed to improve not only crop productivity but also crop resilience to biotic and abiotic stresses and crop nutritional quality. Using the example of cowpea, we have continued to take advantage of the genetic diversity existing within the more than 15 000 landraces maintained at the International Institute of Tropical Agriculture (IITA) Genetic Resources Centre.

To exploit this genetic diversity, core collection and minicore collection of 2 062 and 374 accessions respectively were determined. Genotyping-by-sequencing was conducted on the IITA cowpea minicore lines to understand the underlying genetic diversity and population structure among the cowpea germplasm maintained at IITA. The three complementary methods (hierarchical clustering analysis, the model-based structure analysis and discriminant analysis of principal components of the tested accessions) used in determining the number of clusters all show the presence of three major clusters. However, population structure in the University of California-Riverside Minicore (having 368 accessions genotyped using illumina iSelect platform with 42K SNPs) shows six clusters.

Several sources of key traits were thus identified among the 15 000 accessions at IITA including drought tolerance (both seedling stage drought and terminal drought tolerance, e.g. Danila, TVu557, TVu1438, TVu4574, TVu6443 and TVu11982). For insect resistance/ tolerance the following were identified: aphid (e.g. TVu 36, TVu 410, TVu 801, Tvu 3000), leafhoppers (e.g. TVu 59, TVu 123, TVu 662, TVu1190), flower bud thrips (e.g. TVu 1509, TVu 2870, Sanzi), legume pod borer (e.g. TVu 946, Kamboinse Local), pod sucking bugs (e.g. TVu 1, TVu 1890) and storage weevil (e.g. TVu 625, TVu 2027, TVu 11952, TVu 11953)). Lines with disease resistance (anthracnose (e.g. TVu 201, TVu 408, TVu 537, TVu 697), cercospora (e.g. TVu 1190, TVu 1283, TVu 2430, TVu 3415), septoria (e.g. TVu 12349, TVu 11761, TVu 456), scab (e.g. TVu 12349, TVu 843, TVu 1404), bacterial Blight (e.g. TVu 347, TVu 410, TVu 456) and viruses such as CYMV, CAbMV, BCMV, CMV, CCMV (e.g. TVu 201, TVu 410, TVu 1190) were also identified. Lines with resistance to root knot nematode (TVu 1560), parasitic weed (*Striga gesnerioides* and *Alectra vogelii*) (e.g. B301, TVu 9238, TVu 11788), were also discovered. Lines with high nutritional quality protein (e.g. TVu-2508, TVu-408, TVu-3638), Fe (e.g. TVu-2723, TVu-526, TVu-2356), Mg (e.g. TVu-2723, TVu-1877, TVu-3638), K (e.g. TVu-2723, TVu-3638, TVu-7654), P (e.g. TVu-2723, TVu-2508, TVu-3638), Zn (TVu-10342, TVu-1877, TVu-2723) and Ca (e.g. TVu-526, TVu-3638, TVu-2723)) were detected.

These sources of key traits are being used in the development of improved cowpea lines including several already released varieties across more than 60 countries: IT07K-318-33, IT07K-292-10 and IT07K-297-13 for drought tolerance; IT88D-867-11, IT89KD-245, IT89KD-288, IT89KD-374 for aphid resistance; IT82D-716, IT84S-2246-4, IT86D-719 for thrips tolerance; IT90K-277-2, IT93K-452-1, IT97K-499-38 for pod sucking bug tolerance; IT81D-994, IT81D-985, IT82D-716 for bruchid tolerance; IT98K-205-8, IT97K-819-118, IT81D-994 for septoria resistance; IT84S-2246-4, IT89KD-288, IT89KD-391, IT90K-76, IT90K-59 for root knot nematode resistance; IT81D-994, IT90K-59, IT90K-76, IT90K-82-2, IT97K-499-35 for striga and alectra resistance.

Key approaches to harness diversity in the germplasm collections were also presented namely: (i) characterization through high throughput phenotyping that includes automated platforms and statistical methods for quick and precise evaluation of landraces; (ii) introgression of the identified genes of interest through hybridization followed by selection; (iii) genome wide association mapping and marker assisted backcrossing through fine-mapping or cloning quantitative trait loci (QTL) for precise introgression of QTL, background selection to avoid linkage drag and pyramiding of several QTLs in the same background; and (iv) genomic selection, which is more appropriate for polygenic traits.

Given the potential contributions of landraces to food and nutrition security, we strongly recommended that: (i) awareness should be increased on the threats to landraces' survival (identity and health) through control of genetic erosion and strengthening the protection of genetic diversity – these can be accomplished through coordination and integration of *in situ* and *ex situ* conservation of landrace diversity at international, regional and national levels; (ii) plant breeding programmes should be encouraged to exploit landraces through efficient genetic diversity management by systematic genotyping and phenotyping.; and (iii) donors should be invited to increase support to pre-breeding activities including landraces acquisition and conservation as currently their support is mainly targeting crop genetic improvement for enhanced genetic gain (elite x elite).

In conclusion, landraces are critical resources for food and nutritional security. They contribute significantly to a high frequency of useful genes, wider crop adaptability and a broad genetic base in the breeding programmes. Therefore, breeding programmes should be supported to develop appropriate strategies that harness the genetic diversity of landraces.

5.3.2 Development of farmers' varieties/landraces

Martha Willcox, University of Wisconsin-Madison, United States of America

Mexico is the centre of origin of maize. There are 59 documented races of maize that have evolved under farmer selection in the boundaries of what is now known as Mexico and have continued to be planted and conserved by farmers in Mexico. One reason that these races of maize have been conserved is the diversity of culinary uses of maize in Mexico. There are more than 700 dishes using maize in Mexico and many of these are best prepared with a specific landrace.

Mexico also has a variety of climatic regions. Maize is cultivated from 0 to 3 000 metres above sea level and from tropical rainforests to deserts. There are microclimates in every valley of Mexico where maize has been under selection by farmers for thousands of years and is well adapted. Many of those micro-environments are not served by professional breeders and, therefore, the farmer-held local landraces are the best option for farmers.

It is estimated that more than 60 percent of the hectares sown to maize every year in Mexico are planted to unimproved maize – most of which is landrace maize or native maize. The distribution of unimproved maize is not homogeneous throughout Mexico. There are certain states where the vast majority of maize produced is from hybrid maize, such as Sinaloa and Sonora, and other states where almost all maize produced is native maize, such as Oaxaca, Yucatan and Hidalgo. The rest of the country is made up of states with pockets of both types of maize in differing proportions.

The areas producing native maize are farmed mostly by subsistence farmers. The characteristics of the subsistence farming system in Mexico are that farmers save and select their own seed, they consume their own grain and they inherit seed from their ancestors. They often grow multiple races of maize with different colours and textures in a single village for specific dishes. They generally plant enough to feed their family and are reticent to invest time and resources in producing excess grain if there is not a dependable market.

Over the last ten years while working at CIMMYT with native Mexican maize and the farm families who conserve it, it became clear that every village in Mexico is different and the treatment of each village must be specific to that village. However, to summarize different types of interventions, the strategies can be divided into two broad categories:

(i) interventions for villages that are self-sufficient in grain production with some excess grain production; and (ii) interventions for villages that are not self-sufficient because of low grain yield or high disease loss.

For those villages that produce insufficient grain to feed habitants because of low yields or high disease pressure, the strategy is to first evaluate the diversity of farmer-held maize within the community using replicated trials. With information gained from those trials the objective is to increase heterosis or increase disease resistance to improve yield. With sufficient genetic diversity of samples held by farmers, increased yield can often be achieved by crossing between the best farmer samples within the village that are identified through evaluation trials. If the diversity held within the village is low, identification and crossing with other landraces with a very similar grain type, and climatic adaptation from another geographic region of Mexico or from genebank samples with a specific disease resistance lacking in the local seed samples, are carried out. The idea is to increase allelic diversity without changing climatic adaptation or grain type, and therefore improve yields by increased heterosis from diversity within the same or similar maize race.

There are a number of selection schemes of that can be used for yield and disease improvement of landrace maize populations. One is a half-sib recurrent selection also known as ear to row selection where more than 200 farmer-held maize samples are collected, as ears, for each type of maize grown in the village and are evaluated in trials. Remnant seed of the best farmer samples, which demonstrate highest yield, best agronomics and least disease symptoms, are recombined through pollination and the selection cycle can continue for more generations of selection.

Grain yield can also be increased by improving soil fertility and biological control of pests. An example of a village experiencing food insufficiency because they do not produce sufficient grain is San Antonio Nduayaco in the Mixteca Alta region of Oaxaca. A highland community with low rainfall, it has soil that is stony, low in fertility and organic matter, with a number of biotic pests, and abiotic challenges of drought and frost. In this village they grow two different races of maize, Chalqueno and Conico, under two different production systems called cajete and temporal. Temporal means planting at the initiation of the rainy season, while in the cajete system seeds are planted deep in the soil into residual moisture from the last year's rainy season a month or two before rainfall starts again.

Results of pilot trials in half-sib recurrent selection that were conducted in this village in 2019 had yields in half-sib families ranging from the equivalent of one tonne per hectare to about 50 kg per hectare, indicating that there is a great deal of variation for yield from the ears we collected from local farmers for the blue version of Chalqueno maize sewn in the cajete system. We felt that with a large population size significant improvement through selection could be made, so in early 2020 my technicians went to the village and were able to obtain sufficient ear samples for large trials. Unfortunately the trials were cancelled due to the COVID-19 pandemic. In ear to row recurrent selection each farmer sample is an open pollinated ear of the type of maize or types of maize that the farmer grows and, to identify samples, each ear is given the name of the farmer and then numbered consecutively for however many ears were collected from that farmer. Trials were grouped by type of maize with the white cajetes or the blue cajetes, the white or blue temporales, and put into separate trials that were randomized and replicated. One thing important to note is that the farmer grain samples were stored within the village until planting and we never removed them from their original site, following the advice of Mexican scientists responsible for the implementation by Mexico of the Nagoya Protocol.

In villages where grain production is sufficient for family and local consumption with some excess, we worked on collective commercialization of excess grain. That involved adequate grain storage to preserve not only the grain for the family to eat for the year, but also for grain to sell to culinary markets. We worked with the community on grain cleaning, hermetic bagging and forming cooperative structures, including tax and bank accounts. We made connections to chefs and exporters and helped to document the cost of production per kilogram to help the farmers with pricing. In one village in the Central Valley of Oaxaca, indigenous male and female farmers formed a cooperative allowing them to have more control over pricing and to receive a larger proportion of the sales price. We went through each step from the beginning to the end of local maize production costs for a baseline cost and a range of costs per hectare. This village in particular grows four different colours of maize of the same race. The yield of each colour variant is different, so to establish the sales price per kilogram for each type of maize, we divided the average yield of each colour variant by production cost. Such differentiated pricing allows farmers to grower rarer but lower-yielding variants without losing money.

To promote these small native maize farmers, we formed a non-profit association made up of the experts in native maize – geneticists, socio economists, ethnobotanists, farmers. This non-profit, called ProMaiz Nativo, worked to create a collective trademark known as Milpaiz, for native maize and products of the milpa. The collective trademark, Milpaiz, signifies to buyers that this is native maize verified by experts, grown by smallholder farmers and that the native maize is documented to be grown in its historic area of distribution (to prevent delocalization of maize from small communities to large production areas), and that the price is compensatory with the quality and history of the maize. This national collective trademark was approved by the Mexican Government in June of 2019. It is a voluntary system that is meant to promote these indigenous small farmers who have been the guardians of native maize for millennia in the marketplace and allows buyers to know that, under Milpaiz, the farmers are receiving higher prices.

5.3.3 Alternative breeding approaches: participatory plant breeding

Salvatore Ceccarelli, International Center for Agricultural Research in the Dry Areas (ICARDA) (retired), Italy

Introduction

Participatory research, as a form of collaboration between farmers and scientists is the most recent, albeit controversial, development of the relationships between the scientific and the farmer communities. After millennia of independent management of diversity and plant improvement, the end of the eighteenth century and the beginning of the nineteenth century witnessed a constructive relationship between scientists and farmers, often solicited by the scientists themselves.

In 1908 Professor Herbert J. Webber, a plant breeder and botanist in the United States Department of Agriculture, wrote *Plant-breeding for farmers*. In the introduction he writes "No farmer, however, is so poor that he cannot have his breeding patch of maize, wheat or potatoes. Indeed, if they but knew it, they can ill afford not to have such a breeding patch to furnish seed for their own planting". In 1918, Henry A. Wallace encouraged farmers to experiment with crossing varieties of corn and thought that the only way for breeders to discover new strains was to rely on the expertise of the knowledgeable corn farmers. There are other examples of this collaboration, which ended, for example in the United States of America and Italy, with the introduction of hybrid corn. The idea of participatory research re-emerged in the 1980s.

Applied to plant breeding, participatory research has been implemented as participatory plant breeding (PPB) defined as the participation of clients (often, but not only, farmers) in all of the most important decisions during all the stages of a breeding programme.

Participatory plant breeding

Breeding programmes are characterized by three main stages: (i) generating genetic variability; (ii) selection of the best genetic material within the genetic variability created in stage one; and (iii) testing of breeding lines emerging from stage 2 using the appropriate experimental and analytical methodologies.

Commonly, the key stages of a plant breeding programme take place on research stations under optimum or near-optimum agronomic conditions including use of fertilizers and pesticides. A centralized plant breeding programme finds it difficult to address issues such as the client profile (namely breeding for whom) and the product profile (namely breeding which type of variety), which vary, even considerably, from location to location and with time. Moreover, breeding efficiency is affected due to the negative effect of genotype x environment interaction on genetic gains. The main consequence of these problems is that varieties developed are specifically adapted to environments similar to the research station or made similar by using the same agronomic management including chemical plant protection.

Decentralized selection can solve these problems: it is defined as selection conducted in the target population of environments. However, where used in the form of multi-environment trials, it fails to do so, because only the best varieties *across* the range of environments are selected, rather than the best varieties *in each* environment.

A breeding programme using decentralized selection becomes effective when combined with the collaboration of the stakeholders, particularly if the stakeholders' collaboration begins with the identification of priorities and objectives, thus developing itself into a PPB programme. A decentralized-participatory breeding programme is particularly suited to serve organic agriculture.

A distinction needs to be made between PPB and participatory variety selection (PVS), the latter term being used when participation begins in stage 3, namely in testing of breeding lines. PVS is technically easier to organize than PPB because it implies evaluating a limited number of lines; on the other side it leaves to participants a limited number of choices to make. With PVS there is a risk for breeding material desirable to farmers to be discarded before they see it.

The main features of PPB are: (i) objectives are established together with the stakeholders and may differ from location to location within the same country and between countries, and may change with time; (ii) breeding material is tested at the earliest possible stage; (iii) stakeholders are involved in all major decisions and particularly in deciding which material to select and which material to discard at the end of each cropping season – details on how this is actually done change with the crop and with the country; and (iv) locations are chosen to sample the target population of environments and users, and are treated as independent units of selection, namely, selection is done within each location regardless of how the best breeding lines in that location perform in other locations. Selection is fully decentralized and for specific adaptation.

Why farmers' participation is still marginal

Over the years, PPB collected success stories and had a number of recognitions. However, the use of PPB is still marginal. It has been argued that when the concept of participatory research was proposed in the mid-1980s and was applied to plant breeding, it represented a reversal of the model defined "delegative" (from the French *délégatif*), in which agricultural production, seed production, varietal innovation and conservation of genetic resources changed from being part of farmers' activities to be functionally separated and delegated to specialized scientists, while the farmers lost the responsibilities for innovation and conservation.

There was a process of dispossession of both genetic material and of knowledge; PPB implies changes on such a system and was considered very radical and perhaps even subversive. The likely reason PPB never "made it in a big way" is that it represents the reversal of the dispossession mentioned before, by actually making possible a repossession by farmers of the entire process, but mostly of seed production and exchange. Therefore, if we want to reverse the trend towards uniformity and monoculture, with all their consequences including those on our health, and we want to shift from *"cultivating uniformity"* to *"cultivating diversity"* we need to use an approach such as evolutionary plant breeding, which makes the participation of institutions an option rather than a necessity as it is in PPB.

Conclusions

Wherever applied, PPB has reached the most remote, least endowed and poorest farmers and improved their livelihood by empowering them to become full partners of the scientists. The methodology could fit well with the crop improvement programmes of the CGIAR given their structure, with access to a unique amount and diversity of germplasm and to a wide range of modern breeding techniques, a wide network of national partners, and a strong capacity-building capability. Therefore, there are no real scientific reasons to reject PPB if not the reluctance to share with others the credit for obtaining a new variety.

PPB is based on a methodology, which includes the most advanced experimental designs and statistical analysis, and is very powerful in increasing agrobiodiversity because it is based on specific adaptation, thus increasing resilience, as driven by crop diversity. By increasing agrobiodiversity, it becomes a breeding strategy capable of continuously adapting crops to the complexity of climate change particularly by incorporating mixtures and evolutionary populations.

5.4 Theme 3: Addressing local needs through on-farm management

Jogimara community seed bank, Nepal
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5.4.1 The thriving diversity of Peru's Potato Park

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Peru is an important centre of domestication and diversity where culture-based *in situ* and on-farm conservation strategies are allowing indigenous farmers to continue to grow diverse, nutritious and healthy food with little external inputs. As a result, their resilience is strengthened and local food security and livelihoods are ensured. The case of the Potato Park in Cusco, Peru, is provided as an example of successful implementation of culture-based conservation of local agricultural diversity in a reserve.

The Potato Park is an indigenous-led conservation initiative, focusing on local crop and animal diversity. The initiative has nurtured one of the world's most diverse collections of indigenous potato varieties, the third most important food crop in the world and a staple, feeding more than a billion people worldwide. The Potato Park was established in early 2000 by six indigenous Quechua communities in the Sacred Valley of the Incas in Cusco as a means to celebrate its rich potato diversity. Over 5 000 inhabitants of the Park occupy an area close to 10 000 hectares in this high mountain ecosystem, which is considered a secondary centre of domestication of potato. Potato is the major species that unites these communities. Focusing on the potato as a cultural symbol has been key to their efforts to maintain the approximately 1 400 potato varieties held by the communities.

The Potato Park was modelled following the structure of the local traditional biocultural territorial arrangement, representing three interconnected mutually supportive spatial and temporal elements: people, nature and religious beliefs. Achieving a balance between the needs and aspirations of these elements is known as *Sumak Causay* (or holistic living) and is the ultimate goal of the system. Food and seeds connect these elements, and their diversity is the main driver of this indigenous paradigm. This approach incidentally also matches up well with modern concepts of integrated on-farm conservation, where *Sallka* translates into conservation, *Auki* into ethics and policy and *Runa* into livelihoods and community economic development.

This cultural approach has been successful in the creation of benefits associated with the conservation and use of landraces. These benefits have local and global dimensions, and are captured from each of the components of the system (conservation, policy and community development) and their interactions. This indigenous framework is presented below to provide some examples of benefits, while focusing on those that address the social, economic, cultural and environmental concerns of the local population.

Sallka Ayllu **(conservation element):**

Benefits in this area are many.

- The highest potato diversity in the world is conserved and used sustainably. The Potato Park maintains 1 347 locally identified varieties of native potato out of the more than 3 000 varieties found in the region. This rich collection comes in many sizes, shapes, colours and textures. Keeping this diversity in the farmers' fields and landscapes is allowing crop evolution to generate the novel variations and maintain the capacity of these local varieties to adapt to change.

- A community-managed genetic reserve for five prominent potato wild relatives present in the Park has been implemented. Local farmers intentionally plant cultivated varieties close to these wild relatives to reincorporate strength and resistance to pests and disease and adapt to changing climatic conditions. This is an ancient approach of improving local varieties on-farm.

- A landscape focused on *in situ* conservation helps to maintain key ecosystem services, such as water harvesting, keeping pollinators, nutrient cycling and improving the quality of the soil and water, which is helping to cope with increasing pests and pathogens.

- A dynamic *in situ/ex situ* collaboration model between the Potato Park and the International Potato Center (CIP) includes the conservation of the local collections; repatriation of materials held in the CIP genebank to the communities; participatory research on climate change; and various training activities.

- The national government has recognized the Potato Park as an Agrobiodiversity Zone, which is a new category that seeks to protect agrobiodiversity areas that harbour a broad range of genetic diversity.

Auki Ayllu **(sociocultural element)**

This element includes how the Potato Park uses customary laws and institutions to develop instruments and policies for sustainable management.

- The formation of the Association of Communities of the Potato Park as the governance institution is helping the coordination and cooperation with government sectors (e.g. environment, agriculture, culture, tourism and education).

- Cooperation with universities and research centres is generating new knowledge and information through participatory research activities involving research institutions, genebanks and universities. This also has created spaces for knowledge exchange and co-learning with other farming communities

- Customary laws have been the source of a biocultural rights approach, which has helped to support the development of biocultural protocols, indications and collective trademarks, an intercommunity benefit-sharing protocol, traditional knowledge data base about local potato taxonomy, molecular information, and native crops traditional knowledge and uses. The Potato Park has also been instrumental in the development of the Cusco Region's Ordinances declaring biopiracy an unlawful activity and banning genetically modified organisms from the region.

- The Potato Park is one of the local communities that has included its collection into the Multilateral System of the Seed Treaty and made a deposit of close to 1 000 accessions to the Svalbard Seed Vault in Norway as insurance against the uncertainties brought by climate change.

- Finally, all this experience is being systematized and used in the development and implementation of a "pluriversity" on indigenous food systems and biocultural landscapes.

Runa Ayllu **(human element)**

This element includes all the productive and economic activities of the communities.

- The strengthening of the traditional indigenous agrifood system has resulted in a more resilient production system. In the past 15 years, the Potato Park communities have increased food production by better managing pest control, and preserving and rebuilding traditional agricultural structures such as terraces and irrigation systems.

- A local seedbank to conserve the local collection has been built with support of the Benefit-sharing Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) and is managed along with an emerging Community Seed Enterprise that aims to provide high-quality potato seeds to communities and farmers in the region.

- A key activity of the Park's has been the stimulation of economic activities through implementing agrobiodiversity-based microenterprises, which include: a potato-focused restaurant that promotes the local culinary traditions; marketing of potato-based natural products including for health and personal care; and implementing a vibrant agroecotourism programme, among others. The business model is one led by women, with the goal of generating monetary and non-monetary benefits that are compatible with the local concept of well-being. The approach has generated opportunities for employment and incentives for conservation.

- Developing new biocultural innovations has also been a focus of the approach, including natural products based on agrobiodiversity, and the integration of technological developments such as wireless technologies and solar energy to improve the efficiency of the traditional system.

- The use of collective trademarks and biocultural indications has helped to increase the marketing of local products and allowed the recognition of the indigenous biocultural identity.

- Migration out of the Park is low; on the contrary, because of the COVID-19 pandemic, the number of urban dwellers returning to the communities in search of food, health and livelihood has increased dramatically in the last year.

In conclusion, the biocultural heritage approach to conservation of agrobiodiversity in the Potato Park has been effective in catalysing the strong sociocultural ties that Quechua people have for nature and its elements. This has been the basis for developing an effective conservation and restoration model of the genetic diversity of potato and of its unique potato-producing habitats. Biocultural heritage can be the source of new pluralistic paradigms not only for reversing genetic erosion but also for generating bottom-up approaches to *in situ* conservation and on-farm management of agrobiodiversity. These approaches are multi-scalar and multi-stakeholder, and effectively contribute to integrating agrobiodiversity in broader policies though multilateral agreements such as the Treaty, the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, the Millennium Development Goals and the Sustainable Development Goals, among others.

5.4.2 Role of community seed banks in the management of PGRFA on-farm

Pitambar Shrestha, Local Initiatives for Biodiversity, Research and Development, Nepal (LI-BIRD), Nepal

Though Nepal occupies only 0.03 and 0.3 percent of land area in the world and Asia respectively, it is globally known for its rich and unique diversity of both wild and domestic animal and plants including plant genetic resources for food and agriculture (PGRFA). However, the rich diversity of PGRFA is shrinking from its natural habitat and farmers' fields due to various reasons. Realizing the importance of PGRFA for current and future food security, nutrition, climate change adaptation, etc., LI-BIRD mobilizes and empowers local communities and collaborates with government entities within the country and international agencies for on-farm management of PGRFA. The community seed bank is one of the initiatives of LI-BIRD promoted for on-farm management of PGRFA since 2003. It is a holistic approach that educates and empowers the local community to identify, conserve, promote, add value and use local crop diversity for the benefit of the local community and society.

Community seed banks (CSBs) provide easy access to quality seeds and planting materials of diverse crops and varieties, strengthen the local seed supply system and contribute to increasing food production, the income of the people and help realize farmers' rights on seed and food sovereignty. So far, LI-BIRD has facilitated establishing 23 CSBs in Nepal. These CSBs have conserved 1 407 local varieties (with some duplications) of 75 crops species. They produce, sell and distribute more than 16 tonnes of seed of local varieties annually. More than 2 500 farmers receive local varieties of seed from CSBs each year. This is done by preparing small pockets of local varieties of seed and distributing them to the farmers. CSBs establish diversity blocks of local crop diversity for regenerating seeds that are not in high demand, and produce and market seeds in higher quantities that have higher demand in the area.

The majority of the CSBs supported by LI-BIRD deal with seed but some also procure local variety-based produce and market it for enhancing the income of the farmers. Some CSBs are also involved in participatory plant breeding and grassroots breeding as part of the enhancement of local varieties. This type of work is more closely supported by LI-BIRD and some other relevant organizations. The promising local varieties are registered in the National Seed Board as per the schedule 'D' of the Seed Regulation (2013). This allows CSBs to produce and market seeds of the local varieties in a branded form. To date, 12 local varieties of six crop species have been registered under the leadership of six CSBs following the Schedule 'D'.

Facilitated by the Community Seedbank Association of Nepal, local seed exchange festivals are organized among the member CSBs. In an event organized in June 2019, ten terai-based CSBs brought 381 different local varieties of seeds and planting materials of 43 crop species for exchange. Of these, 353 samples of 27 crop species (cereal, vegetable and other crops) were exchanged.

Despite several benefits, contributions and positive impact on several aspects, the sustainability of community seed banks has been an issue around the world. But LI-BIRD has developed some mechanisms that are working well and CSBs supported by LI-BIRD are functioning well without external support after some years of establishment. A farmers' organization overseeing CSBs has a central role in effectively managing them. While establishing community seed banks, LI-BIRD not only provides technical, financial and facilitation support to the farmers' organization but also works on empowerment of farmers' organizations on legal, social, technical, financial and governance aspects. All these aspects are equally important for sustaining CSBs but regular income or a financial resources generation mechanism has been seen as a critical area.

LI-BIRD facilitates the establishment of a Community Biodiversity Management (CBM) Fund and seed fund at each community seed bank. The CBM fund consists of approximately one million Nepalese Rupees (USD 1=120 NPR) and the seed fund of approximately NPR 500 000. The CBM fund is mobilized as a loan among the community seed bank members for production activities such as rearing livestock, seed production, honey, mushroom, vegetable, etc. while the seed fund is used by the farmer's organization for conducting seed business activities (buying seed from the seed producer farmers, storing it until next season at the CSBs and selling it at the appropriate time). Both funds directly contribute to increasing the income of the farmers and the farmers' organization managing the CSBs. In Nepal's context, this mechanism has worked well and CSBs are functioning well without external support after some years of their establishment.

Some challenges of Nepalese community seed banks include a lack of legal framework, financial resources, technical capacity, and governance and management. The Agrobiodiversity Policy (2007, first amended in 2014) and the National Seed Vision 2013–2025 have praised the CSBs. There are also a few guidelines concerning implementing CSBs, but there is no 'Act' that talks about them. There is no legal provision for registering a "community seed bank" as such. It is operated by a cooperative or by an organization registered as a non-governmental organization. This sometimes creates confusion, and the purpose of the community seed bank is also diluted. Similarly, the community seed bank is managed by farmers, and the quality seed production, handling, storage and marketing are too technical for some community seed bank members and staff. Poor governance of the farmers' organization managing the CSBs also becomes a challenge for their smooth functioning.

To conclude this abstract, the rich diversity of local crops and associated traditional knowledge in Nepal is unrecognized, underutilized and under pressure of erosion from the farmers' field and natural habitat. The community seed bank is a solution not only to promote on-farm conservation of PGRFA but also to increase access to quality seeds and planting materials to farmers that contributes to food security, food sovereignty, nutrition and farmers' rights. Many local varieties can be registered/released through a simple selection/enhancement process so that the quality seeds of the local varieties can be legally produced, sold/distributed. This can easily be done through CSBs; the empowerment of the farmers' organization (legal, social, financial, technical and governance aspects) and development of a self-financing mechanism are key to sustain them.

5.4.3 Viet Nam seed clubs: an integrated approach to on-farm seed management

Normita Ignacio, Southeast Asia Regional Initiatives for Community Empowerment (SEARICE), Philippines

Farmer seed clubs evolved from farmer field schools (FFS), which is the main methodology used by SEARICE to build capacities of farmers in seed conservation and development. Each FFS is conducted for one cropping season and is participated in by 20–30 members. The training is conducted by a partnership of local government and academic institutions.

Underpinning the ground initiatives of SEARICE in the Mekong Delta is the multi-stakeholder partnership consisting of farmers, the Mekong Delta Development Research Institute of Can Tho University (MDI–CTU*)*, provincial and district government institutions (seed centres, extension centres, Department of Agriculture and Rural Development) and community level organizations (Farmers' Union, Women's Union, commune leaders).

After graduating from the FFS, those individuals who wish to continue crop breeding and seed production activities voluntarily organize themselves into seed clubs. Seed clubs usually have 10–20 members. As organizations, the seed clubs engage in breeding and selection to develop varieties that are locally adapted. Once varieties are up to their standard, they go into seed production so they can supply affordable good-quality seeds in their communities.

Because of the intensive training that farmers undergo under the FFS, they become highly skilled especially in breeding and selection and seed production. In addition, SEARICE local partners, particularly the MDI –CTU*,* seed centres and extension centres at the district and provincial levels, provide technical assistance and mentoring, which further enhance the skills of farmers and seed clubs

Seed club development

Initially four seed clubs were organized in 1996. By 2018, the number has grown to 365 with more than 10 000 members. All the provinces in the Mekong Delta have seed clubs as a result of the support from local government institutions, which were among SEARICE partners in the implementation of participatory plant breeding initiatives in the Delta.

Contributions of seed clubs in the Mekong Delta

Seed clubs have made significant contributions beyond the communities where they exist. Among the major contributions are the following:

- The development of farmers' varieties contributes to climate change adaptation and to broaden the on-farm genetic base. Seed club members have developed varieties that suit various conditions particularly in the Mekong Delta. For areas that often experience drought and where soils are acidic, the varieties include Nang Nhen, AG1, NV1, NV21, HD1 and NV14. In irrigated areas, some varieties developed are Nep AG, LH1, LH9, NDHD, HMT1, TC26 and HNOE. And for farms with saline and rainfed conditions, farmers can use Mot Bui Do, Tài Nguyên, HD1, TC7, ND4, SH31, NT1, GR22, LH8, TM16 and GR13.

- Seed clubs have contributed to the diversity of rice varieties so much so that in 2018 the numbers of seed club varieties exceeded those that came from the formal system. The number of farmers' varieties produced was 34 and only four of these varieties were produced through the formal seed system. This is a testament that farmers' varieties are of good quality and that they pass the standards of the formal supply sector. Seed clubs also produced 20 OM identified varieties, with 10 from the FSS. OM varieties are developed and released by Cuu Long Delta Rice Research Institute (CLRRI), the largest rice-breeding institution in the Mekong Delta. There were also two MTL identified varieties produced by seed clubs. MTL varieties are developed by MDI. Among the other varieties produced were traditional and high-yielding.

- Seed clubs have enhanced the accessibility of affordable good-quality seeds to farmers. A study conducted by MDI in An Giang Province reported that the increased utilization of the good-quality seeds from the seed clubs contributed to the steady increase of rice yield in the province.

- Seed clubs have significantly contributed to the seed supply in Mekong Delta. From 2015 to 2018, farmers in the seed clubs have produced and distributed over 770 000 tonnes of seeds in the Mekong Delta. And in 2019, seed clubs ranked second in terms of sources of rice seeds providing 35 percent of the needs of communities. In contrast, the formal seed system provided only 7 percent of the supply. More than half of the supply (58 percent) came from farmers' own saved seeds.

- Seed clubs contribute in educating agriculture students. Since MDI–CTU is a partner of SEARICE in project implementation, agriculture students have the opportunity to learn directly from the farmers through various activities such as FFS training, on-farm studies, diversity fairs where farmers present the varieties they develop/select, and work in the seed clubs. Undergraduate, graduate and post-graduate students have also completed their theses based on the work of farmers and the seed clubs. The experience provided by the farmers and the seed clubs enhances the learning of students in understanding the seed supply system and significance of farmers in this entire supply system. The enhanced education is a contribution in developing prospective extension agents and development practitioners.

- Seed clubs have added to the number of officially registered and certified varieties under the Ministry of Agriculture and Rural Development in Viet Nam. These varieties are the HD1, NV1, AG1, TC7 and LH8. The registration and certification came into fruition with the support of local partners. MDI assisted the farmers in documenting the technical processes involved in breeding while local institutions such as the seed centres and extension centres covered the costs of registration and certification of the farmers' varieties.

- Other contributions of seed clubs are:
  - shared the benefits to other farmers within and from neighbouring communities;
  - strengthened the networks of farmers within and among seed clubs;
  - contributed to household food and livelihood security;
  - established strong links with support institutions; and
  - empowered farmers as managers of their local seed systems.

Main challenge of the farmers' seed clubs

Seed clubs are facing two major challenges: limitations resulting from current national legislation and the implementation of the plant variety protection law.

Seed registration and certification processes under the current laws are not appropriate for farmers. Farmers on their own cannot afford the requirements of both processes in terms of resources and technical requirements. The registration and certification of the five varieties would not have been possible had the MDI–CTU not provided support in documentation and the local government institutions extended financial support for the fees. A resolution would be the drafting of a parallel system of registration and certification that is applicable to the conditions of farmers.

As for the plant variety protection law, in the past, seed clubs were able to conduct seed multiplication using any varieties preferred by most farmers and distribute these in their communities. But the implementation of the law has curtailed farmers' traditional practices of exchanging farm-saved seeds and selling seeds they produced especially when these are the protected varieties. The restriction results in limiting the number of varieties produced and shared by farmers in their own communities.

6. SESSION 4: THE WAY FORWARD: CREATING COMMUNITIES OF PRACTICE

Family Farmers, Egypt
© James Pursey

6.1 Session summary

During Session 4, speakers discussed the contributions of existing networks and communities of practice for conserving PGRFA outside of genebanks and the sustainable use of crop diversity. The interventions highlighted the important role of communities of practice for sharing knowledge, lessons learned and best practices. Key elements for successful communities of practice were described in this regard, including the need to: provide incentives for stakeholders, including farmers; develop capacities through inclusive training programmes; and build upon existing initiatives.

An example of a crop-specific network, the Cocoa of Excellence Programme was presented as a successful approach in establishing standards for cocoa quality and flavours. The initiative aims at improving farmers' livelihoods through the recognition and promotion of superior quality cocoa. Producers from around the globe submit samples for rigorous evaluation, selection and recognition of quality, flavour diversity and unique origins. The Global Network for Cacao Genetic Resources (CacaoNet), a cacao-based community of practice, was presented as an example of the successful coordination and implementation of priority research, breeding and use related to cacao genetic resources. CacaoNet was established to bring together public and private stakeholders from the cocoa and chocolate industries, governments, farmers' associations and research institutions to improve the overall conservation and use of cacao genetic materials to benefit growers.

Lessons learned from communities of practice in the Southern African Development Community region and in Europe illustrated the development of an evidence-base as a key element for successful *in situ* conservation and/or on-farm management activities. Experiences of these communities of practice demonstrate the importance of multi-stakeholder dialogues to develop effective partnerships, share knowledge and disseminate best practices. It was also stressed that harmonized national and/or regional policies, including national plans, frameworks and regulatory systems, are important for enhancing the contribution of PGRFA enhancement to food security and improved nutrition.

Public–private partnerships were presented as a successful strategy for promoting conservation for sustainable use of PGRFA. For example, participatory varietal selection was mentioned as an area where private and public breeders could collaborate with farmers to deliver demand-driven outputs. Another linkage discussed was that of public genebanks with private sector breeders who could contribute to national genebanks through multiplying accessions at no cost, while undertaking detailed studies on characterization and evaluation. The outputs of this collaboration would include the production of quality seeds for conservation in genebanks, as well as providing characterization and evaluation data to public genebank information management systems.

6.2 Creating communities of practice for *in situ* conservation and management of PGRFA in Europe: lessons learned

Nigel Maxted,[1] Nora Castañeda-Álvarez,[2] Ehsan Dulloo,[3]
Joana Magos Brehm,[1] Holly Vincent,[1] José Iriondo[3] and Shelagh Kell[1]

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The environmental impacts of climate change are causing significant challenges for agricultural production and food systems. More nutritious and climate-resilient crop varieties are required, but the lack of available and accessible novel trait diversity is limiting crop improvement. Crop wild relative (CWR) and crop landrace (LR) populations are rich sources of traits for biotic and abiotic stress resistance and other desirable characteristics, such as nutritional qualities. Therefore, their effective conservation is increasingly critical for food and nutritional security and the health and improved livelihoods of large segments of populations worldwide.

Currently CWR and LR taxon and genetic diversity is increasingly threatened by mismanagement of the environment and changes in agroecological practices. The vast majority of plant genetic resources for food and agriculture (PGRFA) genetic diversity is conserved *ex situ*, with little effective *in situ* or on-farm conservation. To achieve sustainable food production in the face of these challenges, strategies for systematic *in situ* conservation of CWR and LR with adequate backup *ex situ* need to be implemented in each country, region and globally.

In recent years, a community of practice for *in situ* or on-farm conservation has been developing a significant evidence-base, a prerequisite for active *in situ* or on-farm conservation implementation, notably including the efforts of two projects: the EU-funded project, ”Farmer’s Pride”, is addressing this challenge by establishing a European network of stakeholders and sites for *in situ* conservation of CWR and LR diversity across Europe and the United Kingdom Darwin Initiative project, ”Bridging agriculture and environment: Southern Africa crop wild relative regional network”, has similar goals in the Southern African Development Community. This is enabling core questions to finally be answered, such as:

Which taxa should we target for global food security?

The two most important elements within PGRFA that are of most value for sustaining food security are CWR and LR. PGRFA comprise the genetic material of plants that is of value as a resource for the present and future generations of people. CWR can be defined as wild plant taxa that have an indirect use derived from their relatively close genetic relationships to crops; these relationships are defined in terms of the CWR belonging to gene pools 1 or 2, or taxon groups 1 to 4 of the related crops, and, in practical terms, as all taxa within the same genus of a crop. A LR is a dynamic population of a cultivated plant species that has historical origin, distinct identity and lacks formal crop improvement. LRs are generally genetically diverse, locally adapted, associated with traditional farming systems and often have cultural associations.

Which populations to sample for ex situ *conservation?*

It is estimated there are about 50 000–60 000 CWR taxa globally, but based on crop value, CWR utilization potential and threat status, there are globally 1 394 priority CWR related to 194 crops. They are primarily located north and south of the equator between 45°N and 15°S in the 12 Vavilov Centres of Diversity. The number of crop landraces is unknown, but they are believed to be much more numerous, also associated with the 12 Vavilov Centres of Diversity and, due to replacement by higher-yielding cultivars in fertile land, are increasingly restricted to marginal agri-environments where they are still competitive in terms of production or retain a cultivation/production niche.

What combination of in situ *or on-farm conservation sites best conserves overall diversity?*

There is virtually no long-term active *in situ* conservation of CWR and further, 95 percent of CWR are regarded as under conserved *ex situ*. Therefore, any active conservation action is preferable. With maximum CWR diversity present in the 12 Vavilov Centres of Diversity, effective *in situ* conservation in those regions would be the most cost-effective. There is no estimate for either the number of LR or the number of locations where LR are cultivated, or even how well their diversity is conserved, either *ex situ* or *in situ* or on-farm. Therefore, any active *in situ*/on-farm conservation with effective complementary *ex situ* conservation is desirable, but maximum efficiency would result from implementation in the 12 Vavilov Centres of Diversity.

Is it better to have standalone* in situ *sites or should they be linked within a collaborative network?

A network of *in situ* or on-farm sites is preferable because it would:

- facilitate systematic coordination and reporting (e.g. Second Global Plan of Action);
- foster stronger partnerships and mutual support;
- help integrate global, regional and national actions;
- link local communities of practice with common goals;
- facilitate consensual access and benefit-sharing for protected areas and farmers/farming communities
- enable integrated, long-term complementary *in situ–ex situ* conservation;
- promote access to PGRFA held in protected areas and farmers/farming communities via Genetic Resource Centres (GRC), thus doubling the resources available to users; and
- put permanent safeguards in place to conserve evolving *in situ* PGRFA populations for perpetuity.

How will users gain access to the* in situ*/on-farm conserved resource?

Instinctively, it would appear simplest and most beneficial for the protected area manager or farmer to each grant access to the genetic resources they conserve and for users to contact them directly. However, in practice this is unlikely to ever work smoothly, because *a priori* we do not know which populations conserved *in situ* or on-farm are likely to be requested by the user. Therefore, it is impractical that all protected area managers or farmers are sufficiently aware of their rights and obligations to supply germplasm and ensure their own access and benefit rights are secured through international agreements (Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity and the International Treaty for Plant Genetic Resources for Food and Agriculture). The better option is that the protected area manager or farmer supply population backup samples to a local/national named genebank or genetic resources centre, and the centre supplies to users, securing the suppliers rights and ensuring the users' needs are met.

Won't users' needs being met by genetic resources centres mean significant additional workload and resource expenditure by them?

Not necessarily: there are four options:

- Option 1 – the routine route that germplasm enters the GRC follows: population samples are either collected from the wild or on-farm location. On entering the genebank, the seed samples are registered and documented, and then cleaned and dried. The germination rate is tested and, if over 85 percent, the sample is packaged and stored. Upon user request, a viable seed sample of approximately 40–50 seeds is made available. The sample is tested periodically for germination and, if less than 85 percent, the sample must be regenerated to ensure the seed viability is maintained at above 85 percent.

- Option 2 – the sample would be treated similarly to an *ex situ* "black box" sample. The sample is registered and documented, cleaned and dried, the germination tested, then packaged and stored, with the stored sample tested periodically for its germination level. The difference with option 1 is that the sample is not made available to users and is only available to the donor as part of a population reinforcement/reintroduction programme.

- Option 3 – the user identifies the *in situ* population they wish sampled, communicating this to the relevant GRC, which then collects and supplies samples on user demand.

- Option 4 – backup samples are treated similarly to *ex situ* samples but excludes periodic regeneration to maintain germination levels. When the seed viability of the *in situ* sample stored *ex situ* falls below 85 percent, a further sample is taken from the host *in situ* population.

Considering the four options, option 1 would place significant additional workload and resource expenditure on the GRC as they are treated the same way as *ex situ* collections. Option 2 does not facilitate access to the *in situ* or on-farm conserved resource. Option 3 is based on supply and demand and, because of seasonality of population seed supply, could significantly delay provision of the conserved resources to the user but would be the cheapest for GRC to implement. Option 4 is most preferable as it would be relatively inexpensive to implement and would mean *in situ* population samples would be made accessible alongside the material conserved *ex situ*. The regular resampling of the host population would mean the sample would better reflect the current genetic diversity content of the *in situ* populations that are continually evolving. Presence of the *in situ* sample in the GRC would mean the sample could be characterized and evaluated alongside the *ex situ* samples. Accessibility to *in situ* population samples via the genebank would leverage expertise in user seed conservation.

Having addressed these issues as a community and suggested solutions, we now need to apply them to be able to establish a global *in situ* PGRFA network. This will ensure PGRFA are available to underpin food security for all our futures.

6.3 Experiences in Zambia through the Darwin Initiative

Dickson Ng'uni and Graybill Munkombwe, ZARI, Zambia

Crop wild relatives (CWR) are unique resources for crop improvement and have potential to sustain food production and mitigate the impact of climate change. However, CWR species diversity is under threat due to habitat degradation arising mainly due to human activities. Zambia is one of the Southern Africa Development Community (SADC) participating countries, in addition to the United Republic of Tanzania and Malawi, in the Darwin Initiative for building up the Southern Africa crop wild relative regional network from 2019–2022.

The project aims at strengthening collaborative partnership among conservation agencies, agricultural researchers and farmers to identify networks of *in situ* conservation sites. This work was implemented within the framework of Zambia's Second National Biodiversity Strategy Action Plan in addressing its strategic goal to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity, and the strategic target that by 2025 the genetic diversity of cultivated plants and farmed and domesticated animals and of CWR including other socio-economically as well as culturally valuable species is maintained and strategies developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity. The expected outcome of the project is greater appreciation of the value of CWR among stakeholders for the sustenance of cost-effective measures that will help secure CWR populations and inform developing protocols to facilitate use of native CWR diversity in the crop improvement programmes for food security and prosperity. Through this article, we share Zambia's achievements from the implementation of the project activities.

Following the inception of the project, Zambia has established a national participative multi-stakeholder committee of CWR whose participants were drawn from 11 national institutions namely: Department of National Parks and Wildlife, National Heritage and Conservation Commission, Forestry Department, Zambia Agriculture Research Institute, Community Technology Development Trust, University of Zambia, Department of Biological Sciences, SADC Plant Genetic Resources Centre, Zambia Alliance for Agro Ecological Biodiversity, World Wide Fund for Nature, Climate Change Department and Participatory Ecological Land Use Management Zambia.

The committee held a meeting during which the National Strategic Action Plan (NSAP) for the conservation and sustainable use of priority CWR taxa was reviewed. In addition, the committee upheld the listed priority CWR taxa and recommended the integration of CWR species conservation in the general parks' management plans by the Department of National Parks and Wildlife. Further, through use of the occurrence information of priority CWRs and from the conducted field validation visits, the committee identified Kafue, Kasanka and South Luangwa National Parks as potential *in situ* conservation sites for priority CWR. The selected sites occur within the national protected areas and are hotspots for *Oryza* spp, *Dioscorea* spp, *Solanum* spp, *Sorghum* spp and *Pennisetum* spp.

The national *in situ* conservation sites formed part of the approved SADC CWR *in situ* network within the existing Regional Plant Genetic Resource Network. As a follow up to this, in-depth studies of priority CWR taxa were carried out in the identified potential conservation sites, which confirmed the occurrence of *Oryza longistaminata*, *O. birthii*, *Dioscorea* spp, *Solanum* spp and *Pennisetum* spp. In order to achieve gap-filling collecting of CWR genetic resources and local knowledge associated with *in situ* conservation sites, plans were underway to undertake the collection mission targeting wild rice and sorghum. This intervention has enabled strategizing the maintenance of the CWR plant genetic diversity and thus contributing to the Sustainable Development Goal 2, Target 2.5, which calls for maintenance of genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species. To foster enhanced utilization and establishment of functional procedures on potential use of CWR in breeding programmes, wild rice and *Vigna* spp. were planted under the screen house conditions for identification of traits for crop resilience in collaboration with the breeders within the Zambia Agriculture Research Institute.

Key areas for sustaining the conservation and sustainable utilization of CWR species diversity have also been discussed. Among others, areas for improvement in the sustained conservation and sustainable use of CWR PGRFA include the involvement of a wide range of stakeholders in the conservation and sustainable use programmes, sustained support for the National Plant Genetic Resources for Food and Agriculture Programme through enabling policies, support strategies and action plans, increased inclusiveness in the assumption of roles and responsibilities, and strengthening of linkages and platforms for information sharing and exchange. By and large, strategies and action plans for the conservation of CWR species diversity have been integrated in the Second National Biodiversity Strategy Action Plan, as a national policy document.

6.4 Communities of practice in cacao networks: Cocoa of Excellence and the importance of genetic diversity

Brigitte Laliberté, Alliance of Bioversity International & CIAT, Italy

Part A – The case of cocoa

Originating from the tropical regions of the Americas, the tree *Theobroma cacao* is one of 22 known species of the genus *Theobroma*, and is the source of chocolate's core ingredient. Today, it is grown across the tropical regions of Africa, Asia and Latin America. Cocoa is among the top ten most traded commodities in the world with a global market size of over USD 44 billion. Around five million tonnes of cocoa beans are produced each year and over 75 percent from West Africa.

There are about seven million cacao farmers and 40–50 million people depend on the crop for their livelihoods. Some 95 percent of global cocoa production comes from small growers who have an average of three hectares, producing about one tonne of dried beans per year. Almost 50 percent of cocoa is consumed in Europe, 30 percent in North America and 15 percent in Asia. Global demand for chocolate continues to grow. Cocoa production needs to be at least tripled in the coming years – a target requiring investment in research, breeding and value chain development to deliver fairer returns to growers.

The chocolate industry faces multiple threats to the supply of its key ingredient, cocoa, despite its steadily increasing demand. A danger that has received little attention is the lack of genetic diversity in current cacao varieties as well as threats to the genetic resources that cacao breeders rely on to create the varieties of the future. Decreasing cacao genetic diversity (*in situ*, on-farm and conserved in collections) is a serious problem and all of its many causes need to be urgently addressed, such as the destruction of the Amazonian rainforests, changing patterns of land use, the spread of pests and diseases, sudden changes in climate, and threats from natural disasters and extreme weather.

Compared to other crops like wheat, maize and rice, there has been very little attention given to researching and breeding different varieties of cacao, so the majority of planting material comes from a very narrow genetic base. This lack of genetic diversity makes the crop vulnerable to the effects of climate change such as heat and drought and highly susceptible to pests and diseases. Brazil, for example, was the third largest cocoa-producing country in the early 1980s, but a fungus called witches' broom disease wiped out almost its entire crop. Low-quality, low-yielding crops with low genetic diversity deliver only small returns to farmers.

A long value chain that includes several stages of processing means that value is not added at the point of production, and producers miss out on profit. Additionally, most cocoa producers are not consumers of chocolate, leading to low knowledge of product quality and bargaining power. Despite growing demand for chocolate globally, cocoa production remains critically unsustainable.

Part B – *Ex situ* conservation of genetic diversity – CacaoNet

Access to greater genetic diversity is critical to creating a more sustainable cocoa sector through which farmers can improve their incomes, enhance their quality of life and secure the future of cocoa. A considerable portion of this diversity is *in situ*, in farmers' fields and held in genebanks around the world, including two international collections maintained at the Cocoa Research Centre of the University of the West Indies, Trinidad and Tobago, and at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica. In addition to these two international collections, the International Cocoa Quarantine Centre at the University of Reading in the United Kingdom of Great Britain and Northern Ireland allows for the safe transfer of germplasm around the world. An increasing reluctance of countries to share materials emphasizes the importance of the international collections as the basis for a global system of conservation and use.

The Global Network for Cacao Genetic Resources (CacaoNet) was established to meet these challenges, bringing together public and private stakeholders from the cocoa and chocolate industries, governments, farmers' associations and research institutions. In 2012, a global strategy was published to improve the overall conservation and use of cacao genetic material and to benefit the livelihoods of its growers. Effective management of cacao genetic resources can only occur through international collaboration. Global efforts are underway to secure a sustainable future for a much-loved but highly vulnerable commodity.

Part C – On-farm conservation along the cocoa route – Cocoa of Excellence

The Cocoa of Excellence programme was established in 2009 to provide a way to safeguard cocoa flavour diversity and improve farmers' livelihoods through the recognition and promotion of superior quality cocoa origins for the sustainability of the supply chain.

The programme celebrates producers and encourages them to adhere to quality standards to earn recognition as the best cocoa producers in the world. It brings together leading sensory evaluation experts, the chocolate industry and sector-leading organizations to value excellence in cocoa and generate market opportunities. It provide incentives and tools for safeguarding diversity while benefiting the entire value chain, from the farming communities to the consumers. Cocoa producers from around the globe submit samples for rigorous evaluation, selection and recognition at the awards ceremony to celebrate quality, flavour diversity and unique origins.

For its 2019 Edition, Cocoa of Excellence received over 225 samples from more than 55 producing countries. These samples are given a three-digit blind code to ensure the knowledge of origins, producers and varieties remain unknown to evaluators. The beans undergo physical examination for their size, moisture, butter fat content and other characteristics. Next, samples are prepared through roasting, grinding and refining into cocoa liquor to be rigorously evaluated by an expert Technical Committee. Tasting notes list flavours ranging from fresh fruit to floral, woody or nutty, containing hints of sweetness or spice. Based on professional experience and market potential, each sample is attributed a Global Quality score. The 50 best samples are selected and nominated for the Cocoa of Excellence Awards. They are processed into a dark chocolate and evaluated by a broad panel of professionals such as chocolate-makers, pastry chefs and cocoa specialists.

To gain a better negotiating position, growers need to understand the value of their product. At the end of a long value chain, small-scale growers receive very little feedback about the quality of their cocoa. Just like any other commodities such as wine, coffee and olive oil, all cocoa has the potential for excellence. It is not only about genetics, but it is about the care to produce healthy trees and pods, the skills and experience to know just when to harvest, how to crack the pods, extract the beans and which fermentation process to apply and finish with drying. Each variety, clone and type has a unique optimal process. This art, skill and work of cocoa producers are what Cocoa of Excellence values and rewards.

Producers urgently need the tools to evaluate their cocoa quality and flavour independently of the buyers. Cocoa of Excellence developed a rigorous process for analysing quality. Building from this experience, efforts are now underway to develop international standards for the assessment of cocoa quality and flavour. These are used to conduct training in sensory evaluation and to establish competitions in cocoa-producing countries, giving local stakeholders the knowledge to improve crops and bargain for a fair price. The implementation of the protocols benefits all actors in the value chain. Farmers will be able to prove the quality and uniqueness of flavours of their beans and ask for a better price. Buyers, traders and chocolate-makers will more easily find the diversity of flavours to create a wide range of chocolate products that satisfy a growing and more demanding market. An important part of the implementation is the establishment of cocoa quality laboratories at a national level, and training in sample preparation and sensory evaluation.

Networking is about more than exchanging information. It is about establishing and nurturing long-term, mutually beneficial relationships. Improving the capacity of individuals and institutions to collaborate effectively is critical for impact. It centres on new opportunities and different perspectives. By conserving and celebrating cacao diversity, efforts by CacaoNet and Cocoa of Excellence aim to secure a more sustainable future for cocoa and for the livelihoods of its growers. We are grateful to our many partners for joining us in this important cocoa journey.

6.5 Synergies among public and private sectors

Niels P. Louwaars, Plantum NL, Netherlands

This paper discusses different values of plant genetic resources for food and agriculture (PGRFA) and motivations for their management and conservation, in order to facilitate the creation of synergies between public and private actors.

Management strategies

In the management of PGFRFA three basic strategies are distinguished: *in situ* (in natural habitats), managed on-farm in farmers' fields and conserved *ex situ* in genebanks. These are significantly different and complementary.

- *In situ* diversity changes with the environment – currently climate change is quite challenging. The speed of ecological changes may cause significant shifts in the genetic diversity. Certain diversity will disappear and new may arise due to the natural processes. Conservation thus relates to the evolutionary pressures rather than the genetic resources themselves.
- On-farm management of crop genetic resources relates to the diversity that farmers use, which depends on the farmers' management decisions with regard to their farming systems and the materials that fit best. Also here, the question is how the changes in management (due to population and market pressures) and ecology will impact the outcome in terms of genetic resources.
- Where *in situ* and on-farm strategies basically focus on managing diversity, *ex situ* strategies focus on actual conservation of the genetic resources themselves. However, some losses through drift may occur in genebanks.

Values of genetic resources

It is important to analyse the arguments to conserve when discussing roles and responsibilities. Steven Brush, University of California – Davis, identified three values of PGRFA: the *direct use value*, the value in breeding but also other local and industrial (medical and other) uses; the *indirect use value*, notably related to environmental services; and the *option value* i.e. the currently unknown, but possible use value of the resources in the future. Ekin Birol adds two more: *existence value*, being the sheer satisfaction that a resource exists, and *bequest value*, the benefit accruing to an individual from the knowledge that others may benefit from the resource.

- For *in situ* conservation of PGRFA, the option value is a major driving force next to the indirect use. Also the existence and bequest values contribute to this strategy.
- For on-farm management, direct and indirect use value may be the most important for farmers to manage diversity next to the bequest value – farmers all over the world get a satisfaction that other farmers appreciate and use their varieties. Many farmers may not have the luxury to think every day about the option and the existence values, but they remain relevant.
- For *ex situ* conservation of PGRFA, the direct use and option values are key. These values differentially contribute to the argument to conserve. All values may play a role, but the *direct use value* and the *option value* are the most common arguments to invest in *ex situ* conservation – and central in the job of the breeder.

When considering the roles of the private sector in the management of PGRFA, it may be clear that the primary focus will be on direct use, both for breeders and their value chain partners: farmers, traders, retail and finally consumers, and that they fully recognize the importance of the option value, i.e. future use.

Diverse motives for contributing

The values of PGRFA also relate to the different motives that stakeholders may have to contribute. This accounts for the sharing of knowledge, but more specifically to the financial contributions to PGRFA management.

I identify the following five main motivations: *self-interest*; *enlightened self-interest*; i.e. contributing to something larger but with a longer-term self-interest as well; *communal interest*, i.e. the interest of the breeding community at large; *charity* and *obligation*. Let us run them through and see how they may relate to the different strategies.

Breeders always maintain their working collections, which they hold dearly and expand where useful. Second, investing in the use of more distant materials contributes to conservation through use as breeding has shown to contribute to diversity in farmers' fields in Europe over the past few decades. This is connected in the literature to the emergence of marker-assisted selection, the operation of plant breeder's rights and consumer demands for diversity. The *self-interest* in PGRFA-management is a clear motive in these actions.

Public–private cooperation in research could be done out of an *"enlightened" type of self-interest*. The self-interest component is to jointly prioritize and formulate research topics. The longer-term contribution to society relates to the results becoming publicly available to all others including competitors. Participatory variety selection (PVS) is also such a case, where breeders involve farmers in variety trials not just to let farmers choose, but also to learn what the farmers' selection criteria are. Including farmers' varieties is a very good way to do that. Third, I could imagine individual agreements with farmer groups or governments.

Communal interest is, for example, where various private sector operators jointly support a genebank (like the one in the Netherlands as mentioned) or even broader through voluntary contributions to the Benefit-sharing Fund or the Crop Diversity Trust.

Enlightened self-interest and communal interest could be clustered into the term *Corporate Social Responsibility* (CSR).

Charity is a fundamentally different motive. Where CSR is undertaken within the business operation of the company, charity focuses on actions beyond. Examples are programmes by corporate foundations, support by companies and not-for-profit organizations. Charity can be very nice, but there may be clear limitations to becoming dependent on charity like conservation of PGRFA. For example, the long-term commitment required may be lacking. An exception to this may be NGOs such as the World Wide Fund for Nature.

Finally, obligatory financial contributions are there. The private sector contributes through taxes (part of which may be used for government conservation policies), and obligatory benefit-sharing, which is of course commonly directed to conservation efforts.

Contributions by the private sector

When focusing on contributions of breeders and the seed sector in general, we can identify knowledge and funds. Since *ex situ* is closest to the daily work of breeders, there is much more knowledge to share on this strategy than towards the other two. Breeders in the Netherlands significantly contribute to the national genebank by multiplying accessions for free, producing quality seeds that can be stored for many years, and in the meantime making detailed descriptions of the plants that are entered in the genebank information systems. Obviously, such multiplication is done under strict SMTA conditions. Through this work, the private sector contributes some 10–15 percent of the running cost of the genebank.

The breeder's knowledge that is relevant for on-farm management is much less clear. Breeders can use their variety testing skills towards assessing the value of farmers' varieties (next to scientifically bred ones) in participatory variety selection programmes. Experience is that farmers may explicitly select the farmers' varieties from such trials, thus contributing to "conservation through use". A collaboration between public and private breeders in such PVS initiatives may also extend to participatory breeding.

For *in situ* strategies, private sector parties could be asked to contribute through making available their laboratory facilities towards measuring genetic diversity as a monitoring tool of the evolutionary developments. They could also contribute their taxonomic knowledge where that would be a limitation.

Financial contributions, voluntary through various projects that are currently running, and obligatory as discussed above, complement the options.

Conclusion

PGRFA has different values; direct use and option values are closer to the goals of (public and private) breeders than the others. There is a parallel situation with collaboration in research, where private responsibilities are more on direct use values (applied research), and joint and public responsibilities on longer-term fundamental research.

Special efforts are needed to motivate private sector parties in the agricultural value chains to contribute; from breeders, through producers and traders to retail organizations. Different motivations to contribute have been presented that may facilitate to connect the needs in the area of PGRFA management with private sector interests and capabilities, and by doing so to create new, effective and sustainable synergies.

6.6 Panel discussion: opportunities, necessary actions and recommendations

For the final Session of the Symposium, nine experts on *in situ* conservation and on-farm management of PGRFA provided their perspectives on: (i) the main technical and scientific challenges in promoting *in situ* conservation and use of CWR and wild food plants, and on-farm conservation and use; (ii) how these can be addressed; and (iii) how global communities of practice could address these challenges. Multi-stakeholder collaboration, together with iterative planning, as well as building on existing initiatives, were emphasized as important considerations in this regard.

The nine panelists were: Maria Francisca José Acevedo, CONABIO, Mexico; Maria Andrade, International Potato Center; Niels Louwaars, Plantum NL, Netherlands; Nigel Maxted, University of Birmingham, United Kingdom; Kebadire Khola Mogotsi, National Agricultural Research and Development Institute, Botswana; Chris Ojiewo, International Crops Research Institute for the Semi-Arid Tropics; Johan Robinson, United Nations Environment Programme; Kuldeep Singh, National Bureau of Plant Genetic Resources, India; and Martha Willcox, University of Wisconsin-Madison, United States of America.

Specifically, the discussions highlighted the issues below.

i. Technical and scientific challenges

The key gaps highlighted for CWR included: limited knowledge on taxonomy and reproductive biology necessary for their effective management *in situ* and in *ex situ* conservation facilities; the need for increased screening of CWR for economically important traits; and greater use of CWR in pre-breeding globally. The lack of data on the characterization and evaluation of farmers' varieties/landraces was identified as a major constraint to their use.

ii. Local solutions to address global issues

The importance of setting priorities for conservation, identifying comprehensive conservation approaches (*in situ, ex situ* and/or on-farm) and the target beneficiaries, as applicable, was stressed. Value chains, associated with access to quality seeds and planting materials, were also highlighted as necessary for linking conservation to sustainable use of crop diversity. When designing and implementing activities for conservation and use of PGRFA, it is crucial to take into account the prevailing local sociocultural conditions. The importance of developing harmonized national and/or regional policies, including national plans, frameworks and regulatory systems, was also stressed.

iii. Knowledge management and information exchange

Sharing information through publicly accessible platforms was identified as a pressing need for promoting the use of crop diversity. The need to share best practices, tools and approaches, including for the agronomic management of crops and varieties, was also emphasized. The panelists offered perspectives on the setting of common research priorities and goals, especially through participatory and collaborative approaches.

iv. Building communities of practice

The importance of greater dialogue among the agriculture, environment, forestry and health sectors was highlighted as a means to promote *in situ* conservation and on-farm management of PGRFA. Effective, successful communities of practice will need to be as inclusive as possible, with a high degree of transparency in a neutral forum. The panelists also agreed that addressing common problems could be a starting point for building a community of practice. Such a community could initially undertake joint actions of mutual benefit, e.g. fundraising, sharing lessons learned and developing guidelines for best practices.

7. CONCLUSION OF SYMPOSIUM

Harvesting vegetables, Kyrgyzstan

7.1 Conclusion

The Symposium brought together a range of diverse, relevant stakeholders. The number and participation of stakeholders demonstrated a need for the exchange of information currently unmet through other channels.

The Symposium highlighted that FAO, as a neutral forum, would be well placed to convene stakeholder meetings, coordinate information exchange and capacity development, for example though webinars, and facilitate the reflection of stakeholder experiences and best practices in global policies, work programmes and funding priorities. Therefore, a symposium format may serve as a means for fostering a community of practice underpinned by a shared interest in the best practices for *in situ* conservation and on-farm management of PGRFA, especially farmers' varieties/landraces.

In follow-up to the Symposium, the Commission at its Eighteenth Regular Session,[3] commended FAO for convening, in collaboration with the Crop Trust and the Treaty, the First International Multi-stakeholder Symposium on Plant Genetic Resources for Food and Agriculture. The Commission requested FAO to finalize, publish and distribute widely the proceedings of the Symposium. It also requested FAO to organize, subject to the availability of the necessary extra-budgetary resources, symposia (that may be held virtually) and webinars on *in situ* conservation and on-farm management of PGRFA, at regular intervals, in collaboration with the Treaty and other relevant international instruments or organizations, in support of the implementation of the Second GPA and relevant articles of the Treaty.

3 CGRFA-18/21/Report, paragraph 100.

7.2 Closing remarks

Stefano Diulgheroff, Secretary of the Commission's Intergovernmental Working Group on PGRFA, FAO

First of all, I would like to thank all participants for having contributed to the discussions; all of the presenters for sharing their experiences and making their presentations available weeks ago; all chairpersons for guiding us all through their sessions – all very appreciated.

Many people have worked hard to organize this event – many of them behind the scenes – including colleagues from the steering committee of the co-organizers – the Secretariats of the Commission and the Treaty, the Global Crop Diversity Trust and the Seeds and Plant Genetic Resources Team of FAO's Plant Production and Protection Division. Among these, in particular, Bonnie Furman and Arshiya Noorani had the responsibility of pushing this forward and I wish to acknowledge their effort and the efforts of all. Special thanks go to the interpreters, the staff of communication services and all other support staff who have contributed to the success of this event.

We will report the outcomes of the Symposium to the Commission and to the Commission's Intergovernmental Technical Working Group on PGRFA that will meet next June; the Commission will meet at the end of the year.

There has been an interesting discussion, which I hope will bear fruit. I personally agree that we need to come up with a concrete proposal, other projects or mechanisms to boost the conservation and sustainable use of crop wild relatives, wild food plants and farmers' varieties/landraces. All these three groups are in danger. We all know it and time is not on our side – especially since the scale of our interventions is huge. If we do not move quickly we may find ourselves still discussing when these resources will no longer be with us.

Irene's interventions on the very first day asked us for some concrete developments. As a participant role, we need to overcome conceptual barriers between sectors and stakeholders. Understanding and trust are key and it seems to me that a common agreement among us all is that we need to foster collaboration on the basis of understanding and trust. And with this, I really thank everybody and, as I said, the outcome of this Symposium will go to the Working Group and the Commission that will meet later this year.

Thank you very much to all.

ANNEXES

Annex 1: Provisional Agenda

First International Multi-stakeholder Symposium on Plant Genetic Resources for Food and Agriculture

Technical Consultation on *in situ* conservation and on-farm management of PGRFA

29–30 March 2021

Virtual Zoom Event

Technical Presentations for Sessions 2, 3 and 4 have been pre-recorded and made available online in official FAO languages on the Symposium webpage. Discussions will be streamed live during the event. Interpretation will be available in all six official FAO languages.

DAY 1: 29 March 2021	
Opening and Welcome: Live Session	
Chair: ***Jingyuan Xia***, Director, Plant Production and Protection, FAO	
10:00–11:00	**Beth Bechdol**, Deputy Director-General, FAO **Irene Hoffmann**, Secretary, Commission on Genetic Resources for Food and Agriculture, FAO **Kent Nnadozie**, Secretary, International Treaty on Plant Genetic Resources for Food and Agriculture, FAO **Stefan Schmitz**, Executive Director, Global Crop Diversity Trust
Session 1: Setting the Scene: The challenges and opportunities for sustainably managing crop diversity	
Session Chairs: Session chairs: ***Luigi Guarino***, Global Crop Diversity Trust ***Mario Marino***, Treaty Secretariat	
Presentations and discussions: held live during event	
11:00–12:30 Keynote speeches	Crop diversity for sustainable development: bridging the gaps between *in situ* and *ex situ* conservation ***Kuldeep Singh,*** *National Bureau of Plant Genetic Resources, India* Successful approaches and practices for the sustainable use of crop diversity ***Maria Andrade,*** *International Potato Center* Conserving crop diversity *in situ* and on-farm: balancing the needs of diverse stakeholders ***Johan Robinson,*** *United Nations Environment Programme*
12:30–14:30	*Break*

Session 2: *In situ* conservation of crop wild relatives and wild food plants	
Session chairs: ***Chikelu Mba***, FAO ***Mariana Yazbek,*** ICARDA	
Presentations: Pre-recorded and available online prior to event *Discussions:* Held live during event	
14.30–15:30 Moderated discussion	**Theme 1: *Securing wild PGRFA diversity* in situ *and in complementary* ex situ *programmes*** • Bridging *in situ* and *ex situ* conservation in the field ***Ehsan Dulloo***, *Alliance of Bioversity International & CIAT* • Complementary conservation strategies: experiences from the Crop Trust ***Hannes Dempewolf***, *Global Crop Diversity Trust* • Identification of promising species, collecting plant germplasm and *in situ* conservation in Brazil ***Jose Francisco Montenegro Valls***, *Cenargen, Brazil*
15:30–16:30 Moderated discussion	**Theme 2: In situ *conservation and integration with plant breeding*** • Pre-breeding using crop wild relatives ***Shivali Sharma***, *ICRISAT* • Experiences in crop wild relative conservation and use ***Maria Francisca José Acevedo***, *CONABIO, Mexico* • *In situ* conservation of crop wild relatives in China ***Qingwen Yang***, *CAAS, China*
16:30–17:30 Moderated discussion	**Theme 3: *Wild food plants: their conservation and use*** • Wild food plants for a sustainable future ***Tiziana Ulian***, *Royal Botanic Gardens Kew, United Kingdom of Great Britain and Northern Ireland* • Wild food plants: increasing dietary diversity ***Jessica Fanzo***, *Johns Hopkins University, United States of America* • Indigenous peoples and local communities and the importance of wild food plants in Botswana ***Kebadire Khola Mogotsi***, *National Agricultural Research and Development Institute, Botswana*

DAY 2: 30 March 2021	
Session 3: On-farm management of farmers' varieties/ landraces	
Session chairs: ***Devra Jarvis***, Platform for Agrobiodiversity Research ***Mario Pagnotta***, University of Tuscia, Italy	
Presentations: Pre-recorded and available online prior to event *Discussions:* Held live during event	
09:30–10:30 Moderated discussion	**Theme 1: Measuring and securing on-farm diversity** • Richness and evenness of farmers' variety/landrace diversity maintained by farming communities ***Maedeh Salimi**, CENESTA, Islamic Republic of Iran* • Complementarity of on-farm management and *ex situ* conservation ***Ximena Cadima**, Fundación PROINPA, Plurinational State of Bolivia* • From the genebank back to the farm ***Lee Hickey**, The University of Queensland, Australia*
10:30–11:30 Moderated discussion	**Theme 2: Harnessing on-farm diversity for resilience** • Harnessing landrace diversity for resilience ***Ousmanne Boukar**, IITA* • Development of farmers' varieties/landraces ***Martha Willcox,** University of Wisconsin-Madison, United States of America* • Alternative breeding approaches: participatory plant breeding ***Salvatore Ceccarelli**, ICARDA (retired), Italy*
11:30–12:30 Moderated discussion	**Theme 3: Addressing local needs through on-farm management** • The thriving diversity of Peru's Potato Park ***Alejandro Argumedo**, Asociación ANDES, Peru* • Role of community seed banks in the management of PGRFA on-farm ***Pitambar Shrestha**, LI-BIRD, Nepal* • Viet Nam seed clubs: an integrated approach to on-farm seed management ***Normita Ignacio**, SEARICE, Philippines*
12:30–14:30	*Break*

***Session 4:* The way forward: creating communities of practice**	
Session chairs: ***Jennifer McConnell***, Irish Seed Savers, Ireland ***Elcio Guimares***, Brazilian Agricultural Research Corporation (Embrapa), Brazil	
Presentations: Pre-recorded and available online prior to event. *Discussions:* Held live during event	
14:30–15:30 Moderated discussion	• Creating communities of practice for *in situ* conservation and management of PGRFA in Europe: lessons learned ***Nigel Maxted***, *University of Birmingham, United Kingdom of Great Britain and Northern Ireland* • Experiences in Zambia through the Darwin Initiative ***Dickson Ng'uni***, *Zambia Agriculture Research Institute, Zambia* • Communities of practice in cacao networks: Cocoa of Excellence and the importance of genetic diversity ***Brigitte Laliberté***, *Alliance of Bioversity International & CIAT* • Synergies among public and private sectors ***Niels P. Louwaars***, *Plantum NL, Netherlands*
15:30–17:30 Panel discussion: Opportunities, necessary actions and recommendations	
Moderators: ***Bonnie Furman,*** FAO; ***Arshiya Noorani***, FAO; ***Alvaro Toledo,*** Treaty Secretariat	
Panelists:	***Maria Francisca José Acevedo***, *CONABIO, Mexico* ***Maria Andrade***, *International Potato Center* ***Niels Louwaars***, *Plantum NL, Netherlands* ***Nigel Maxted***, *University of Birmingham, United Kingdom of Great Britain and Northern Ireland* ***Kebadire Khola Mogotsi,*** *National Agricultural Research and Development Institute, Botswana* ***Chris Ojiewo***, *International Crops Research Institute for the Semi-Arid Tropics* ***Johan Robinson***, *United Nations Environment Programme* ***Kuldeep Singh***, *National Bureau of Plant Genetic Resources, India* ***Martha Willcox,*** *University of Wisconsin-Madison, United States of America*
Closure of the Symposium ***Stefano Diulgheroff,*** FAO	

Annex 2: Participant biographies

Opening and Welcome

- **Beth Bechdol** is the Deputy Director-General of FAO. Ms Bechdol received her bachelor's degree from Georgetown University in international law and international affairs, and completed her master's degree at Purdue University in agricultural economics. She is responsible for FAO's Partnership and Outreach work, including Partnerships and UN Collaboration, Resource Mobilization and Private Sector Partnerships, South–South and Triangular Cooperation. Ms Bechdol also leads programmes in the area of plant production and protection and oversees FAO's main technical advisory committee on agriculture, the Committee on Agriculture (COAG) as well as the International Plant Protection Convention Secretariat.

- **Irene Hoffmann** is the Secretary of the Commission on Genetic Resources for Food and Agriculture at FAO. Ms Hoffmann is an agricultural scientist with a PhD from Hohenheim University and an MSc from Göttingen University. Between 1994 and 2002, she was assistant professor at the Institute of Livestock Ecology, Giessen University, where she coordinated international and interdisciplinary research programmes. Between 2002 and 2015, Ms Hoffmann was Chief of the Animal Genetic Resources Branch and Chief of the Animal Production Service in FAO, and acted as Secretary of the Commission's Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture.

- **Kent Nnadozie** is the Secretary of the International Treaty on Plant Genetic Resources for Food and Agriculture. Mr Nnadozie holds a Doctorate in Law from McGill University, Montreal, Canada, with a focus on international relations and international legal systemic issues regarding genetic resources. Prior to his appointment as Secretary, he was the Senior Officer of the Treaty, overseeing various technical areas of the Programme of Work of the Secretariat. Over the last decade, Mr Nnadozie has worked on legal and policy matters and intergovernmental processes, with both the International Treaty and FAO's Commission for Genetic Resources for Food and Agriculture.

- **Stefan Schmitz** is the Executive Director or the Global Crop Diversity Trust. Mr Schmitz received a PhD in geosciences from the Free University of Berlin in 2000. He joined the Crop Trust as Executive Director in January 2020. For more than ten years prior, he led the food security, agriculture and rural development work at the German Federal Ministry for Economic Cooperation and Development (BMZ). He has worked as Deputy Director-General and Commissioner for the "One World – No Hunger" Initiative at BMZ and chaired the Steering Committee of the Global Agriculture and Food Security Program.

- Session Chair: **Jingyuan Xia** is the Director of the Plant Production and Protection Division at FAO. Prior to his present position, from 2015 to 2019, Mr Xia was the Secretary of the International Plant Protection Convention (IPPC) at FAO. From 2012 to 2014, he served as Permanent Representative and Minister Plenipotentiary at the China Mission to FAO in Rome. Mr Xia has had a distinguished career in China where he served as Director General and Extension Professor at the National Agro-Tech Extension and Service Centre of the Ministry of Agriculture in China and as Assistant Director General, Deputy Director General and Director General at the China Cotton Research Institute of the Chinese Academy of Agricultural Sciences. Mr Xia, holds a PhD in Entomology from Wageningen University and Research Centre in the Netherlands, a MSc in Entomology from the University of Philippines, and a BSc in Agronomy from the Central China Agriculture University.

Session 1 Keynote Addresses

- **Kuldeep Singh** is the Director of the National Bureau for Plant Genetic Resources in India, starting in 2016. From 1999 until 2015, he served as a Molecular Geneticist, Senior Molecular Geneticist and Director at the School of Agricultural Biotechnology, Punjab Agricultural University, Ludhiana, India. His work involved wide hybridization in wheat and rice, using wild varieties, gene identification and mapping, molecular breeding and genome sequencing. Mr Singh holds a PhD and MSc in Plant Breeding from Punjab Agricultural University, Ludhiana, and a BSc in Agriculture from Sukhadia University, Udaipur. He was a Post-Doctoral Fellow at the International Rice Research Institute in the Philippines. Mr Singh has successfully funded over 30 research projects, for a total of approximately USD 7 million. He has to his credit 102 research papers in prestigious refereed journals.

- **Maria Andrade** is the Lead of the Sweet Potato Support Platform in Southern Africa for the International Potato Center (CIP). She joined CIP in 2006, with a research emphasis on breeding drought-tolerant sweet potato varieties. Her overall research interests include technology transfer, breeding seed systems and the enhancement of value chains for income-generation. She has released 30 bio-fortified sweet potato varieties of which 20 are drought-tolerant. Ms Andrade has 30 years of working experience in Africa. She has spent the last 21 years working in Mozambique. The first ten of these, she served as a regional cassava and sweet potato agronomist for the Southern Africa Root Crop Research Network, a programme run conjointly by IITA and CIP. From 2002 to 2006 she coordinated a five-year IITA project on accelerated multiplication and distribution of healthy planting materials of the best high-yielding varieties of cassava and sweet potato. Over one million farmers received improved planting material under this project in 98 of the 141 districts of the country with Maria collaborating with 124 partners to achieve this challenging objective. Ms Andrade was one the recipients of the 2016 World Food Prize.

- **Johan Robinson** is Senior Programme Officer at the United Nations Environment Programme, responsible for the UN Environment/Global Environment Facility Biodiversity and Land Degradation portfolios. He is an Environmental Specialist with over 20 years of applied experience in biodiversity conservation and addressing land degradation and its role in sustainable development. He has specific expertise in the areas of protected area management and finance, mainstreaming biodiversity into production sectors (such as fisheries, forestry, agriculture and tourism), landscape management and ecosystem-based climate change adaptation and mitigation. He is widely recognized for innovation in design and implementation of environment-related projects and his expertise in mobilizing partnerships for environmental management with states, NGOs and the private sector. He has worked within the United Nations system for the last 12 years. Mr Robnson holds an Executive MBA from the University of Cape Town, South Africa, an MSc in Protected Landscape Management from the University of Greenwich, United Kingdom of Great Britain and Northern Ireland, and a Postgraduate Diploma in Applied Environmental Economics from the University of London, United Kingdom of Great Britain and Northern Ireland.

- Session co-chair: **Luigi Guarino** is the Science Director at the Global Crop Diversity Trust, where he oversees the Crop Trust's programmatic work while leading the Science Team. He has a long career in plant genetic resources and has worked with FAO and the International Board for Plant Genetic Resources (now Alliance of Bioversity International & CIAT), working in the South Pacific, Middle East, Africa and South America. Mr Guarino is an Italian national and holds BA and MA degrees in Applied Biology from the University of Cambridge, United Kingdom of Great Britain and Northern Ireland.

- Session co-chair: **Mario Marino** is a member of the Secretariat of the International Treaty on Plant Genetic Resources Plants for Food and Agriculture, joining in 2008. He is currently the responsible Officer for Conservation and Sustainable Use of PGRFA, Farmers' Rights, supporting projects and partnerships activities of the Treaty. Before joining the Treaty Secretariat, he worked in Italy at the Ministry of Agriculture for almost 20 years in seed certification, production and protection and as governmental representative in the access and benefit-sharing area. Mario holds a PhD in Agrochemistry and Agrobiology.

Session 2: *In situ* conservation of crop wild relatives and wild food plants

- **Ehsan Dulloo** is a Principal Scientist at the Alliance of Bioversity International & CIAT. He is Team Leader, Integrated Conservation Strategies and Effective Genetic Resources Conservation and Use Initiative. He is also the co-cluster leader of the Genetic Diversity Cluster of Flagship 1 of the CGAIR Research Programme on Roots, Tubers and Bananas. Mr Dulloo is also a co-chair of the Crop Wild Relative Specialist Group of IUCN/Species Survival Commission. He previously served as Senior Policy Officer, Plant Genetic Resources, at FAO, and was Project Manager of a World Bank GEF Biodiversity restoration project in Mauritius. Mr Dulloo holds a PhD in Conservation Biology and a MSc in Conservation and Utilization of Plant Genetic Resources from the University of Birmingham and BSc in Environmental Biology form Queen Mary University in London.

- **Hannes Dempewolf** is the Director of External Affairs and a Senior Scientist at the Crop Trust. He is responsible for coordinating the Crop Trust's External Affairs Team and works at the interface of partnerships, resource mobilization, project development, science and policy. Before joining the Crop Trust, he led several field research projects on plant genetic resources in Peru, the Caribbean, Kenya and Ethiopia. His scientific interest focuses on the evolution, maintenance and conservation of agrobiodiversity, the importance of such diversity for farming communities and the role it can play for sustainable development and food security in times of a rapidly changing climate. Mr Dempewolf studied Plant Science at the University of Edinburgh and the Royal Botanic Gardens Edinburgh in Scotland and completed his PhD training in Botany at the University of British Columbia in Vancouver, Canada.

- **José F.M. Valls** works at the Brazilian Agricultural Research Corporation National Centre for Genetic Resources and Biotechnology in Brazil where he is the Curator of the Embrapa Wild *Arachis* Genebank. His work focuses on the collection, characterization and conservation of germplasm from South American CWR and native forage grasses. José is a Brazilian agronomist, dedicated to agricultural botany. Mr Valls received the Frank N. Meyer Medal of Plant Genetic Resources, from the Crop Science Society of America, and the Frederico Menezes Veiga Award from the Brazilian Agricultural Research Corporation/Embrapa, and has a Research Productivity Scholarship from CNPq/Brazil. José holds a PhD in Range Science from Texas A&M University in the United States of America and a Specialization in Plant Genetic Resources from the University of Birmingham. He has served as a Graduate Advisor at several Brazilian universities.

- **Shivali Sharma** worked as Theme Leader –Pre-breeding at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)-HQ, Patancheru, India. She provided technical leadership to drive pre-breeding research for germplasm development and enhancement in both self- and cross-pollinated crops. Ms Sharma has more than 20 years of research experience in areas such as breeding, germplasm conservation and enhancement through pre-breeding. She has published more than 65 research articles in reputed International journals and an additional 60 web articles, book chapters, conference papers, etc. Ms Sharma holds a PhD and MSc in Plant Breeding from Himachal Pradesh Agricultural University, Palampur, India, and a BSc in Agriculture from the same university.

- **Francisca Acevedo** is the Coordinator of Agrobiodiversity at the National Commission for the Knowledge and Use of Biodiversity (CONABIO), in Mexico. Her work focuses on issues related to agrobiodiversity, primarily on native crops from Mexico and their wild relatives. She has been working for the past 18 years at CONOBIO and previously held the position of Coordinator of Risk Analysis and Biosecurity. Ms Acevedo holds a PhD in Plant Molecular Biology from the Polytechnic University of Madrid, Spain, a MSc in Molecular Biology from Postgraduate College in Mexico and a BSc in Biology from Grinnell College, Iowa, United States of Americe.

- **Qingwen Yang** is a Professor and principal expert in the Research Group of Wild Rice, Institute of Crop Sciences, at the Chinese Academy of Agricultural Sciences. He is the leading expert of agrobiodiversity conservation for the Ministry of Agriculture and Rural Affairs and the Deputy Director of the Consultant Association of Environment and Ecosystem Protection. His work focuses on the investigation, collection and *ex situ* conservation of wild plant species, and studies and practices of technical issues on *in situ* conservation of agricultural related wild plant species using theoretical approaches of biology, ecology, genetics and agronomy. Mr Yang holds a PhD in Plant Genetics and Breeding, China Agriculture University, Beijing, China, a MS in Agricultural Biotechnology from the University of Adelaide in Australia and a BSc in Plant Genetics and Breeding, Huazhong Agriculture University, Wuhan, China. He has published approximately 100 papers in Chinese and English, and eight books. His achievements in wild rice *ex situ* and *in situ* conservation were rewarded by the Chinese Central Government in 2017.

- **Tiziana Ulian** is the Senior Research Leader of Diversity and Livelihoods at the Royal Botanic Garden, Kew, United Kingdom of Great Britain and Northern Ireland. She leads a research group developing plant diversity approaches to support communities in locations and economies where nutritional, income and biodiversity issues are of paramount importance. She also works on the conservation biology of threatened plant species and has a strong interest in their *in situ* conservation and reintroduction. She was previously International Projects Coordinator – Africa and Latin America and Useful Plants Project Coordinator – Africa and Mexico. Ms Ulian holds a PhD in Natural Resources from the Natural Resources Institute and a BSc in Ecology and Conservation from the School of Earth and Environmental Sciences – University of Greenwich, United Kingdom of Great Britain and Northern Ireland.

- **Jessica Fanzo** is the Bloomberg Distinguished Professor of Global Food Policy and Ethics at the Johns Hopkins University in the United States of America. At Hopkins, she holds appointments in the Berman Institute of Bioethics, the Bloomberg School of Public Health and the Nitze School of Advanced International Studies. She also serves as the Director of Hopkins' Global Food Policy and Ethics Program, and as Director of Food and Nutrition Security at Hopkins' Alliance for a Healthier World.

Ms Fanzo is the Editor-in-Chief for the Global Food Security Journal and leads on the development of the Food Systems Dashboard, in collaboration with the Global Alliance for Improved Nutrition. She has also held positions at Columbia University, the Earth Institute, the Food and Agriculture Organization of the United Nations, the World Food Programme, Bioversity International and the Millennium Development Goal Centre at the World Agroforestry Centre in Kenya. Ms Fanzo holds a PhD in Nutrition from the University of Arizona.

- **Kebadire Khola Mogotsi** is a Plant Physiologist and chairs the Board of the National Agricultural Research and Development Institute, which is mandated to revitalize the agricultural sector in Botswana. She has taught horticulture**,** plant physiology**,** ecophysiology**,** legumes, fibre and oilseed science and agroforestry at Botswana University of Agriculture and Natural Resources and the University of Namibia, Faculty of Agriculture. Ms Mogotsi has coordinated agroforestry education and learning across sub-Saharan Africa and a network for universities and colleges of agriculture, forestry and natural resources and communities for relevance and service delivery at the World Agroforestry Centre. She has conducted research on ecophysiology and genetic diversity of desert plants and other natural resources, including the conservation for utilization of indigenous plants (climate-smart emerging crops).

- Session co-chair: **Chikelu Mba** leads the Seeds and Plant Genetic Resources Team of the Plant Production and Protection Division of FAO. He is responsible for the quality assurance of FAO's global work on crop improvement. A Plant Breeder Geneticist, his previous work include leading the Plant Breeding and Genetics Laboratory of the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture in Austria and as Coordinator of the Cassava Biotechnology Network for Latin America and the Caribbean at International Center for International Agriculture (CIAT) in Colombia. Mr Mba holds a PhD in Plant Breeding and Genetics, a Postgraduate Diploma in Education and a BSc in Botany **–** all from the University of Nigeria.

- Session co-chair: **Mariana Yazbek** is an ICARDA Scientist and the Genebank Manager at ICARDA Lebanon, where she is responsible for the conservation and management of the rich and unique "crop wild relatives collection" originating in the Fertile Crescent. She is a member of the Executive Committee of the CGIAR Genebank Platform and acts as a co-chair of the IUCN Species Survival Commission - Crop Wild Relative Specialist Group. In addition to *ex situ* conservation, her research also extends to promoting *in situ* conservation of agrobiodiversity (landraces and wild relatives of agricultural crops) in the Middle East and North Africa region. Ms Yazbek holds a PhD in Plant Biology (Plant Systematics) from Cornell University in the United States of America.

Session 3: On-farm management of farmers' varieties/ landraces

- **Maedeh Salimi** is working with the Centre for Sustainable Development and Environment (CENESTA) as a programme manager and community facilitator in the Islamic Republic of Iran. She is the project manager for the project "Use of genetic diversity and evolutionary plant breeding for enhanced farmer resilience to climate change, sustainable crop productivity, and nutrition under rainfed conditions". She has considerable experience in agroecology, agricultural heritage systems, participatory-evolutionary plant breeding and climate change. Ms Salimi holds a MA in Environmental Economy from the Islamic Republic of Iran and is currently a PhD student in Agroecology.

- **Ximena Cadima** works at the PROINPA Foundation in the Plurinational State of Bolivia as a researcher and is in charge of the agrobiodiversity programme. She has been worked for more than 15 years in *ex situ* conservation activities and during the last ten years she has been involved in strengthening on-farm management of Andean crops and their wild relatives, working with indigenous communities and rural municipalities, and conducting research on agricultural biodiversity (state of the art, identification of weaknesses and opportunities) and climate change. Ms Cadima is an Agronomist and holds a PhD and MSc from Wageningen University.

- **Lee Hickey** is an Associate Professor at The University of Queensland, Australia. He is a plant breeder and crop geneticist within the Queensland Alliance for Agriculture and Food Innovation. He leads a diverse research team that specializes in plant breeding innovation to support development of more productive food crops such as wheat, barley, mung bean and chickpea. His research includes understanding the genetics of key traits such as drought adaptation and disease resistance, plus the development of novel technologies to assist plant breeders. He has a strong interest in the integration of breeding technologies, such as the rapid generation advance technology "speed breeding" with genomic selection and genome editing. Mr Hickey holds a PhD in Quantitative and Molecular Plant Breeding and a Graduate Certificate in Research Commercialization from the University of Queensland.

- **Ousmane Boukar** is a Cowpea Breeder at the International Institute of Tropical Agriculture (IITA) based at Kano, Nigeria. His work focuses on developing improved varieties for sub-Saharan African farmers as well as building human capacity of National Agricultural Research Systems in cowpea breeding. Mr Boukar has also worked as Head of Station and IITA Representative, Kano, Principle Investigator for over seven donor-supported projects, and Lead of Cluster of activity (5.1) under the CGIAR Research Program on Grain Legumes and Dryland Cereals. Prior to his appointment with IITA, he was a cowpea breeder and regional scientific coordinator with the Agricultural Research Institute for Development, Maroua, Cameroon.

Mr Boukar holds a PhD and MSc from Purdue University, West Lafayette, Indiana, United States of America, and a BSc in Agronomy from the National Advanced School of Agriculture in Cameroon.

- **Martha Cameron Willcox** works in the Department of Agronomy at the University of Wisconsin where she is working with maize landraces and culinary connections for organic and indigenous farmers in the United States of America and Mexico. Previous to this position, she worked at the International Maize and Wheat Improvement Center in Mexico in various positions, most recently as the Maize Landrace Coordinator, focusing on farmer participatory improvement of native maize landraces in the states of Oaxaca, Michoacán and Mexico in marginalized, mostly indigenous, communities. As part of this project, she fostered linkages between traditional farmers and culinary markets. Ms Wilcox holds a PhD in Plant Breeding and Plant Genetics from the University of Wisconsin-Madison, a MSc in Crop Science and BSc in Agronomy from North Carolina State University.

- **Salvatore Ceccarelli** is presently an independent consultant. He is currently involved in projects in Uganda, Ethiopia, Jordan, the Islamic Republic of Iran, Nepal, Bhutan and different countries in Europe. From 1980 until 2006, Mr Ceccarelli conducted research at the International Center for Agricultural Research in Dry Areas in Aleppo, Syrian Arab Republic. His areas of expertise are international plant breeding, genotype x environment interactions, breeding strategies, drought resistance, participatory and evolutionary plant breeding, crop adaptation, use of genetic resources and relationships between biodiversity, food, health and climate change. Mr Ceccarelli has been a full Professor of Agricultural Genetics at the Institute of Plant Breeding, University of Perugia. During his career, he published about 300 papers of which nearly 170 in peer review journals and has been an invited speaker at nearly 30 international conferences.

- **Alejandro Argumedo** is Director of the Asociación ANDES, a Cusco-based indigenous people's non-governmental organization working to protect and develop Andean biological and cultural diversity and the rights of indigenous peoples of Peru. He is also the international coordinator of the Indigenous People's Biodiversity Network and Senior Research Officer for Peru of the Sustaining Local Food Systems, Agricultural Biodiversity, Livelihoods' Programme of the International Institute for Environment and Development for England and the Sowing Diversity = Harvesting Security Program of Oxfam Novib of the Netherlands. Mr Argumedo is an agronomist by training and has served in various expert panels of the UN and other relevant bodies, and has been a consultant for various international organizations.

- **Pitambar Shrestha** is the Programme Operations Director at Local Initiatives for Biodiversity, Research and Development (LI-BIRD) in Pokhara, Nepal. LI-BIRD is a non-profit, non-governmental organization committed to improving livelihoods of smallholder farmers and was established in 1995. He has a long record of involvement in on-farm agricultural biodiversity management, participatory crop improvement, participatory plant breeding and community empowerment. Mr Shrestha holds a MSc in Rural Development from Indira Gandhi National Open University, attended the International Summer School at the University of Oslo and has a BA in Economics from Tribhuvan University in Nepal.

- **Normita Ignacio** is Executive Director of the Southeast Asia Regional Initiatives for Community Empowerment, a regional civil society organization based in the Philippines that aims to strengthen farmers' conservation and sustainable use of plant genetic resources. She has more than two decades of experience in rural development, specializing in sustainable agriculture, food security and organizational capacity development. Ms Ignacio holds a Master's Degree in Development Management from the Asian Institute of Management, Makati City, Philippines, and a BSc in Agriculture from the University of the Philippines at Los Baños.

- Session co-chair: **Devra Jarvis** is Coordinator of the Platform for Agrobiodiversity Research and Principal Scientist at Bioversity International, where she leads Bioversity's Team on Genetic Diversity Productivity and Resilience. She is also Adjunct Faculty at Washington State University, United States of America, and Adjunct Professor at the Institut Agronomique et Veterinaire Hassan II, Morocco. Ms Jarvis holds a PhD in Botany/Quaternary Palynology and a MSc, in Forest Research Management from the University of Washington and BA Honours in Cultural Anthropology from the University of California, Berkeley.

- Session co-chair: **Mario Pagnotta** is an Associate Professor of Agricultural Genetics at University of Tuscia. His current activities include project management, student supervising, lecture and participation in several national and international projects. He carries out research on the assessment of the genetic variability in natural populations, landraces and the characterization of plant germplasm of several species, as well as on topics related with the biodiversity conservation, adaptation and variety identification. Mr Pagnotta is a graduate of Agricultural Sciences at the University of Perugia. He holds a PhD in Genetic Ecology from Reading University, United Kingdom of Great Britain and Northern Ireland.

Session 4: The way forward: creating communities of practice

- **Nigel Maxted** is a Professor of Plant Genetic Conservation at the University of Birmingham, United Kingdom of Great Britain and Northern Ireland. He is also the International Scientific Advisor for Bioversity International; Co-Chair of the IUCN SSC Crop Wild Relative Specialist Group; Chair of Wild Species Conservation in Genetic Reserves WG; Co-Chair for Genetic Resources for the Ecosystem Services Partnership; and Chair of the United Kingdom of Great Britain and Northern Ireland Plant Genetic Resources Group. His has been Coordinator/Director of national and international research projects addressing *in situ* and *ex situ* conservation of plant genetic resources in Europe, Asia and Africa for various international agencies (FAO, IPGRI, the World Bank and the United Nations). Mr Maxted holds a PhD and a M Phil from the University of Southampton, United Kingdom of Great Britain and Northern Ireland and a BSc in Biological Sciences from The Polytechnic, Wolverhampton, United Kingdom of Great Britain and Northern Ireland. He has published over 350 scientific papers and 24 books, including most recently a textbook on plant genetic conservation.

- **Dickson Ng'uni** is Chief Agricultural Research Officer, Crop Improvement and Agronomy, with the Zambia Agriculture Research Institute His responsibilities include coordination and undertaking crop improvement and agronomy research for the development of improved crop varieties. He has worked his entire career in the public sector, specifically with the Ministry responsible for agriculture, as an agricultural researcher and more specifically as a crops researcher. He is a National Focal Point on Biodiversity for Food and Agriculture for the Commission on Genetic Resources for Food and Agriculture. Mr Ng'uni holds a PhD from the Swedish University of Agriculture Sciences, an MSc in Conservation and Utilization of Plant Genetic Resources from the University of Birmingham, United Kingdom of Great Britain and Northern Ireland, and a BSc in Agricultural Sciences from the University of Zambia.

- **Brigitte Laliberté** is a Scientist at the Alliance of Bioversity International & CIAT. She is the leader of the Cocoa of Excellence programme. She also coordinates the development of the International Standards for the Assessment of Cocoa Quality and Flavour and the Global Network for Cacao Genetic Resources. She has over 25 years of experience in agrobiodiversity and crop genetic resources. She coordinated the Global Strategy for the Conservation and Use of Cacao Genetic Resources and 20 regional and global crop strategies guiding the allocations of funds from the Global Crop Diversity Trust. Ms Laliberté holds an MSc in Conservation and Utilization of Plant Genetics Resources from the University of Birmingham, United Kingdom of Great Britain and Northern Ireland, and a BSc in Agricultural Sciences in horticulture from Mc Gill University, Montreal, Canada.

- **Niels Louwaars** is the Managing Director at Plantum NL, Netherlands. Since 2013, he has also chaired the board of Top Sector Horticulture and Starting Materials. In the past, he worked at the Centre for Genetic Resources Netherlands, where he focused on intellectual property and sharing access to and profits from genetic resources. Niels has also spent a significant amount of time abroad working in Sri Lanka and Uganda, and short periods in countries such as Bangladesh, Ethiopia, Kyrgyzstan, Syrian Arab Republic, Türkiye, Turkmenistan and Yemen. During this period, he was involved in plant breeding and seed legislation. It was during that time that he first experienced the importance of bringing stakeholders together: farmers, governments and the business community. Mr Louwaars holds a PhD in Plant Breeding from Wageningen in the Netherlands.

- **Chris Ojiewo** is a Principal Scientist, Plant Breeding and Seed Systems, at the International Crops Research Institute for the Semi-Arid Tropics. He is the Global Coordinator and Co-PI AVISA Project, Global Theme Leader, Seed Systems and Cluster Leader, Scaling Seed Technologies. His experience in international agricultural research focuses on basic, applied and adaptive plant breeding and seed systems research and development. He has more than 20 years of professional experience working on improving productivity and profitability for smallholder farmers. He has extensive experience in Africa and Asia. Mr Ojiewo holds a PhD and MSc in Plant Breeding from Okayama University, Japan, and a BSc. in Horticulture from Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya. Together with various co-workers, he has researched and published over 100 scientific, technical and policy articles in his area of expertise.

- Session co-chair: **Jennifer McConnell** was the General Manager of the Irish Seed Savers Association, which curates Ireland's collections of over 600 varieties of heritage open pollinated vegetable seeds and 180 varieties of heritage apple trees. She was responsible for developing Irish Seed Savers' strategic sustainability, increasing the relevance in protection of food seed and fruit tree collections, as well as contributing to partnerships. Prior to joining Irish Seed Savers, she held senior management roles in development organizations in Papua New Guinea, and human resources roles in Jamaica and Haiti. Ms McConnell will be starting work towards her PhD this autumn, exploring the impact of global trade on food sovereignty and human rights.

- Session co-chair: **Elcio Guimares** is the Director General at Embrapa Rice and Beans Research Center in Brazil. Previous to this he was the Regional Director for Latin America and the Caribbean at CIAT in Colombia and a Senior Officer Cereal/Crops Breeding at FAO in Rome. Mr Guimares has also been Senior Rice Breeder CIAT and Rice Breeder and Director of Plant Breeding at Embrapa. He holds a PhD in Genetics and Plant Breeding from Iowa State University, United States of America.

- Panel discussion co-moderator: **Bonnie Furman** is an Agricultural Officer in the Seeds and Plant Genetic Resources Team at FAO, where her work focuses on conservation of PGRFA. Prior to FAO, she worked in genebank curation and management with ICARDA in Aleppo, Syrian Arab Republic; the United States Department of Agriculture, and with the CIMMYT Maize Genebank in Mexico. She has also held academic positions in Costa Rica and the United States of America. Ms Furman holds a PhD in Genetics from North Carolina State University, a MS in Plant Genetics Resources and Plant Breeding from the University of California-Davis and a BSc in Agronomy from the University of Wisconsin-Madison – all in the United States of America.

- Panel discussion co-moderator: **Arshiya Noorani** is an Agricultural Officer in the Seeds and Plant Genetic Resources Team, FAO. Her work focuses on the conservation, assessment and management of biodiversity, including protected areas. Prior to joining FAO ten years ago, she worked for ten years on *in situ* conservation and on-farm management of plant genetic resources at Bioversity International. She also taught ecological surveying and protected area management planning in both terrestrial and freshwater habitats at the University of Edinburgh for three years. Ms Noorani holds a PhD in Plant Conservation Genetics from the University of Tuscia, a MSc in Environmental Protection and Management and a BSc Honours in Zoology – the latter two from the University of Edinburgh, United Kingdom of Great Britain and Northern Ireland.

- Panel discussion co-moderator: **Alvaro Toledo** is a Technical Officer at the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture, where he coordinates the enhancement of the functioning of the Treaty mechanisms, in particular the Multilateral System for Access and Benefit-sharing, the Funding Strategy and the Treaty's Benefit-sharing Fund. He has worked for FAO for the last 18 years in the area of genetic resources and biodiversity. Prior to the Treaty, Mr Toledo worked in the Secretariat of the Commission on Genetic Resources for Food and Agriculture to support the development of the Multi-year Programme of Work of the Commission. In Spain, he coordinated the Spanish seed network, a platform of farmer organizations, local development groups, researchers and genebank curators supporting conservation and use of local crop varieties. He is an agricultural engineer with a MSc in Crop Sciences and a master's degree in Plant Genetic Resources, all from the University Polytechnic of Madrid.

Closing remarks

Stefano Diulgheroff is the Information Management Officer in the Seeds and Plant Genetic Resources Team of the Plant Production and Protection Division. He is the Secretary of the Commission's Intergovernmental Working Group on Plant Genetic Resources for Food and Agriculture, a subsidiary group of the Commission on Genetic Resources for Food and Agriculture. Mr Diulgheroff has extensive experience in seeds systems and plant genetic resources, having worked as research fellow at CIAT during 1988-1991 and FAO since 1991, both in the field and headquarters. He oversees the World Information and Early Warning System for PGRFA (WIEWS) and the plant component of SDG Indicator 2.5.1. He holds a MSc in Agricultural Sciences and Renewable Natural Resources from the Tropical Agricultural Research and Higher Education Center (CATIE), Costa Rica.

This book represents the proceedings of the First International Multi-stakeholder Symposium on Plant Genetic Resources for Food and Agriculture: Technical Consultation on *in situ* conservation and on-farm management of PGRFA, held virtually on 29 and 30 March 2021. The proceedings provide a record of the Symposium, including the opening and welcome addresses and the four sessions: 1) challenges and opportunities for sustainably managing crop diversity; 2) *in situ* conservation of crop wild relatives and wild food plants; 3) on-farm management of farmers' varieties/landraces; and, 4) creating communities of practice.

The Symposium highlighted the current state of knowledge and the enabling environment for *in situ* conservation and on-farm management of PGRFA. It contributed to an increased understanding of the role and importance of *in situ* conservation of crop wild relatives and wild food plants, and on-farm management of farmers' varieties/landraces. The Symposium provided a forum for the exchange of information and experiences among experts, practitioners and other stakeholder.

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