April 2023 CGRFA/WG-PGR-11/23/3/Inf.1

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联合国粮食及农业组织 | Food and Agriculture Organization of the United Nations | Organisation des Nations Unies pour l'alimentation et l'agriculture | Продовольственная и сельскохозяйственная организация Объединенных Наций | Organización de las Naciones Unidas para la Alimentación y la Agricultura | منظمة الأغذية والزراعة للأمم المتحدة

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Item 3 of the Provisional Agenda
INTERGOVERNMENTAL TECHNICAL WORKING GROUP ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE
Eleventh Session
Rome, 18–20 April 2023
DRAFT THIRD REPORT ON THE STATE OF THE WORLD'S PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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Draft Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture

(Not for Quotation or Citation)

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Chapter 1. Introduction

1.1 Plant genetic resources for food and agriculture

Plant genetic resources for food and agriculture (PGRFA) refer to any genetic material of plant origin, including reproductive and vegetative propagating material, containing functional units of heredity of actual or potential value for food and agriculture (FAO, 2009). PGRFA therefore encompass (i) cultivated crop varieties, i.e. cultivars, in current use and newly developed varieties; (ii) obsolete cultivars; (iii) primitive cultivars (landraces) and farmers' varieties; (iv) crop wild relatives (CWR), i.e. wild populations related to cultivated varieties; (v) wild food plants; (vi) weeds; and (vii) breeding and research materials or special genetic stocks (including elite and current breeders' lines and mutants). While the deoxynucleic acids and other hereditary materials of these plants are also considered PGRFA, the term is usually used in reference to whole plants and their propagules. PGRFA are therefore typically found in the wild, on farmers' fields and in experimental fields. They are also safeguarded in genebanks, i.e. *ex situ* – as germplasm accessions, and in their natural habitats, i.e. *in situ* – with or without deliberate conservation interventions.

With a continually increasing global population, devastating impacts of climate change, dwindling agricultural water resources and arable lands, strife, pandemics and myriad socioeconomic drivers, food insecurity and malnutrition have been worsening progressively over the past several years (FAO, 2018, 2019, 2020, 2021, 2022). Healthy nutritional diets are increasingly unaffordable while progressively more people do not have access to enough food. The yet evolving COVID pandemic and the Russian Federation – Ukraine conflict are two recent global events that have exacerbated food insecurity and malnutrition, especially in the developing South. Indeed, with food production levels lagging behind the projections to meet increasing demands for food, it is probable that the efforts to eradicate hunger and malnutrition are not on track to achieve the target by 2030 as committed to in the United Nations Sustainable Development Goals (United Nations General Assembly, 2015). Considering that 80 percent of foods are plant-based, PGRFA are critically important to efforts to attain food security and nutrition.

1.2 Multilateralism for the conservation and use of PGRFA

Sonnino (2017) reviewed the intergovernmental collaborations for the conservation and sustainable use of PGRFA over the past five decades. The international community has consistently called attention to the importance of PGRFA to food security and nutrition and the interdependence of countries on their conservation and sustainable use, access to and the equitable sharing of benefits accruing from them. For these reason, a significant amount of efforts and resources has been invested in making PGRFA freely available, especially for research and development, through various normative processes and instruments.

As an example, soon after its establishment as a specialized agency of the United Nations mandated with global food security and nutrition, FAO started publishing a newsletter on plant genetic resources in 1957 and at the 10th Session of its Conference in 1959, called for immediate action for the collecting and conservation of landraces and CWR (FAO, 1997). This was followed shortly afterwards by major technical meetings on plant genetic resources. In 1961, there was the Technical meeting on Plant Exploration and Introduction, which was a prelude to the establishment of an FAO Panel of Experts on Plant Exploration in 1963, which was tasked with advising the Organization on, and set international guidelines for, the collecting, conservation and exchange of germplasm. Also, soon afterwards in 1967, there was a landmark conference, the International Technical Conference, which was organized jointly by FAO and the International Biological Programme (IBP). The results of these initiatives included streamlined germplasm conservation and distribution and the establishment of exploration centers in regions of greatest diversity, which were enabled by the guidelines for the establishment of a global network for *ex situ* conservation and the associated plan of action developed by the Panel of Experts (Frankel and Hawkes, 1975; Scarascia-Mugnozza and Perrino, 2002). The 1973 FAO/IBP Technical Conference and subsequently the Technical Advisory Council of the CGIAR considered the proposal by the Panel of Experts. This proposal formed the basis for the creation of a coordinating center, the International Board on Plant Genetic Resources (IBPGR) in FAO – that would later evolve into the International Plant Genetic Resources Institute, a CGIAR center later renamed Bioversity International, which now is a constituent part of the Alliance of Bioversity International and CIAT.

Ever since, the international community, mostly under the auspices of the mechanisms of FAO, have collaborated on both the conservation and use of PGRFA, including through the devising of means of access and the equitable sharing of the benefits of these resources. FAO's programme of normative work in this domain has been implemented through its Commission on Genetic Resources for Food and Agriculture (Commission), which was established in 1983 as the Commission on Plant Genetic Resources (FAO, 2010). In 1995, its remit was expanded to encompass the other sectors of agricultural biodiversity, i.e. animal, aquatic and forest genetic resources.

1.3 The Global System on Plant Genetic Resources for Food and Agriculture

Through the Commission, FAO avails its members and myriad partners with a forum to discuss and negotiate matters relevant to genetic resources for food and agriculture. It was in this capacity that the Global System on Plant Genetic Resources for Food and Agriculture (Global System) was created under the Commission's auspices. The Global System is a set of policy instruments and mechanisms to promote the safeguarding of PGRFA, their availability and sustainable use (FAO, 2010; Frison *et al*., 2011).

The principal agreements under the Global System are:

- The *International Undertaking on Plant Genetic Resources for Food and Agriculture*, which was adopted by FAO's Conference in 1983, with the objective "to ensure that plant genetic resources of economic and/or social interest, particularly for agriculture, will be explored, preserved, evaluated and made available for plant breeding and scientific purposes. This undertaking is based on the universally accepted principle that plant genetic resources are a heritage of mankind and consequently should be available without restriction" (FAO, 1983).
- The *Convention on Biological Diversity* (CBD), which is the international agreement for "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" (United Nations, 1993). PGRFA, as enunciated in the Strategic Plan for Biodiversity 2011–-2020, including the Aichi Biodiversity targets, and the subsequent yet evolving Post 2020 global biodiversity framework, are constituent parts of biodiversity.
- The *International Treaty on Plant Genetic Resources for Food and Agriculture* (Treaty), the revision to the International Undertaking, in line with the CBD, which was adopted by the 31st session of the FAO Conference on 3 November 2001 and entered into force on 29 June 2004. The Treaty, in harmony with the CBD, caters specifically to PGRFA and therefore is the governance mechanism for PGRFA outside of the CBD.

The actions proposed by the United Nations Conference on Environment and Development (UNCED) in June 1992 to strengthen the FAO Global System, included the preparations of periodic reports on the state of the world's PGRFA and a rolling global cooperative Plan of Action on PGRFA (FAO, 1997). The ensuing periodic reports and rolling global plans have been:

- **The first Report on the State of the World's Plant Genetic Resources for Food and Agriculture (First Report)**, was developed pursuant to the agreement of the Twenty-sixth Session of FAO's Conference in 1991 (FAO, 1997). Information for compiling the First Report was obtained primarily from 154 Country Reports, which had been prepared based on guidelines developed by FAO. Through these, countries produced status updates on "indigenous plant genetic resources, national conservation activities (*ex situ* and *in situ*), in-country uses of plant genetic resources, national goals, policies, programmes and legislation, and international collaboration". Additional information was obtained from the FAO-managed database, the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS), which contained countries' responses to FAO's two questionnaires on PGRFA and forest genetic resources, respectively. Information provided by CGIAR centres; obtained from the then recently conducted external review of the CGIAR genebanks; and FAO's electronic conferences on plant breeding and genetic diversity – in which about 200 individual scientists participated, was also incorporated in the First Report. Thus, the First Report provided the first comprehensive status updates on the states of diversity, genetic vulnerability and genetic erosion for crops and plants and relevant to food security and nutrition and on the capacities for the conservation and use of these resources. The draft of the First Report was welcomed as the first comprehensive worldwide assessment of the state of plant genetic resource conservation and use at the Fourth International Technical Conference on Plant Genetic Resources, which was convened by FAO and held in Leipzig, Germany, from 17 to 23 June 1996, and attended by representatives of 150 countries.

- **The Global Plan for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (GPA)** was also adopted along with the "Leipzig Declaration" at the 1996 Technical Conference (FAO, 1996). The GPA was conceived as a costed plan to make the Global System fully operational. It was prepared from the Country Reports and visits by Secretariat staff and consultants to more than 100 countries on the bases of which, 15 sub-regional synthesis reports were prepared. These reports were then used for discussions at most of the 12 regional and sub-regional meetings held between July 1995 and 1996, in which a total of 143 countries and several international and non-governmental organizations participated. Recommendations for the Global Plan of Action were formulated and adopted at each of these meetings. Thus, the GPA – envisaged as a rolling plan to be reviewed periodically – became the internationally agreed framework for the conservation, exploration, collecting, characterization, evaluation and documentation of crop genetic resources. The GPA consisted of 20 priority activity areas, which were presented under four main themes: *In Situ* Conservation and Development; *Ex Situ* Conservation; Utilization of Plant Genetic Resources; and Institutions and Capacity Building.

- **Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture (SoW2).** The Commission, at its at its Eighth Regular Session in 1999, agreed that a second Report on the State of the World's Plant Genetic Resources for Food and Agriculture, and an amendment to the GPA, should be considered. At its Ninth Regular Session in 2002, the Commission agreed that work should progress on the development of the second report on the State of the World's Plant Genetic Resources for Food and Agriculture and that the country-driven preparatory process for the second report should be fully integrated with that for monitoring the implementation of the Global Plan of Action on the basis of a set of indicators that was under development. Subsequently at its Tenth Regular Session in 2004, the Commission, envisaging that the second Report would be completed in 2008, reiterated that it should provide objective information and analysis and identify priorities, as a basis for updating the rolling GPA. The Commission confirmed that the second report should focus, as far as possible, on changes that had occurred since the adoption of the first report, approved the list of thematic background studies and took note of the draft Guidelines for Country Reports, which it observed should be further considered and refined at regional meetings. At its Eleventh Regular Session in 2007, the Commission requested that the Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture at its fourth meeting in 2009, review and guide the finalization of the draft of the second report for the consideration of the Commission at its next Regular Session in 2009. It requested that FAO also submit to the same Session a proposed plan for the process of updating the GPA. The Commission endorsed the SoW2 as the authoritative assessment of this sector at its Twelfth Regular Session in 2009 (FAO, 2010). It provided a snapshot of the status of the conservation and sustainable use of PGRFA and the institutional and human capacities that underpin the activities. Importantly, the report, in addition to describing the changes that occurred in the different domains for the management of PGRFA, also identified the respective gaps and needs.

  The Second Report was prepared based mostly on information provided by countries through 113 country reports, following the Guidelines for the Preparation of the Country Reports, which were made available for the preparatory process in 2005. The preparation of many of the country reports benefitted from information that had been lodged on National Information Sharing Mechanisms (NISMs). The information thus provided by countries was augmented by scientific literature, thematic background studies and other relevant technical publications. Additionally, specific information from the CGIAR and other regional and international genebanks was gathered in 2008 under the coordination of the System Wide Genetic Resources Programme.

- **Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA)**. For 15 years, 1996 to 2011, the GPA was the internationally agreed framework for national, regional and global efforts to conserve and use PGRFA sustainably and to share equitably and fairly the benefits that derive from their use. In endorsing the Second Report in 2009, the Commission agreed to update the GPA and requested FAO to prepare the updated Global Plan of Action based primarily on the Second Report, factoring in especially the identified gaps and needs and envisaged further contributions from Governments, and inputs to be received from foreseen regional meetings and consultations. Considering that the GPA was a supporting component of the Treaty, the updated GPA was envisaged as being important for the identification of future priorities of its Funding Strategy. The Commission requested the involvement of the secretariat of the Treaty in the updating process. At its Thirteenth Regular Session in July 2011, the Commission agreed on the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA), welcomed it as a major achievement in global efforts for the conservation and sustainable use of PGRFA and emphasized its essential role for the implementation of the Treaty. The Second GPA, which was subsequently adopted by the FAO Council in November 2021, on behalf of the FAO Conference (FAO, 2011), contained 18 Priority Activities, grouped into four main themes: *In Situ* Conservation and Management; *Ex Situ* Conservation; Sustainable Use; and Building Sustainable Institutional and Human Capacities (FAO, 2012).

1.4 Preparation of the Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture

The Commission, at its Fourteenth Regular Session in 2013, endorsed the proposed timeline for the preparation of The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture (Third Report), with the presentation of the draft report foreseen at its Eighteenth Regular Session in 2021. It stressed that the monitoring of the Second GPA and the preparation of the Third Report should be fully integrated and invited FAO to engage with relevant international organizations to ensure their participation in the preparation of the Third Report from an early stage. In 2017, at its Sixteenth Regular Session, the Commission revised the timeline for the preparation of the Third Report and postponed its launch to its Nineteenth Session in 2023.

Timeline

Just as with the previous global assessments, it was envisaged that the Third Report would be based on information provided by countries, relevant international organizations, and thematic background studies. In a departure from the previous assessments, the preparation of the Third Report would no longer rely on stand-alone country reports but would instead be based on data gathered during two reporting periods: from January 2012 to June 2014, with the reports due by 30 November 2015; and from July 2014 to December 2019, with reports due by 31 December 2020. Due to delays, National Focal Points reported on the first reporting period between January 2015 and December 2017, and commenced reporting on the second one in January 2020.

Reporting format

A questionnaire, consisting of the 63 indicators for monitoring the implementation of the 18 Priority Activities of the Second GPA and 51 questions to clarify the indicators, constituted the reporting format that was accessed through the online WIEWS Reporting Tool for the first reporting cycle. For the second cycle, the Commission agreed on a slightly revised reporting format based on 58 indicators and 48 questions. During the second reporting cycle, in 2020, NFPs complemented the data provided with a summative narrative, which detailed the progress made in the implementation of the Second GPA between January 2012 and December 2019 and on remaining constraints. FAO published the Guidelines for the Preparation of the Third Report to facilitate the use of the WIEWS Reporting Tool, which was in all FAO official languages. The use of the WIEWS Reporting Tool facilitated standardized data reporting by NFPs and national stakeholders, and the eventual collation and analyses of data.

Reporting process
A total of 78 countries participated in the first reporting period (2012–2014), even though not every country replied to all questions.
In 2019, FAO invited Member Nations to participate in the second reporting period by December 2020. The opportunity to retrospectively report, revise or complement data related to the first reporting period was also provided. More detailed information, including on the online WIEWS Reporting Tool, the user manual, the guidelines for country reporting, was made available online in all FAO official languages. Furthermore, a comprehensive list of frequently asked questions (FAQs), including detailed explanations for all questions and indicators, and a glossary, was provided online. Over 440 participants from more than 75 countries participated in FAO-organized online training sessions in English, French and Spanish, which were aimed at assisting NFPs and stakeholders in reporting for the Third Report. Recordings of the training sessions were made available to the participants through the Internet. Additional on-line supporting sessions for individual countries were held upon request of NFPs.

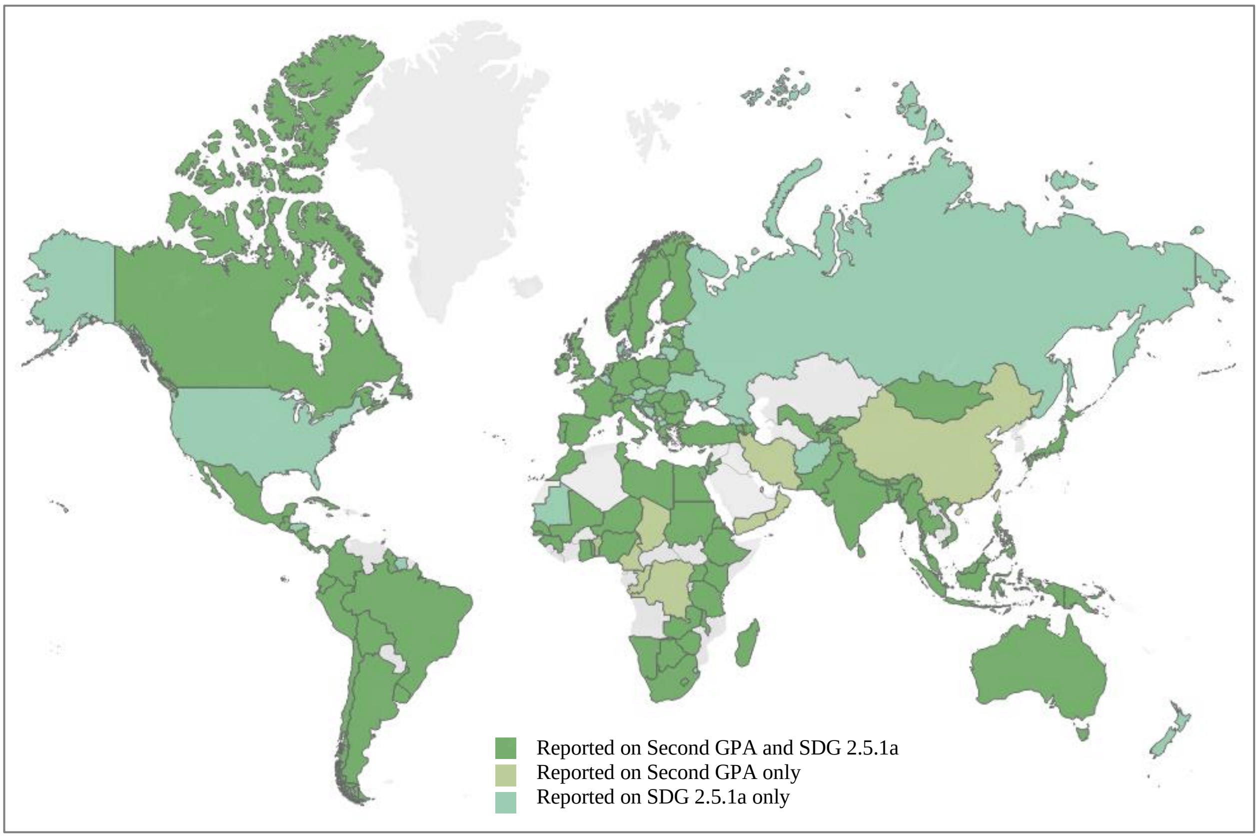
Meanwhile, following the adoption by the United Nations General Assembly of the 2030 Agenda for Sustainable Development, including 17 Sustainable Development Goals (SDG) and 169 targets (UN General Assembly, 2015), and, two years later, of the indicators for monitoring progress towards the SDGs (UN General Assembly, 2017), the indicator in use to oversee progress on conservation of *ex situ* collections under the Second GPA, became SDG indicator 2.5.1a, a Tier I indicator[1] of the SDG monitoring framework reported every year. Therefore, since 2017, countries started reporting annually on SDG indicator 2.5.1a to FAO, the custodian agency of this indicator. In light of this new development, the number of countries reporting on SDG 2.5.1a grew rapidly from 75 to 115 over the period 2014-2021. Data reported were used to complement those received from the two reporting cycles on the Second GPA implementation mentioned earlier.

As of 29 June 2021, a total of 129 countries had nominated a NFP, 55 had completed online reporting for the second reporting cycle, while one country had provided a stand-alone report. In addition, 16 countries were in an advanced stage of the reporting process while 18 had just begun. Furthermore, 50 of these countries also provided information pertinent to the first reporting period. Six of these 50 countries reported for the first time on the first reporting period, bringing the total number of countries that reported in the first period to 84. In all, 12 international organizations participated in both reporting periods. At its Eighteenth Regular Session in October 2021, the Commission, taking into account the delays to reporting posed by the COVID-19 pandemic, agreed to extend the deadline for country reporting to the end of December 2021.

Finally, as at March 2022 a total of 127 countries and four regional and 13 international research centres had provided information sourced from 1 637 stakeholders that contributed to the preparation of the Third Report. Of these, 115 countries, all regional and international research centres have provided information on their base collections in line with SDG indicator 2.5.1a; and 105 countries and 12 international organizations have provided information on the implementation of the Second GPA between 2012 and 2019 (Figure 1.1). These data, which emanated from the two reporting cycles, January 2012 to June 2014 and July 2014 to December 2019, respectively, together with the country summative narrative on progress and remaining gaps and constraints, and the reports on SDG 2.5.1a constituted the core source of information of this draft report.

[1] i.e. an indicator with internationally agreed methodology and a global reporting rate equal to or higher than 50 percent.

Figure 1.1. Countries contributing to the Third Report



1.5 Structure of the Third Report

Information the Third Report is presented under four chapters. In Chapter 1 – Introduction, the multilateral efforts, spanning several decades, to conserve and use PGRFA, are reviewed. With this, the Third Report is presented as the most recent addition to the continually growing suite of policy instruments and mechanisms that constitute the Global System for PGRFA**.** Importantly, the role of global periodic assessments, such as the Third Report, in setting internationally agreed priorities through a rolling global plan of action is underscored. The snapshots of the global statuses of the institutional and human capacities for the conservation and use of PGRFA are presented in Chapters 2 to 4. Chapter 2, which is dedicated to the conservation of PGRFA, is divided into two sections: *in situ* conservation and *ex situ* conservation. The latter is devoted to the management of genebank accessions while in the former, the management of crop wild relatives and wild food plants in the natural habitats is treated. Chapter 3, which is on the sustainable use of PGRFA, addresses both the direct use of PGRFA by farmers and other end-users and the indirect uses in plant breeding and research. Seeds systems, the vehicle for getting the benefits of PGRFA to people, are also treated in this chapter. Finally, in chapter 4, the status of the institutional and human capacities that underpin the functioning of National PGRFA Programmes, networks, and information systems is reviewed.

Presented as complement to the substantive volume of the Third Report are five thematic background studies on climate change; nutrition; genotyping and phenotyping of PGRFA; novel biotechnologies; and germplasm exchange. The findings of the studies will be reflected in the final Third Report.

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Chapter 2. State of *in situ* conservation and on-farm management

2.1 General introduction

The conservation and management plant genetic resources for food and agriculture (PGRFA) *in situ* and on-farm is essential for allowing evolution and adaptation processes derived from the interaction between the genotype and the environment continue to occur. *In situ* conservation of PGRFA of crop wild relatives (CWR) and wild food plants (WFP) entails the conservation in protected areas as well as in areas of other high conservation value. The management of farmers' varieties/landraces (FV/LR) includes all practices for the conservation and sustainable use of these genetic resources within the agricultural systems in which they have evolved. In contrast, *ex situ* conservation safeguards PGRFA away from where they grow naturally (FAO, 2014) (see Chapter 3). While the conservation of PGR *in situ* and *ex situ* are often seen as competing conservation strategies, as stressed in Article 9 of the Convention on Biological Diversity (CBD), the two approaches must be complementary and applied in combination (CBD, 1992). One of the key linkages is the use of *ex situ* material to improve *in situ* populations or to reintroduce extinct species or varieties into cultivation. Consequently, *ex situ* materials also perform a role of a safety net as species and varieties may be lost *in situ* due to extreme events or habitat destruction.

In this regard, FAO has developed guidelines for the conservation of germplasm, *in situ* (FAO, 2017), and on-farm (FAO, 2019b). These guidelines aim to support national authorities in developing a systematic approach to the management of these PGRFA, outlining the process for preparing national plans for the conservation and sustainable use of wild and cultivated PGRFA. FAO also developed guidelines for the effective conservation of PGRFA *ex situ* (FAO, 2014). In all three of these guidelines, the linkages between complementary *in situ*/on-farm and *ex situ* conservation is advocated as diversity is most effectively conserved using these strategies.

Recognizing the need to provide a neutral platform for sharing knowledge, FAO organized an international symposium on *in situ* conservation of wild and cultivated PGRFA[2] in March 2021 (FAO, 2022) as part of ongoing efforts of FAO's Commission on Genetic Resources for Food and Agriculture (Commission) to facilitate collaboration among practitioners involved in the conservation and sustainable use of PGRFA. The symposium was organized in cooperation with the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) and the Global Crop Diversity Trust. It underscored the important contributions that the conservation and sustainable use of crop diversity makes to collective efforts to eliminate hunger and malnutrition and in achieving the Sustainable Development Goals.

This chapter describes the state of PGRFA in the wild and on-farm based on information reported by countries, reported through the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)[3,4]. In addition to the quantitative data, countries also provided key achievements, changes and trends as well as gaps and needs in implementing the first four Priority Activities of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA) (FAO, 2010), which focus on *in situ* conservation and on-farm management of PGRFA. Additionally, relevant global, regional and national initiatives are described and provide a broader context for the reviewing the state of PGRFA in the wild and on-farm.

2.2 Inventory and state of knowledge on PGRFA

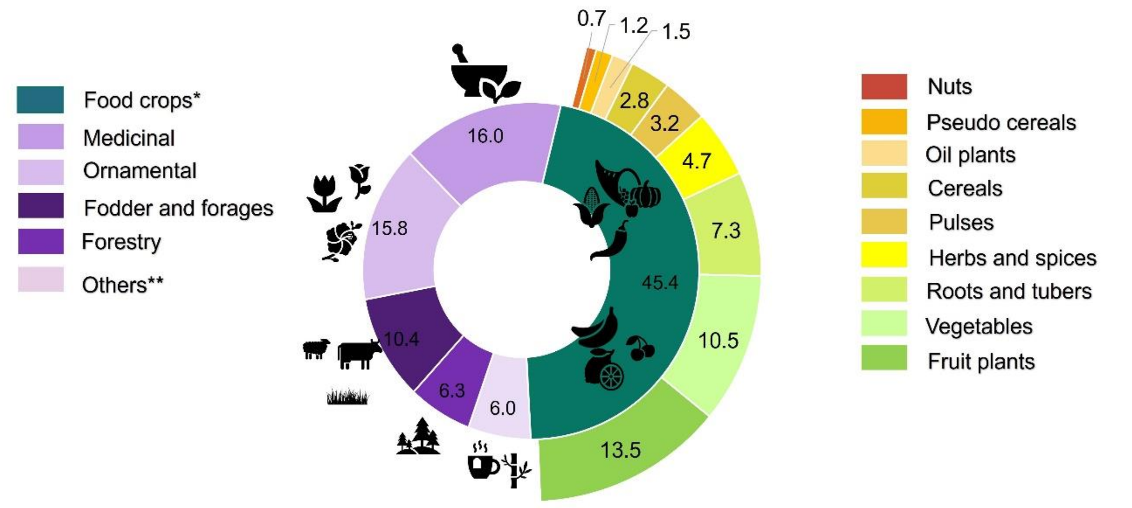
The state of knowledge on wild PGRFA (CWR and WFP) has greatly improved during the last decade, evidenced by the increased number of surveys and inventories of wild PGRFA (mostly CWR) reported by

[2] https://www.fao.org/about/meetings/multi-stakeholder-symposium-on-pgrfa/en/
[3] https://www.fao.org/wiews/en/ - For each of the priority activities of second GPA, countries were asked specific questions to report on as well as to provide summary narratives.
[4] https://www.fao.org/fileadmin/user_upload/wiews/docs/Reporting_Guidelines_2020e.pdf

countries and from the literature (FAO, 2019a). Analyses of the number of CWR species resulted in a total of 1 133 food-related CWR species recorded.[5]

With regard to surveying and inventorying PGRFA, countries reported on the number of species of CWR, WFP and FV/LR surveyed or inventoried *in situ*, including on-farm. Countries also identified those species inventoried that are considered to be 'threatened PGRFA', considered as 'any crops, crop varieties, CWR or WFP that are no longer cultivated or no longer occur *in situ* in most of their previous areas of cultivation or occurrence'[6]. Over 6 200 taxa of PGRFA have been surveyed or inventoried with each taxon being assigned to crop groups, including wild and cultivated PGRFA. Of these taxa, 45 percent of are food crops, which consist of nine crop groups (Figure 2.1).

Figure 2.1. Percentage of taxa reported by countries under the different use categories



*composed of nuts, pseudo cereals, oil plants, cereals, pulses, herbs and spices, roots and tubers, vegetables and fruit plants
**composed of plants used for other purposes, including research, sugar crops, fiber plants and stimulants

Surveys/inventories of wild and cultivated PGRFA were carried out in 81 countries. Surveys of wild PGRFA were carried out in Botswana, Madagascar, Togo, South Africa and Uganda in Sub-Saharan Africa, Lebanon

Box 2.1. Surveying wild food plants in Togo

Recognizing the important role of wild food plants in diets, in 2017, an inventory of non-timber forest products in Togo was undertaken, and identified 16 species whose leaves, fruits and seeds are actively used in the diet of both rural and urban populations. The study also identified 87 wild species producing edible fruits consumed by the local populations/settlers. Some species, notably *Vitellaria paradoxa*, *Xylopia aethiopica* and *Monodora myristica* are traded internationally. The species sought for their seeds are *Blighia sapida*, *Borassus aethiopium*, *Borassus akeassi*, *Garcinia kola*, *Cola nitida*, *Cola millenii*, *Cola gigantea*, *Vitellaria paradoxa* and *Pentadesma butyracea*, *Parkia biglobosa*, *Adansonia digitata*, *Bombax costatum*, *Moringa oleifera*, *Elaeis guineensis* and for their saps and wines (*Elaeis guineensis*, *Raphia* spp). During the period 2016 and 2018, about 100 species of medicinal plants were also surveyed and documented.

[5] In order to estimate the number of CWR species, the method described in Kell *et al.* (2008) was used to identify the CWR of food crops, which was then matched against the list of genera of food crops from Groombridge and Jenkins (2002).
[6] https://www.fao.org/fileadmin/user_upload/wiews/docs/Reporting_Guidelines_2020e.pdf

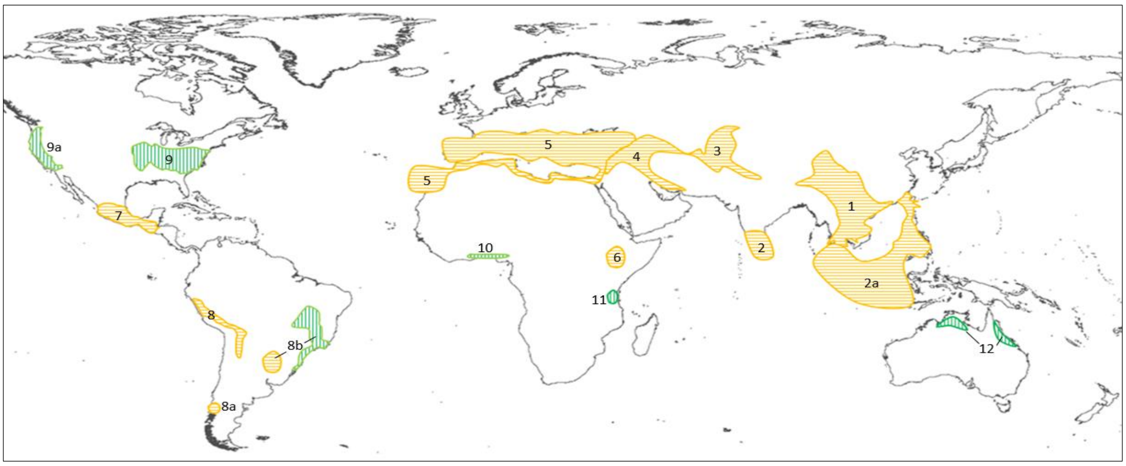
in Asia and Brazil, Ecuador and Mexico in Latin America. Other countries also reported having carried out surveys of the whole flora of the country (for example, Egypt, Kenya, South Africa, Zambia in Africa, Azerbaijan, Cyprus, Mongolia and Jordan in Asia, and Albania, Belarus and Romania in Europe and Brazil in Latin America), which *de facto* include both CWR and WFP. An example of the survey carried out by Togo is presented in Box 2.1.

During the reporting period significant advances have also been made in surveying FV/LR to improve knowledge of existing diversity and distribution of crop diversity in the farming systems. Most of the inventories have been carried out within the framework of ongoing programmes and projects involving different public (national genebanks, research institutes, universities etc.), civil societies and private sector (seed companies, associations), focusing on specific geographical areas. The number of systematic surveys and assessments of FV/LRs reported is moderate (less than one third of the countries), carried out within the framework of research projects, with limited geographical coverage and often reflecting single points in time. Countries reported that national surveys of FV/LR need to be standardized as they range from literature reviews only to interviews with farmers, to field surveys and observations. While the importance of carrying out inventories and assessment of FV/LR is globally recognized, the capacity of countries to perform comprehensive assessments representative of the diversity at national level, rather than at provincial/district/site level, is limited by the lack of human and financial resources at national level.

Many countries highlighted the lack of expertise in systematics and taxonomy leading to a decreased capacity in undertaking taxonomical analyses, crucial for the identifying and monitoring PGRFA diversity. The report from Guatemala mentions a high level of concern due to a lack of technical personnel to deliver training and oversight in research. The same concern was voiced by other countries, including Cyprus, which also mentioned the lack of institutional mandates for carrying out surveys and inventories. Countries further highlighted challenges in undertaking comprehensive regular surveys due to the lack of technical capacity. Funding is also always a major issue as field surveys are time and resource intensive. Another major issue reported in undertaking surveys is related to coordination among the forestry, environmental and agricultural sectors, especially with regard to wild PGRFA.

A global inventory of prioritized CWR of 173 priority crops important for global food security was undertaken by the University of Birmingham, Global Crop Diversity Trust (Crop Trust) and Millennium Seed Bank of the Royal Botanic Gardens, Kew (Vincent *et al.*, 2013). The study identified 1 392 priority CWR species, with the highest concentrations being found in western Asia, China, and south-eastern Europe respectively. The ecogeographic dataset was also used to identify the top 100 sites where genetic reserves could be established within protected areas globally, as well as a further 50 *in situ* sites outside of protected areas (Vincent *et al.,* 2019). The same dataset was used to review the correlation between CWR distribution and the eight Vavilov centres of diversity (Vavilov, 1926), resulting in the addition of four centres (Figure 2.2), including in the western seaboard, eastern seaboard and great plains of United States of America, coastal and central Brazil, coast of Southwest Africa, coast of the United Republic of Tanzania and Northern Australia (Maxted and Vincent, 2021). Furthermore, an in-depth review of crop strategies of four priority crops - potato, yams, groundnut, and millets - was undertaken by the Global Crop Diversity Trust to assess the *in situ* conservation status of their CWR diversity (Crop Trust, 2022) . Most inventories and surveys have focused on priority CWR species for specific crops and/or at different geographic scales (national, regional or global).

Figure 2.2. Revised Vavilov centres of diversity (Source: Maxted and Vincent, 2021)**.**



Revised Vavilov centres of diversity and the countries associated with them.

1. Chinese (China, Viet Nam. Laos and Cambodia)
2. Indian (India and Sri Lanka)

2a. Indo-Malayan (Thailand, Malaysia, Indonesia and Philippines)

3. Central Asian (Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan)
4. Near Eastern (Türkiye, Transcaucasia, Turkmenistan and Iran)
5. Mediterranean countries bordering the Mediterranean Sea
6. Abyssinian (Ethiopia)
7. Mesoamerican (Mexico and Guatemala)
8. South American (Peru, Ecuador and Bolivia)

8a. Chiloe, Chile

8b. Brazil and Paraguayan

9. Western and Eastern USA (United States of America)
10. Coastal West African (Ghana, Togo, Benin, Nigeria and Cameroon)
11. East African (United Republic of Tanzania and Kenya)
12. Northern Australian (Australia)

Two separate initiatives were carried out in Southern African Development Community (SADC) countries[7] on *in situ* conservation of CWR resulted in an inventory of 1 900 priority CWR (Allen *et al.*, 2019; Khaki Mponya *et al.*, 2021; Bissessur *et al.*, 2019; Holness *et al.*, 2019; United Republic of Tanzania Government, 2022; Ng'uni *et al.*, 2019).

In Europe,[8] a European CWR priority list of 863 taxa related to human and animal food crops was developed and an *in situ* database of population occurrences with georeferenced data has been generated for Europe and Türkiye (Rubio Teso *et al.*, 2021). In Mesoamerica, a list of about 3 000 CWR was compiled, including 310 priority species from Mexico, 105 taxa from Guatemala, 50 from El Salvador, and 54 taxa from Honduras (Contreras-Toledo *et al.*, 2018 and Goettsch *et al.*, 2021). In Nicaragua, ethnobotanical studies have documented 293 species of wild and domestic flora used by indigenous and non-indigenous communities (Miskito, Mayagna and Branches) (Nicaragua, country report).

Various estimates have been proposed for the number of plants species once or still used as food. In the late 1980 to early 1990, the estimated number of plants with edible parts ranged between 7 000 and 70 000 (Kunkel, 1984; Wilson, 1992), while more recent estimates range between 100 and 30 000 plant species (Van Wyk, 2019; French, 2019). FAO invited countries to list wild food species and those conserved *in situ* for the preparation of the *State of the World's Biodiversity for Food and Agriculture* (SoW BFA) (2019a), and 69 countries listed a total of 1 955 wild plant species used as food (FAO, 2019a, Table 4.9, p163), of which 150 species are conserved *in situ* (FAO, 2019a)[9]. Another comprehensive study conducted by a consortium of scientists led by Royal Botanic Gardens Kew recorded 7 039 edible plant species, defined as

[7] http://www.cropwildrelatives.org/sadc-cwr-project/ ; http://www.cropwildrelatives.org/sadc-cwr-net/
[8] http://www.farmerspride.eu/
[9] See Table 7.3 p 355.

species with ‘human food’ use (which also includes CWR) (Ulian *et al.*, 2020; Antonelli *et al.*, 2020). An extensive global review of WFP was also undertaken also in South America, Mediterranean and Southeast Asia (Borelli *et al.*, 2020).

The Useful Plants Project,[10] working with local communities, identified 615 species of WFP across five countries (Botswana, Kenya, Mali, Mexico and South Africa). Through the Biodiversity for Food and Nutrition (BFN) project,[11] 42 wild edible plants were prioritized in Türkiye (Hunter *et al.*, 2019) and across Morocco, a list of 246 wild plant species used as food were compiled (Nassif and Tanji, 2013). Several studies also reviewed and documented the use and diversity of WFP in specific geographical areas. For example, in Catalan Spain, Gras *et al.* (2021) recorded 291 wild food plant taxa, while in Western Sumatra 106 wild food plant taxa included in 85 species were identified (Pawera *et al.*, 2020) and 40 wild food plant taxa were identified in two valleys in Northern Pakistan (Aziz *et al.*, 2020), 70 wild food plant taxa in the northwest of the Russian Federation (Kolosova *et al.*, 2020) and 31 wild food plant taxa of fruits species in the Mpumalanga province of South Africa (Shai *et al.*, 2020), while Ray *et al.* (2020) assessed the diversity WFP in India and found 1 403 WFP species from 184 families.

2.3 *In situ* conservation of crop wild relatives and wild food plants in protected areas

There is still little evidence that wild populations of CWR, WFP and other categories of PGRFA are effectively conserved *in situ*. An analysis of the data provided by reporting countries shows that only 10 percent of *in situ* conservation sites in 69 reporting countries have management plans that specifically address CWR and wild food plant conservation. At regional level, Latin America has the highest percentage with 35 percent followed by Europe (13 percent), Africa (9 percent) and Asia with 7 percent (Table 2.1). Although Oceania (specifically Australia) reported over 10 000 *in situ* conservation sites, none of these have any management plans that address wild PGRFA conservation and management. One of the key elements that should be clarified for future assessments is the definition of *in situ* conservation sites with regard to the size of sites, species richness and/or species evenness.

In situ conservation sites including protected areas are generally not set up with the aim of targeting CWR and WFP conservation and these resources are therefore mostly passively mantained. *In situ* conservations sites are under considerable pressure from climate change, invasive species, overharvesting, and other threats that lead to the degradation of the ecosystems and decline in species richness (IPBES, 2019a). The continuous monitoring of conservation sites and management plans of wild PGRFA is essential for the effective conservation of these resources *in situ*.

Table 2.1. *In situ* conservation sites according to geographical region and with management plans addressing wild PGRFA

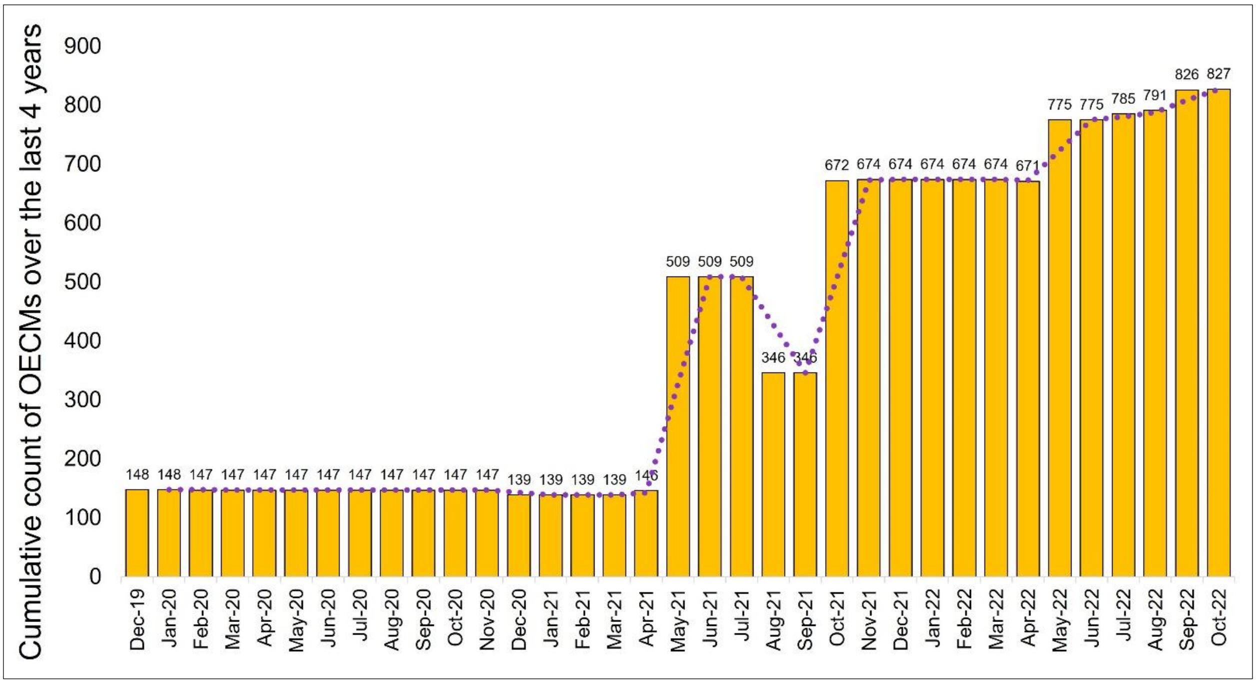
Region (Number of reporting countries)	Number of *in situ* conservation sites	Total number of sites with management plans	Percentage of sites with management plans
Latin America and the Caribbean (11)	639	122	19
Northern Africa (3)	139	27	19
Sub-Saharan Africa	4 326	439	10
Europe (21)	39 626	2 852	7
Asia (15)	2 243	160	7
Oceania (1)	10 500	0	0

[10] https://www.kew.org/science/our-science/projects/project-mgu-useful-plants-project#:~:text=Since percent202007 percent2C percent20the percent20Project percent20MGU,are percent20important percent20to percent20local percent20communities.
[11] http://www.b4fn.org/

One of the greatest challenges affecting *in situ* conservation is the lack of coordination among Ministries of agriculture, forestry and environment. This leads to ineffective, fragmented, and uncoordinated conservation activities, which could in turn enhances risk of genetic erosion of CWR and wild food plants. For example, although Kenya has a number of protected areas, the protection of CWR and wild food plant populations in these areas is just an indirect consequence of the establishment of these protected areas as there is no active CWR management. This is true for the vast majority of countries. While substantial efforts and progress has been made in collecting crop wild relatives, thereby ensuring their *ex situ* conservation, the same cannot be said of *in situ* conservation of wild PGRFA, which has to date remained comparatively neglected and therefore poorly implemented (see Chapter 3).

Globally, there exist different natural sites that are targeted for *in situ* biodiversity conservation, these include Important Plant Areas (IPAs) (Anderson, 2002), Key Biodiversity Areas (KBAs) (IUCN, 2016), and UNESCO Man and Biosphere sites[12] and the active use of these networks for agrobiodiversity should be investigated. The Community Conservation Research Network in the Kyrgyzstanmaintains a number of protected areas including the Issyk Kul Biosphere Reserve (Box 2.2). More recently, the International Union for Conservation of Nature (IUCN) (IUCN, 2018) has introduced the concept of '*Other Effective area-based Conservation Measures*' (OECM)[13], which provide an array of further conservations sites for CWR and WFP (as well as FV/LR) conservation. The number of OECM have increased significantly since 2019 (Figure 2.3).

Figure 2.3. Cumulative number of other effective area-based conservation measures (OECMs) from December 2019 to October 2022



The dotted line shows the trend in the average number of OECMs through time. Data source: UNEP-WCMC and IUCN (2022), Protected Planet: World Database on Other Effective Area-Based Conservation Measures (WD-OECM) [On-line], [October 2022], Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.

[12] https://en.unesco.org/mab

[13] OECM is a geographically defined area other than a protected area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the *in situ* conservation of biodiversity, with associated ecosystem functions and services and, where applicable, cultural, spiritual, socioeconomic, and other locally relevant values are maintained.

Box 2.2. *In situ* conservation of wild PGRFA in the Kyrgyzstan

Currently, in the Kyrgyzstan, the Community Conservation Research Network, a network of protected areas, covers 7 percent of the country's area and includes 10 state nature reserves (509 900 hectares), 13 state natural parks (724 900 hectares), 64 reserves (including integrated, botanical, zoological, forest areas totaling 241 500 hectares), 1 biosphere territory (4 314 400 hectares). In 2012, the Dashman State Nature Reserve addressed the conservation of wild walnut (*Juglans regia*) as a particularly valuable tree species. The walnut is also protected in the state biosphere reserve of Sary-Chelek, the purpose of which is to protect the unique walnut-fruit forests. In 2016, Sary-Chelek and the state nature reserves of Besh-Aral and Padyshata as part of the transnational (transboundary) category "Western Tien Shan" (prepared jointly by the Kyrgyzstan, Kazakhstan and Uzbekistan) were included in the list of UNESCO World Natural Heritage Sites. In addition to wild walnut, 11 species of wild food plants and wild relatives of cultivated plants, listed in the Red Book of the Kyrgyzstan, are actively conserved: twelve-dentate onion (*Allium dodecadontum*), pskem onion (*Allium pskemense*), Semenov's onion (*Allium semenovii*), Kashgarian barberry (*Berberis kaschgarica*), Central Asian pear (*Purus asiae-mediae*), Korzhinski's pear (*Pyrus korshinskyi*), Niedzvetzki's apple (*Malus niedzwetzkyana*), Sievers's apple (*Malus sieversii*), Knorring's hawthorn (*Crataegus knorringiana*), Petunnikov's almond (*Amygdalus petunnikowii*), Uzunakhmat grape (*Vitis usunachmatica*).

Programmes on in situ conservation of CWR and WFP

A total of 70 countries reported 415 programmes directly related to *in situ* conservation of CWR and WFP, which have been implemented over the reporting period. Six countries implemented more than 10 *in situ* programmes, while most countries (48) implemented between 1 and 5. Programmes targeted CWR (35 percent) more than they did WFP (23 percent), while some programmes (18 percent) focused on both plant groups. In the remaining *in situ* conservation programmes CWR or WFP were addressed only partially.

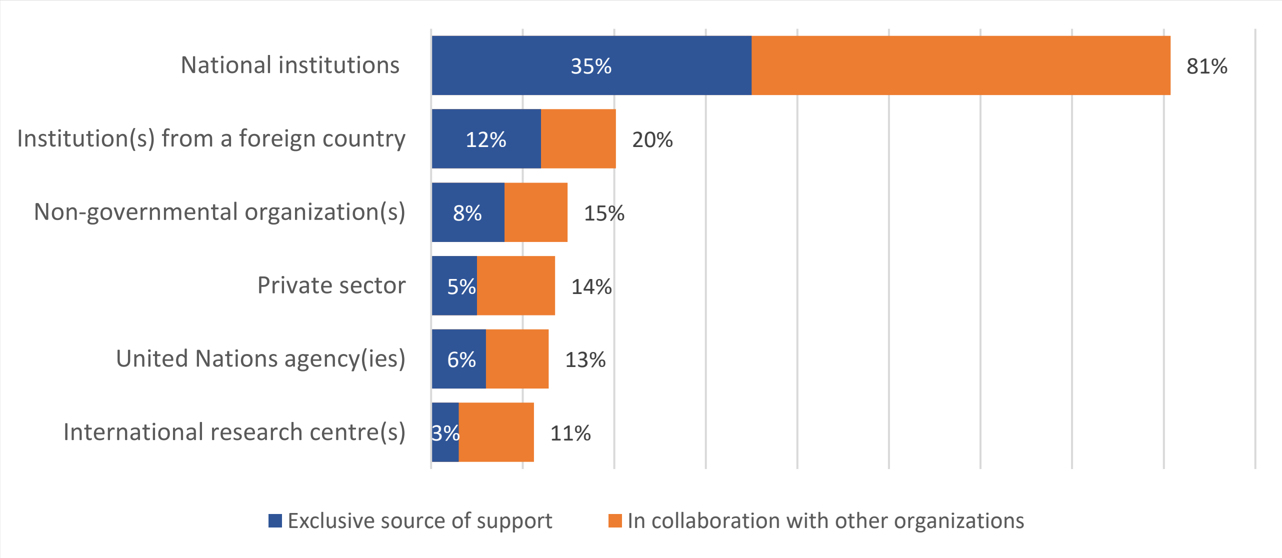
Countries also indicated those *in situ* programmes that specifically include the implementation of management practices to maintain high levels of genetic diversity, involvement of local communities, arrangements for *ex situ* conservation of threatened and endangered populations, and/or plans for encouraging public participation. Most countries have implemented more than one of these programmes (Table 2.2).

Table 2.2. Topics covered during implementation of *in situ* conservation programmes

Topic	Number of programmes	Number of countries
Implementation of management practices to maintain a high level of genetic diversity	53	14
Arrangements for *ex situ* conservation of threatened and endangered populations	35	14
Involvement of local communities	31	2
Implementation of plans to encourage public participation	5	31

Support for the implementation of *in situ* programmes was provided by different, often multiple, sources (Figure 2.4). The large majority of programmes were supported by national institutions (81 percent), either exclusively (35 percent) or in collaboration with other organizations (46 percent). Support for *in situ* conservation came through institutions from foreign countries (20 percent), non-governmental organizations (NGOs) (15 percent), the private sector (14 percent), UN agencies (13 percent) and international research centres (11 percent).

Figure 2.4. Percentage of support to programmes on *in situ* conservation of CWR and wild food plants, by source



During 2012-2019, FAO supported 14 countries in Sub-Saharan Africa[14] in developing national strategies for the conservation and sustainable use of PGRFA under their Technical Cooperation Project programmes. Moreover, the diversity of CWR in the SADC region, which was assessed under the UK Government/Darwin Initiative project 26-023, identified priority protected areas with the highest diversity of CWR species *in situ* (Magos-Brehm *et al.*, 2022). Under this initiative, Malawi and the United Republic of Tanzania established genetic reserves for the *in situ* conservation of CWR in at least two national protected areas respectively. Mauritius, South Africa, Tunisia, and Zambia have also prepared National Protected Areas Expansion Strategies (NPAES), which aim at including high priority areas for CWR in their network of protected areas. Together with NPAES, these countries have also established policies, legislation and laws governing these areas. For example, in South Africa, the 2016 NPAES include 10 of the CWR priority sites and an additional 46 priority sites are intended to be included in the 2024 NPAES.

In Europe, as part of the Farmer's Pride project, funded by the European Union's Horizon 2020 initiative, sites containing priority CWR (Box 2.3) have been mapped with the aim of developing a systematic approach to conserve CWR in the Europe region.[15] The project also recognized the need to focus on those CWR and WFP occurring *in situ* outside of protected areas, which often grow in anthropogenic, disturbed habitats (Jarvis *et al.*, 2015).

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[14] Angola, Burundi, Eswatini, Ethiopia, Kenya Madagascar, Malawi, Namibia, Rwanda, Somalia, South Sudan, United Republic of Tanzania, Uganda, and Zimbabwe

[15] https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/10/MS19_Crop_Wild_Relatives_in_the_Natura_2000_Network.pdf

Box 2.3. Potential of Natura 2000 network for *in situ* conservation of crop wild relatives

It is impractical to establish a parallel CWR *in situ* conservation network without considering working with existing broader biodiversity networks due to the inherent costs – the ideal is to work in partnership with existing biodiversity networks to actively conserve CWR diversity. Europe has an extensive network of protected areas established under the Natura 2000 network, the largest existing network of protected areas in the world, with approximately 26 000 sites stretching across all 27 EU countries and the UK, both on land and at sea. It is also one of the most important instruments of the European Union's policy for the conservation of biodiversity. Under the Farmers' Pride Horizon 2020 project[16], the potential of the Natura 2000 network of protected areas in Europe was assessed to secure CWR diversity *in situ*. The project also developed a tool[17] for managers of these areas to find out which CWR are found in Natura 2000 protected areas and guidelines on how to manage CWR populations *in situ* (Iriondo *et al.*, 2021). Finland, France, the Netherlands (Kingdom of) and the UK have reported the number of Natura 2000 sites specifically targeting the maintenance of CWR species in them (Source: Country reports and literature).

2.4 On-farm management and improvement of PGRFA

Farmers' varieties and landraces (FV/LR) are a result of natural and human managed selection and include populations of cultivated species that are often highly genetically diverse with high local adaptation to the growing environment (FAO, 2019b; IPBES, 2019). Their management on-farm is important for livelihoods and contribute to the functioning of ecosystem services. On-farm management and improvement, particularly maintenance of locally adapted crop varieties in agricultural production system, has gained importance since the publication of the State of the World's Plant Genetic Resources for Food and Agriculture (SoW1) (FAO, 1997) and the Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture (SoW2) (FAO, 2010).

Many countries have reported increased number of programs, projects and activities for the on-farm conservation and management of FV/LR. These are mainly carried out with public and private funding by public (national genebanks, research institutes and universities), private (seed companies and private foundations) and civil society organizations, NGOs, seed networks, farmers associations, etc.). However, most of the activities that support on-farm management globally have generally involved pilot project-based studies and are therefore short-term initiatives.

Data on supporting PGRFA on-farm management and breeding from 69 countries provides useful information on the numbers of farmers involved in on-farm PGRFA management, percentage of land that has been cultivated to FV/LR, and numbers of FV/LR returned to farmers from national or local genebanks (either directly or through intermediaries). However, action needs to be taken to understand and monitor FV/LR that farmers conserve autonomously, i.e., without interventions, and to improve the ability to document the diversity farmers conserve autonomously. This approach represents a vital contribution to maintenance of crop diversity both within and outside centres of diversity.

Whereas research and plant breeding have helped to raise crop yields, improve resistance to pests and diseases and enhance quality of food products, especially in favourable environments, many farmers have made conscious decisions to continue to maintain significant crop genetic diversity, constituted by traditional varieties and landraces, on-farm.[18] This diversity represents an important element in the livelihood strategies of farmers. FV/LR are often adapted to marginal, heterogeneous and/or steadily changing environments, suited for meeting changes in market demands, labour availability and other socioeconomic factors, and preferred for culinary, cultural and religious reasons. Consequently, there is a need to integrate PGRFA on-farm management into existing conservation strategies, as well as to pay more attention to underutilized crops/species, many of which are "hidden" in local production systems and are *de facto* neglected by research and breeding.

[16] https://more.bham.ac.uk/farmerspride/
[17] https://www.ecpgr.cgiar.org/crop-wild-relatives-in-natura-2000
[18] Referred to in the Second GPA as "farmers' varieties/landraces".

The degree of replacement of landraces and traditional varieties by modern varieties in specified areas of high diversity is of particular interest for monitoring potential risks of genetic erosion, as replacement is possibly one of its most important drivers. Unfortunately, the data available are not sufficient to give a comprehensive picture of the current incidence of FV/LR in cropping systems around the world. Nonetheless, they provide some anecdotal evidence of the relevance of these materials for certain crops in specific areas.

In the reported areas of high diversity, the average percentage of crop area still sown with landraces or farmers' varieties is 46.1. A total of 51 countries reported on the cultivation of FV/LR from over 160 crops and 60 mixed crop groups in 45 percent of over 83 256 914 ha in 272 localities. Cereals had the largest cultivation area of FV/LR (23 073 560 ha), which accounted for 44 percent of the total area under this crop group in the 89 reported sites and 62 percent of the total reported areas planted with FV/LR. Maize, sorghum, teff, pearl millet, rice and wheat were among the most represented cereals with total cultivated areas ranging from 4.8 to 1.6 M ha under FV/LR in 36 sites of 21 country and 17 sites of 10 countries, respectively.

Incidence above 25 percent of FV/LR against the corresponding total crop areas, was reported for pulses (25 percent), vegetables (28 percent), root and tuber crops (43 percent), forages (56 percent), oil plants (80 percent) and stimulant crops (86 percent), mainly coffee. Variation over time of the incidence of FV/LR, based on data on FV/LR cultivation from both reporting periods (2012-2014 and 2014-2019) at 39 sites[19] for 28 crops and 6 crop groups as provided by 10 countries,[20] is shown in Table 2.3.

[19] The countries reported on the same areas for both 2012-2014 and 2014-2019 making comparison between the two time periods possible.
[20] Albania, Armenia, Azerbaijan, Bangladesh, Eritrea, Ethiopia, Guyana, Indonesia, Nepal, Tunisia.

Table 2.3. Percentage of FV/LR for selected crops/crop groups and areas reported by 10 countries for both 2012-2014 and 2014-2019, and the percent difference between the two reporting periods

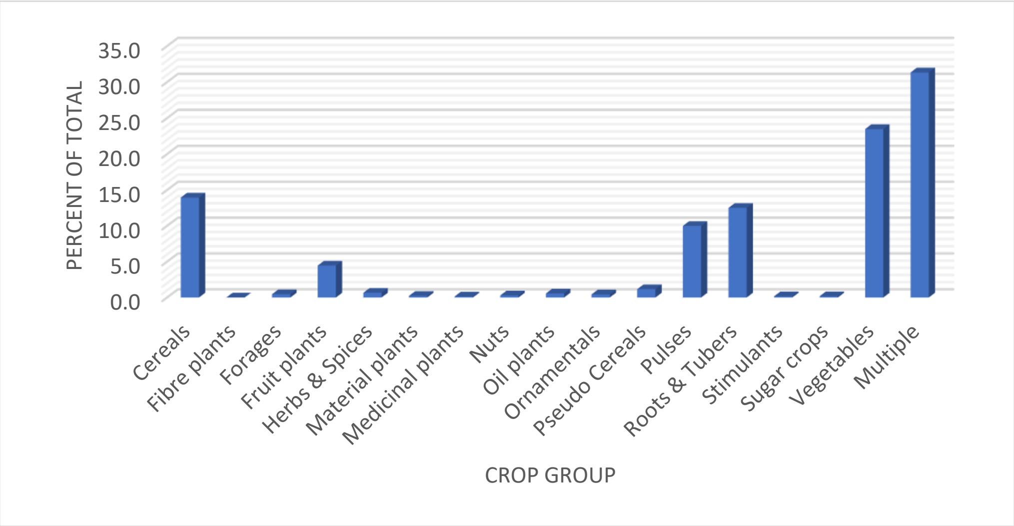
Crop/Crop group	Area, Country	2012-2014		2014-2019		Difference, percent
		Total area, ha	Area under FV/LR, percent	Total area, ha	Area under FV/LR, percent	
Apples	(unspecified), Armenia	11 098	4	11 152	3	**-1**
	Eastern and Southern Greater Caucasus, Azerbaijan	25 000	20	24 000	25	**5**
Apricots	(unspecified), Armenia	10 404	97	10 404	97	**0**
	Babek, Shahbuz, Julfa and Ordubad regions of Nakhchivan AR, Azerbaijan	2 200	90	2 100	90	**0**
Barley	Plain and lower mountain areas, Azerbaijan	320 000	10	325 000	4	**-6**
Cassava	Kumaka-Santa Rosa Farming Community, Moruca, Region # 1, Guyana	500	100	320	100	**0**
CEREALS	Lamjung, Nepal	43 200	82	34 100	75	**-7**
	Menzel Habib (Essagui), Tunisia	3 500	75	3 500	75	**0**
Cherries	(unspecified), Armenia	1 531	6	1 531	5	**-1**
Citrus	Lankaran Astara region, Azerbaijan	3 500	25	3 900	20	**-5**
Figs	Absheron, Azerbaijan	3 500	80	3 400	85	**5**
Grapevine	(unspecified), Armenia	17 465	17	16 099	25	**8**
	Plain and lower mountain areas, Azerbaijan	15 000	30	17 000	25	**-5**
Hazelnuts	(unspecified), Armenia	157	97	157	96.8	**0**
Maize	Fier, Shkodra, Dibra, Albania	31 790	18	21 882	26	**8**
	Southern Greater Caucasus, Azerbaijan	30 000	3	32 000	1	**-2**
	Debub, Eritrea	14 081	99	11 191	90	**-9**
	Sothern and Western low to mid altitude areas, Ethiopia	1 994 814	51	2 274 102	43	**-8**
Melon	Aran regions, Azerbaijan	8 000	60	7 700	50	**-10**
OIL PLANTS	Kailali, Nepal	20 000	92	20 500	87	**-5**
Olives	Absheron, Azerbaijan	1 526	4	1 756	2	**-2**
Peach	Nakhchivan AR, Azerbaijan	2 200	75	2 600	50	**-25**
Pearl millet	Anseba, Eritrea	26 222	85	24 856	90	**5**
	Sindhupalchok, Nepal	19 200	86	24 600	74	**-12**
Pears	(unspecified), Armenia	2 928	48	2 957	47	**-1**
	Eastern and Southern Greater Caucasus, Azerbaijan	5 400	70	5 200	65	**-5**
Pomegranate	Aran regions, Azerbaijan	16 000	92	19 000	85	**-7**
Potatoes	Ganja-Gazakh zone, Azerbaijan	28 200	24	31 500	28.9	**5**
PULSES	Gusar, Azerbaijan	12 200	15	10 200	11	**-4**
	Plain and lower mountain areas, Azerbaijan	27 000	85	27 380	78	**-7**
Rice	Dang, Nepal	11 372 071	20	11 670 000	12	**-8**
	Hilly, coastal and haor areas, Bangladesh	6 000	12	5 880	11	**-1**
Rye	Aceh Tengah, Aceh Timur, dan Pidie Jaya, Simeulue, Indonesia	100	8	110	2.7	**-5**
Sorghum	Aran regions, Azerbaijan	156 525	80	137 445	90	**10**
	Gash Barka, Eritrea	1 677 486	99	1 828 182	99	**0**
Sour cherries	Northern and Eastern low to mid altitude areas, Ethiopia	844	98	844	96	**-2**
Stone fruits	(unspecified), Armenia	27 000	70	27 500	75	**5**
Sugar beet	Sheki-Zaqatala, Azerbaijan	5 700	4	6 200	2	**-2**
Tea	Aran regions, Azerbaijan	1 000	70	1 600	55	**-15**
Tef	Lankaran Astara, Azerbaijan	3 016 522	97	3 101 178	93	**-4**
VEGETABLES	North-Western and Central Highlands, Ethiopia	10 000	50	11 000	55	**5**
	Azerbaijan, Azerbaijan	9 980	48	14 170	74	**26**
Walnuts	Khotang, Nepal	1 729	97	1 729	97	**0**
Watermelons	(unspecified), Armenia	10 000	5	10 500	3	**-2**
Wheat	Aran regions, Azerbaijan	450 000	2	470 000	1	**-1**
	Plain and lower mountain areas, Azerbaijan	1 605 654	92	1 789 373	83	**-9**
Total		**21 047 227**	**46**	**22 045 798**	**41**	**-6**

Repatriation of FV/LR to farmers is an indication of prior crop diversity loss. The number of FV/LR distributed during the reporting period by national or local genebanks to farmers was 58 323 (Table 2.4). It is important to note that it is likely that different institutes may have distributed the same varieties and thus this number may be inflated. Six countries reported the distribution of over 18 000 FV/LR of multiple crop groups, 31 percent of the total distributed reported by countries (Figure 2.5). For those crop groups identified, vegetables (24 percent of the total) and cereals (14 percent) were the most distributed by genebanks, followed by roots and tubers, and pulses (12.5 and 10 percent, respectively). The highest numbers of FV/LR for these four crop groups were distributed by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), including over 5000 of vegetables, 2 200 cereals (27 percent of all cereals distributed), 4 705 roots and tubers (65 percent) and 1 355 pulses (23 percent).

Table 2.4. The number of samples of farmers' varieties/landraces (FV/LR) distributed by national or local genebanks to farmers during the reporting period

Crop Group	Number of countries	Number of FV/LR
Cereals	52	8 132
Fibre plants	2	6
Forages	18	271
Fruit plants	25	2 599
Herbs and Spices	17	383
Material plants	5	133
Medicinal plants	4	83
Nuts	4	171
Oil plants	19	328
Ornamentals	6	254
Pseudo Cereals	12	676
Pulses	48	5 826
Roots and Tubers	26	7 291
Stimulants	4	98
Sugar crops	7	104
Vegetables	45	13 690
Multiple	6	18 278
	Total	58 323

Figure 2.5. Percentage of farmers' varieties/landraces distributed by national or local genebanks to farmers during the reporting period according to crop group

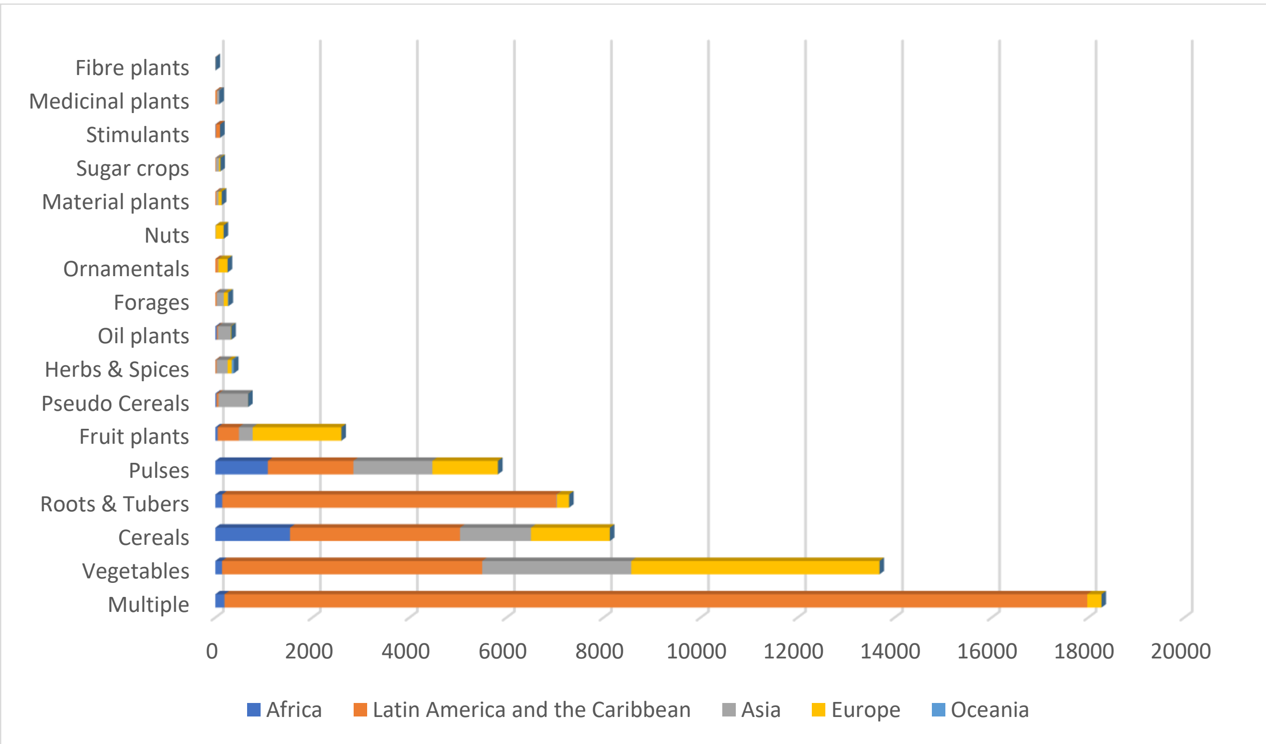


The number of FV/LR distributed to farmers by genebank categorized by crop group and geographic regions is provided in Table 2.5. Genebanks in Latin America and the Caribbean and Europe distributed the largest number of FV/LR overall (over 36 000 and 11 100, respectively). Genebanks distributed the majority of roots and tubers, vegetables, cereals and pulses, as well as of the undefined multiple group (Figure 2.6). Genebanks in Europe distributed over 5 000 FV/LR of vegetables, over 1 800 fruit plants and 1 300 pulses.

Table 2.5. Number of farmers' varieties/landraces distributed to farmer by national and local genebanks by crop group and geographic regions

Crop Group	Africa	Latin America and the Caribbean	Asia	Europe	Oceania	Total
Cereals	1 539	3 503	1 464	1 626	0	8 132
Fibre plants	0	4	2	0	0	6
Forages	1	26	147	86	11	271
Fruit plants	49	437	285	1 828	0	2 599
Herbs & Spices	3	25	225	86	44	383
Material plants	0	22	42	69	0	133
Medicinal plants	0	34	49	0	0	83
Nuts	1	0	10	160	0	171
Oil plants	30	23	261	14	0	328
Ornamentals	0	50	14	190	0	254
Pseudo Cereals	26	38	610	2	0	676
Pulses	1 081	1 764	1628	1 353	0	5 826
Roots & Tubers	144	6 888	13	246	0	7 291
Stimulants	10	88	0	0	0	98
Sugar crops	2	10	63	29	0	104
Vegetables	139	5 362	3 072	5 117	0	13 690
Multiple	189	17 793	0	296	0	18 278
Total	3 214	36 067	7 885	11 102	55	58 323

Figure 2.6. Cumulative number of farmers' varieties distributed to farmer by national and local genebanks by crop group and geographic regions



The reintroduction of FV/LR back into the farmers' fields is an important measure that contributes to PGRFA conservation, however returning FV/LR to farmers is not sufficient to ensure conservation, as farmers may decide not to maintain the varieties over time. For example, in Peru, 14 950 samples representing 1 519 accessions of repatriated material of potato FV/LR were distributed to 135 communities between 1997 and 2020. Yet after four years, 56 percent of the households abandoned the repatriated material due to biotic and abiotic stresses, insufficient labour or knowledge and lack of planting material, and the *in situ* survival probability of the remaining material stabilized between 36 percent in year 5 and 18 percent in year 15 (Lüttringhaus *et al.*, 2021). The factors influencing the rate of conservation included age of the plot manager (those over 60 years old were reported to be more likely to maintain the repatriated FV/LR for longer time periods, gender (farms where women were in charge of the plots were more likely to maintain repatriated material), education level (educated farmers had easier access to technical information), availability of labour, economic status, level of food insecurity and geographic location within Peru. One positive outcome of repatriation reported in the study was the re-establishment and enhancement of culinary diversity and traditions. Findings from Gatto *et al.,* (2021) showed an increasing reduction of crop varietal diversity linked to the spatial displacement of traditional landraces at a faster rate in Asia compared to Africa. Among cereal, pulse, and root and tuber crops, varietal diversity was lowest for cereals in Asia and highest for root and tubers in Africa.

2.4.1 Initiatives for on-farm management and improvement of PGRFA

A number of initiatives have been undertaken over the reporting in support of on-farm management of FV/LR. Activities carried out related to assessments of environment and socioeconomic features and farmers' knowledge for on-farm PGR management, FV/LR characterization, on-farm participatory plant breeding (PPB), and pilot sites selection for PPB and demonstration plots. Among the activities described by countries, FV/LR characterization and evaluation (15 percent) and FV/LR utilization and management assessment (13 percent) were most prevalent. Regions with the highest number of initiatives were Latin America and the Caribbean, Sub-Saharan Africa and Asia.

Since 2012, recognition of farmers' role in managing local crop diversity (mainly FV/LR) has increased in many countries. Many donors increasingly require the participation of Indigenous Peoples and Local Communities and/or the implementation of participatory approaches, in order to access funds. For participatory approaches to be effective, they need to create a demand-driven, inclusive environment where all stakeholders, including farmers, are able to express their needs and interests, to share knowledge. On-farm conservation is most often a process led by farmers, and is recognized by the inclusion of the Farmers Rights clause in the Treaty.

The unique role that farmers play in managing FV/LR is gaining in importance. For example, in Peru, the farmer-led Association of Potato Guardians or AGUAPAN[21] works with associated custodian farmers from different regions to promote knowledge exchange. Also in Peru, the Potato Park, a reserve of more than 15 000 hectares located in the Andean region of Cusco, Peru, is a conservation initiative led by local stakeholders, and established in early 2 000 by six indigenous Quechua communities in the Sacred Valley of the Incas. Focusing on the potato as a cultural symbol, the Potato Park has successfully promoted the conservation and use of the almost 1 400 potato varieties, safeguarded by local communities (FAO, 2022).

Other countries have also adopted community-based approaches for managing local crop diversity. These include strengthening farmers' groups, cooperatives and establishing community seed banks, conducting agrobiodiversity (seed) fairs, food fairs, diversity-based farmers' field schools, community biodiversity registries, community biodiversity management (CBM). Within the framework of a UNEP/GEF project on the management of crop genetic diversity in the montane environment in Nepal[22], 22 successful and effective practices were documented as contributing to on-farm management and improvement (Joshi *et al.,* 2020a).

Globally Important Agriculture Heritage System (GIAHS), is another community-based approach, developed by FAO, to identify and safeguard GIAHS and their associated landscapes, encompassing agricultural biodiversity, knowledge systems and culture. During the period 2005 to 2020, FAO designated 62 GIAHS systems in 24 countries as agricultural heritage sites. The establishment of these GIAHS sites helps to

[21] https://aguapan.org/
[22] www.himalayancrops.org

promote the conservation and sustainable use of local, well-adapted germplasm, and value chain development (see Box 2.4).

Box 2.4. Nishi Awa Steep Slope Land Agriculture System, Japan
Along the steep mountains of Nishi Awa, Japan, family farmers have been cultivating crops through traditional methods. Cultivation in this area, in the form of slash-and-burn agriculture, predates the introduction of rice cultivation in Japan. The grasslands that are essential for maintaining the sloping fields are home to various rare plants and animals, contributing to the preservation of biodiversity. Locally adapted, resilient crops have been traditionally cultivated here, including local varieties of buckwheat, foxtail millet, barnyard millet and proso millet, as well as tea, fruit trees, and vegetables. These represent a valuable source of food for local communities but were gradually abandoned in favour of rice cultivation. Only a few farmers continued to cultivate local varieties of the millets and buckwheat, and it is thanks to them that this germplasm has been conserved and cultivated.

Through the GIAHS designation of this area,[23] conservation, multiplication and distribution of local germplasm was actively fostered at the community level. The produce is consumed locally and shipped to the Japan Agricultural Cooperatives and farmers' markets, providing a valuable source of income. The GIAHS designation has also promoted a new form of tourism, with activities such as hands-on experience of farming being offered to visitors.

2.4.2 Community Seed Banks

Community seed banks (CSBs) refer to saving and sharing seeds among farmers and gardeners, and can be defined as local, informal or formal institutions whose core function to collectively maintain seeds for local use (Development Fund, 2011; Vernooy *et al.*, 2017; Andersen *et al.*, 2018). CSBs are specific interventions and generally focus on conserving and using local crop varieties at the community level with a view to strengthen local seed systems and improving food and nutrition security of smallholder farmers. CSBs have recently been recognized for their importance in providing local solutions to produce, store and supply seeds and thereby increasing access and use of crop diversity (Vernooy *et al.*, 2015; Andersen *et al.*, 2018; Porcuna-Ferrer *et al.*, 2020). In this regard, 21 countries reported the establishment of CSBs during this reporting period for a total of over 600 CSBs.

In Europe, it is estimated that there are more than 100 CSBs (Diversifood, 2018) even though only two countries (Norway and Portugal) mentioned them in their country reports. While CSBs were initially established and promoted within the framework of donor-funded projects and CSOs and NGOs, national public sector institutions are now establishing and promoting CSBs in some countries (e.g., the 2018 National Seed Policy in Uganda specifically refers to CSB as part of the strategy to "strengthen research and development for the seed sector").

Recognizing the role of CSBs in strengthening the conservation and sustainable use of PGRFA on-farm, in 2018, FAO, in collaboration with Bioversity International, conducted a survey in order to inventory CSBs, and to characterize their functions, composition and foci. Responses were received from 82 CSB representatives in 37 countries. Eighty-three CSBs had legal status (registered as an association or cooperative) and all but two operated as non-profit. The majority of CSBs were involved in short-term storage of FV/LR, multiplication and distribution to farmers. Other activities reported education and training, awareness raising, PPB and seed production. Membership ranged from less than 10 to over 14 500, with the number or women members ranged from zero to 5 000. For some CSBs, distribution of seed was high (from 1 000 to 10 000 recipients), though over half of the CSBs distributed to less than 100 recipients. The surveyed CSBs identified a range of limitations for their effective implementation, including a lack of sufficient financial and human resources, storage capacity, equipment, land availability seed and varieties, supportive seed laws and policies, and market incentives. Forty-four CSBs are part of larger networks that enable sharing of resources, experiences and technical knowledge. All respondents reported that they could both contribute and benefit from being part of a larger knowledge-sharing platform.

[23] https://www.fao.org/giahs/giahsaroundtheworld/designated-sites/asia-and-the-pacific/nishi-awa-steep-slope-land-agriculture-system/en/

CSBs, seed fairs, diversity fairs, school programs promote exchange of seeds and knowledge (as reported by Brazil, Lebanon, Mali, Mexico, Nepal, Nicaragua, South Africa, Uganda, Zambia,), therefore have a role in supporting all, women, young, and indigenous and local peoples. In Mali and South Africa, most active participants in CSB management are women; in Lebanon, all generations of both men and women all involved in the management of CSBs. Nicaragua highlights that "a large number of men manage seed banks, yet women show better and more efficient management of seed banks". NGOs have also contributed to implement and promote these activities.

2.4.3 Participatory breeding (development, registration and commercialization of farmers varieties)

Participatory crop improvement is a well-established framework for breeding local crops. Depending on the parental materials and breeding approach used, participatory crop improvement aims to strengthen local seed systems and on-farm conservation of crop genetic resources. Several diverse approaches to participatory crop improvement have been documented in the past such as participatory plant breeding (PPB) and participatory varietal selection (PVS) (Sperling *et al.*, 2001; De Haan *et al.*, 2019; Ceccarelli and Grando, 2020). The reports from countries highlighted predominantly the use of PPB and PVS activities in crossing, selection and field evaluation of FV/LR. Among geographic regions, Latin America followed by Africa[24] reported the highest number countries implementing PPB/PVS, while in Asia two countries (Jordan and Nepal) mentioned use of PVS. France is the only country in Europe that reported PPB and PVS activities, but a review paper on PPB practiced in European countries (including France, Germany, Italy, and Spain) has identified 26 projects including 14 crops, of which 13 started after 2011 (Colley *et al.*, 2021). A more dynamic and decentralized form of participatory plant breeding is being piloted in six countries (Bhutan, Ethiopia, Iran, Jordan, Nepal and Uganda) to increase farmers' crop varieties cultivated in rainfed farming system, with a view to more sustainable production systems (IFAD-funded project implemented by Bioversity International, 2018-2022).

Registering farmers' varieties represents a successful approach that contributes to conserving FV/LR. Latest global evidence shows that some countries such as Bolivia, Laos, Nepal, and Zimbabwe have been piloting registration of farmers' varieties, which, after developing an alternative registration system, has resulted in the registration and release of FV/LR improved through PVS (De Jonge *et al.*, 2021). The formation of seed clubs in Viet Nam enabled working with farmers to promote varietal selection through participatory plant breeding and the national varietal registration of local varieties, which has enhanced farmers' access to the quality seeds and planting materials of preferred varieties (Furman *et al*., 2021; FAO, 2022) (Box 2.5). Farmers' variety registration provides legal pathways to their commercialization that can help generate more income and other benefits to smallholder farmers in addition to conserving them through use.

[24] Chile, Costa Rica, Cuba, Guatemala, Mexico, Nicaragua, Trinidad & Tobago Latin America; Ethiopia, Nigeria South Africa, Zambia, Zimbabwe in Africa

Box 2.5. Seed clubs in Viet Nam provide a link between formal and informal seed sectors

In Viet Nam, the Southeast Asia Regional Initiatives for Community Empowerment (SEARICE) and the Mekong Delta Development Research Centre of Can Tho University (MDI-CTU) have been collaborating with communities on the formation of seed clubs to enable local seed supply systems through seed conservation, exchange, and crop improvement activities. SEARICE and MDI-CTU facilitate activities in: (i) participatory variety rehabilitation to restore the original characteristics of the farmers' variety/landrace through selection; (ii) participatory plant breeding, which involves the participation of farmers in the process of crop varietal development throughout the decision-making process; and (iii) participatory variety selection, where farmers grow and select varieties in their own fields, enabling breeders to learn which varieties are preferred by farmers and perform well on-farm.

These activities bridge the formal and informal seed systems (Tin *et al*., 2011), and have resulted in the development of 360 farmers' varieties, five of which are nationally certified (Manalo, 2019). The formal registration of farmers' varieties is made possible through funding provided by SEARICE and by the policy and technical assistance provided by MDI-CTU. This approach empowers communities and is fundamentally important to improve access to and availability of quality seeds, maintain local crop diversity, and enhance linkages between the formal and informal seed sectors.

2.4.4 Capacity building for on-farm management

Strengthening and supporting farmers' capacities to conserve and manage crop diversity on-farm was promoted during this reporting period. Capacities were strengthened for value addition, marketing local crop varieties, inclusion of crop diversity modules into secondary and tertiary education, engaging with extension workers, and farmer-field schools.[25] Twenty-one country reports across the Africa, Asia, Europe and Latin America[26] mentioned the participation of farmers in research, training and awareness building.

Enhancing capacities of conservation practitioners supports more robust on-farm management and monitoring of FR/LR populations, decision support and options for enhanced linkages between genebanks and the on-farm conservation community. In this regard, the Department of Environmental Biology of Sapienza University (Rome, Italy) held a summer course (Grow: Agrobiodiversity in changing climate) in 2017. The course targeted students and researchers around the globe, as well as professionals and practitioners from public and private sector. It was developed by Bioversity International and further expanded by FAO's Mountain Partnership Alliance, and discusses the importance of biodiversity in agriculture, its role enhancing resilience and adaptability of cropping and farming systems, and tools for monitoring FV/LR on-farm.

Many countries reported on capacity development initiatives targeting farmers and other stakeholders (researchers, extension officials, policy makers and planners) through holding seminars, workshops, policy dialogues and awareness raising for promoting on-farm conservation. Country reports have consistently mentioned an increase in the number of activities actively involving farmers in research related to crop improvement, seed production and conservation, management practices and documentation. CSBs, agrobiodiversity fairs and food fairs of local crops and varieties are important for creating awareness and building capacity of farmers and stakeholders (Joshi *et al.*, 2020a). Nepal, South Africa, and Uganda reported the use of agrobiodiversity /traditional seed and food fairs and CSBs as part of capacity building for promoting on-farm conservation.

[25] https://www.fao.org/farmer-field-schools/home/en/

[26] Africa: Benin, Botswana, Ghana, Kenya, Namibia, South Africa, United Republic of Tanzania , Uganda, Zambia, Zimbabwe; Asia: Azerbaijan, Indonesia, Lebanon; Europe: Moldova; Latin America: Argentina, Costa Rica, Cuba, Ecuador, Guyana, Mexico, Trinidad and Tobago

2.4.5 Market and policy incentives for promoting the on-farm management of PGRFA

Market and non-market-based incentives have been shown to be successful on promoting on-farm conservation and sustainable use of agrobiodiversity (Gauchan *et al.*, 2005; 2020; Drucker *et al.*, 2021). Countries reported incentive mechanisms to promote on-farm conservation, including free distribution of FV/LR seeds of to farmers, support for cultivation and registration of local varieties, training and capacity building of farmers in on-farm conservation, awareness raising through publicity, mass media, support for market and value chain development of landraces, policy incentives, ownership rights, reward recognition payment for on-farm conservation of agrobiodiversity.

Another novel model concerns voluntary direct payments made to farmer associations. For example, AGUAPAN[27] in Peru provides direct monetary payments to their members currently representing over 100 communities through direct agreements with the private sector. Each member is a locally recognized household maintaining at least 50 potato landraces. AGUAPAN also provides its members with other options, such as health care and access to high value markets for varietal mixtures. AGUAPAN has created a collective brand called Miski Papa,[28] which offers a high value market for its members. The association conserves an estimated number of around 1 500 unique landraces. A recent genetic study comparing of the landrace pools of AGUAPAN members from 2 out of 9 regions documented 88 landraces that were not yet covered in genebanks[29].

Distribution of diverse FV/LR from national genebanks and public research centres to smallholder farmers is the simplest and most important activity that can implemented as an incentive. In addition, there are other incentives indicated for FV/LR as outlined above. Most FV/LR are conserved and used on-farm as they are part of local food systems but require efforts for these to be mainstreamed into value chains. Therefore, incentives that target strengthening FV/LR value chains are essential.

2.5 Restoration of crop systems after disasters

During the reporting period (2012-2019), as recorded by EM-DAT, the International Disaster Database, over 4000 disasters were reported around the world linked to droughts, floods, earthquakes, volcanoes, frost, hail, snow, civil wars, instability, crisis, storms, pests or diseases, and have affected nearly 1.3 billion people around the world. The agricultural sector – crops, livestock, forestry, fisheries and aquaculture – absorbed twenty-six percent of the overall damages and losses caused by medium- to large-scale disaster events, which implies significant impacts on the livelihoods, as well as the nutrition, of affected population (FAO, 2021). These impacts were estimated in terms of monetary and nutrition costs, but not in terms of cultivated diversity loss. A gap recognized by many of the reporting countries is a more generalized assessment of disasters' impacts on crop diversity. In this context, 49 countries reported 497 interventions, essentially the supply of seeds for restoration of cropping systems after disasters (country reports). Most of the countries which reported interventions following disasters were in Africa (20 countries – 132 interventions), while the highest number of interventions was reported by Latin America and the Caribbean (162 interventions in 10 countries). In Asia, 13 countries reported 159 interventions. In Europe, five countries reported 11 interventions and in Oceania, Papua New Guinea, the only country which submitted a report, reported 33 interventions (Figure 2.7). Between 2020 and 2022, FAO alone assisted vulnerable smallholder farmers affected by diverse crises to access quality seeds and planting materials of food crops in over 70 Member Nations, via over 300 different emergency projects. The country reports cited above may underestimate the range of disaster response activities in a country, as this information is not always centrally-gathered.

Altogether, interventions due to climatic events (drought, flood, typhoon, hurricane, storms, frost, hail, snow) represent nearly three fourths of all interventions, drought being the prominent one (36 percent) followed by floods (25 percent) (Figure 2.8). This corroborates with FAO's report (2021), which identified drought and floods as the two most important causes of damage and loss to agriculture.

[27] https://aguapan.org/
[28] https://yanapai.org/2020/12/19/catalogo-miski-papa-regalo-de-los-andes/
[29] https://cgspace.cgiar.org/handle/10568/116855

Figure 2.7. Number of countries reporting interventions and number of interventions to restore cropping systems by region, 2012 to 2019

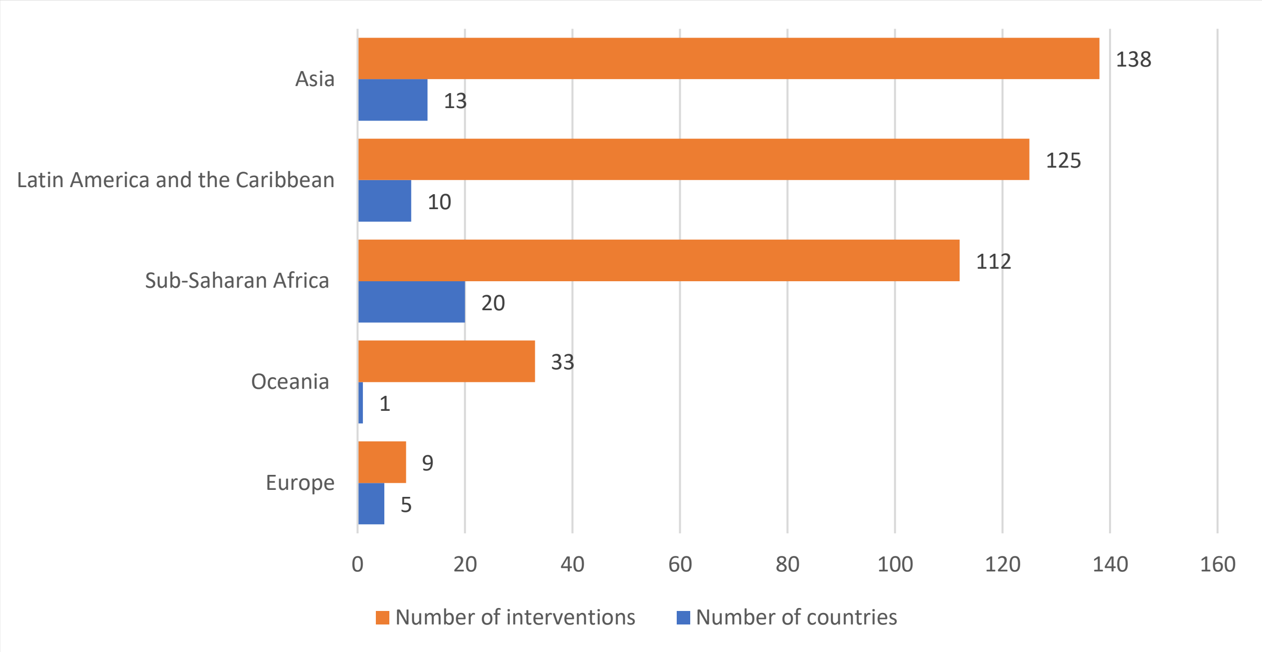
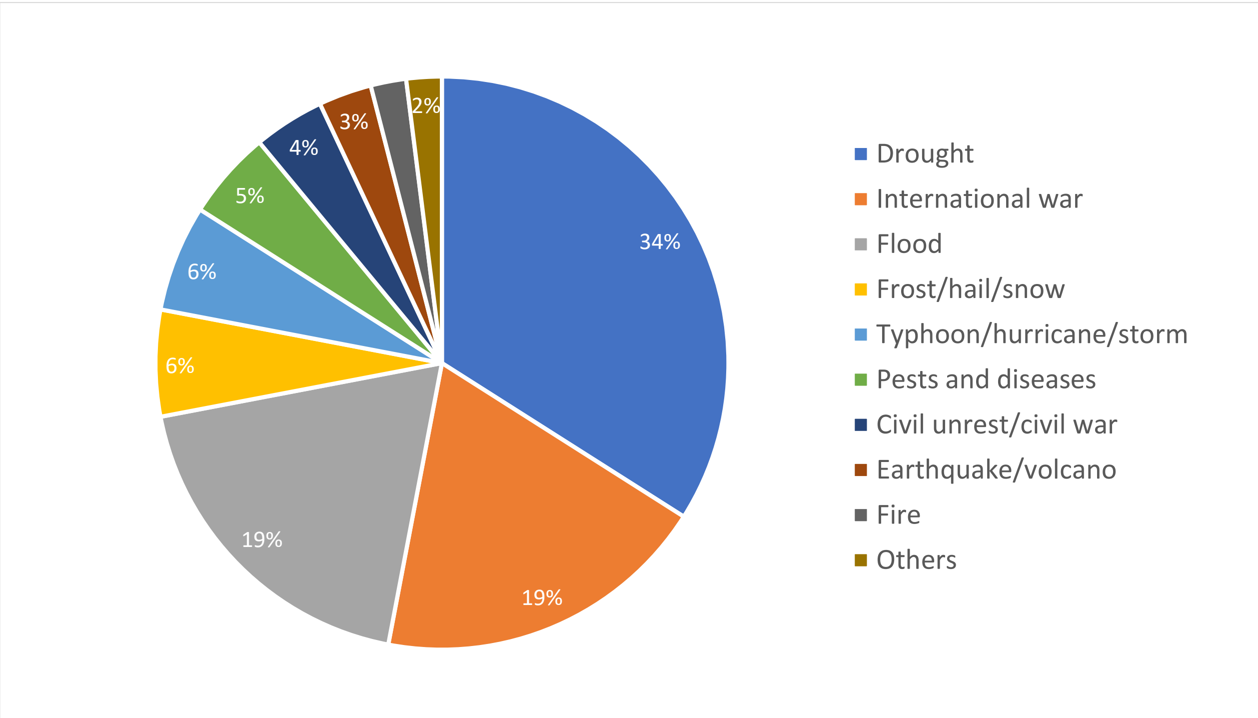
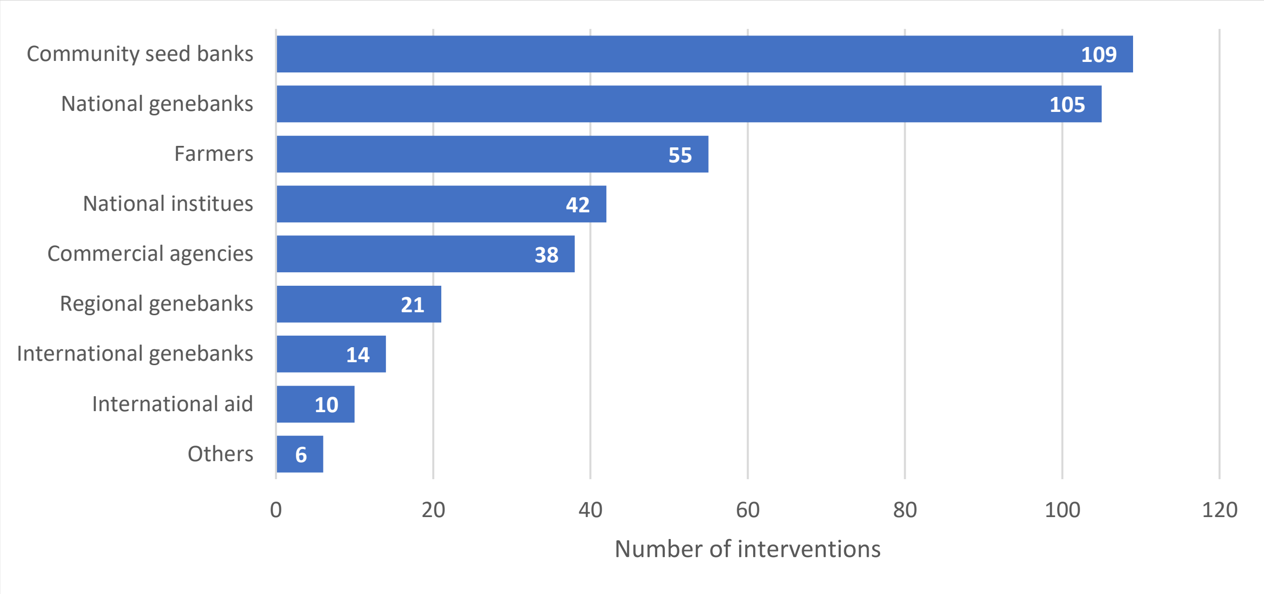


Figure 2.8. Percentage of interventions to restore cropping systems by types of disaster during the reporting period



Combinations of different interventions are often used to support farmers in restoring their cropping systems. In 50 percent of the interventions reported by countries, seeds and planting materials were distributed directly to farmers, and in 13 percent to community seed multiplication sites while 26 percent were a combination of both. One of the major difficulties when distributing seeds and other planting materials after a disaster situation is the availability of quality seeds and planting materials of adapted varieties for distribution. These materials must be free of pests and diseases, must respond to farmers' needs and must be available in sufficient quantities (Sperling and McGuire, 2010). With the unpredictability of disasters, it is quite a challenge to identify reliable sources of materials. Sources of the germplasm distributed to farmers for cropping systems restoration were reported for 348 of the interventions reported by countries and comes from diverse sources (Figure 2.9). Farmers and community seedbanks played a major role, as together they were used as sources for 41 percent (164) of reported distribution of seeds and planting materials to affected areas. National genebanks and national institutions provided the germplasm in 37 percent (147) of the interventions. Seeds and planting materials were sourced internationally in 11 percent (45) of the cases. Commercial agencies account for 10 percent (38) of the sources reported.

Figure 2.9. Sources of germplasm/seeds distributed to farmer after disasters



Category ‘International aid’ encompasses neighbouring states, FAO, NGOs; category ‘National/State Institutions’ comprises research, educational and agricultural national institutions, Departments of Agriculture; category ‘Farmers’ includes farmers, seed producers’ associations. (Data source: Country Reports)

Restoration of agricultural production systems rather than crop diversity was the primary focus of most of the interventions reported. In the urge of providing quality seeds and planting materials to affected farmers, the germplasm distributed may not always be fully adapted to the local conditions or to the cultural environment, for example as reported by Cameroon or Mali. After cyclone Pam hit Vanuatu in 2015, international aid has shipped 700 kg of seeds of various species to support affected communities. To comply with Vanuatu importing rules, these seeds were all quality assured, mainly of hybrid varieties. It induced a shift in time of the problem of availability of planting material (Calandra, 2020). In many other cases, only a few crop species and varieties per crop are selected for distribution. These limited numbers of species and varieties distributed can result in the dominance of the distributed germplasm over other varieties, and ultimately to the loss of traditional varieties, as it was reported by the Philippines or Togo. In most circumstances, emergency seed assistance provides no more than a few percent of the quantities of seed sowed by all farmers, so significant impacts on diversity profiles would not be expected.

In its report, Zimbabwe highlighted the importance of projects promoting on-farm conservation as well as the interventions of multi-levels actors, including international funders, governmental organizations, NGOs and community-based association to efficiently mitigate the effects of disasters. A disaster relief project in response to Cyclones Idai and Kenneth was carried out in Malawi, Mozambique and Zimbabwe, and is an example collaboration among farmers, genebanks, international organization and governments in supporting local seed systems (Box 2.6). The Government of Kenya worked in partnership with the Red Cross Society, other NGOs and local actors to assist farmers after natural disasters (Box 2.7)

Box 2.6. Seed system support to Malawi, Mozambique and Zimbabwe in response Cyclones Idai and Kenneth

When Cyclones Idai and Kenneth made landfall in Southern Africa in March and April 2019 respectively, the consequences were devastating for farmers, who lost local seed reserves including crop wild relatives and crops ready for harvest. The cyclones and related floods affected more than 3.8 million people in Southern Africa and destroyed nearly 800 000 hectares of standing crops in Malawi, Mozambique and Zimbabwe.

Rebuilding local seed systems is crucial for food and nutrition security, but is often not implicit in national emergency response and preparedness plans that focus on immediate distribution of quality seed and planting material of adapted varieties. To address this gap, the Treaty and FAO partnered with the national genebanks of Malawi, Mozambique and Zimbabwe on a three-year project with support from the Government of Germany and the Kingdom of Norway. The project, Foundations for rebuilding seed systems post Cyclone Idai: Malawi, Mozambique and Zimbabwe, aimed to improve food and nutrition security and livelihoods in the longer term.

In the project, national gene banks and farmers collaborated to rescue, regenerate and return seed to affected communities in Malawi, Mozambique and Zimbabwe, and to strengthen national and regional planning for the protection of local seed systems in the future. The national gene banks of Malawi, Mozambique and Zimbabwe integrated emergency response measures for PGRFA into national strategies, so that governments and communities are better prepared for future emergencies.

Among the main achievements of the project were the inclusion of seed system protection and restoration in national and regional strategies, the rescue of crop varieties that were at risk of becoming lost, and the multiplication and distribution of varieties that respond to farmers' needs and preferences, as well as to current and future climate conditions. At the same time, the project has strengthened the capacities of multiple stakeholders in Malawi, Mozambique and Zimbabwe to benefit from and contribute to the mechanisms of the Treaty. Furthermore, the participating countries enhanced their National Strategies on Plant Genetic Resources for Food and Agriculture to better manage PGRFA in emergency situations.

Box 2.7. Partnerships for emergency response in Kenya

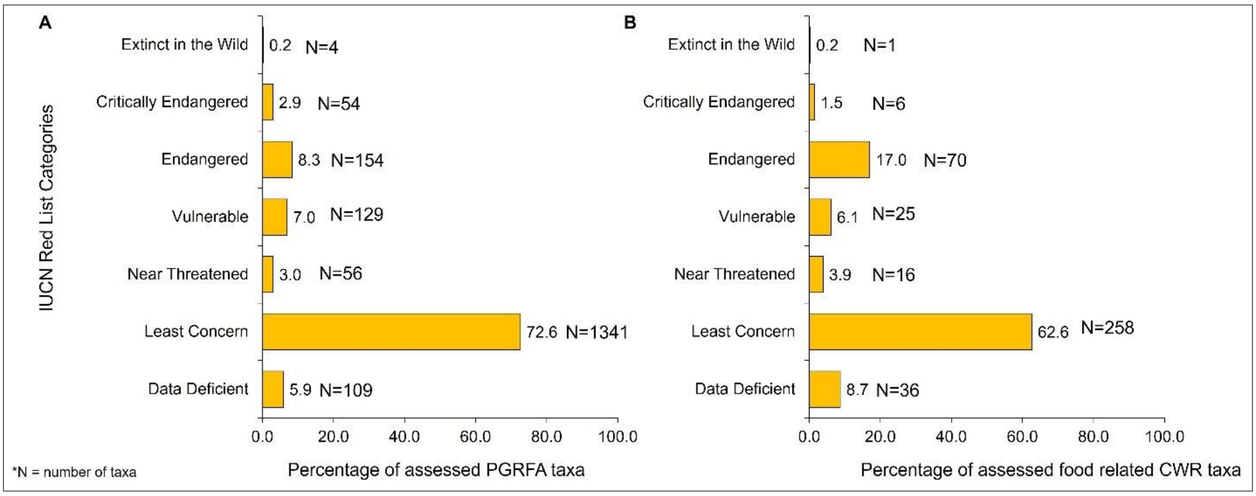
The government of Kenya, in partnership with various NGOs such as the Red Cross Society, has over the years provided emergency response aimed at assisting farmers to restore their crop systems after natural disasters particularly drought and flood. This has mainly involved the direct distribution of seeds and other planting materials, use of seed vouchers, and organizing of seed fairs to allow seed exchange. In one example, the Kenya Red Cross Society has in partnership with other government agencies, among them the Kenya Forestry Research Institute and Kenya Forest Service, provided over 1 million indigenous tree and fruit species to households in different counties. These have played a great role in income generation, restoring degraded areas, increasing national forest cover, increasing resilience of livelihoods to shocks and reduced risk from environmental degradation and climate change impact. As another example, the Kenya Red Cross Society with support from the British Red Cross Society provided 43 metric tonnes of DH 04 hybrid seeds as an El Nino preparedness. A total of about 21 000 households (approx. 126 000 beneficiaries) from Mwingi West, Mwingi Central and Kitui West sub-counties have benefited from this intervention. In addition to assisting farmers with seed and planting materials, support has also been offered through the supply of agrochemicals, land preparation, capacity building, and repair of irrigation infrastructure.

2.6 Threats and challenges to *in situ* conservation and on-farm management of PGRFA

2.6.1 Threats to *in situ* conservation and on-farm management of PGRFA

An assessment of the data from country reports showed that during the full reporting period 2012-2019, a total of 2 326 PGRFA taxa (including FV/LR, CWR and WFP) were reported as being threatened (defined as any crops, crop varieties, CWR or WFP that are no longer cultivated or no longer occur *in situ* in most of their previous areas of cultivation or occurrence),[30] which represents 37 percent of the total number of PGR taxa (6 204). However, the degree of threat to wild PGRFA is not specified. To complement this dataset, an analysis of the threat status of identified PGRFA and food-related CWR taxa was undertaken using IUCN Red List Categories and criteria (IUCN, 2022a), which is the world's most used tool for assessment of the extinction risk of species and data from the IUCN Species Information System[31]. Results showed that 1 847 PGRFA taxa (30 percent of total PGRFA taxa) and 412 food-related CWR taxa (36 percent of total food-related CWR taxa) have been assessed according to the IUCN Red List Categories. The majority of the assessed PGRFA and CWR taxa fall under the "Least Concern" category (Figure 2.10 A, B).

Figure 2.10. A) Threat status of PGRFA taxa; B) Threat status of crop wild relatives of food crops as assessed under the IUCN Red List Categories in increasing order of extinction risk



(Data source: IUCN Red List Species Information System; country reports)

Limited literature is available on the degree to which wild PGRFA are threatened. However, global assessments made to date on biodiversity (which *de facto* include wild PGRFA) unanimously agree that the world is facing an unprecedented biodiversity loss and that the rates of loss will accelerate if we continue with business as usual (RBG Kew, 2016; RBG Kew 2020; FAO, 2019a; IPBES, 2019a; IPBES 2019b; CBD, 2021). The State of the World's Plants and Fungi 2016 (RBG Kew, 2016) stated that 21 percent of 391 000 global plant species are threatened with extinction according to the IUCN Red List criteria (IUCN, 2022a). However, the Kew SoW Plants and Fungi 2020 (Antonelli *et al.*, 2020) estimated that 40 percent of plants species were then threatened with extinction, almost double the estimate in 2016. The IPBES Global Assessment Report on Biodiversity and Ecosystem Services (IPBES, 2019a;b) also states that nature is declining globally at unprecedented rates in human history and some 1 million species are threatened with extinction, specifically including many CWR species that are important for food and nutrition security and lack protection. It should also be noted that within the framework of the Strategic Plan for Biodiversity 2011-2020 of the UN Convention on Biological Diversity, none of its Aichi targets including Target 13[32] which aims at conservation of genetic diversity of PGRFA, have been achieved, noting that no indicators for evaluating *in situ* conservation of PGRFA for this target are available.

[30] Reporting guidelines for the preparation of country reports for the Third Report on the state of the world's plant genetic resources for food and agriculture.

[31] https://www.iucnredlist.org/assessment/sis#:~:text=The percent20IUCN percent20Species percent20Information percent20Service,on percent20The percent20IUCN percent20Red percent20List

[32] Aichi Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity

The SoW BFA (FAO, 2019a), which specifically addresses different components of genetic resources for food and agriculture, including PGRFA, reports on the decline of CWR species in specific places affected by climate change and also on the status of wild species used for food. The report also analyzed the extinction risk of species used as food, using the IUCN Red List Categories (IUCN, 2022a) and found 804 plants listed as threatened (either Critically Endangered, Endangered or Vulnerable; FAO, 2019a, p363). The two largest specific IUCN Red List assessment of CWR taxa in Europe assessed 571 CWR species and found 11 percent were threatened (Kell *et al.*, 2012), while in Mesoamerica assessed 224 CWR species and found 27 percent were threatened (Goettsch *et al.*, 2021). Ulian, *et al.* (2020) in their threat assessment of WFP reported that nearly 30 percent of 7 000 species are listed on the IUCN Red List of Threatened Species (IUCN, 2022b) and 11 percent of these, more than 234 species are threatened with extinction. Furthermore, Borelli *et al.*, (2020) undertook a review of threats to WFP and presented local threat assessments of 24 WFP with local communities in specific countries and found that only three species (*Butia eriospatha*, *Dipteryx alata* from Brazil and *Sideroxylon spinosum* from Morocco) belongs to IUCN 'Vulnerable' category, six were of the 'Least Concern' category and the remaining were unassessed.

In contrast to wild PGRFA, our knowledge of the threat status of FV/LR on-farm is very limited, although most countries reported that the diversity of FV/LR is declining (FAO, 2019a). This gap is recognized in the SoW BFA and calls for methodologies for measuring the extent of on-farm diversity. For example a study in India highlighted that more than 50 percent of documented FV/LRs in 17 study sites across five agroecologies in India were considered as threatened, suggesting that conservation interventions are required to prevent large-scale genetic erosion on-farm (Dulloo *et al.*, 2021a).

2.6.2 Causes of threats to *in situ* conservation and on-farm management of PGRFA

There were diverse threats to wild and cultivated PGRFA reported by countries (Table 2.6). The negative impact of climate changes, disasters (both natural and climate-induced), leading to an increased incidence and severity of biotic and abiotic stresses (heat stress, floods, disease, pests etc.), were reported by the majority of countries. Box 2.8 highlights the impact of climate change on local PGRFA in Eritrea.

Other challenges reported by countries included the replacement of traditional varieties with improved varieties, market pressure, land use and food habits change due to modernization and urbanization that threaten the diversity of FV/LRs. The migration of younger people to urban areas has led to an erosion in the knowledge in management local diversity on-farm. Moreover, some countries mentioned that also Indigenous Local Knowledge (ILK) and Traditional Knowledge (TK) may be threatened. For instance, in Uruguay, ILK and TK is reported to be decreasing among young people as they migrate from rural to urban areas. Similarly in the Philippines, changes in eating habits causing changes in diet, have led to a decrease in demand for landraces, therefore, resulting in an overall decrease in the cultivation of FV/LRs.

Table 2.6. List of threats to wild and cultivated PGRFA reported by countries

Threats to wild and cultivated PGRFA	No of countries
Climate change (severe droughts, cyclones, flooding, frequent bush fires) and natural disasters (seismic activity: earthquakes, volcanic eruptions)	32
Loss of cultivation skills and knowledge	21
Replacement of traditional varieties by improved varieties	19
Change in land use due to urbanization (deforestation, infrastructural development)	18
Overexploitation (e.g., transhumance and over-grazing, overharvesting, increased demand)	10
Invasive alien species and pest & disease outbreaks	9
Ecosystem degradation (wetland encroachment, soil depletion and erosion)	4
Lack of specialized equipment to aid cultivation, sowing, and harvesting	2
Large-scale mining	2

Box 2.8. Impact of Climate Change on local PGRFA in Eritrea

In recent years, climate change has begun to seriously affect production. Several pasture plant species growing wild and farmers' varieties of barley, sorghum, maize, finger millet and others are classified as endangered. Some varieties of these crops (sorghum, maize, finger millet) are sown in autumn. Should here be insufficient rainfall during autumn, theses varieties cannot be sown. In addition, farmers turned to sowing cash crops such as teff (*Eragrostis tef*) in cultivation areas that were previously planted with sorghum. This was seen in Adi quala administrative sub-region of the Central-Highland agro-ecological zone. Cultivation areas have also been significantly reduced for local, six row, barley varieties, Kuento and Dessie which require relatively high moisture comparing to other barley varieties. Grain legumes were the most affected mostly due to drought, and as a result, local broad bean and peas are threatened. With regard to wild PGRFA, it was noted that the frequency and abundance of several crop wild relatives are endangered. Wild leafy vegetables, important as source of food, are also endangered as the result of many climate change and overgrazing.

Overall, the reasons reported by countries are aligned to what has been reported in recent literature (Antonelli *et al.*,2020; Engels and Ebert, 2021; Gatto *et al.*, 2021; Khoury *et al.*, 2022), which attribute the major causes of genetic erosion of plant species to intensive, monocultural agriculture, use of improved varieties, overharvesting in the wild, habitat modification, habitat loss/deforestation, fragmentation and destruction of natural ecosystems; rapidly expanding residential and commercial developments; pollution; introduction of invasive species, loss of traditional food culture, overuse of herbicides and climate change.

2.6.3 Challenges to in situ conservation and on-farm management of PGRFA

Understanding the status of PGRFA *in situ* including identifying the threats and gaps in knowledge requires adequate tools and monitoring mechanisms in place to do so. A major challenge is the absence of adequate baselines and tools for long-term monitoring, acknowledged by several countries in their country reports [e.g., Indonesia, Republic of Moldova, the Netherlands, Papua New Guinea]. There is a general lack of data regarding the extent and distribution of PGRFA, due to limited financial resources, inadequate methodology to monitor temporal changes in the diversity of wild and cultivated species and inadequate documentation systems for existing information.

For wild plant species, the IUCN Red List of Threatened Species[33] provides the best tool to date for assessing species' extinction risk to inform conservation policies, planning and priority actions. It is increasingly being applied to PGRFA for the assessment of global extinction risks of species at different geographical scales (Blitz *et al.*, 2011; Goettsch *et al.*, 2021). The IUCN Red List Index[34] has been developed to monitor progress towards achieving such global biodiversity targets, but also for specific groups of biodiversity including plants and CWR (Brummitt, 2015). Using the IUCN Red List Categories and criteria are limited in that this only applies to threat assessment at the taxonomic (primarily species) level and not at the subspecies or ecosystem levels. Therefore, this tool cannot be used provide information on the conservation of entire CWR and wild food plant genepools. However, indication of species level threat is likely to be correlated with taxonomic threat and therefore does provide a crude indication of genetic diversity threat.

The World Database on Protected Areas[35], and the global database for other effective area-based conservation measures (OECMs) managed by UN Environment World Conservation Monitoring Centre (UNEP-WCMC) are the key tools used for assessing the area covered by protected areas and OECMs (which passively conserve wild PGRFA) to measure progress towards achieving Aichi Target 11, over the last decade (IPBES, 2019; UNEP-WCMC and IUCN 2020; CBD, 2021; CBD, 2022). The Protected Planet

[33] https://www.iucnredlist.org/
[34] https://www.iucnredlist.org/assessment/red-list-index
[35] https://www.protectedplanet.net/en

reports (UNEP-WCMC and IUCN, 2016; 2018, 2020, 2021) provide regular updates on the coverage of protected areas around the world.

For crop varieties, especially FV/LR, there is currently no globally accepted methodology for the assessment of the risk of extinction and genetic erosion (FAO, 2019a). The SoW BFA (FAO, 2019a) reported that diversity of FV/LR on-farm is declining leading to genetic erosion, but with little evidence to substantiate and quantify that decline. Long-term monitoring of diversity could be done by setting up a network of hotspot areas in centres of crop origin where baseline assessment of crops and their varieties could be conducted. The Platform for Agrobiodiversity Research has also developed a tool (Diversity Assessment Tool for Agrobiodiversity and Resilience)36 that allows to monitor crop and animal diversity at varietal and breed levels.

2.7 Indigenous Peoples and Local Communities in *in situ* conservation and on-farm management of PGRFA

The new Global Biodiversity Framework set global targets for living in harmony with nature and mitigating biodiversity loss. The importance of the rights of Indigenous Peoples (IPs) and Local Communities (LCs), and the associated knowledge held by them, is reflected directly in seven of the 23 targets adopted (CBD, 2022).

With regard to the *in situ* conservation of CWR and WFP a number of countries highlighted the roles of IP ad LCs, among these: Cameroon, Namibia, South Africa, Zambia (Africa); Canada, Costa Rica, Cuba, Guyana, Nicaragua (the Americas and the Caribbean); and Bangladesh (Asia). While most of the countries presented partial views regarding IPs, Canada provided a much deeper review of the development, research, national policies of indigenous knowledge. To this effect, Canada launched the Indigenous Agriculture and Food Systems Initiative (2018-2022/23) that includes programmes and projects such as “Indigenous Pathfinder”, supporting the indigenous people to enter the Agrifood sector, and the “Indigenous support of awareness office” that provides awareness resources (dissemination material on plant genetic resources and related traditional knowledge) for IPs.

The analysis of the country reports from an ILK perspective in relation to wild PGRFA identified two emerging topics:

- Legal Framework for Access and Benefit Sharing (ABS) on Genetic Resources and Associated ILK. In Africa, Namibia emphasized the importance of TK by mainstreaming it into national plans in line with the Nagoya Protocol and the international agenda. South Africa reported that its National Strategy for Plant Conservation (implemented in 2015) is well aligned to the Global Strategy for Plant Conservation, with a specific focus on CWR and the associated traditional knowledge. Zambia’s Act of 2016 includes a reference to “PGR and expressions of folklore” as a mean to protect WFP and other PGR. In Latin America, Costa Rica has further addressed ABS legal framework in the Biodiversity Law 7788 and is aware of the need to further strengthen TK on PGR stakeholders. In Asia, Bangladesh developed a draft “Biodiversity and Community Knowledge Protection Act”, which highlights the country’s concern on preserving TK on PGR, including CWR/WFP. All these regulations seem to be related to the implementation of the Nagoya Protocol on ABS about genetic resources and associated traditional knowledge, ratified by 138 countries.
- Ethnobotanical studies. Canada reported that ethnobotanical studies have greatly contributed to understand the sustainable use of wild PGRFA by indigenous and local people. The report mentioned 550 different species of plants used in the traditional diet of Indigenous People, including 75 species for food, 52 for beverages, and 400 for medicinal use. Similarly, Nicaragua reported 293 wild and domestic species that are used by afro-descendant, Miskito, and other indigenous groups. Guyana also mentioned that CWR are quite common for indigenous people.

An interest in assessing ILK/TK was reported in Africa (Benin, Cameroon, Ghana), the Americas (Brazil, Canada, Costa Rica, Uruguay), Asia (Mongolia, Nepal, Philippines) and Middle East (Jordan, Lebanon). Some countries highlight the enhancement and acknowledgement of ILK/TK (Benin, Brazil, Lebanon) and

[36] https://www.datar-par.org

that it is necessary to document it as part of the evaluation/characterization as well as for the protection of landraces and local seeds and varieties (Brazil, Cameroon, Costa Rica, Jordan, Mexico, Mongolia, Nepal). Namibia, South Africa, Uganda, the United Republic of Tanzania (Africa), Nepal (Asia), and Cuba (Latin America) report that projects on *in situ* conservation on-farm have contributed to recognizing and maintaining TK associated with traditional/local seeds and landraces. Building a broad base of ILK/TK specific to PGRFA has been shown to have the potential to improve economic development by promoting the production, conservation, and consumption of PGRFA (CBD, 2021). For example, in Benin, markets and development of cotton commodity production was greatly strengthened when ILK/TK of middle-aged men is linked to its production. This was also seen in Cuba, where TK of local foods is believed to have a high-income generation potential.

Greater inclusion in the targeting women and youth was reported by a number of countries. A number of countries reported that projects undertaken in the past few years focusing on on-farm activities have targeted women. Several countries such as Albania, Estonia (Europe), Brazil, Cuba, Guatemala, Mexico, Peru, Uruguay (Latin America), Nigeria, the United Republic of Tanzania, Zambia (Africa) and Nepal (Asia) have emphasized the need to have gender equity or women and youth inclusion in on-farm conservation projects or programmes. Increased participation of youth may be linked to the economic value of crops (Nigeria) or to the education level of the young (especially men) who are interested in on-farm activities such as organic agriculture (Estonia, Portugal). In Nicaragua, women are also reported as plant breeders who develop varieties, yet no decrease/increase female trend has been identified.

Regulatory frameworks supporting ILK/TK and greater gender inclusion have been developed. For example the National Seed Policy of Uganda (2018) and the Traditional Knowledge Act of Namibia (2017) are regulatory frameworks that encourage both women participations, legitimize and strengthen of ILK/TK, which is gender disaggregated.

2.8 Changes since First and Second State of the World's PGRFA

The SoW1 and SoW2 reports (FAO, 1997; 2010) have laid emphasis on the need to develop specific conservation measures and tools for an effective and efficient conservation of wild and cultivated PGRFA and highlighted that more needed to be done for *in situ* conservation CWR in non-Protected areas. Since their publication, several key changes could be highlighted:

- Growing awareness about the importance and value of CWR as evidenced by the increased number of surveys and inventories reported by countries and number of articles published and grey literature relating to CWR in contrast with the limited inventories of WFP and FV/LR.
- The coverage of terrestrial protected areas increased from 20.2 million km^2 in 2012 to 22.4 million km^2 in 2019 (UNEP-WCMC and IUCN, 2020).
- OECMs have been introduced as a new concept (IUCN, 2018) for recognizing the conservation of biodiversity in non-protected areas and provides an opportunity for PGRFA conservation outside protected areas.
- Significant appreciation of the value and practical developments toward national, regional and international networks for agrobiodiversity conservation, which also ensure the conserved resources is available for farmer and breeder-based utilization.
- Major threats to PGRFA *in situ* remain unchanged from what has been reported in SoW2 (e.g., climate change, habitat modifications, invasive alien species and replacement of traditional with modern varieties).

2.9 Gaps and needs

Several gaps and needs for both *in situ* conservation of wild PGRFA and on-farm management and improvement of FV/LR have been reported by countries (Table 2.7). For instance, ten countries in Africa[37] mentioned the lack of capacity building programmes and activities for both farmers and government officers, and lack of coordination among stakeholders to maximize resources and interventions as major gaps and needs. In addition, lack of infrastructure together with human and financial resources required for inventory

[37] Benin, Botswana, Egypt, Eritrea, Madagascar, Mali, Nigeria, South Africa, Togo and Tobago, Zambia,

and characterization and monitoring of existing diversity of PGRFA remains an important constraint common in the region. In Asia, main gaps include lack of data and information, limited awareness, low interest of farmers towards on-farm conservation, lack of adequate markets and limited program and policy support. Similarly, in Europe, the gaps include lack of distribution, active management and characterization data, information and inventory of landraces, poor level of awareness and interest, as well as lack of policy, legislation and strategies for on-farm management of FV/LRs. In Latin America, all the gaps reported by the countries converge towards the need to increase financial resources, develop and lack of adequate markets and limited program and policy support.

Broadly, the specific policy needs include increased policy, legal and sustainable funding support for on-farm management, increased awareness, knowledge systems, farmers' involvement and support in data and information generation including human resource development for strengthening on-farm management and improvement for FV/LRs. In addition, participatory involvement of famers in field testing and evaluation and promoting linkages between genebanks and farmers and their community seed banks are important.

Table 2.7. Summary of gaps and needs outlined in country summative narratives

GAPS	NEEDS
Weak collaboration among key-stakeholders for conservation of CWR and WFP and on-farm management of FV/LR.	• Improved collaboration, through a consultation framework, between Departments of Environment, Forestry and Agriculture, and within them nature conservation authorities and genetic resources institutions for the joint development of management plans addressing FV/LR, CWR and WFP as well as systematic and coordinated monitoring status of these resources. • Integrated networks of national, regional and global *in situ* and on -farm conservation and promote integration of national, regional and global biodiversity and genetic resource conservation efforts. Strengthen linkages between actively conserved *in situ* CWR/WFP populations and FV/LR management sites to enable systematic coordination and reporting (e.g., Second GPA), foster stronger partnerships and mutual support, and integrate global, regional and national actions. • Monitoring networks in diversity hotspots in centres of crop origin and diversity to track the conservation sustained by family farmers and Indigenous Peoples. • Strengthened linkages among genebanks and protected areas authorities and farmers/ landowners in supporting of *in situ* conservation of CWR and WFP, and FV/LR management through targeted collecting missions by the NPGRC to ensure conserved population safety backups in genebanks, and provision of seeds for restoration and utilization purposes. • Improved cooperation with university staff, botanical gardens and other stakeholders including Provincial and Territorial governments to develop comprehensive inventories of PGRFA. • Linkages and cooperation with stakeholders including farmers and Indigenous people as an integral part of *in situ* conservation and on-farm management of PGRFA for a more collegiate and inclusive environment.
Access to and sharing of information on PGRFA.	• Improved access and benefit sharing among owners and users of genetic resources, especially when Traditional Knowledge is involved. • Easy access to specific information, such as occurrences of CWR and WFP in protected areas, OECMs, herbaria, genebanks, CSBs registries, botanic gardens of national, regional and global databases. • More efforts to make information easily accessible to the public.

	• Regional and international cooperation among countries with a relatively high level and specialized skills in CWR/WFP to share their expertise. • Establishment and support for national, regional and global inventories and networks for *in situ* conservation of CWR and WFP, and FV/LR management. • Updated information of available species to the national focal point particularly species relating to food and agriculture.
Insufficient financial resources and long-term funding.	• Creation of long-term financial investment in a well-coordinated manner for *in situ* conservation and on-farm management of PGRFA to ensure the sustainability of current conservation actions, possibly by governance and networking structures linking sites and management activities. • Increased funding to ensure complementarity between *in situ* and *ex situ* conservation. • Financial and in-kind incentives for *in situ* conservation, on-farm management and sustainable use of PGRFA inside and outside of protected areas and farmers' fields. • Increased government allocation of additional resources to CWR and WFP programmes to support *in situ* conservation activities, both through networked protected areas and OECMs. • Provision of direct benefits to farmers /owners of PGRFA.
Insufficient human resources and inadequate qualified personnel.	• Improved skills and knowledge concerning CWR, WFP and FV/LR classification and identification as a basis for practical field conservation. • Increased capacity of NPGRC and PA managers with training of staff on relevant survey methods and technologies and taxonomic identification. Provision of dedicated human resources to carry out comprehensive inventories and *in situ* conservation of PGRFA. • Enhanced capacity of farmers for on-farm management and crop improvement. • Enhanced national capacity of NPGRC staff for carrying out PGRFA characterization and breeding in the national agriculture research systems.
Lack of infrastructure.	• Developed and strengthened physical and social infrastructure / networking for promoting *in situ* conservation and on-farm management with designated linkages to *ex situ* conservation facilities for population backup and farmer/breeder use. • Support for the procurement of necessary equipment to carry out the surveys and inventories of FV/LR, CWR and WFP.
Lack of knowledge of conservation status of CWR/WFP and FV/LR and their coverage in protected areas and outside.	• Improved knowledge of gene pool concepts for less well studied crop gene pools. • Improved collaboration with IUCN to enhance: o Re-formulation of KBA designation to include globally important agrobiodiversity. o Reconsideration of IUCN protected area categories to add an additional category that focuses on genetic rather than species level conservation within protected areas. • Development of generic informatics tools that to facilitate conservation planning, and implementation of *ex situ* and *in situ* conservation of CWR, WFP and FV/LR. • Improved methodologies for threat assessment of genetic diversity. • Assessments of threat status of FV/LR and CWR/WFP species to focus the efforts of conservation, management and utilization.

	• Comprehensive surveys and inventories of CWR/WFP and FV/LR inside and outside protected areas, identifying populations / sites for complementary active *in situ* conservation of CWR/WFP diversity.
Limited access to seeds/planting material.	• Strengthened participatory research including PVS and PPB with farmers and improve linkages of genebanks with farmers and community seed banks. • Actively conserved *in situ* / on-farm genetic diversity that is available to potential farmers / breeders as that conserved *ex situ* in genebanks.
Lack of documentation.	• Needs surveys, inventories, and documentation of crop landraces • Improved awareness and knowledge on crop landraces • Characterization, evaluation and documentation on crop landraces, CWR and WFP
Lack of technology and monitoring framework to monitor changes.	• Development and use of appropriate technologies and frameworks for active management and monitoring wild and cultivated species populations.
Lack of awareness of the importance of PGRFA especially at the level of policy makers	• Development of policy briefs/statements on FVs/LRs, CWR and WFP value targeting key policy makers and decision makers. • Promotion of socioeconomic research that establishes the value of conservation and use of FVs/LRs, CWR and wild food plant diversity. • Mainstream information on FVs/LRs, CWR and WFP in sectoral policies and development plans. • Awareness raising among PA managers about the occurrences of CWR and needs for their conservation and their specific inclusion in management plans. • Awareness raising on FVs/LRs, CWR and WFP using social media, journalists. • Participate in environmental and biodiversity events (conferences, meetings) to raise awareness of the value to society of FVs/LRs, CWR and WFP diversity. • Including FV/LR, CWR and WFP knowledge in primary, secondary and tertiary curricula to improve appreciation of value to society of their diversity.
Lack of Farmers' interest, particularly among the young and new generation	• Enhanced involvement of farmers in field testing and evaluation of farmers varieties • Promotional support/ incentives to farmers, particularly focusing on youth and new generation of farmers for on-farm conservation • Awareness building to farmers and stakeholders on landraces
Lack of coverage of conservation of CWR/WFP and FV/LR within national strategies and action plans, country reports, and management plans, development plans and other programmes	• Mechanisms to motivate countries to develop national PGRFA strategies and Action plans for conservation and use, including CWR/WFP and FV/LR in a fully participatory manner involving all key national stakeholders. • Increased communication among National Focal Points of the CBD, Commission and Treaty to include the status of conservation and management of CWR/WFP and FV/LR in the National Biodiversity Strategic Action Plan (NBSAP), and other country reports.
Lack of Market Support	• Support for the promotion of FVs/LR through market methods • Market development for diversity mixtures and FV/LR • Support for buy back guarantees for FVs/LRs

Lack of adequate policies, legislation and laws governing the *in situ* / on-farm conservation of PGRFA	• Review of the policy and regulatory framework (policy reforms) on *in situ* conservation /on-farm management to define and streamline the institutional mandates of the various agencies bearing responsibility in biodiversity and PGRFA conservation. • Development of clear policy statements on CWR in the various policy documents and development Conservation Action Plans. • Prioritization of activities on *in situ*/ on-farm surveys/inventories of PGRFA in the Plans of the Departments of Agriculture, to enable resource allocation and monitoring of such activities. • Promotion of the use of *in situ* conserved CWR/WFP and on-farm diversity to demonstrate value of CWR/WFP and FV/LR diversity to society. • Encouragement by governments to take policy, legislative and regulatory measures on PGRFA to ensure their systematic conservation and facilitate their use.

2.10 Conclusions

There has been progress in recent years in areas such as surveys and inventories, community seed banks, and protected areas coverage, as well as in regions (Europe, southern Africa) concerning *in situ* conservation and on-farm management. Countries, however, highlighted significant gaps and needs that remain a major bottleneck in undertaking effective *in situ* conservation and on-farm management of PGRFA.

- Greater efforts are required at the national level for the effective conservation of wild PGRFA in *in situ* in both protected areas and outside of formal protected areas. This should include establishing wild PGRFA reserves within protected areas and OECMs, and the development and implementation of *in situ* management plans for wild PGRFA.

- Of major importance is the need for greater technical capacities, especially in plant taxonomy, for national stakeholders, including protected area managers. Aligned with is the need to monitor wild PGRFA diversity more systematically in order to assess changes over time and to raise awareness of their importance for food security and nutrition.

- A more comprehensive and precise understanding of the state of FV/LR use and conservation is necessary based on their contribution to local food security, nutrition and local cultures. These PGFRA possess traits for environmental resilience and adaptation to local conditions in low input production systems. In this regard, monitoring of the levels and use of this diversity, including in centres of crop domestication and diversification, is essential to understand changes over time as well as the management and use of these PGRFA by family farmers, Indigenous Peoples and Local Communities.

- As emphasized by countries, more efforts and resources are required to integrate complementary *in situ*/on-farm initiatives with *ex situ* conservation. Countries reported limitations in funding, knowledge, capacities and methodologies regarding documenting, collecting and protecting wild and cultivated PGRFA, as well as for ensuring that these resources are safeguarded in *ex situ* storage.

- Countries highlighted the importance of approaches that integrate contributions from various stakeholders, to promote the contribution of farmers, protected areas managers, youth educators and other stakeholders in the conservation and use of PGRFA. The creation or enhancement of short production-consumption chains and niche markets should be fostered to promote the sustainable use of local PGRFA.

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Chapter 3. The state of *ex situ* conservation

3.1 Introduction

Plant genetic resources for food and agriculture (PGRFA) are increasingly threatened by urban encroachment into farmland and forests, unsustainable use of natural resources, environmental changes such as climate change and the emergence of novel pests and diseases, the promotion of genetically uniform varieties, changing patterns of human consumption, and inadequate legislative and policy frameworks. Efforts to conserve PGRFA aim to harness their diversity to enhance food security and nutrition. These efforts have a strong focus on *ex situ* conservation, i.e. safeguarding PGRFA outside their natural or cultivated environments. In addition to providing a controlled environment in which diversity can be safeguarded, e*x situ* conservation facilitates targeted access to crop diversity by plant breeders, researchers and other users needing to obtain specific genotypes and traits. It complements *in situ* conservation in the natural or cultivated habitats where the respective PGRFA acquired their specific, and often unique, characteristics.

The conservation methods used in genebanks depend on the biological nature of the accession in question and can include storage of orthodox seed at low temperatures, maintenance of living plants in fields or greenhouses, storage of plant materials under slow growth conditions *in vitro* or storage of cryopreserved plant materials. These methods all involve the following elements: identification of accessions; maintaining viability; maintaining genetic integrity during storage and regeneration; maintaining germplasm health; ensuring the physical security of collections; promoting the availability, distribution and use of germplasm; ensuring the availability of information; and proactive management (FAO, 2014) , which includes the development of risk-management plans, standard operating procedures and quality-management systems (CGIAR Genebank Platform, 2021). FAO has developed international standards and guidelines (FAO, 2014; 2022 a,b,c) to support *ex situ* conservation .

The importance of *ex situ* conservation of PGRFA is highlighted by its mention in Target 2.5 of the Sustainable Development Goals (SDG) (FAO, 2023a): “By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.” Countries’ annual reporting obligations under this target include providing data for Indicator 2.5.1a: “Number of plant genetic resources for food and agriculture secured in medium- or long-term conservation facilities.”

This chapter addresses *ex situ* conservation efforts worldwide. The focus is predominantly on genebanks, but the role of botanic gardens is also discussed, as many of them conserve PGRFA, including crop wild relatives (CWR) and wild food plants (WFP). The structure and elements of *The Second Report on the State of the World’s Plant Genetic Resources for Food and Agriculture* (SoW2) (FAO, 2010) are followed in order to facilitate comparisons between the two reports.

The assessment of the status of *ex situ* conservation is based mainly on data provided by countries to FAO through the World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS) Reporting Tool (FAO, 2022a) as part of their reporting on progress in the implementation of the Second Global Plan of Action for Plant Genetic Resources (Second GPA) and on SDG Indicator 2.5.1a (FAO, 2022b). It also draws on data provided by regional and international research centres, on country narrative reports (FAO, 2019a) and where applicable on the wider literature. Where feasible, comparisons with the previous State of the World reports are highlighted. A brief summary is provided at the end of each section. Data on *ex situ* base collections discussed in this chapter are based on those reported for SDG Indicator 2.5.1a to FAO in 2022 and include national, regional and international genebank holdings as of the end of 2021, unless otherwise specified.

3.2 Overview of *ex situ* collections

Germplasm holdings of over 5.8 million accessions are conserved under medium- and long-term storage conditions in base collections of 827 national genebanks in 115 countries, four regional and 13 international genebanks (Figure 3.1). They represent a 17 percent increase over the base collections of the same genebanks in 2009. The biological status of the germplasm conserved is documented for 71 percent of the accessions reported; about 1 427 000 are farmers' varieties/landraces, 716 000 wild materials, of which approximately 541 000 accessions are crop wild relatives (CWR) and 45 000 are wild food plants. The remaining accessions are improved varieties and breeding materials. The country of origin is known for approximately 69 percent of the accessions. The crop groups with the largest numbers of accessions conserved are the major food crops, including cereals, pulses, roots and tubers and vegetables. The vast majority (79 percent) of accessions are conserved as seed, followed by conservation in the field and *in vitro*.

At the end of 2021, approximately 35 percent of all *ex situ* holdings were safety duplicated, a significant increase from 10 percent in 2015. More than half of the safety duplicated holdings were deposited at the Svalbard Global Seed Vault (SGSV), demonstrating that countries are taking increasingly advantage of the SGSV as a long-term black-box storage facility. However, there is still a need to provide a sustainable, long-term cryo-storage backup for species that are vegetatively propagated or produce recalcitrant seeds.

Degree of uniqueness is estimated to be around 38 percent of total holdings. Continued rationalization efforts have resulted in some progress made at country level and by international genebanks with regard to unwanted duplications. However, redundancy within and among collections has remained poorly documented overall and requires continued attention. There are a number of species that are conserved in only one or very few genebanks, which is a concern, given that failure to conserve the material in those genebanks could mean a complete loss.

During 2011 – 2019, almost 250 000 samples were collected by 366 institutes in 87 reporting countries. A number of countries reported having strategies for targeted collections, including addressing missing genetic diversity and eco-geographic coverage, incomplete coverage of the targeted taxa, including CWR, and trait-specific gaps, such as resistance to pests and diseases. Although acquisition of germplasm through collecting has improved, many genebanks could still benefit from more and more targeted collecting based on gap analyses. Despite renewed interest in the acquisition of CWR, collecting wild species often fails due to the unavailability of staff specialized in relevant disciplines, such as taxonomy and phenology.

Germplasm health issues are becoming increasingly important in the conservation, distribution and use of PGRFA. The increased movement of germplasm within and between countries and continents also enhances the potential spread of pests and diseases. Overall, the awareness of these issues as well as the actual management of germplasm-health issues seem to have improved during the reporting period. However, a number of national genebanks still lack adequate human and financial resources to properly monitor germplasm health, which greatly affects germplasm exchange.

Approximately one third of the accessions reported by countries have been regenerated between 2012 and 2019, while 24 percent are in need of regeneration, which remains one of the main challenges for many countries and genebanks. In particular, the regeneration of CWR and out-crossing species is problematic for many genebanks.

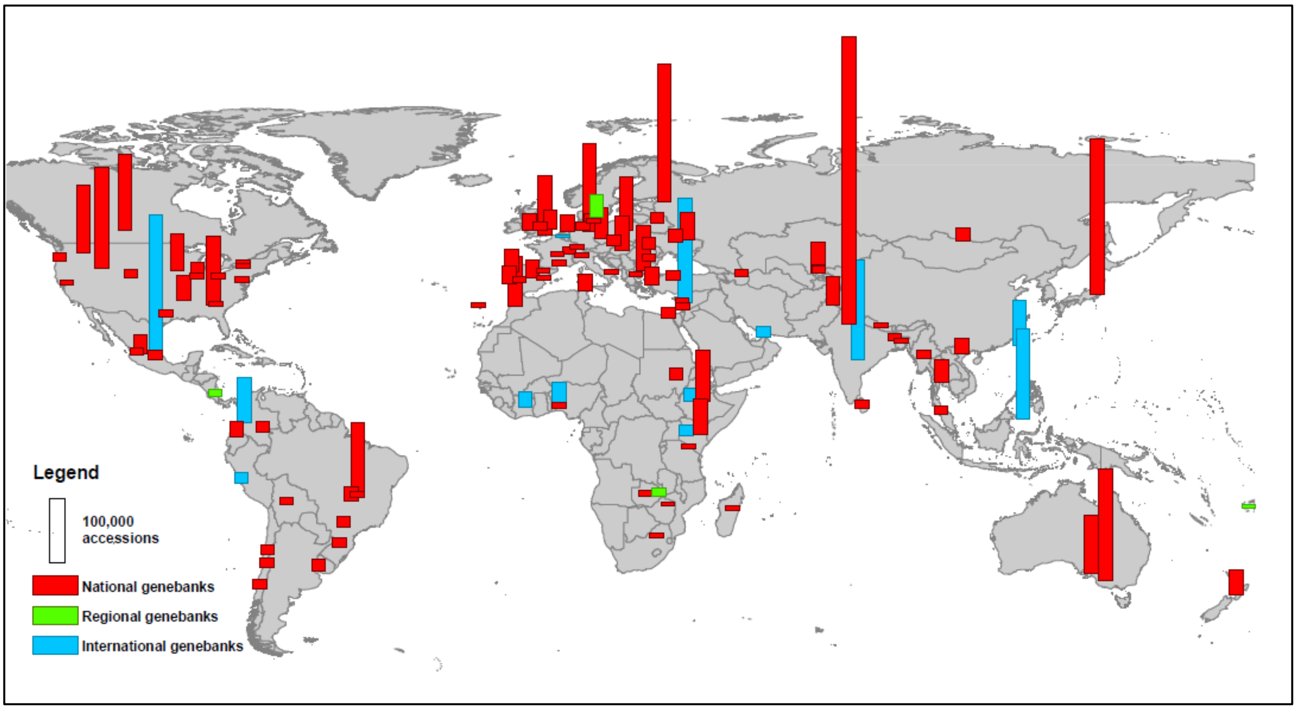
Although documentation has been highlighted as an essential part of genebank management for many years, and despite the support provided in this regard, including by the Crop Trust, many countries still lack genebank management information systems and thus struggle to document passport and other genebank-management data. With the increasing availability of improved open-source software for genebank data management, such as the new Grin-Global Community Edition, the situation shows signs of improvement. Standardized passport data and Data Object Identifiers (DOIs) are increasingly being applied for germplasm exchange and for cross-referencing germplasm in publications. Greater efforts are still needed to train data specialists and genebank managers to adopt and use these improved systems.

National genebanks in 87 countries distributed almost 1.3 M accessions between 2012 and 2019, with well over 90 percent made within the respective country. The main recipients included national agricultural research centres, farmers, NGOs and the private sector.

As of 31 December 2021, materials under the Multilateral System of Access and Benefit Sharing (MLS) of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) totalled over 2.3 million accessions reported by 76 contracting parties and 15 regional and international centres (Article 15 bodies). The MLS materials of the contracting parties and Article 15 bodies account for about 54 percent of their total *ex situ* holdings as reported for SDG Indicator 2.5.1a.

The number of botanic gardens in the world is more than 3 000, about 20 percent more than in 2009. Ten countries have more than 100 botanic gardens each. At least 350 botanic gardens in 74 countries have associated seed banks. The expansion of seed banks in botanic gardens has led to an increase in research on the seed physiology of wild species, an essential component of determining seed-storage protocols.

Figure 3.1. Geographical distribution of national genebanks holding more than 6 000 accessions,[38] regional genebanks and international genebanks



3.3 Acquisition of germplasm

Collecting germplasm in the wild or from farmers' fields is by default the most important means of obtaining genetic diversity for *ex situ* conservation. Past collecting efforts were frequently undertaken to obtain regional coverage of a given crop genepool and to capture crop diversity at large. However, this approach has changed over the years, and there is now a clearer focus on collecting taxa that are missing from given collections, from areas where target species have not yet been collected, and filling trait-specific gaps.

3.3.1 Germplasm acquired through collecting

Targeted collecting based on gap analyses

Gap analysis has become an important tool for planning targeted collecting missions to fill gaps that can't be filled by accessing material from other genebanks (Ramirez-Villegas *et al*., 2010, 2020). The need for

[38] The Nottingham Arabidopsis Stock Centre is not included. *Arabidopsis thaliana* is widely used as a model species for plant biology research. In 2000, it was the first plant to have its genome sequenced.

targeted collecting is reported for 483 genera and 174 mixed groups[39] in 326 genebanks in 89 countries (Table 3.1). Two hundred and sixty-nine genebanks in 79 countries are reported to have a strategy in place for identifying gaps in their collections, covering a total of 452 genera and 154 mixed groups. Of these, 168 genebanks in 61 countries also have a strategy in place for targeted collecting the missing diversity, covering a total of 423 genera and 111 mixed crop groups. Eighty-one genebanks in 35 countries[40] reportedly lack both a strategy for the identification of gaps and a strategy for targeted collecting (covering a total of 119 genera and 26 mixed groups).

Incomplete coverage of the targeted taxa, including CWR, and incomplete ecogeographical coverage are among the most frequently reported gaps in genebank collections, applying to 66 percent and 62 percent of collections, respectively[41]. Farmers' varieties/landraces are, however, relatively well collected: gaps in these groups are reported for only 32 percent of the conserved crops[42]. Gaps in the conservation of biotic and abiotic stress resistance traits are reported for 41 percent of collections, leaving room for further collecting but also for greater use of the available diversity for crop improvement.

The methodology most frequently used to identify gaps is reported to be comparing stored material against geographical references. This method was used for almost 70 percent of the 2 608 taxa or groups of taxa for which gaps have been identified. Other frequently used approaches compared existing collections with the mandate of the organization or genebank.

Table 3.1. Types of gaps in *ex situ* collections

	Total number	*Ex situ* collection gaps (%)			
		Incomplete coverage of targeted taxa, including missing crop wild relatives	Missing known farmers' varieties /landraces or historical varieties	Incomplete ecogeographical coverage	Incomplete biotic and abiotic stress resistance coverage
Genera	483	64	32	59	47
Mixed groups	174	72	33	73	26
Genebanks	326	70	55	62	45
Countries	89	93	79	85	65

Other motivations for collecting

A number of countries report the need to increase the genetic diversity in collections, either from a conservation[43] or a breeding perspective[44] (including the need for specific traits or characteristics). Jordan reports re-collecting accessions that were collected in farmers' fields ten or 20 years previously in order to gather newly adapted genetic diversity. Tajikistan reports collecting materials to replenish accessions with low viability. The loss of accessions from collections is also mentioned.[45] A few countries report specifically on wild species. Armenia reports collecting threatened wild species. Belarus expresses concern about not being able to represent wild species adequately in its collections. Brazil reports collecting wild species of groundnut. Botswana reports collecting wild species in general. Egypt indicates that 1 percent of its holdings are wild species. France reports that 11 of its botanical gardens conserve wild species. Guyana mentions that

[39] Mixed groups include more than one genus or crop group.
[40] Bhutan, Botswana, Brazil, Chad, Colombia, Costa Rica, Cuba, Cyprus, Ecuador, Estonia, Ethiopia, Germany, Ghana, Iran (Islamic Republic of), Kyrgyzstan, Madagascar, Mexico, Myanmar, Namibia, Norway, Panama, Papua New Guinea, Peru, Philippines, Poland, Portugal, Republic of Moldova, Senegal, Serbia, Spain, Sri Lanka, Togo, Trinidad and Tobago, United Kingdom, Uruguay.
[41] Calculated as the weighted averages of genera and mixed groups under Table 3.1.
[42] Same as above.
[43] For example, Azerbaijan, Brazil, Canada, Czechia, France, Latvia, Lebanon, Myanmar, Niger, Norway, Philippines, South Africa, Zambia.
[44] Azerbaijan, Brazil, Chile, Poland.
[45] Guyana, Papua New Guinea, Philippines, Romania, Sweden, Tajikistan, and Trinidad and Tobago.

it has added a wild species of cassava to its collection. Hungary reports collecting wild species used as food plants. Portugal reports that more attention has been paid to wild species in specific ecological areas.

Global collecting efforts

A total of 249 920 collected samples, belonging to 1 216 genera and 3 121 species from 167 botanical families, are reported by 366 institutes in 87 countries (Table 3.2). Collecting efforts were significantly higher during the second reporting period (2014 to 2019) than during the first (2012 to 2014). Additionally, 39 percent of the samples collected during the 2012 to 2014 period were added to medium- and/or long-term storage facilities.[46] During the 2012 to 2019 period, 31 240 samples were collected annually.[47]

Table 3.2. Summary of collecting activities 2012 to 2019

Countries and taxa	Reporting periods		Total
	January 2012 to June 2014	July 2014 to December 2019	January 2012 to December 2019
Countries	61	79	87
Collected taxa and samples			
Collected families	119	159	167
Collected genera	598	1 112	1 216
Collected species	1 234	2 717	3 121
Collected samples	49 909	200 011	249 920
Average collected samples per year	19 964	36 366	31 240
Average samples per country and year	327	460	359

Collected samples by crop groups

A summary of the distribution of the collected samples across crop groups is presented in Table 3.3. The crop group with the highest number of collected samples is cereals, which account for 29 percent of all collected samples, followed by vegetables, pulses, fruit plants, oil plants, forages, and roots and tubers. The remaining crop groups have fewer than 10 000 samples each, with sugar crops, nuts and material plants (including species that provide timber, other construction materials, charcoal, firewood and rubber), each having fewer than 1 300 samples.

Comparing these data with those presented in the SoW2 shows that there has been an increase in the percentage of samples of vegetables collected (+0.3 percent) and of fruit and nut plants[48] (+5 percent). Similarly, a greater percentage of collected samples were reported for oil plants (+4 percent), roots and tubers (+3 percent) and fibre plants (+3 percent). It is noteworthy that herbs and spices (including aromatic plants) and medicinal and stimulant plants together accounted for 5 percent of all the collected samples, an increase for 3 percent relative to the figures reported in the SoW2. Collection of pulses (or food legumes) dropped by 7 percent, forages by 8 percent, and cereals and pseudo-cereals[49] by 5 percent. These results show a greater interest and effort overall to collect fruits and nut plants, oil plants, fibre plants, and roots and tubers.

[46] Data on percentage of collected samples successfully stored under medium- or long-term conditions were no longer requested during 2014-2019.

[47] The Sow2 reported about 20 000 samples per year collected. This figure cannot be fully compared with the present data in view of the discrepancies in the number of and countries reporting.

[48] Fruit and nut plants were grouped together in the SoW2.

[49] Cereals and pseudo-cereals were grouped together in the SoW2.

Table 3.3. Distribution of collected samples by crop group 2012 to 2019

Crop group				Crop wild relatives			Wild food plants		
	Species, number	Samples, number	Samples, percent	Species, number	Samples, number	Samples, percent	Species, number	Samples, number	Samples, percent
Cereals	101	73 097	29	73	2 236	18	2	13	0
Vegetables	364	30 981	12	126	1 968	16	125	2 502	47
Pulses	100	24 936	10	62	1 050	8		244	5
Fruit plants	364	24 444	10	70	1 076	9	89	1 917	36
Forages	456	17 016	7	163	2 238	18			
Oil plants	35	15 492	6	8	135	1	2	104	2
Roots and tubers	68	11 761	5	34	756	6	3	18	0
Fibre plants	51	10 154	4	10	80	1			
Ornamentals	555	8 058	3	26	65	1			
Herbs and spices	184	4 968	2	36	246	2	49	386	7
Stimulants	20	3 892	2	3	203	2			
Medicinal plants	540	3 699	2	37	130	1			
Pseudo cereals	29	2 315	1	8	67	1	5	161	3
Material plants	75	2 057	1	2	3	0			
Sugar crops	8	1 284	1	6	153	1	1	1	0
Nuts	20	1 138	1	5	12	0	5	10	0
Other	151	14 628[a]	6	42	2 192[b]	17			
Total	**3 121**	**249 920**	**100**	**711**	**12 610**	**100**	**281**	**5 356**	**100**

[a] Mixed aggregations (13 321 samples), wild flora (1 237 samples) and unspecified taxa (47 samples).
[b] Unspecified taxa (1 980 samples).

Samples collected by region

Collecting activities in the different regions and subregions of the world, as reported by countries, are presented in Table 3.4. Asia is the region with the most collecting activities (54 percent of the total number of samples – only slightly less than the 54 percent reported in the SoW2). Eastern Asia has by far the most collected samples, with 46 percent of the total samples collected in Asia and 25 percent of those collected worldwide. Latin America and the Caribbean reports a total of 50 982 samples or 20 percent of the global total. Similar numbers of samples were collected in Europe and sub-Saharan Africa, in each case around 10 percent of the global total.

Table 3.4. Regional and subregional breakdown of sample collection figures, 2012 to 2109

Regions and subregions	Countries, number	Species, number	Samples, number	Samples, percent	Crop wild relatives		Wild food plants	
					Species, number	Samples, number	Species, number	Samples, number
Northern Africa	4	229	4 669	1.9	29	309	19	83
Northern Africa	4	229	4 669	1.9	29	309	19	83
Sub-Saharan Africa	21	389	24 613	9.8	57	636	27	383
Eastern Africa	9	335	13484	5.4	48	408	23	371
Middle Africa	2	3	344	0.1				
Southern Africa	3	46	546	0.2	4	8	5	9
Western Africa	7	72	10239	4.1	9	220	1	3
Northern America	1		4 000	1.6				
Northern America	1		4 000	1.6				
Latin America and the Caribbean	15	790	50 982	20.4	78	1 495	41	1 892
Central America	5	636	24 988	10	51	359	28	788
Caribbean	2	92	583	0.2	3	27	2	2
South America	8	133	25 411	10.2	25	1 109	11	1 102
Asia	24	1 616	134 154	53.7	476	6 011	166	1 820
Central Asia	3	50	2 506	1	11	163	5	79
Eastern Asia	3	63	61 577	24.6	8	1 494	1	343
South-eastern Asia	4	133	21 656	8.7	3	199	2	64
Southern Asia	7	1 069	39 766	15.9	185	1 824	115	988
Western Asia	7	577	8 649	3.5	298	2 331	54	346
Europe	20	793	26 309	10.5	179	3 899	61	765
Northern Europe	5	119	1 357	0.5	30	138	9	22
Eastern Europe	5	452	4 973	2	78	419	29	146
Southern Europe	6	413	15 487	6.2	106	1 212	34	528
Western Europe	4	46	4 492	1.8	9	2 130	5	69
Oceania	2	8	5 193	2.1	2	260	3	413
Melanesia	1	8	718	0.3	2	207	3	413
Australia and New Zealand	1		4 475	1.8		53		
Total	87	3 121	249 920	100	711	12 610	281	5 356

Samples collected by country

At the county level, China (59 847 samples), Mexico (22 925), India (15 519), Brazil (9 169) and Ethiopia (7 611) had the highest number of collected samples. Nine counties[50] report having collected the germplasm of more than 150 species. The four countries collecting the most interspecific diversity were India (842 species), Mexico (635), Cyprus (339) and Poland (248).

The genera collected by the largest number of countries include *Zea* (50 countries), *Solanum* (48 countries), *Phaseolus* (41), *Capsicum*, *Cucurbita* and *Cucumis* (38 countries each) and *Allium* and *Vigna* (37 countries each). *Echeveria* and *Solanum* were the two genera with the highest number of collected species (77 and 76 species, respectively), followed by *Allium* (58 species), *Tillandsia* (50), *Trifolium* (46) and *Vicia* (40). All species of *Echeveria* and *Tillandsia*, which are mainly used for ornamental purposes, were collected in

[50] Belarus, Cyprus, India, Iran (Islamic Republic of), Kenya, Mexico, Poland, Portugal and Spain, .

Mexico, whereas the two legume genera *Trifolium* and *Vicia* were collected in 25 and 34 countries, respectively.

A number of countries received support for collecting missions through international projects, especially for the collection of CWR. The organizations providing this support included the Global Crop Diversity Trust (Crop Trust) (Box 3.1), the Millennium Seed Bank (MSB) (e.g. in South Africa), the Darwin Initiative (in Madagascar and Zambia), FAO (Technical Cooperation Programme projects in Armenia, Lebanon, Namibia and Zimbabwe), the Islamic Development Bank (in Namibia), the Global Environment Facility (GEF) (in Ecuador), the United Nations Development Programme (UNDP) (in Lebanon); the International Fund for Agricultural Development (IFAD) (in Namibia), the European Union (EU) (also in Namibia), the United States Agency for International Development (USAID) (in Kenya) and CGIAR centres (e.g. the International Crops Research Institute for the Semi-Arid Tropic [ICRISAT] in Niger, the United Republic of Tanzania and Zimbabwe; the International Center for Agricultural Research in the Dry Areas [ICARDA] in Lebanon; the International Rice Research Institute [IRRI] in the United Republic of Tanzania; the International Maize and Wheat Improvement Center [CIMMYT] in Azerbaijan; Bioversity International in Papua New Guinea and South Africa; and the World Vegetable Center [WorldVeg] in Madagascar). Many of the CGIAR centres have also conducted MSB carried out collecting activities in 12 countries, collecting a total of 418 samples of 176 CWR taxa (Elinor Breman, personal communication). Collecting CWR has been supported by new tools and reference materials for conservation planning (see Magos Brehm *et al*., 2019; Engels and Thormann, 2020).

Collecting crop wild relatives and wild food plants

CWR are wild taxa closely related to crops. They continue to evolve in the wild and as such are locally adapted and represent a potential source of genes and alleles for enhancing crop resilience to changing environmental conditions and human needs. The genetic diversity of CWR is threatened by climate change and the occurrence of natural calamities, changes in land use and agricultural practices, overexploitation or excessive use, nitrogen deposition, desertification, etc. (FAO, 2017). Additional factors contributing to the genetic erosion of CWR are the lack of knowledge about their biology, the absence of adequate infrastructure for their *ex situ* cultivation, and inadequate funding for their conservation. WFP consist of a wide range of different species, which often play an important role in the nutrition and food security of many rural communities, particularly during periods of food scarcity. WFP are often closely related to domesticated species. They may therefore contribute to the improvement of crops and their domestication may benefit from crop genepools. WFP are threatened by overharvesting, agricultural intensification, the expansion of the agricultural borders, increased pesticide use and removal of trees.

Most reporting countries carried out targeted collecting of CWR and WFP. Sixty-two countries report collecting a total of 12 610 samples of CWR belonging to 711 distinct species. Fifty countries report collecting a total of 5 356 samples of WFP belonging to 281 distinct species. In general, most of the collected WFP species are either vegetables (47 percent of total samples) or fruit plants (36 percent). The average numbers of samples collected per species is similar for CWR and WFP (18 and 19, respectively), which is well below the average number of samples per species for all collected germplasm materials (80 samples per species).

Countries that collected over 700 CWR samples during the reporting period include Germany (2 120 samples), India (1 587 samples from 162 species), Cyprus (1 016 samples from 233 species), China (881 samples from four species) and Brazil (715 samples from four species).

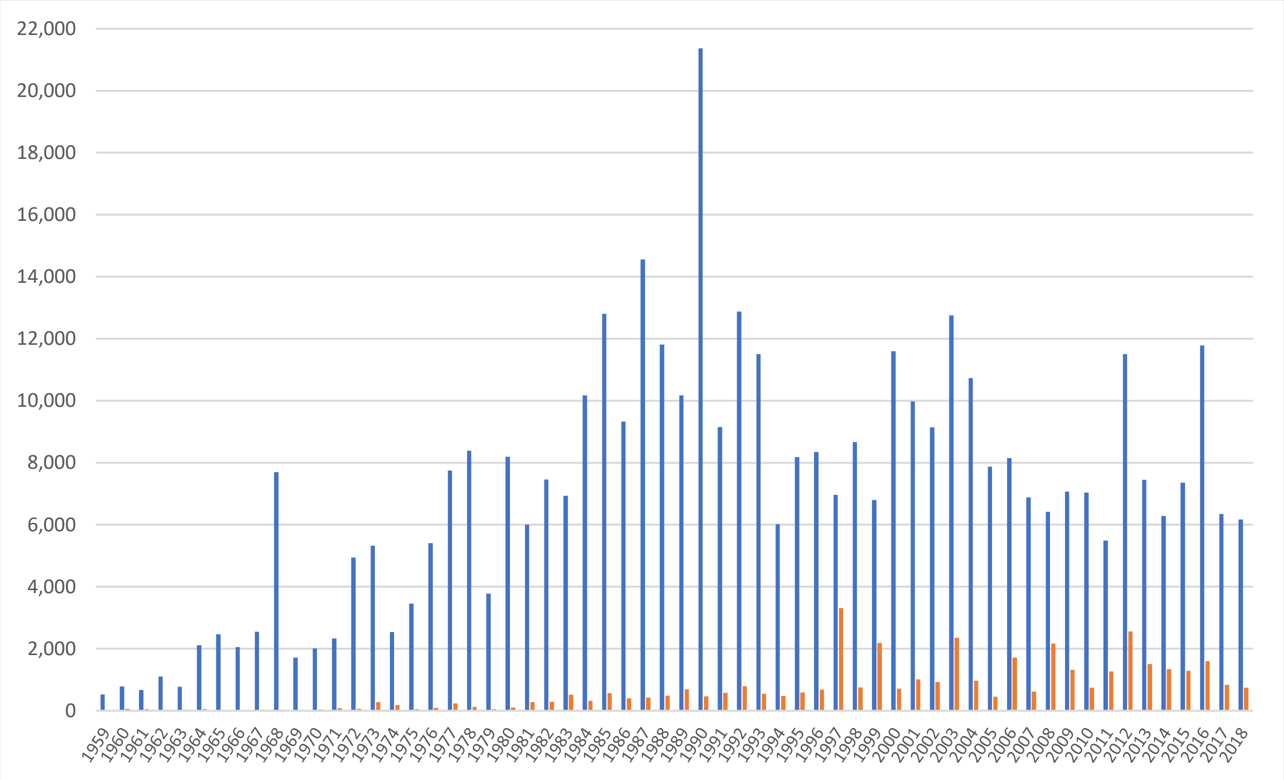
The genera represented by the highest number of collected CWR samples include *Solanum*, with 966 samples or 8 percent of all collected CWR samples, *Oryza* (687 samples), *Aegilops* (541 samples), *Lactuca* (489), *Trifolium* (467), *Manihot* (408), *Medicago* (385), *Actinidia* (335), *Lathyrus* (299) and *Vicia* (288). These ten genera accounted for 39 percent of all collected CWR samples. *Allium* was collected in the largest number of countries (18), followed by *Solanum* (15), *Trifolium* (14), *Aegilops* and *Medicago* (13 each); *Avena*, *Lathyrus* and *Vica* (12 each), and *Melilotus*, *Malus* and *Hordeum* (11 each).

Fifty-one countries report collecting a total of 5 517 WFP samples from 281 species, with Mexico ranking first with 788 samples from 28 different species. India ranked second with 791 samples from 100 species, followed by Chile (555 samples from three species); Ecuador (535 samples from six species), Papua New Guinea (413 samples from three species of *Musa*), Japan (343 samples of wild soya) and Spain (339 samples from 13 species).

Genera with the highest number of collected WFP samples include *Physalis* (669 in four countries), *Lactuca* (458 in nine countries), *Aristotelia* (437 samples of *A. chilensis,* all collected in Chile), *Musa* (417 samples total from four wild species, collected in Papua New Guinea and India), *Vaccinium* (390 samples from five berry-shrub species, collected in seven countries) and *Solanum* (289 samples, collected in seven countries). Samples of edible species of *Allium* were collected in the largest number of countries (12), followed by *Lactuca* (nine). The nine highest ranked WFP genera accounted for 3 271 samples in total (55 percent of all WFP samples collected).

The annual number of accessions of CWR and WFP added to genebanks[51] during the 50-year period 1959 to 2018 is shown in Figure 3.2. While the highest annual addition of CWR occurred between 1984 and 1993,[52] the inclusion of these materials in *ex situ* collections has been sustained since then. For WFP, there has been a positive trend over the past 40 years, although significantly less than for CWR.

Figure 3.2 Number of accessions of crop wild relatives (blue) and wild food plants (orange) added to *ex situ* collections, 1959 to 2018



It is noteworthy that over 3 880 samples belonging to 135 wild species classified under the International Union for Conservation of Nature (IUCN) categories of global major concern (IUCN, 2022), namely Extinct in the Wild, Critically Endangered, Endangered, Vulnerable and Near Threatened, have been collected in 26 countries. Forty-five of these species were CWR and 11 were WFP.

[51] Accessions added may have been from collecting missions or from donations (Section 3.3).
[52] The peak in 1990 is due to the incorporation of more than 7 000 accessions of CWR of *Avena* and almost 2 000 of *Hordeum* into the genebank of the Plant Gene Resources of Canada, as well as over 1 000 accessions each into the National Small Grains Germplasm Research Facility (USDA), the Western Regional Plant Introduction Station (USDA), ICARDA and CIMMYT.

Box 3.1. The global crop wild relative project coordinated by the Global Crop Diversity Trust
One important source of collected crop wild relative (CWR) samples has been the Global Crop Diversity Trust CWR project *Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives*, which was funded by the Norwegian Government and ran from 2011 to 2021 (Crop Trust, 2022a). The project covered collecting activities, regeneration of collected samples, evaluation and prebreeding activities for 19 selected CWR and also addressed capacity building. The project's collecting activities were based on a comprehensive inventory, a detailed global gap analysis and a priority-setting procedure for selecting the target species. Collecting activities were undertaken between 2013 and 2019 by 47 partner institutions jointly with the Millennium Seed Bank (MSB).

A total of 4 587 seed samples were collected from 25 genepools selected by scientists from 25 countries across four continents, covering 27 families and at least 355 taxa and 321 species (Eastwood *et al*., 2022). Eighty-five of the species were new to the MSB, and the seeds of 13 of the taxa had not previously been available under the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture.

The materials collected were deposited in 30 genebanks in the partner countries as well as in some additional national genebanks. Duplicates were sent to MSB for long-term conservation. A third subsample consisting of a total of 3 279 unique accessions was sent to six of the CGIAR centres and four national genebanks for regeneration and safety duplication; the samples are predominantly intended for prebreeding purposes. Backup storage at the Svalbard Global Seed Vault will be the responsibility of the recipients of the third subsample.

Regeneration/multiplication of some of the collected taxa was undertaken by the International Center for Agricultural Research in the Dry Areas and the International Potato Centre (Eastwood *et al*., 2022). Other important outputs from the project include:

- the inventory, which is a comprehensive master list of 1 667 globally important CWR taxa of 173 crops, covering 37 families, 108 genera and 192 species[53]; and
- a searchable, curated occurrence dataset containing 5 647 442 records, including 3 022 064 records for the 29 priority genera, and 375 602 records for the 445 priority CWR taxa within these genera[54].

This section provides a summary of the country narrative reports by subregion and of the reports provided by international agricultural research institutes and regional organizations.

Sub-Saharan Africa
A number of countries, including Benin, Ghana and Mali, report a focus on local minor crops, in particular roots and tubers, and pulses. The possible loss of genetic diversity via genetic erosion is mentioned by Ghana and Niger as a reason for collecting. Togo reports collecting cocoa with the assistance from the International Institute of Tropical Agriculture (IITA).

In Eritrea, Ethiopia, Kenya, Uganda, Zambia and Zimbabwe, the focus of collecting has also been on local minor crops and farmers' varieties (mentioned by). Most of these countries, as well as Madagascar, report the collection of CWR and WFP (e.g., Kenya and Zimbabwe). Madagascar, the United Republic of Tanzania, Zambia and Zimbabwe mention collaboration with international organizations and projects in the collection of germplasm, including germplasm from some major cereal and pulse crops.

Targeted collecting, particularly of minor and local crops and varieties, is reported by Botswana, Namibia, and South Africa. Collection of CWR and some WFP is reported by Botswana and South Africa. Namibia lists additional – predominantly native – priority crops but notes that a lack of funds and human capacity has prevented their collection.

Northern Africa

[53] http://www.cwrdiversity.org/checklist/
[54] https://www.cwrdiversity.org/checklist/cwr-occurrences.php

Egypt, Tunisia and Sudan reported collecting CWR, the two latter countries indicating that this has involved assistance from international centres. Tunisia mentions that its national genebank has used the focused identification of germplasm strategy (FIGS) technique in setting ecogeographic collecting priorities. Sudan mentions training staff on sample collection with the help of the Crop Trust and MSB. Morocco reports collecting samples from 77 species, many of them spices.

Latin America and the Caribbean
Cuba reports that only 40 percent of its research institutes provided feedback on collecting activities and that *Manilkara* and *Theobroma* were the two most important targeted genera. Trinidad and Tobago reports collecting local crops in order to be better prepared for the impact of climate change and to replace accessions lost from the collection.

Among the four reporting countries from Central America, El Salvador, Guatemala and Mexico report the collection of CWR. Mexico reports that 40 percent of the 22 000 samples collected were CWR. All three countries also mention local and/or native species of field and horticultural crops. Costa Rica reports the collection of samples of maize, beans and rice.

The South American countries reported collecting a large variety of crops and species. Argentina reports a focus on the *Prosopis* genepool. Chile reports targeting native species such as Chilean guava (*Ugni molinae*) and potato. Colombia and Ecuador report collecting local cocoa, *Passiflora* and *Annona* and other fruit-tree species. Guyana mentions that it prioritized native species such as breadfruit, avocado, pineapple and sweet potato. Ecuador mentions collecting CWR. Uruguay reports collecting CWR and WFP.

Northern America
Canada was the only country from this region that reported on collecting activities. According to its narrative report,[55] more than 8 500 samples were collected from 218 taxa, predominantly species native to Canada, many of them forages. CWR of *Linum*, *Helianthus*, *Lupinus* and *Hordeum* were also collected. In addition, 200 samples of *Avena* were collected as part of the Crop Trust-coordinated Crop Wild Relatives Project, and these were recently added to the global *Avena* base collection maintained by the national genebank. *Lonicera caerulea* (blue-berried honeysuckle) was collected jointly with the Federal Research Center N. I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR), Saint Petersburg.

Asia
Nineteen Asian countries completed a narrative report, more countries than any other region.

Armenia, Azerbaijan, Jordan and Lebanon report collecting CWR and some local or native field crops and fruit-tree species. In addition to the support provided by international organizations, including FAO and MSB, some foreign private companies also supported collecting in a few countries. Jordan mentions re-collecting crops, especially vegetable crops that have been stored for an extended period in order to capture the effects of more recent evolutionary changes. Yemen indicates that it has been able to collect germplasm materials despite the ongoing war, primarily thanks to project funding from the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty)'s Benefit Sharing Fund (FAO, 2023b).

All three Central Asian countries that provided country narratives report the collection of native crop genepools, including *Lactuca*, *Allium*, *Brassica*, *Daucus*, *Hordeum* and *Aegilops*, and *Spinacia turkestanica*. Tajikistan reports genetic erosion in many of its traditional crops and CWR and that it has conducted targeted collecting missions for cereals, legumes, nuts and fruit-tree species. Uzbekistan reports that it has mainly collected cereals, fruit crops and grapevine, all genepools with significant local diversity.

Bangladesh and India report a focus on CWR and local minor crop varieties. In India, the need to increase preparedness for climate change was reportedly an important motive and criterion for prioritizing species. India also indicates that the need for Indian collectors to collect samples in Central Asian countries, especially samples of vegetables and fruits. Nepal reports the adoption of a "red listing of landraces" approach as a basis for successful collection of threatened materials.

[55] These data are not reflected in the database used for the analysis of this section (Table 3.4).

Indonesia reports that close cooperation between its extension service and research and university stakeholders has improved collecting activities significantly. Malaysia, Myanmar and the Philippines report that they have collected local rice landrace varieties as well as other crops and CWR. The Philippines notes that it has had to undertake a major recollection effort to replace accessions lost because of a fire and flooding at its national genebank and that it has undertaken extensive training of staff at several institutions. It further notes that the dramatic spread of commercial varieties of vegetables, legumes and maize in the country is threatening local materials and that the release of genetically modified maize varieties means that there is an urgent need to collect traditional varieties.

Japan reports that restrictions on the introduction of germplasm from other countries are severe because of the isolated location of Japan relative to the Asian continent and that strict quarantine measures therefore hamper the collecting and introduction of germplasm from abroad. Mongolia reports the collection of native wild plant species used for pasture, fodder and medicinal purposes.

Oceania

Papua New Guinea reports that it focuses on collecting cultivated and wild banana to fill gaps in its collection and that it has also collected sweet potato and sugar cane samples.

Europe

Limited collecting activities are reported from this region. Portugal reports that it focuses on vegetatively propagated species, namely fruit and olive trees, grapevines and hops. It also mentions that more importance was being given to CWR and to threatened species and that more training was needed. Serbia mentions that it has been able to identify gaps and to fill these through targeted collecting. Spain reports that most of the institutes that answered an internal survey have strategies in place for filling gaps identified in their collections.

Most Eastern European countries report collecting species for which gaps in collections have been identified. Czechia mentions that it has identified diversity hotspots to set priorities and carried out five CWR missions. Hungary, the Republic of Moldova and Romania also report targeted collection of CWR species. In the Republic of Moldova this was done on the basis of an inventory of CWR in forest ecosystems. Romania reports that its national genebank has carried out collecting missions for vegetables in Bulgaria and the Republic of Moldova.

Most Northern European countries report collection efforts focused on local and minor crops and forage species. Finland, Norway and Sweden mention collecting to address identified gaps and/or increase geographical representation of taxa in their collections. Norway and Sweden report re-collecting accessions that have been lost or need to be replaced in their collections. Estonia, Germany, the Kingdom of the Netherlands, Norway, Sweden, Switzerland and the United Kingdom report collecting CWR.

The Kingdom of the Netherlands reports that its national genebank (CGN) has carried out international collecting missions in Armenia (asparagus and lettuce), Azerbaijan (asparagus and lettuce), Uzbekistan (carrot, melon and lettuce), Kyrgyzstan (carrot) and Jordan (lettuce). France mentions focused collecting by botanic gardens of genetic resources threatened with extinction. Germany reports that more than 400 advanced cultivars were deposited in its national genebank after they lost variety protection status.

International research centre genebanks

The 11 international agricultural research centres of the CGIAR and WorldVeg report collecting 22 327 samples of more than 30 crops or crop genepools in 34 countries in five regions during the reporting period. In many instances, these collecting activities were undertaken by the country's national agricultural research system. The centre that collected the most samples was ICARDA (a total of 6 614 samples of ten crop genepools in three regions), followed by ICRISAT (a total of 6 210 samples of three crop genepools in three African countries), IITA (a total of 4 321 samples of six crop genepools in three African countries) and AfricaRice (1 996 samples of one crop genepool in eight African countries). Two centres (CIMMYT and ILRI) did not conduct any collecting themselves but participated, along with six other centres, in the Crop Wild Relatives Project coordinated by the Crop Trust and supported by the Norwegian Government. IRRI did not actively participate in collection missions but reports having received samples collected under the Crop Wild Relatives Project.

The regional origin of the samples collected by the international centres is as follows: sub-Saharan Africa – 13 993 samples or 63 percent of the total; Europe – 3 761 samples or 17 percent; Asia – 3 340 samples or 15 percent; Latin America and the Caribbean – 631 samples or 3 percent; Northern Africa – 400 samples or 2 percent; and Oceania – 202 samples or 1 percent. It should be noted that 22 percent of the samples were collected in the countries where the respective international research centres are located.

3.3.2 Germplasm acquired through donation and other means

In addition to acquisition through collecting, germplasm samples can also be acquired by genebanks through exchange with other genebanks or institutions, through accession management (for instance by splitting mixed accessions into uniform components) or from research and breeding programmes (single seed descent populations, breeding lines, etc.).

Country and international situation

Eight countries report germplasm acquisition activities other than through collecting, for example through repatriation of lost materials (e.g. Botswana, Estonia, Lebanon, Togo and Tunisia), accepting breeding materials from researchers, receiving traditional varieties from farmers' groups (e.g. Belarus and Finland) and donation of materials from other institutions in the country (e.g. from public research programmes [Canada] and advanced cultivars from the Federal Plant Variety Office [Germany]). Between 2012 and 2021, the genebanks of the CGIAR and WorldVeg added 61 955 accessions received through donations to their collections.

3.3.3 Summary assessment

The number of samples collected per year increased from 20 000 during the reporting period for the SoW2 to over 31 000 samples during the current reporting period. Many countries report that collecting has focused on vegetables, fruit plants, ornamentals, herbs and spices, and medicinal plants, including farmers' varieties/landraces or wild species. Over 3 000 distinct species were collected over the reporting period.

Collecting efforts over the reporting period show a clear trend towards national rather than international activity. The trend away from international collecting may have been caused by the increasing restrictiveness and complexity of the legal requirements that non-national entities have to meet if they intend to collect genetic material within a country.

Overall, the number of species of CWR and WFP collected declined over the past decade, although interest has increased, especially though projects such as the one coordinated by the Crop Trust. As a result of these efforts, the quality of CWR and WFP collecting has improved. However, many countries still have problems carrying out targeted collecting without additional technical and scientific assistance and financial support.

Acquisitions through donations and other means were not well reported, and information on them is limited. However, some countries report that they have received accessions through repatriation and donations from farmers' groups, breeding programmes and other institutions. The CGIAR genebanks received a substantial number of accessions through donations, but specific details are not available.

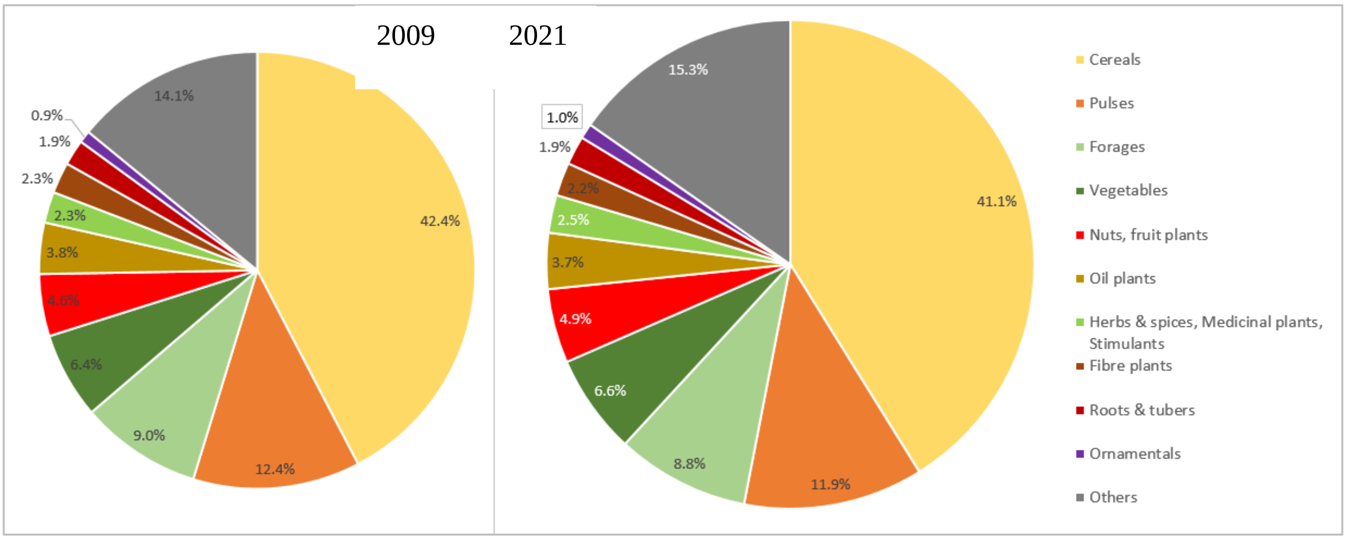
3.4 Types and status of *ex situ* collections

3.4.1 National and international genebanks

According to the report of the SDG Indicator 2.5.1a, 5 830 175 accessions are conserved in base collections by 115 countries, four regional genebanks and 13 international genebanks. This represents an increase of 17 percent over the 2009 holdings (Figure 3.3). Overall, the increase was distributed roughly equally among the different crop groups. The following groups showed net percentage increases over the reporting period: vegetables; nuts and fruit plants; herbs and spices, medicinal and stimulant plants; and "others".[56]

[56] Others include *Arabidopsis* plus wild flora.

Figure 3.3. Contribution of crop groups to total *ex situ* collections in 2009 and 2021



Notes: Number of accessions in 2009 = 4 994 051 and in 2021 = 5 830 175. 2021 percentages that are higher than the 2009 equivalents are shown in white or with a border line.

The holders of the five largest *ex situ* collections of selected crops and percent increase from 2009 to 2021 are shown in Table 3.5. The crops with the largest number of accessions maintained *ex situ* are wheat, rice and barley, with a combined total of over 1.6 million accessions. Global holdings for *Triticum* grew by 15 percent from 2009. CIMMYT holds the largest share globally (19 percent; 143 000 accessions), while the National Small Grains Germplasm Research Facility, United States of America (NSGC USA) holds the largest national collection, with 63 941 accessions (9 percent of the total). IRRI holds 27 percent of the global total for rice (over 132 000 accessions), while the National Board of Plant Genetic Resource (NBPGR) India has the largest national collection, with 111 415 accessions (22 percent). The increase in global rice holdings between 2009 and 2021 was 16 percent. The Plant Gene Resources of Canada (PGRC) Canada and NSGC USA together hold 20 percent of global barley holdings (a combined 79 543 accessions), while ICARDA holds 8 percent (32 451 accessions). Other large international cereal holdings include the ICRISAT’s sorghum (21 percent of global holdings) and pearl millet (43 percent) collections. The largest national collection of sorghum is held by the Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, Georgia, United States of America (45 794 accessions) and the largest for pearl millet by NBPGR India (10 266 accessions). The global totals of these crops increased by 17 percent and 19 percent, respectively.

CGIAR genebanks conserve global collections of major staple crops and are therefore repositories for the largest numbers of accessions for these species. Bioversity International maintains over 1 600 accessions of banana, 31 percent of global holdings. CIAT conserves the largest collection of bean and cassava. In addition to the largest collection of *Triticum*, CIMMYT also maintains the largest holding of maize with just over 32 000 accessions (14 percent of global holdings). CIP holdings are the largest for potato (7 500 accessions) and sweet potato (7 272 accessions). ICARDA maintains the largest collections of broad bean and lentil and the second largest holdings of wheat and pea. In addition to sorghum and pearl millet, ICRISAT also conserves the largest collections of chickpea and groundnut. IITA holds the largest cowpea and yam collections worldwide and the second largest cassava collection. Another international centre, WorldVeg, conserves the largest collections of tomato and capsicum and the second largest collection of cowpea.

Of the other food crops listed in Table 3.5, the largest holdings are held by national genebanks. For example the largest collection of pea is in Australia, cucurbits in Brazil, oats in Canada, teff (millet) in Ethiopia, olives in Italy, grapes in Portugal, common millet and prunus in the Russian Federation, soy, apple, mango, hazelnut and pistachio in the United States of America, and taro in Viet Nam. In addition to food crops, the largest oil crop collections of sunflower are found in the United States of America, France, the Russian Federation, Brazil and India. The largest collections of sugar crops (mostly sugar beet) are in the United

States of America, Germany, Japan, Poland and Hungary. The largest sugar cane holdings are in Cuba, Japan, Colombia, Bangladesh and the United States of America. The largest national collections of coffee are found in Ethiopia, France, Ecuador and Portugal. The regional Center for Tropical Agricultural Research and Higher Education (CATIE) holds the second largest collection of coffee, with 19 percent of global holdings.

Other crops include fibre and forages. Three institutes in Uzbekistan hold 17 percent, 14 percent and 9 percent of the global holdings, respectively. The United States of America conserves 15 percent and NBPGR India conserves 14 percent of global cotton accessions. The largest national collections of forage crops are held in Australia (clover and medicago) and Poland (fescue and grasses).

Table 3.5. Holders of 5 largest *ex situ* collections of selected crops and percent increase from 2009 to 2021

Genus (crop)	Total world accessions	Increase from 2009 to 2021 (%)	Major holders ranked									
			1	%	2	%	3	%	4	%	5	%
Triticum (wheat)	736 233	15	CIMMYT (MEX002)	19	NSGC (USA029)	9	INRA CRRAS (MAR088)	6	AGG (AUS165)	6	ICARDA (LBN002)	5
Oryza (rice)	498 030	16	IRRI (PHL001)	27	NBPGR (IND001)	22	NARO (JPN183)	8	DB NRRC (USA970)	7	GB-DOA (THA300)	5
Hordeum (barley)	385 688	11	PGRC (CAN004)	11	NSGC (USA029)	9	ICARDA (LBN002)	8	AGG (AUS165)	8	IPK (DEU146)	6
Zea (maize)	229 343	11	CIMMYT (MEX002)	14	NC7 (USA020)	9	VIR (RUS001)	6	BPGV-INIAV (PRT001)	5	NBPGR (IND001)	5
Sorghum (sorghum)	185 630	17	ICRISAT (IND002)	26	S9 (USA016)	25	NBPGR (IND001)	14	EBI (ETH085)	5	ARC (SDN002)	4
Phaseolus (bean)	184 120	10	CIAT (COL003)	21	W6 (USA022)	10	CNPAF (BRA008)	7	CENARGEN (BRA003)	7	IPK (DEU146)	5
Vigna (cowpea)	119 901	15	IITA (NGA039)	17	WorldVeg (TWN001)	13	NBPGR (IND001)	12	S9 (USA016)	11	NARO (JPN183)	10
Glycine (soybean)	117 543	13	SOY (USA033)	19	NARO (JPN183)	12	CNPSO (BRA014)	12	WorldVeg (TWN001)	12	CENARGEN (BRA003)	8
Avena (oat)	115 033	6	PGRC (CAN004)	24	NSGC (USA029)	18	VIR (RUS001)	9	AGG (AUS165)	5	IPK (DEU146)	4
Lathyrus (pea)	94 581	16	AGG (AUS165)	10	ICARDA (LBN002)	10	W6 (USA022)	8	NBPGR (IND001)	7	IPK (DEU146)	6
Cicer (chickpea)	92 385	11	ICRISAT (IND002)	22	ICARDA (LBN002)	17	NBPGR (IND001)	16	AGG (AUS165)	12	W6 (USA022)	8
Trifolium (clover)	82 832	16	APG (AUS167)	26	AGRESEARCH (NZL001)	13	IBERS-GRU (GBR016)	8	ICARDA (LBN002)	7	VIR (RUS001)	6
Vitis (grape)	82 679	33	ISA (PRT018)	31	INRAe-VASSAL (FRA139)	9	DAV (USA028)	4	IMIDRA (ESP080)	4	IVM (UKR050)	4
Medicago (medicago)	81 280	11	APG (AUS167)	36	ICARDA (LBN002)	12	W6 (USA022)	11	VIR (RUS001)	5	INRA CRRAS (MAR088)	4
Gossypium (cotton)	71 094	15	UzRICBSP (UZB036)	17	COT (USA049)	15	IGPEB (UZB001)	14	NBPGR (IND001)	14	UzRIPI (UZB006)	9
Arachis (groundnut)	68 613	6	ICRISAT (IND002)	32	NBPGR (IND001)	20	S9 (USA016)	14	CENARGEN (BRA003)	6	UzRIPI (UZB006)	3
Cenchrus (pearl millet)	67 852	19	ICRISAT (IND002)	43	NBPGR (IND001)	15	PGRC (CAN004)	6	ARC (SDN002)	5	S9 (USA016)	4
Solanum (tomato)	67 371	17	WorldVeg (TWN001)	14	NE9 (USA003)	10	IPK (DEU146)	7	GSLY (USA176)	6	BGUPV (ESP026)	5
Vicia (broad bean)	66 005	15	ICARDA (LBN002)	24	AGG (AUS165)	9	VIR (RUS001)	8	IPK (DEU146)	7	INIA-CRF (ESP004)	5
Solanum (potato)	54 477	9	CIP (PER001)	14	IPK (DEU159)	11	VIR (RUS001)	11	NR6 (USA004)	11	HBROD (CZE027)	5
Malus (apple)	50 187	16	GEN (USA167)	12	VIR (RUS001)	7	PSR (CHE063)	5	NFC (GBR030)	4	NARO (JPN183)	4
Capsicum (capsicum)	49 612	24	WorldVeg (TWN001)	17	S9 (USA016)	10	NBPGR (IND001)	9	NARO (JPN183)	6	IPGR (BGR001)	4
x *Triticosecale* (wheat)	46 205	6	CIMMYT (MEX002)	37	VIR (RUS001)	9	IR (UKR001)	8	IHAR (POL003)	5	NSGC (USA029)	4
Lens (lentil)	43 734	20	ICARDA (LBN002)	33	AGG (AUS165)	14	W6 (USA022)	7	NBPGR (IND001)	6	VIR (RUS001)	6
Aegilops (wheat)	39 600	15	ICCI-TELAVUN (ISR003)	19	ICARDA (LBN002)	13	VIR (RUS001)	9	AGG (AUS165)	7	NARO (JPN183)	6

Panicum (millet)	38 039	12	VIR (RUS001)	24	NARO (JPN183)	23	UDS (UKR008)	13	NBPGR (IND001)	9	GeRRI (KEN212)	6
Prunus (prunus)	36 998	15	VIR (RUS001)	8	CREA-OFA-RM (ITA378)	6	DAV (USA028)	5	NBS (UKR036)	4	UzRIPI (UZB006)	4
Cucurbita (cucurbita)	34 030	23	CNPH (BRA012)	8	CATIE (CRI085)	6	CENARGEN (BRA003)	5	WorldVeg (TWN001)	4	S9 (USA016)	4
Helianthus (sunflower)	26 787	16	NC7 (USA020)	20	INRAe (FRA015)	8	VIR (RUS001)	8	CENARGEN (BRA003)	7	NBPGR (IND001)	6
Festuca (fescue)	25 483	16	IHAR (POL003)	16	NARO (JPN183)	11	W6 (USA022)	10	IPK (DEU271)	9	APG (AUS167)	9
Dactylis (grasses)	21 256	8	IHAR (POL003)	29	NARO (JPN183)	11	IPK (DEU271)	9	W6 (USA022)	8	AGRESEARCH (NZL001)	6
Ipomoea (sweet potato)	19 700	15	CIP (PER001)	37	NARO (JPN183)	18	S9 (USA016)	6	CNPH (BRA012)	6	INIVIT (CUB006)	5
Manihot (cassava)	17 414	16	CIAT (COL003)	34	IITA (NGA039)	18	CNPMF (BRA004)	13	INIA-EEA.DONOSO (PER034)	4	INIVIT (CUB006)	4
Beta (sugar beet)	12 429	14	W6 (USA022)	22	IPK (DEU146)	19	NARO (JPN183)	7	IHAR (POL003)	6	NODiK (HUN003)	4
Chenopodium (chenopodium)	11 558	24	EE-Toralapa INIAF (BOL317)	33	E.E.A. Illpa-Puno (PER014)	17	ICBA (ARE003)	11	IPK (DEU146)	9	DENAREF (ECU023)	8
Saccharum (sugar cane)	10 750	9	INICA (CUB041)	30	NARO (JPN183)	15	CENICAÑA (COL115)	14	BSRI (BGD015)	11	MIA (USA047)	9
Coffea (coffee)	10 300	5	EBI (ETH085)	44	CATIE (CRI134)	19	IRD (FRA254)	8	EETP (ECU330)	5	ISA (PRT018)	5
Eragrostis (millet)	9 750	13	EBI (ETH085)	51	W6 (USA022)	14	GeRRI (KEN212)	11	IGB (ISR002)	4	ICBA (ARE003)	4
Dioscorea (yam)	9 268	63	IITA (NGA039)	64	INRAe-ANTILLE (FRA109)	5	PRC (VNM049)	4	CePaCT (FJI049)	4	INIVIT (CUB006)	3
Musa (banana)	6 154	31	ITC (BEL084)	27	BPI-DNCRDC (PHL024)	8	IITA (NGA039)	6	CNPMF (BRA004)	6	INIVIT (CUB006)	6
Colocasia (taro)	3 786	52	PRC (VNM049)	33	CePaCT (FJI049)	31	MRC Bubia (PNG041)	7	NARO (JPN183)	6	EBI (ETH085)	4
Olea (olive)	2 735	11	CREA-OFA-REN (ITA401)	36	IFAPACOR (ESP046)	16	INIAV-Elvas (PRT196)	10	BNG (TUN029)	7	DAV (USA028)	6
Corylus (nut)	2 317	28	COR (USA026)	13	IRTAMB (ESP014)	6	IFG (BLR017)	6	KPS (UKR046)	4	FTGRİ (AZE009)	4
Mangifera (mango)	1 583	25	MIA (USA047)	18	ISOPlexis (PRT102)	14	CPAMN (BRA142)	11	ICIA (ESP048)	11	AGROSAVIA (COL017)	10
Psophocarpus (bean)	1 446	22	WorldVeg (TWN001)	42	NBPGR (IND001)	13	S9 (USA016)	11	AGG (AUS165)	8	PRC (VNM049)	7
Bactris (peach palm)	1 380	24	CATIE (CRI134)	21	AGROSAVIA (COL096)	16	ICRAF (KEN056)	13	INIA-EEA.SR. (PER016)	13	CNPSO (BRA014)	12
Pistacia (pistachio)	748	15	DAV (USA028)	29	BNG (TUN029)	25	RBG (GBR004)	7	CREA-OFA-RM (ITA378)	6	IGB (ISR002)	6

Germplasm holdings in national genebanks

The 2021 report on SDG Indicator 2.5.1a states that 4 872 408 accessions are conserved in base collections under medium- and long-term storage conditions in national genebanks in 115 countries. These accessions represent 50 959 species from 394 families. Annex X provides an overview of national holdings, including the total number of genera and species.

Ten countries hold over 100 000 accessions (Table 3.6)[57]. The United Kingdom, the United States of America, Germany, Australia, Spain and Kenya conserve the highest level of taxonomic diversity. Eighteen genebanks in 13 countries[58] conserve over 1 000 species, ranging from 1 003 to 4 233. In addition to these, by far the largest number of species (34 837) are conserved by the MSB at the Royal Botanic Gardens, Kew, United Kingdom. Although this collection mainly focuses on the world's wild flora, it includes numerous CWR and WFP.

It is important to note that 44 percent (22 630) of all species conserved worldwide are represented by only one accession and that only 14 percent (7 217) are represented by ten or more accessions. Furthermore, 3 794 accessions maintained in 75 genebanks have not been taxonomically classified. A total of 118 115 accessions maintained in 364 genebanks have been taxonomically classified/identified at the genus level only. Of these, 108 481 accessions are in 349 national genebanks, with the others in regional and international genebanks. Taxonomic identification at species level of wild samples is lacking for 21 596 accessions belonging to 1 393 genera in 195 national genebanks, 64 accessions belonging to 14 genera in three regional genebanks, and 4 519 accessions belonging to 176 genera in eight international genebanks.

Table 3.6. Countries conserving the ten largest number of accessions, genera or species

Country	Genebanks	Accessions	Genera	Species
United Kingdom	9	846 289 (1)	5 885 (1)	35 301 (1)
United States of America	27	584 724 (2)	2 536 (2)	13 364 (2)
India	1	420 324 (3)	817 (5)	1 744 (9)
Australia	2	249 056 (4)	575 (11)	3 059 (4)
Japan	1	227 052 (5)	356 (27)	998 (22)
Brazil	21	203 302 (6)	549 (12)	1 679 (11)
Russian Federation	1	200 717 (7)	215 (38)	1 165 (17)
Germany	48	183 493 (8)	814 (6)	3 420 (3)
Canada	3	115 185 (9)	282 (31)	1 038 (18)
Ukraine	55	107 675 (10)	503 (14)	1 527 (13)
Spain	38	78 782 (12)	744 (7)	2 529 (5)
Mexico	58	76 970 (13)	547 (13)	1 968 (8)
Bulgaria	3	69 767 (16)	577 (10)	1 696 (10)
Kenya	1	51 405 (21)	1 017 (3)	2 528 (6)
Israel	3	27 239 (35)	679 (9)	1 628 (12)
Greece	13	9 570 (53)	696 (8)	1 470 (14)
Belgium	12	9 311 (54)	825 (4)	1 982 (7)

Note: Numbers in parenthesis indicate the country ranking in terms of accessions, genera and species conserved.

Europe has the largest number of genebanks (445 or 54 percent), followed by Latin America and the Caribbean (180 or 22 percent) and Asia (102 or 12 percent). Sub-Saharan Africa reports 55 genebanks (7 percent), Northern America 30 (4 percent), Oceania 10 (1 percent) and Northern Africa 5 (1 percent) (Table 3.7).

[57] The numbers reported for United Kingdom include the specialized research collection held at the Nottingham Arabidopsis Stock Centre.
[58] Australia, Belgium, Bulgaria, Germany, Greece, India, Israel, Kenya, New Zealand, Poland, Russian Federation, Spain, United States of America.

Table 3.7. Number of national genebanks, accessions, genera and species stored, by region and subregion

Regions and subregions (number of countries)	Accessions	Genera	Species	Genebanks
Northern Africa (5)	130 391 (3%)	653	1 434	5 (1%)
Northern Africa (5)	130 391	653	1 434	5
Sub-Saharan Africa (23)	202 168 (4%)	1 257	3 349	55 (7%)
Eastern Africa (9)	167 016	1 079	2 771	28
Southern Africa (5)	16 396	454	855	8
Western Africa (9)	18 756	54	90	24
Northern America (2)	699 909 (14%)	2 558	13 541	30 (4%)
Northern America (2)	699 909	2 558	13 541	30
Latin America and the Caribbean (19)	454 668 (9%)	1 407	4 952	180 (22%)
Central America (7)	83 873	627	2 113	77
Caribbean (2)	20 452	386	713	19
South America (10)	350 343	937	2 860	84
Asia (26)	1 033 859 (21%)	1 755	5 894	102 (12%)
Central Asia (3)	75 582	118	270	10
Eastern Asia (2)	246 645	360	1 019	2
South-eastern Asia (6)	98 198	331	561	37
Southern Asia (7)	517 190	938	2 103	30
Western Asia (8)	96 244	1 007	3 373	23
Europe (37)	2 063 707 (42%)	6 319	40 483	445 (54%)
Northern Europe (9)	860 377	5 889	35 370	62
Eastern Europe (10)	666 042	1 063	4 586	136
Southern Europe (12)	231 632	1 190	4 343	122
Western Europe (6)	305 656	1 358	5 367	125
Oceania (3)	287 706 (6%)	768	3 765	10 (1%)
Melanesia (1)	2 506	20	27	7
Australia and New Zealand (2)	285 200	756	3 745	3
Total	4 872 408	7 292	50 959	827

Germplasm holding in international genebanks

The genebanks of the CGIAR international centres(AfricaRice, Bioversity International, the International Center for Tropical Agriculture [CIAT], CIMMYT, CIP, ICARDA, ICRISAT, IITA, ILRI, IRRI and the World Agroforestry Center [ICRAF]), WorldVeg and the International Center for Biosaline Agriculture (ICBA) manage germplasm collections on behalf of the world community. These collections consist predominantly of materials that are in the public domain, are under legal arrangements with the Treaty and largely represent species that are included in the Treaty's Annex I.

Germplasm holdings in international genebanks total 899 915 accessions from 671 genera and 3 326 species. The collections of CIMMYT (maize, wheat), ICARDA (dryland cereals, grain legumes, temperate forages), ICRISAT (sorghum, millets, grain legumes) and IRRI (rice) all conserve more than 100 000 accessions each. These genebanks hold 819 825 accessions of 573 genera and 3 005 species from 203 countries and territories of origin.

The WorldVeg genebank maintains the world's largest public vegetable germplasm collection, which has 64 948 accessions belonging to 134 genera and 312 species and coming from 150 countries. WorldVeg holds the largest collections of *Solanum* (13 313 accessions, including tomato and eggplant) and *Capsicum* (8 372 accessions) worldwide and the fourth largest collection of *Glycine* (13 663 accessions). The ICBA genebank focuses on germplasm with proven or potential salinity tolerance and comprises 15 142 accessions belonging to 94 genera and 277 species from 159 countries. The centre holds the third largest *Chenopodium* collection (1 306 accessions) worldwide.

Germplasm holdings in regional genebanks

Many regional genebanks maintain important collections. Examples of such institutions include the following.

- The Nordic Genetic Resource Center (NordGen) conserves 33 344 seed samples of a range of crops, comprising 212 genera and 434 species from 81 countries;
- CATIE conserves about 6 120 orthodox seed accessions belonging to 58 genera and 91 species, and about 4 800 field-genebank accessions belonging to 160 genera and 230 species, including coffee, cocoa and fruit trees. It holds the second largest collections of *Cucurbita* (2 114 accessions), *Coffea* (1 990 accessions) and *Theobroma* (1 245 accessions). Germplasm held at CATIE originated from 72 countries.
- The Southern African Development Community (SADC) Plant Genetic Resources Centre (SPGRC) genebank maintains approximately 11 326 accessions belonging to 41 species in its base collection, deposited by its 12 member countries.
- The Centre for Pacific Crops and Trees (CePaCT) of the Secretariat of the Pacific Community (SPC) in Fiji holds mostly *in vitro* collections, which comprise 2 232 accessions of 18 genera and 23 species from 47 countries, including taro, yam, sweet potato and coconut. Its *Colocasia* collection is the largest worldwide (1 181 accessions) and its *Dioscorea* collection is the fourth largest (330 accessions).

3.4.2 Source of samples in genebanks

Country of origin is known for approximately 77 percent of the 4 187 913 accessions in national genebank holdings (excluding the Nottingham Arabidopsis Stock Centre). Of these, 40 percent originated in the country where the collection is maintained (Table 3.8).

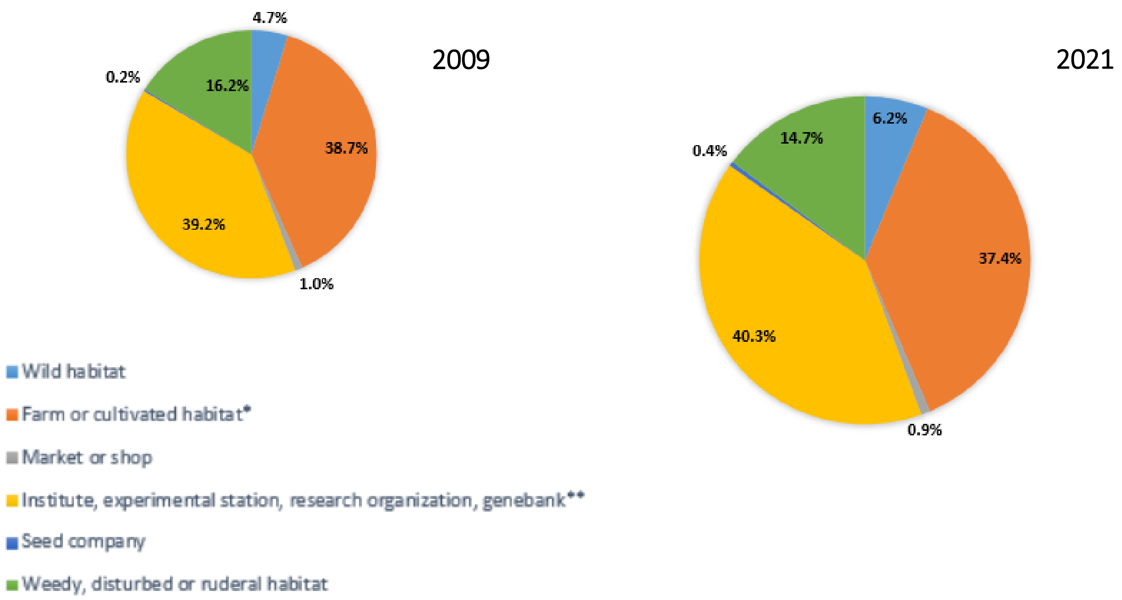
Table 3.8. Number of accessions conserved in national genebanks by subregion and percentage of accessions that originated in the country where conserved

Region	Subregion	Total number of accessions*	Percentage originating in country where held
Northern Africa	Northern Africa	130 391	44
Sub-Saharan Africa	Eastern Africa	167 016	82.5
	Southern Africa	16 396	99.7
	Western Africa	18 756	92.9
Northern America	Northern America	699 909	24.2
Latin America and the Caribbean	Central America	83 873	95.7
	Caribbean	20 452	51
	South America	350 343	36.8
Asia	Central Asia	75 582	18.6
	Eastern Asia	246 645	0.6
	South-eastern Asia	98 198	71
	Southern Asia	517 190	74
	Western Asia	96 244	94.4
Europe	Northern Europe	175 882	14.5
	Eastern Europe	666 042	28.9
	Southern Europe	231 632	64.8
	Western Europe	305 656	25.6
Oceania	Melanesia	2 506	91.5
	Australia and New Zealand	285 200	13.2
World		4 187 913	39.7

* Collection held by the Nottingham Arabidopsis Stock Centre is excluded.

In addition to the country of origin, the source of germplasm in collections is known for 56 percent and 58 percent of holdings in 2009 and 2021, respectively. Only minor changes occurred in the relative importance of the six different categories over this time period (Figure 3.4).

Figure 3.4. Sources of accessions in genebank collections in 2009 and 2021

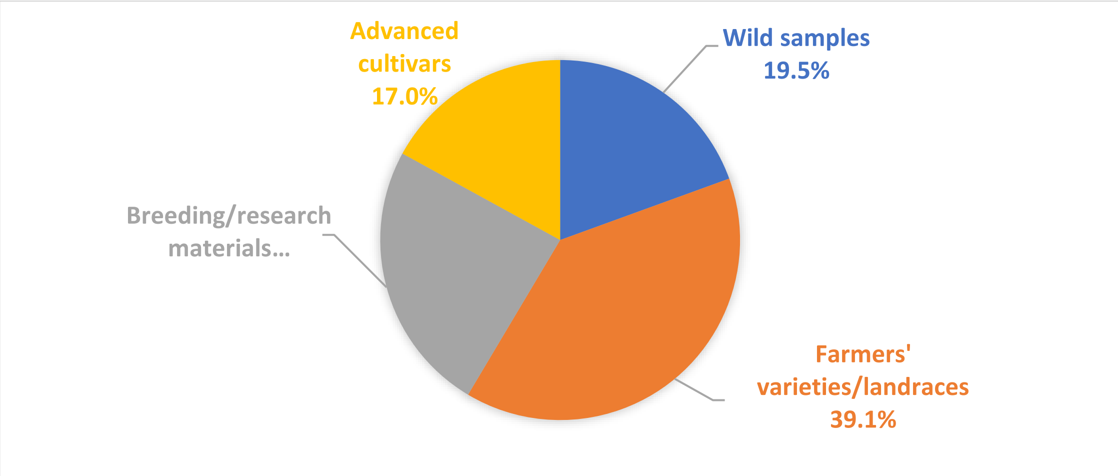


Notes: Data include national, regional and international genebanks. The size difference in the charts represents the growth in the numbers of accessions held *ex situ* and documented for this descriptor between 2009 and 2021.
*Accessions of landraces and farmers' varieties that have been reported without collecting source information have been included in this category.
**Accessions of "Breeding/research materials" that have been reported without collecting source information have been included in this category.

3.4.3 Biological status of crop germplasm accessions stored in genebanks

In terms of biological status germplasm can be grouped into the following categories: wild samples (populations) from nature; farmers' varieties/landraces managed on-farm; breeding or research materials; and advanced cultivars (Alercia, Diulgheroff and Mackay, 2015; Alercia *et al*., 2020). Figure 3.5 shows the proportions of the defined biological-status categories in the composition of *ex situ* germplasm collections in 2021.

Figure 3.5. Biological status of samples in *ex situ* collections in 2021



Notes: The percentages are based on reported national and regional/international collections totalling 3 650 839 accessions (excludes collections from the Nottingham Arabidopsis Stock Centre).

The biological status for each crop or species maintained in genebanks, including national (summarized by regions), regional and international holdings, is presented in Table 3.9. On average, biological status is documented for 71 percent of the accessions conserved, ranging from 44 percent in Latin America and the Caribbean to 96 percent in regional centres.

Table 3.9. Biological status of samples *ex situ* collections, by region

Region (number of countries)		Total	Biological status (%)			
			Wild samples	Traditional cultivar/landrace	Breeding/ research material	Advanced/ improved cultivar
National	Northern Africa (5)	114 364	12	41	46	1
	Sub-Saharan Africa (22)	161 176	6	88	5	2
	Northern America (2)	546 052	27	19	26	29
	Latin America & Caribbean (17)	198 568	17	43	18	23
	Asia (25)	569 143	12	43	37	8
	Europe (36)*	1 051 521	22	32	20	26
	Oceania (2)	208 141	42	17	27	14
Total national (109)		2 848 965	21	35	25	20
Regional genebanks		54 798	14	45	33	9
International genebanks		747 076	15	55	22	8
Grand total		3 650 839	20	39	24	17

* Collection from the Nottingham Arabidopsis Stock Centre not included.

Wild materials

For the purposes of this report, wild PGRFA include CWR, WFP and other wild flora. Accessions classified as wild materials make up 20 percent of the global total of accessions whose biological status is documented.

Crop wild relatives

CWR are estimated to make up 9 percent of total holdings and 76 percent of all wild samples[59] (540 682 accessions) (Table 3.10). CWR holdings include 430 genera and 6 101 species. They are held across 421 genebanks in 104 countries and five regional and 12 international genebanks. Eleven countries[60] with the largest holdings, which vary between 9 989 and 80 782 CWR samples each, accounting altogether for 65 percent of all CWR samples conserved *ex situ* globally.

Forages (44 percent of all conserved CWR samples) and cereals (27 percent) are the most represented crop groups.[61] Forages, (1 810 species, fruit plants (801 species) and vegetables (659 species) are the groups represented by the highest numbers of species. In terms of the method of conservation, 95 percent of CWR accessions are conserved as seed, 5 percent in fields, 0.6 percent *in vitro*, 1 percent under cryopreservation and 0.2 percent as DNA.

Geographic origin is reported for 88 percent of all the CWR samples conserved. Of these, 33 percent (155 534) are conserved in the subregion where they were collected (Table 3.10). This proportion varies greatly by region and subregion – highest in Northern America (76 percent), Australia and New Zealand (74 percent) and Eastern Europe (73 percent) and lowest in Central Asia (4 percent), Southern Africa (5 percent), South-eastern Asia (9 percent), Northern Africa (11 percent) and Western Africa (12 percent). CWR are mainly conserved outside of the subregion where they were collected. This is probably a consequence of a lack of capacity, including a lack of knowledge of biology and taxonomy, a lack of funding and a lack of understanding of the potential value of CWR. Whereas subregional CWR *ex situ* holdings are relatively low, regional and international centres play an important role in that they conserve a significant proportion of CWR from these subregions, including from those countries lacking *ex situ* facilities.

[59] CWR were identified based on the species and the biological status of the samples. Samples of known CWR species with wild or unreported biological status and samples of cultivated species with wild biological status were included.

[60] Australia, Canada, Germany, India, Israel, Japan, Poland, Russian Federation, Spain, United Kingdom, and United States of America.

[61] See Section 3.4.4.

Table 3.10. Number of accessions of crop wild relatives collected and conserved *ex situ*, by subregions and by regional/international genebank

		Accessions collected in																						
		Northern Africa	Eastern Africa	Southern Africa	Middle Africa	Western Africa	Northern America	Central America	Caribbean	South America	Central Asia	Eastern Asia	South-eastern Asia	Southern Asia	Western Asia	Northern Europe	Eastern Europe	Southern Europe	Western Europe	Australia and New Zealand	Mela nesia	Micro nesia	Poli nesia	Not specified	**Total accessions conserved**
Accessions conserved in	Northern Africa	**2 918**													1									7 835	**10 754**
	Eastern Africa	1	**3 251**	1		5	6			1					3	1		2	11	22				12	**3 316**
	Southern Africa			**205**																					**205**
	Middle Africa																								**0**
	Western Africa					**552**																		83	**635**
	Northern America	5 090	2 058	779	114	480	**17 701**	3 809	497	6 727	4 293	4 187	204	5 410	32 053	945	4 904	7 461	1 745	1 760	90		9	10 239	**110 555**
	Central America							**4 338**	1	3														16	**4 358**
	Caribbean						4	5	**919**	69			73	14					1		8			119	**1 212**
	South America						125			**4 378**			14	5		4	2	32	17	3	10			7 101	**11 691**
	Central Asia	4	13		4	2	93	37	6	22	**559**	123	3	89	88	2	25		9	15				86	**1 180**
	Eastern Asia											**1**												20 863	**20 864**
	South-eastern Asia												**538**											153	**691**
	Southern Asia	2	118	2		7	271	13		3		32	10	**7 536**	566	1		71	89					2 354	**11 075**
	Western Asia	3	2	3							55	2		31	**29 862**	1	24	9	15					133	**30 140**
	Northern Europe	566	1 451	464	153	897	1 227	819	75	1 029	307	781	378	499	6 933	**6 114**	1 840	4 564	3 155	422	6			3 346	**35 026**
	Eastern Europe	202	25	29	4	8	841	674	8	1 864	3 956	547	6	653	4 810	697	**33 120**	1 632	1 626	234			2	6 615	**57 553**
	Southern Europe	383	41	31		12	171	257	2	729	1	50	34	231	1 813	136	337	**24 510**	513	64	5			1 091	**30 411**
	Western Europe	1 424	927	114	397	170	287	1 171	22	3 574	826	209	30	518	3 337	897	2 041	3 377	**10 020**	62	4			4 312	**33 719**
	Australia and New Zealand	12 020	1 787	1 343	71	240	1 777	1 768	298	4 147	1 787	429	483	2 765	16 245	354	1 489	18 328	1 917	**8 990**	117	4	15	5 186	**81 560**
	Melanesia																				**1**				**1**
	International/ regional centres	5 092	6 923	1 167	699	2 287	867	6 851	352	16 140	1 198	512	4 550	4 403	25 412	4 576	1 316	4 638	703	655	231	1	14	7 128	**95 715**
	Total collected	**27 705**	**16 596**	**4 138**	**1 442**	**4 660**	**23 370**	**19 742**	**2 180**	**38 686**	**12 982**	**6 873**	**6 323**	**22 154**	**121 123**	**13 728**	**45 098**	**64 624**	**19 821**	**12 227**	**472**	**5**	**40**	**76 672**	**540 661**

Note: The diagonal in bold typeface represents those accessions collected and conserved in the same subregion.

Table 3.11. Number of accessions of wild food plants collected and conserved *ex situ,* by subregion and by regional/international genebank

		Accessions collected in																					
		Northern Africa	Eastern Africa	Southern Africa	Middle Africa	Western Africa	Northern America	Central America	Caribbean	South America	Central Asia	Eastern Asia	South-eastern Asia	Southern Asia	Western Asia	Northern Europe	Eastern Europe	Southern Europe	Western Europe	Mela nesia	Australia and New Zealand	Not specified	**Total accessions conserved**
Accessions conserved in	Northern Africa	**458**													1							243	**702**
	Eastern Africa	18	**510**				18							2	12				2		18	6	**586**
	Southern Africa			**74**																			**74**
	Middle Africa																						**0**
	Western Africa					**49**																22	**71**
	Northern America	59	73	153	5	4	**4 472**	114	9	838	72	323	37	105	462	68	391	267	127	3	32	1 660	**9 274**
	Central America							**1 516**														33	**1 549**
	Caribbean							5	**6**	3									1				**15**
	South America						59	1		**892**							1	12	2			5 532	**6 499**
	Central Asia										**115**					2	1				1	2	**121**
	Eastern Asia																					774	**774**
	South-eastern Asia												**89**										**89**
	Southern Asia													**1 147**								169	**1 316**
	Western Asia						2			3	20	1			**1 536**	3	1	1	6			8	**1 581**
	Northern Europe	36	265	147	6	118	144	83	7	71	37	70	39	50	753	**788**	58	200	123	1	52	248	**3 296**
	Eastern Europe	1	4	5		1	51	2	1	68	193	30		4	102	45	**1 186**	99	167			729	**2 688**
	Southern Europe	24		5		5	3	8		204			2	8	38	7	4	**1 099**	16			126	**1 549**
	Western Europe	6	2	2		1	14	14	11	90	183	24	4	33	403	35	240	307	**825**			741	**2 935**
	Melanesia																						**0**
	Australia and New Zealand	111	3	2			4	1		83				10	73		1	109	3		**655**	193	**1 248**
	International/ Regional centres	300	6 286	285	1079	646	46	123	13	632	3	15	352	63	165	131	12	43	16	24	5	167	**10 406**
	Total collected	**1 013**	**7 143**	**673**	**1 090**	**824**	**4 813**	**1 867**	**47**	**2 884**	**623**	**463**	**523**	**1 422**	**3 545**	**1 079**	**1 895**	**2 137**	**1 288**	**28**	**763**	**10 653**	**44 773**

Note: The diagonal in bold face represents those accessions collected and conserved in the same subregion.

Wild food plants

WFP *ex situ* holdings comprise roughly 44 773 accessions from 773 species (Table 3.11). This estimate is based on countries' and regional/international genebank's reporting of wild samples of species that are known to be harvested for food from the wild. WFPs that are used as vegetables account for 41 percent of these accessions, those providing fruit for 34 percent, those providing nuts for 10 percent and those providing herbs and spices for 8 percent. In terms of method of conservation, 65 percent of the WFP accessions are held as seed, 35 percent in fields, 0.8 percent *in vitro*, 0.7 percent under cryopreservation and 0.7 percent as DNA.

The largest *ex situ* holdings of WFP are found in the United States of America (8 857 accessions, 48 percent of which are indigenous, belonging to 390 species), Brazil (4 090 accessions belonging to 52 species) and the United Kingdom (2 919 accessions belonging to 478 species). Other countries with holdings of more than 1 000 accessions include Chile, Mexico, Germany, India, the Kingdom of the Netherlands and Australia. Regional and international centres conserve 10 406 WFP accessions from 113 species.

On average, 45 percent (15 417) of the WFP accessions with known geographic origin are conserved in the subregion where they were collected. This percentage varies significantly among subregion – highest in Northern (93 percent), Australia and New Zealand (86 percent), Central America (81 percent), Southern Asia (81 percent) and Northern Europe (73 percent) and lowest in Western Africa (6 percent), Eastern Africa (7 percent), Southern Africa (11 percent), the Caribbean (13 percent) and South-eastern Asia (17 percent). Whereas subregional WFP *ex situ* holdings are relatively low, regional and international centres conserve a significant proportion of WFP from these subregions, including from those countries lacking *ex situ* facilities. Like CWR, a lack of capacity, interest and funding where these resources were collected appears to be the reason for their conservation outside their areas of origin.

Sub-Saharan African countries, namely Ghana, Niger, South Africa, Togo, Zambia and Zimbabwe stressed the importance of WFP and the need to collect and conserve them. Fifteen of the 91 countries that provided reports for *The State of the World's Biodiversity for Food and Agriculture* (FAO, 2019b) (16 percent) reported regular use of wild foods by their populations. A recent review of wild foods from forests in Zambia revealed that rural households collected about 31 kg of fruits, vegetables, mushrooms and tubers and that 97 percent of households in the Mwekera area collected wild fruits (Steel *et al*., 2022).

Other wild flora

Other wild flora conserved *ex situ* mostly consist mainly of germplasm lacking a defined use in food and agriculture, weeds, forages, medicinal plants, ornamentals and plants providing materials. They include 38 952 species and 194 716 accessions. Many of these species are being studied for their ecological roles, for example in erosion control, nutrient recycling, land restoration and phytoremediation. The within-species diversity of this flora is poorly represented in *ex situ* collections, with fewer than six accessions conserved for 87 percent of species.

Farmers' varieties/landraces

Farmers' varieties and landraces are an important category of germplasm, as they are typically adapted to the prevailing ecological conditions where they are cultivated, which is mostly within traditional agricultural production systems (FAO, 2019c). These PGRFA have traditionally been given the highest priority by collectors and genebanks. The number of accessions of farmers' varieties/landraces are summarized by region in Table 3.9. Overall, 28 percent of all accessions conserved *ex situ* are farmers' varieties/landraces. This increases to 39 percent if only accessions with known biological status are considered (Figure 3.5). The region whose collections contain the highest proportion of farmers' varieties/landraces is sub-Saharan Africa, where they account for 88 percent of all accessions conserved and characterized for biological status. Figures are also relatively high in Asia (43 percent), Latin America (43 percent) and Northern Africa (41 percent).

Farmers' varieties/landraces make up between 68 percent and 41 percent of all accessions with known biological status in the following groups: pseudo-cereals; pulses; roots and tubers; vegetables; fruit plants; stimulants; herbs and spices; and cereals. They represent between 98 percent and 74 percent of pseudo-cereal accessions conserved in Asia, sub-Saharan Africa, and Latin America and the Caribbean. In all regions other than Oceania, they represent over 50 percent of all holdings of pulses, the highest percentages being in

Northern Africa (88 percent) and sub-Saharan Africa (85 percent). They represent between 92 percent and 66 percent of root and tuber accessions across Oceania, sub-Saharan Africa, and Latin America and the Caribbean. Among vegetables, they represent between 61 percent and 90 percent of the totals in in sub-Saharan Africa, Northern Africa, and Latin America and the Caribbean. They represent between 96 percent and 44 percent of fruit plants in Northern Africa, Oceania, Latin America and the Caribbean, Europe and Asia. There are also high percentage of farmers' varieties/landraces among pseudo-cereals, pulses, roots and tubers, vegetables, stimulants and cereals in regional and international genebanks.

Several countries, including Armenia, Malaysia and Mexico, note that there are gaps in the coverage of farmers' varieties/landraces in their collections.

Breeding/research materials

Breeding/research materials represent 17 percent of all accessions conserved worldwide[62] and approximately a quarter (24 percent) of those that are characterized for this descriptor. They also account for about one-third of all cereals (34 percent), sugar crops (33 percent), fibre plants (31 percent) and oil plants (29 percent). Among regions, they range from 5 percent of the characterized holdings in sub-Saharan Africa to 42 percent in Europe and 46 percent in Northern Africa.

Advanced/improved cultivars

Advanced/improved cultivars represent 13 percent of all accessions conserved worldwide[63] and 17 percent of those that are characterized for this descriptor. The proportion of advanced/improved cultivars maintained within regions ranges from 1 percent in Northern Africa to 29 percent in North America. Ornamentals, fibre plants, sugar crops, fruit plants, vegetables, oil plants are the use groups with the highest proporions of advanced/improved cultivars among all accession characterized for this descriptor, ranging from 23 percent to 10 percent.

Unknown

At the global level, 30 percent of accessions have unknown biological status. Asia has the highest percentage of accessions with unknown biological status, almost 40 percent, followed by Latin America with 35 percent and Europe with almost 28 percent. Although these figures are quite high, there was a small decrease in the proportion of accessions with unknown status between 2009 (32 percent) and 2021 (31 percent) (Table 3.12).

3.4.4 Germplasm accessions stored in genebanks categorized by crop group

The numbers of accessions conserved *ex situ* in national, regional and international holdings for the different crop groups are presented in Table 3.12. Unsurprisingly, the groups with the largest numbers of accessions conserved are the major food crops. The one exception is the category "other," which includes the large collections at the Nottingham Arabidopsis Stock Centre.

Forages, medicinal and material plants are the groups with the highest percentages of wild samples, both in 2009 and in 2021 (Table 3.13**)**. Pulses have the lowest percentage of wild samples, followed by oil and fibre plants. Landraces are most prominent among roots and tubers, followed by pulses and pseudo-cereals. They are less common among material plants, forages and ornamentals. Sugar crops and cereals have the highest proportions of breeding materials, while ornamentals have the highest proportion of advanced cultivars. It is noteworthy that the breeding/research category has a high incidence in the "other" group, a consequence of the large proportion of *Arabidopsis* within this group.

[62] The collections at the Nottingham Arabidopsis Stock Centre are excluded.
[63] The collections at the Nottingham Arabidopsis Stock Centre are excluded.

Table 3.12. Number of accessions conserved *ex situ* for different crop groups and their distribution across national, regional and international holdings

Crop group	Accessions	Accessions (%)		
		National	Regional	International
Cereals	2 394 734	76	1	23
Pulses	695 588	73	1	26
Forages	514 665	85	1	14
Vegetables	386 595	90	2	9
Fruit plants	268 668	96	1	4
Oil plants	215 109	90	0	9
Fibre plants	126 207	99	0	0
Roots and tubers	112 301	69	2	29
Ornamentals	58 966	100	0	0
Herbs and spices	54 944	98	1	2
Medicinal plants	52 770	95	2	3
Stimulants	40 834	92	8	0
Pseudo-cereals	40 638	93	1	6
Material plants	36 409	95	0	5
Sugar crops	18 843	100	0	0
Nuts	16 625	97	0	3
Others*	796 279	100	0	0
Total	5 830 175	84	1	15

* Others include *Arabidopsis* plus wild flora.

Table 3.13. Number of accessions conserved *ex situ* for different crop groups and biological types in 2009 and 2021

Crop group	2021						2009					
	No. of accessions	Wild materials* (%)	Landraces (%)	Breeding materials (%)	Advanced cultivars (%)	Others** (%)	No. of accessions	Wild materials* (%)	Landraces (%)	Breeding materials (%)	Advanced cultivars (%)	Others** (%)
Cereals	2 394 734	6	31	25	14	25	2 115 115	6	31	24	14	25
Pulses	695 588	5	40	13	9	35	621 431	4	40	12	9	36
Forages	514 665	54	6	7	7	27	448 101	55	6	6	7	27
Vegetables	386 595	8	30	9	15	39	317 358	7	27	8	16	42
Fruit plants	268 668	11	32	10	18	28	217 011	12	27	11	20	31
Oil plants	215 109	5	21	16	13	45	188 326	5	20	16	14	47
Fibre plants	126 207	4	15	16	17	48	112 542	4	13	16	17	50
Roots and tubers	112 301	16	47	13	10	14	96 562	16	47	13	10	14
Ornamentals	58 966	35	8	6	33	18	45 270	25	7	7	40	20
Herbs and spices	54 944	20	25	7	6	42	41 928	18	25	7	7	44
Medicinal plants	52 770	53	13	5	4	26	35 572	42	17	5	4	32
Stimulants	40 834	10	31	19	12	28	37 918	9	31	20	11	28
Pseudo-cereals	40 638	7	39	4	7	43	34 326	7	34	4	8	48
Material plants	36 409	29	6	8	2	56	27 168	22	7	10	2	60
Sugar crops	18 843	18	15	28	24	14	17 247	16	15	28	26	15
Nuts	16 625	23	27	7	11	32	13 558	16	31	7	13	34
Other***	796 279	12	0	51	0	37	624 618	8	0	49	0	43
Total/overall mean	5 830 175	12	25	22	11	30	4 994 051	11	25	21	11	32

* This category includes weedy accessions (0.5 percent in 2009 and 0.6 percent in 2021).
** This category includes unclassified accessions (99.5 percent in 2009 and 99 percent in 2021) and 6 genetically modified accessions in 2021.
*** Under this group 86 percent of total accessions in 2021 and 90 percent in 2009 were *Arabidopsis*.

3.4.5 Common methods of conservation and types of plant material conserved

PGRFA consist of different types of germplasm that require different conservation approaches. The most common conservation approaches and types of plant material conserved are summarized in Box 3.2. It should be noted that more than one storage method and type of plant material can be utilized (see Engels and Ebert, 2021a). It is not uncommon for species to be maintained in a field genebank and also conserved *in vitro* culture and/or cryopreserved. Similarly, those conserved through more conventional methods may also be stored as pollen or DNA.

Box 3.2 Common methods of conservation and types of plant material conserved

- **Seed genebanks:** Species that produce orthodox seeds (i.e. seeds that can be dried and stored at low temperature) are easily conserved in seed genebanks. Orthodox seeds are typically stored in genebanks after having been dried and packed in airtight containers. In medium-term storage, seeds are maintained under refrigeration at 5–10 °C and a relative humidity of 15±3 percent (FAO, 2014; 2022a). Long-term storage is generally at -70 °C, with seeds stored in hermetically sealed containers.
- **Field genebanks:** Species that produce recalcitrant seed (i.e. seeds that cannot survive drying and storage at low temperature) or intermediate storable seeds and those that are vegetatively propagated are commonly conserved as whole plants in field genebanks. Such species comprise about 8–10 percent of flowering plant species. They can also be conserved through *in vitro* culture and/or cryopreservation.
- ***In vitro* culture:** As an alternative to the conservation of live plants in field genebanks, germplasm can be conserved using tissue culture. Under this approach, tissue is taken from plants to form explants that will grow on a substrate under optimal temperature, light and relative humidity conditions and can be conserved for short- or medium-term durations, especially under slow-growth conditions for which the frequency of subculturing is low. The development of new (or adaptation of existing) *in vitro* culture protocols for each species (and sometimes at the varietal level or even individual genotypes) is a fundamental aspect of optimizing their storage.
- **Cryopreservation:** This method involves the long-term preservation of various plant parts (tissue, meristem, pollen or dormant buds) in liquid nitrogen. As in the case of *in vitro* culture, methodologies are often species, varietal or even genotype specific. Cryopreservation is often used as a means of safety backup for germplasm conserved in field genebanks or under *in vitro* culture. A useful review of this type of germplasm conservation can be found in Reed (2017).
- **Storage of pollen:** Pollen can be stored at -80 °C or cryopreserved, and stays viable and functional for up to ten years. As most species produce storable pollen, this method allows for the storage of vast numbers of samples using relatively little space and at lower costs than other methods. Pollen, however, only provides half of the genome and must be used to fertilize a female egg cell to obtain a new plant. For some crops (e.g. coconuts), pollen provides the only safe way of exchanging genetic diversity and is relatively easy to ship to specialized recipients without spreading diseases.
  Conservation of DNA: DNA extracted from plants is relatively easy to handle and store. With the increasing importance of molecular techniques applied to germplasm materials, the storage of DNA samples from plants is becoming increasingly common. DNA can be maintained at -20 °C in short- and medium-term storage (up to ten years) and at -70 °C in liquid nitrogen for much longer periods, comparable to long-term seed storage.

The total numbers of accessions kept under each type of storage in national genebanks and in regional and international genebanks are presented in Table 3.14 and Table 3.15, respectively. The numbers of accessions kept under each type of storage by region and subregion is shown in Table 3.16 and for specific international and regional genebanks in Table 3.17.

Table 3.14. Storage types used for *ex situ* conservation in national genebanks

Storage type	Genera	Species	Accessions	Percent	Countries	Genebanks
Seed collection	6 535	43 480	3 678 932	76	105	424
Field collection	2 094	8 794	385 366	8	82	555
In vitro collection	152	628	27 633	1	35	77
Cryopreserved collection*	1 594	4 486	693 902	14	12	24
DNA collection	669	1 338	3 683	0.1	7	9
Unspecified**	2 382	10 093	113 422	2	35	201
Total	7 304	50 959	4 872 408		115	827

* *Arabidopsis* accessions stored under cryopreservation account for 682 556 of the accessions in this category.
** Countries and genebanks are counted when storage-type information is unspecified for at least one accession even though the accession is reportedly under medium- or long-term conservation. These data do not include the internal backup collections at the USDA National Laboratory for Genetic Resource Preservation in Ft. Collins, Colorado, United States of America.

Table 3.15. Storage types used for *ex situ* conservation in regional and international genebanks.

Storage type	Genera	Species	Accessions	Percent	Countries	Genebanks
Seed collection	779	3 529	906 700	94.7		15
Field collection	210	355	30 075	3.1		9
In vitro collection	26	124	27 116	2.8		6
Cryopreserved collection	3	28	1 173	0.1		2
DNA collection	0	0	0	0		0
Unspecified	0	0	0	0		0
Total	929	3 869	957 767			19

Table 3.16. Number of accessions held under different types of *ex situ* storage, by region and subregion

Regions and subregions (number of countries)	Seed collection	Field collection	*In vitro* collection	Cryo collection	DNA collection	Number of genebanks
Northern Africa (5)	128 725	1 663	0	0	0	5
Northern Africa (5)	128 725	1 663	0	0	0	5
Sub-Saharan Africa (23)	192 858	9 223	0	0	0	55
Eastern Africa (9)	159 457	7 524	0	0	0	25
Southern Africa (5)	15 900	444	0	0	0	8
Western Africa (9)	17 501	1 255	0	0	0	22
Northern America (2)	617 115	27 672	7 357	0	0	30
Northern America (2)	617 115	27 672	7 357	0	0	30
Latin America and the Caribbean (19)	383 720	69 241	8 965	0	905	180
Central America (7)	69 672	13 366	1 030	0	0	77
Caribbean (2)	10 972	9 642	237	0	287	19
South America (10)	303 076	46 233	7 698	0	618	84
Asia (26)	969 525	51 356	715	1 862	64	102
Central Asia (3)	69 914	5 668	0	0	0	10
Eastern Asia (2)	216 509	30 415	0	1 444	0	2
South-eastern Asia (6)	87 176	9 030	290	8	64	37
Southern Asia (7)	511 314	4 075	424	410	0	30
Western Asia (8)	84 612	2 168	1	0	0	23
Europe (37)	1 101 789	223 709	10 560	692 040	2 714	445
Northern Europe (9)	157 114	9 752	1 108	689 053	2 625	62
Eastern Europe (10)	1 444	67 747	4 684	458	89	136
Southern Europe (12)	161 580	67 899	374	1	0	122
Western Europe (6)	211 403	78 311	4 394	2 528	0	125
Oceania (3)	285 200	2 502	36	0	0	10
Melanesia (1)	0	2 502	36	0	0	7
Australia and New Zealand (2)	285 200	0	0	0	0	3
Total	3 678 932	385 366	27 633	693 902	3 683	827

Table 3.17. Number of accessions held under different types of *ex situ* storage in international and regional genebanks

	Seed collection	Field collection	*In vitro* collection	Cryo collection	Total
International genebanks					
AfricaRice	21 815	0	0	0	21 815
Bioversity ITC	0	0	1 690	1 127	1 690
CIAT	60 596	0	5 965	0	66 561
CIMMYT	211 501	0	0	0	211 501
CIP	10 920	6 708	11 272	0	17 313
ICARDA	151 858	0	0	0	151 858
ICBA	15 142	0	0	0	15 142
ICRAF	6 318	8 848	0	0	15 166
ICRISAT	146 250	0	0	0	146 250
IITA	27 224	9 507	5 856	46	36 731
ILRI	18 512	138	0	0	18 650
IRRI	132 288	2	0	0	132 290
WorldVeg	64 948	0	0	0	64 948
Total	852 230	25 203	24 783	1 127	899 915
Regional genebanks					
CATIE	6 122	4 828	0	0	10 950
CePaCT	0	0	2 232	0	2 232
NordGen	33 206	44	101	0	33 344
SPGRC	15 142	0	0	0	11 326
Total	54 470	4 872	2 333	0	57 852

Table 3.18. Types of storage expressed as percentages of the number of accessions conserved *ex situ* for different crop groups

Crop group	Accessions	Storage types (%)					
		Seed	Field	*In vitro*	Cryo.	DNA	Unknown
Cereals	2 394 734	99	0	0	0	0	1
Pulses	695 588	98	0	0	0	0	1
Forages	514 665	96	1	0	0.1	0.1	2
Vegetables	386 595	94	2	0	0.2	0	3
Fruit plants	268 668	12	81	3	1	0.3	6
Oil plants	215 109	95	4	0	0	0	1
Fibre plants	126 207	94	4	0	0	0	2
Roots and tubers	112 301	32	52	39	2	0.4	2
Ornamentals	58 966	39	53	1	0.8	0.1	7
Herbs and spices	54 944	82	12	1	0.6	0.1	5
Medicinal plants	52 770	83	7	0	1.2	0.4	10
Stimulants	40 834	38	61	0	0	0.4	2
Pseudo-cereals	40 638	96	1	0	0.1	0	4
Material plants	36 409	74	15	0	2	0.2	11
Sugar crops	18 843	47	47	0	0.1	0	7
Nuts	16 625	16	70	1	0.1	0	15
Others	796 279	11	1	0	86	0.1	2

Seed genebanks and their status

Seed storage is by far the most frequently used *ex situ* conservation method, with over 3.6 million accessions maintained in 424 national genebanks in 105 countries (79 percent of the total global germplasm holdings) (Table 3.14). Of these, 40 percent are maintained in medium-term storage, 78 percent in long-term storage and 18 percent in both. Countries with seed holdings above 100 000 accessions include the United State of America, India, Australia, the Russian Federation, Japan, Brazil, the United Kingdom, Germany and Canada. The regions maintaining the largest number of accessions as seed are Europe (198 genebanks in 33 countries), Asia (54 genebanks in 24 countries) and North America (25 genebanks in two countries). Over 900 000 accessions (16 percent of the global total) are conserved as seed in three regional and 12 international genebanks (Table 3.15). CIMMYT, ICARDA, ICRISAT and IRRI each have more than 100 000 accessions in their seed collections (Table 3.16).

Between 94.4 and 99 percent of all *ex situ* holdings of cereals, pulses, forages, vegetables, oil plants, fibre plants and pseudo-cereals are conserved as seed. Fruit plants, nuts and roots and tubers are among the crop groups less represented in seed banks, which account for between 12 percent and 32 percent of holdings in each of these groups (Table 3.18).

Field genebanks and their status

Over 415 000 accessions, approximately 7 percent of global *ex situ* germplasm, is maintained in 564 field genebanks in 82 countries and seven regional or international centres (Table 3.14). These collections represent over 8 900 species. About 36 000 field genebank accessions are also maintained as seed, *in vitro* and/or cryopreserved.

Portugal and Japan lead a list of 13 countries[64] holding almost 11 000 accessions in field collections. Among these, Mexico operates a national network of 44 field genebanks, Germany has 37, Spain has 34 and

[64] Portugal, Japan, Germany, United States of America, Switzerland, Brazil, Romania, Ukraine, France, Spain, Italy, Mexico and Belarus.

Ukraine, Romania, Norway and Italy all have more than 20. In Cuba, 47 percent of the *ex situ* holdings are maintained in 15 field genebanks, while in Papua New Guinea all the *ex situ* holdings are conserved in field genebanks. Europe, Latin America and the Caribbean, Asia and Northern America are the regions with the largest numbers of accessions maintained in field genebanks (Table 3.16).

Among the 10 950 accessions conserved at the regional genebank of CATIE, Costa Rica, 44 percent are maintained in fields (Table 3.17). These collections include coffee (1 990 accessions), cocoa (1 251 accessions), peach palm (614 accessions) and other fruit trees. The international genebanks conserve 25 203 vegetatively propagated accessions in field genebanks. These make up 3 percent of all the accessions maintained by the international genebanks and 0.4 percent of the global total. The international genebanks with the largest field collections include IITA, ICRAF and CIP.

The crop groups with the largest proportions of their total holdings kept in field genebanks include fruit plants (81 percent), nuts (70 percent), stimulant plants (61 percent) and roots and tubers (52 percent) (Table 3.18). More than 90 percent of rubber tree, coffee, *Uapaca*, cocoa, oil palm, avocado, olive tree, mango, *Rhododendron*, grape and sugar cane holdings are conserved in field genebanks. Crops for which more than 80 percent of holdings are conserved in field genebanks include *Malus, Pyrus* and *Prunus*, cassava, sweet potato, hazelnut and walnut.

In vitro *collections and their status*

Only 1 percent of accessions worldwide are maintained through *in vitro* culture, including 27 633 accessions in national genebanks and 27 116 in regional and international genebanks (Table 3.14). More than half of those accessions are also maintained as seed in cold storage, plants in field genebank and/or cryopreserved. Thirty-three countries operate *in vitro* storage facilities and maintain germplasm *in vitro*.[65]

With the exception of Northern and sub-Saharan Africa, all regions maintain *in vitro* collections (Table 2.16). Europe, North America and Latin America and the Caribbean each maintain over 7 000 accessions, while the *in vitro* collections of Asia (715 accessions) and Oceania (36 accessions) are significantly smaller. Four CGIAR genebanks (CIAT, CIP, IITA and the Bioversity International Musa Germplasm Transit Centre (ITC) maintain 24 783 accessions *in vitro* (Table 3.17). CePaCT reports that it maintains 2 232 accessions of 25 taxa *in vitro,* and SPGRC reports 101 accessions.

In vitro conservation is heavily used in important collections of roots and tubers (Table 3.18) such as cassava (66 percent of all accessions), *Ullucus* (48 percent), yams (44 percent), *Ipomoea* (37 percent), *Colocasia* (33 percent), potato (33 percent), *Oxalis* (32 percent), and *Tropaeolum* (24 percent), as well as in collections of fruit plants such as *Musa* (42 percent) and strawberries (35 percent). Since the publication of the SoW2, the amount of germplasm stored *in vitro* has increased by 10 percent overall. There have been significant increases in *in vitro* collections relative to 2009 for yams (31 percent increase at IITA), *Musa* (31 percent at ITC; 67 percent at IITA), potatoes (32 percent in Belarus and Czechia), sweet potatoes (11 percent at CIP), cassava (15 percent at EMBRAPA Cassava and Fruits in Brazil; 11 percent at IITA). In Malaysia, the Malaysian Agricultural Research and Development Institute established a *Musa in vitro* collection, and in Sri Lanka the yam collection at the Plant Genetic Resources Centre has almost tripled in size since 2009.

Cryopreserved collections and their status

If the *Arabidopsis* model plant research collection managed by the Nottingham Arabidopsis Stock Centre is included, cryopreservation is the second most widely used *ex situ* conservation method (12 percent) (Table 3.14). If the *Arabidopsis* collection is excluded, the relative significance of cryopreservation is more modest (0.2 percent).[66] Nonetheless, since 2009, the number of accessions cryopreserved has increased by 52 percent

[65] Argentina, Belarus, Bolivia (Plurinational State of), Brazil, Bulgaria, Canada, Colombia, Costa Rica, Cuba, Czechia, Ecuador, Estonia, Finland, France, Germany, Guyana, India, Ireland, Italy, Malaysia, Mexico, Norway, Panama, Papua New Guinea, Philippines, Poland, Romania, Slovenia, Spain, Sri Lanka, Switzerland, Trinidad and Tobago and United States of America.

[66] These data do not include the 49 200 accessions maintained as internal backup at the USDA National Laboratory for Genetic Resource Preservation in Ft. Collins, Colorado, United States of America.

to 12 533 and the number of genera cryoconserved by 63 percent to 1 596. The number of species cryoconserved has doubled, reaching 4 508. This trend is expected to continue in the short term as capacity improves and needs surge, particularly the need to conserve wild species, including edible fruit plants. Twelve countries have cryopreserved material plants.[67] Cryopreserved accessions are also maintained as seed in cold storage, as plants in field genebanks and/or via *in vitro* culture. *Solanum*, *Musa*, *Morus*, *Allium*, *Fragaria* and *Prunus* are the genera most represented in cryopreserved collections. Bioversity ITC genebank reports that it maintains 1 127 *Musa* accessions using cryopreservation (Table 3.17), an 11 percent increase since 2009.

DNA collections

A total of 3 683 accessions maintained in nine national genebanks of seven countries[68] have associated DNA samples stored (0.1 percent of all global accessions) (Table 3.14**)**. While DNA sample collections are increasing within countries and at international centres, they are often managed by specialized molecular research teams, and hence may not have been reflected in the annual genebank reports for the SDG indicator.

Unspecified

The storage type of 113 422 accessions held in national genebanks (2 percent of national holdings and 2 percent of global holdings) is unspecified, although they are reported under the SDG Indicator 2.5.1a, which relates to germplasm in base collections under medium- or long-term storage.

3.4.6 Redundancy within and between collections and the uniqueness of germplasm accessions

Redundancy within and among collections has remained poorly addressed and documented overall. However, there has been some progress on unwanted duplication within collections thanks to continued rationalization efforts at country level and in international genebanks. These efforts have been facilitated by reductions in the cost, and progress in the application, of new molecular tools and information technologies. The wide adoption of germplasm documentation standards and advanced genebank data management systems, including Genetic Resource Information Global (GRIN-Global), has increased data comparability and allowed more frequent publication of national inventory data through web portals such as the European Search Catalogue for Plant Genetic Resources (EURISCO) and Genesys. Furthermore, the application of the indicators on *ex situ* collections for monitoring the implementation of the Second GPA, and later SDG Indicator 2.5.1a,[69] has helped to mainstream annual reporting on germplasm holdings and to reduce data redundancy for the global assessment of SDG Target 2.5 by focusing on base *ex situ* collections and excluding active collections.

The narrative reports from countries provide some observations on redundancy within and among collections. These included mentions of the identification of unwanted duplicates through management of field collections (Portugal), the application of DNA analysis (Finland), prioritization (Switzerland), the use of GRIN-Global (Chile), and difficulties in eliminating identified duplicates because of a lack of financial resources (Armenia) or a lack of time to eliminate duplications in field collections (Norway). Rationalization of the genebank collection of the Kingdom of the Netherlands is reported to have resulted in the elimination of its barley collection in favour of collaboration with the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) collection in Germany.

A global estimate of the uniqueness of national and international germplasm collections, which is calculated as the proportion of the largest genebank collection for each conserved species against total holdings for that species, stands at 38 percent or 2 113 340 distinct accessions in 2021. Applying this methodology to the 2009 WIEWS *ex situ* dataset gave a result of 24 percent or 1 375 174 distinct accessions, which is below the 25–30 percent range reported in the SoW2. The significant increase in the estimate of uniqueness in global germplasm holdings is probably caused by several factors, including rationalization efforts made at national level to increase efficiency and the more focused coverage of SDG Indicator 2.5.1a, which excludes PGRFA

[67] Czechia, Estonia, Finland, Germany, India, Italy, Japan, Lithuania, Norway, Philippines, Poland and United Kingdom.
[68] Belarus, Brazil, Cuba, Czechia, Ecuador, Malaysia and United Kingdom.
[69] https://www.fao.org/sustainable-development-goals/indicators/251a/en/

in active collections. The methodology used for these estimates may also be a factor, as it benefits from the improved taxonomic characterization of the germplasm at genebanks and the overall higher quality of data reported.

As of September 2022, 34 percent of the 1 395 540 accessions recorded in EURISCO were identified as unique accessions (excluding the *Arabidopsis* collection). These data referred to germplasm maintained by 39 European countries that are part of the European Cooperative Programme for Plant Genetic Resources (ECPGR) network (Personal communication: Stephan Weise). Fourteen countries have over75 percent of the accessions in their national inventories recorded as unique in EURISCO.

There are a number of species that are conserved in one or only a few genebanks globally. The concentration of these PGRFA is a concern, as it may imperil their long-term conservation and consequently reduce options for their sustainable use. Some of these species are also classified by IUCN as at risk in their endemic areas (IUCN, 2022). Appendix 1 presents a subset of these species. Each of the 368 species listed[70] has 95 percent or more of its total global holdings (which range between 20 and 4 173 accessions) conserved in only one genebank. Among these 368 species collections, 92 percent are not safety duplicated (the remaining 29 collections have an average safety duplication level of 80 percent). These species need to be targeted for safety duplication (see Section 3.5), especially those that are not widespread in their natural habitats and are at greater risk for genetic erosion. As most of these species are difficult to conserve (produce recalcitrant seeds or are vegetatively propagated), options for maintaining them under cryopreservation should be considered and, whenever possible, supported. Collaboration both within and outside the country where the collections are held, for example with universities or regional and international research institutes should also be explored. An extract of Appendix 1 is presented in Table 3.19.

Sixty-six genebanks conserve these unique collections (a total of 57 330 accessions), 62 located in 27 countries and four in international centres. Forty-two of the species are CWR; 65 are harvested from the wild and used locally as food (WFP); 41 are fruit plant species (10 945 accessions in 17 genebanks), 17 are vegetables (1 103 accessions in 12 genebanks), 14 are nut plants (7 959 in nine genebanks), 13 are roots and tubers (5 383 accessions in eight genebanks), nine are herbs and spices (1 087 accessions), eight are stimulant plants (743 accessions), seven are pulses (1 062 accessions), six are oil plant species (810 accessions), three are cereal CWR (858 accessions) and one is an endangered pseudo-cereal, *Cycas micronesica* (23 accessions).

[70] Excludes synthetic interspecific hybrids, intergeneric hybrids and graft chimaera.

Table 3.19. Selected examples of species conserved in only one or few collection (Note: CWR = crop wild relative. WFP = wild food plant.)

Crop group	Species	CWR	WFP	IUCN Red list category	Total accessions	Genebanks	Min. genebank collection size (accessions)	Max. genebank collection size (accessions)	Max. genebank collection size (%)	Safety duplication % of the max. genebank collection	Holding institute code	Holding institute acronym
Fruit plants	*Uapaca kirkiana*		Y	Least Concern	2 927	1	2927	2927	100	0	KEN056	ICRAF
Fruit plants	*Euterpe oleracea*				1 828	4	1	1823	99.7	0	BRA018	CPATU
Fruit plants	*Ugni molinae*		Y		126	2	1	125	99.2	0	CHL150	INIA Carillanca
Fruit plants	*Pouteria lucuma*		Y	Least Concern	100	1	100	100	100	0	PER041	INIA-EEA.CAN
Fruit plants	*Persea schiedeana*	Y	Y	Endangered	58	1	58	58	100	0	MEX121	CICTAMEX
Fruit plants	*Curculigo latifolia*		Y		45	1	45	45	100	0	MYS125	UPM
Nuts	*Carya illinoinensis*			Least Concern	3 733	10	1	3615	96.8	0	USA133	BRW
Nuts	*Acrocomia aculeata*		Y	Least Concern	1 526	6	1	1488	97.5	0	BRA034	CPAC
Nuts	*Pinus albicaulis*		Y	Endangered	1 138	4	1	1110	97.5	0	USA476	NSL
Nuts	*Juglans neotropica*	Y	Y	Endangered	23	2	1	22	95.7	0	ECU212	JBQ
Roots and tubers	*Dioscorea rotundata*				4 173	7	1	3974	95.2	0	NGA039	IITA
Roots and tubers	*Ensete ventricosum*			Least Concern	310	6	1	303	97.7	0	ETH085	EBI
Roots and tubers	*Manihot peruviana*	Y			92	1	92	92	100	0	COL003	CIAT
Roots and tubers	*Dioscorea sambiranensis*	Y	Y	Near Threatened	33	1	33	33	100	0	GBR004	RBG
Roots and tubers	*Alocasia odora*			Least Concern	26	1	26	26	100	0	VNM049	PRC
Roots and tubers	*Coleus rotundifolius*				21	1	21	21	100	0	LKA036	PGRC
Vegetables	*Citrullus amarus*	Y	Y		154	2	1	153	99.4	0	USA016	S9
Vegetables	*Solanum lycocarpum*	Y	Y	Least Concern	90	4	1	86	95.6	0	BRA003	CENARGEN
Vegetables	*Apium australe*		Y		86	3	1	84	97.7	0	CHL171	SAG
Vegetables	*Chlorophytum borivilianum*		Y	Critically Endangered	36	1	36	36	100	0	IND001	NBPGR
Vegetables	*Helosciadium repens*	Y			35	1	35	35	100	6	DEU502	BOGOS
Herbs and spices	*Piper aduncum*			Least Concern	747	5	1	742	99.3	0	BRA003	CENARGEN
Herbs and spices	*Lippia dulcis*		Y		54	1	54	54	100	0	MEX006	BANGEV
Pulses	*Vigna minima*		Y		558	7	1	547	98	0	JPN183	NARO
Pulses	*Lupinus gredensis*				176	5	1	170	96.6	100	ESP010	SIAEX
Stimulants	*Ilex guayusa*			Least Concern	161	3	1	157	97.5	0	ECU098	USFQ
Stimulants	*Coffea mauritiana*	Y		Vulnerable	95	3	1	93	97.9	0	FRA254	IRD
Pseudo cereals	*Cycas micronesica*			Endangered	23	1	23	23	100	0	USA047	MIA

3.4.7 Complementarity between *in situ* and *ex situ* conservation

The natural habitats of CWR, WFP and wild flora with some potential value for food and agriculture are the largest reservoirs of genetic diversity for these species. *In situ* conservation is therefore an irreplaceable means of safeguarding this diversity and enabling further evolution and adaptation. However, given the vulnerability of many such natural habitats, there is also a need to also conserve this diversity *ex situ,* in genebanks. Complementary *ex situ* conservation also enhances opportunities for in-depth research into these resources and ultimately for their use.

The genetic diversity of many species found in the wild is threatened by many factors, including climate change. As reflected in countries' collecting efforts (see Section 3.3.1), genebank collections are increasingly safeguarding many vulnerable species. *Ex situ* holdings from 54 countries, two regional and ten international centres conserve almost 21 000 accessions belonging to 2 084 species collected from the wild that are listed in the IUCN categories of major concern (IUCN, 2022)[71]. A subset of these, all of which are CWR, is presented in Table 3.20. It is noteworthy that the number of accessions per species within genebanks is low overall – 7.4 on average. A total of 1 656 species have one accession each, while one species, *Aegilops sharonensis*, a wild relative of wheat that is a source of disease and insect resistance and tolerance of salt, drought and nutrient deficiencies (Wang *et al*., 2021), has 2 623 accessions. The distribution of this threatened germplasm among genebanks is heavily biased toward Northern America, Europe and Asia, which together account for 91 percent of the species and 85 percent of the accessions conserved.

Table 3.20. Selected species conserved *ex situ* and listed in the IUCN categories of major concern

Species	Total number of accessions	IUCN Red List category
Aegilops sharonensis	2 778	Vulnerable
Malus sieversii	1 947	Vulnerable
Cicer reticulatum	1 046	Near Threatened
Pinus albicaulis	926	Endangered
Aegilops bicornis	461	Near Threatened
Pistacia vera	176	Near Threatened
Cicer bijugum	170	Endangered
Avena murphyi	140	Endangered
Coffea Arabica	131	Endangered
Coffea mauritiana	94	Vulnerable
Solanum okadae	89	Endangered
Solanum alandiae	63	Near Threatened
Coffea macrocarpa	63	Vulnerable
Solanum trifidum	57	Near Threatened
Mentha cervina	50	Near Threatened
Amblyopyrum muticum	49	Endangered
Allium altaicum	43	Near Threatened
Brassica villosa	42	Near Threatened
Vigna exilis	42	Near Threatened
Vigna grandiflora	42	Near Threatened
Solanum oxycarpum	42	Endangered
Solanum wittmackii	40	Endangered
Pistacia atlantica	39	Near Threatened
Solanum neocardenasii	39	Endangered

[71] Critically Endangered; Endangered; Extinct in the Wild; Near Threatened; Vulnerable.

Helianthus exilis	35	Near Threatened
Solanum schenckii	35	Endangered
Dioscorea sambiranensis	33	Near Threatened
Solanum chmielewskii	33	Endangered
Brassica rupestris	32	Near Threatened

3.4.8 Gaps in collection coverage

Ensuring adequate coverage of the genetic diversity in germplasm collections, especially at the global level, is important for the conservation and sustainable use of PGRFA. Identification of gaps in collections has therefore gained increasing attention. New tools and methods have been developed to assess these gaps, including through the study of the genetic diversity and geographical representation in collections (e.g. Ramirez-Villegas *et al*., 2010, 2020).

Several countries report gaps in their collections, including gaps in collections of landraces/traditional varieties (Armenia, Botswana and Malaysia), priority crops (Benin), food crops (Ghana, Brazil and Guyana); CWR (Peru, Malaysia and the Kingdom of the Netherlands), fruit species (Germany); small grains (Serbia), vegetatively propagated crops (Namibia) and a number of important species (Republic of Moldova).

The global strategies for the long-term conservation and use of crop-specific genepools developed under the leadership of the Crop Trust offer a reliable source of information on gaps in crop collections of global importance. For most of the crop genepools for which a global conservation strategy has been developed, specific gaps in the existing (global) collections have been highlighted and may serve as a guide for setting new collecting priorities and/or promoting collaboration in targeted collecting. A summary of crop genepool-specific gaps listed in published crop strategies is presented in Appendix 2.

3.4.9 Trends in *ex situ* conservation capacities

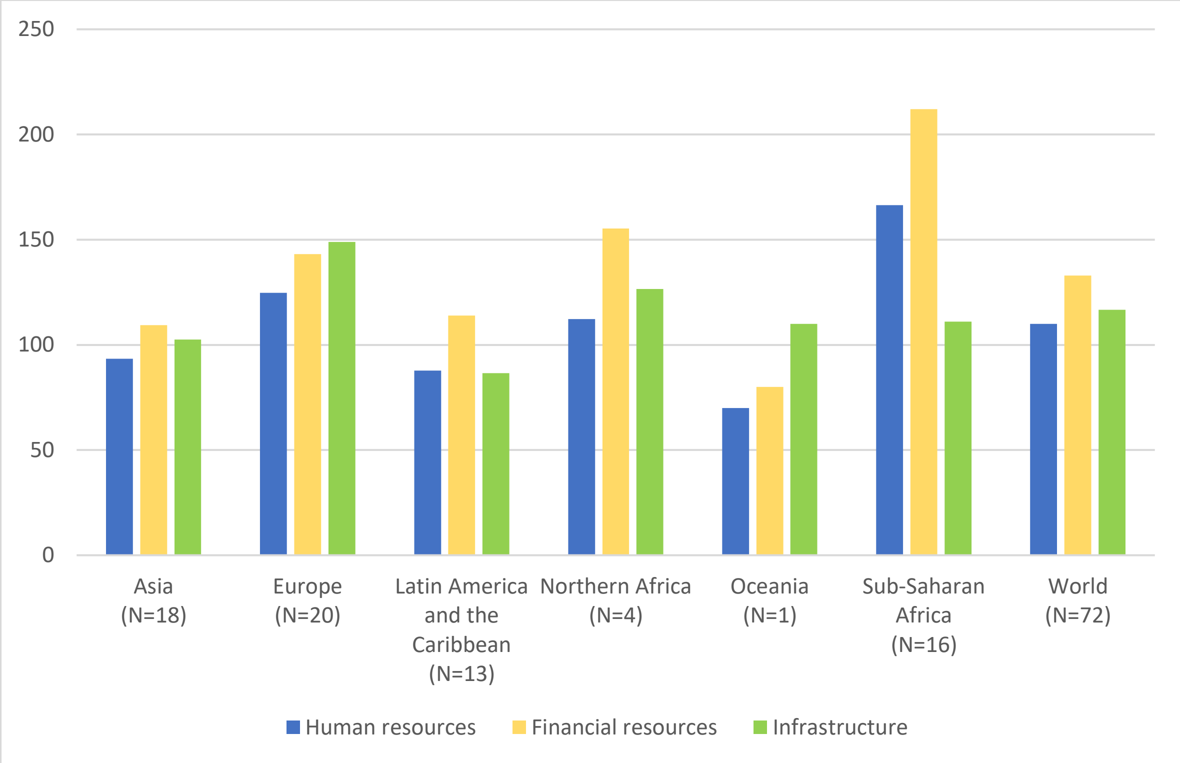
The sustainability of safe, efficient and effective long-term conservation depends on the availability of adequate financial resources to implement them, skilled staff and adequate infrastructure for processing, storing and monitoring activities in genebanks. Countries were asked to report on the state of capacities at national genebanks in terms of infrastructure and human and financial resources in 2019 as compared to 2010. Table 3.21 summarizes the results for each capacity element by region. Figure 3.6 presents a regional breakdown of the average percentages of the different capacity elements in 2019 weighted against the regional germplasm holdings.

Table 3.21. Changes in the status of human resources, financial resources and infrastructure at national genebanks, 2010 to 2019

Region	Number of countries								
	Human resources			Financial resources			Infrastructure		
	↘	=	↗	↘	=	↗	↘	=	↗
Asia	7	2	9	4	2	12	3	5	10
Europe	5	6	9	3	2	15	3	6	11
Latin America and the Caribbean	8	0	5	7	0	5	7	2	3
Northern Africa	0	2	2	0	2	2	0	2	2
Oceania	1	0	0	1	0	0	0	0	1
Sub-Saharan Africa	7	2	7	10	0	6	8	2	6
World	28	12	32	25	6	40	21	17	33

Notes: ↗ indicates increased capacity, = indicates no change in capacity, ↘ indicates decreased capacity in 2019 as compared to 2010.

Figure 3.6. Changes in the status of capacities in terms of human resources, financial resources and infrastructure at national genebanks, 2010 to 2019



Notes: The bars indicate levels of capacity in 2019 as a percentage of those in 2010. The global and regional values are weighted against the global and regional *ex situ* holdings, respectively. N indicates the number of reporting counties.

Globally, there was an overall increase in the various components of capacity between 2010 and 2019, with notable differences between regions. Europe, Northern Africa and sub-Saharan Africa showed increases in all three components of capacity. Although the 2010 baseline does not necessarily indicate whether the capacities were adequate at that time, values below the baseline probably have a negative impact on conservation activities in the respective countries.

Although human-resources capacity at national genebanks increased slightly overall, it decreased in 39 percent of the reporting countries and remained unchanged in 17 percent (Table 3.21). Latin America and the Caribbean had the highest incidence of genebanks whose human-resources capacity declined (62 percent). In Asia, although half the reporting countries indicate an increase in staff capacity, the regional weighted average declined relative to 2010 as a result of reduced capacity in national genebanks with large collections. Conversely, in sub-Saharan Africa, where seven countries report an increase in staff capacity and seven a decrease, overall capacity showed a significant increase because of positive changes in the two largest genebanks (Ethiopia and Kenya).

With regard to financial resources, 35 percent of reporting countries indicate a decrease in 2019 relative to 2010, 56 percent report an increase and 9 percent reported no change. Overall, financial capacity weighted by *ex situ* collection size improved in all regions except Oceania.[72] The region with the highest proportion of reporting countries (75 percent) where funding increased was Europe, while the regions with the highest proportions of reporting countries where funding decreased were sub-Saharan Africa (63 percent) and Latin America and the Caribbean (58 percent). As in the case of human resources, a large increase in the availability of financial resources at the largest genebank in sub-Saharan Africa (over 400 percent) doubled the weighted regional average relative to that of 2010. Concerningly, in 16 percent of reporting countries,

[72] Reported only by Papua New Guinea.

financial resources fell by 50 percent or more. One of these countries was from Asia,[73] five from sub-Saharan Africa[74] and five from Latin America and the Caribbean.[75] National genebanks in countries experiencing a reduction in funding availability compared to 2010 also had to cope with an overall 14 percent increase in the number of accessions conserved (from 445 126 to 507 843).

With respect to infrastructure capacity, 47 percent of reporting countries (conserving a total of about 900 000 accessions) indicate improvements in 2019 relative to 2010. However, almost one-third of reporting countries (conserving a total of more than 459 000 accessions) indicate that the state of their infrastructure declined. Infrastructure remained unchanged in the remaining countries, even though their total germplasm holdings increased by 99 406 accessions or 14 percent. The two regions where the largest numbers of reporting counties enhanced their national genebank facilities were Europe (11 countries) and Asia (10 countries).[76] On the other hand, 58 percent of reporting countries in Latin America and the Caribbean indicate a deterioration of their infrastructure capacity, despite a 26 percent increase in their genebank holdings (to 152 038 accessions). Similarly, in sub-Saharan Africa, 50 percent of reporting countries indicate reduced infrastructure capacity, despite conserving 88 317 accessions in 2019, 9 percent more than in 2010. Overall, these figures are concerning, as high levels of capacity reduce the risk of unwanted losses of genetic resources conserved *ex situ*, some of which may no longer exist at the original collecting sites.

The following is a summary of significant improvements and problems reported by countries: 17 countries[77] report improvements in *ex situ* seed storage facilities; 25 countries[78] report on the problems and needs of their respective storage facilities, which included the need to increase and modernize storage capacity and facilities, to replace lost storage infrastructure (rather frequently reported), to re-establish or restructure the national genebank, to address power cuts and erratic power supply, to acquire new laboratory equipment and to establish in-house (germination) testing facilities.

The SoW2 indicated that there had been an increase in storage capacity during the respective reporting period, particularly as a result of new genebanks being built. However the situation at the end of the current reporting period seems to be less positive. Many countries report that they either do not have the type of storage facilities they need (predominantly long-term facilities) or that their equipment is outdated and/or malfunctioning. Linked to this is the fact that many genebanks have difficulties processing materials in a timely manner – the capacity of their testing facilities is insufficient and/or they lack qualified staff. However, a number of countries also report that they have been able to increase the capacity of their medium- and long-term storage facilities (e.g. Brazil, Japan, Türkiye and Uzbekistan), that new genebanks or facilities have been built (e.g. Japan, Lebanon and Poland) and/or that they have been able to streamline procedures. Some countries (e.g. Lebanon and the Republic of Moldova) also mention that they have been able to attract project funding to improve their conservation infrastructure.

It should be noted that several countries report a lack of sufficient funding to allow secure and smooth operation of their storage facilities (e.g. Indonesia, Mongolia, Yemen and Spain). Many more countries, particularly countries on the African continent, note a lack of adequate funding for their *ex situ* conservation operations, including for collecting, monitoring and regeneration/multiplication (see Section 3.13).

3.4.10 Update on genebank and collection management practices

Ex situ conservation has substantially and steadily increased across the world as a way of conserving PGRFA safely and effectively. Genebanks have been built and collections established for all the major crops and

[73] Myanmar.
[74] Botswana, Madagascar, Togo, Uganda, Zambia.
[75] Cuba, Ecuador, Guyana, Mexico, Trinidad and Tobago.
[76] Germplasm holdings of 524 631 and 159 330 accessions, respectively, in these groups of countries.
[77] Belarus, Brazil, Costa Rica, Czechia, Finland, India, Japan, Lebanon, Mali, Poland, Republic of Moldova, Serbia, Tajikistan, Tunisia, Uzbekistan, Yemen, Zimbabwe.
[78] Albania, Argentina, Azerbaijan, Botswana, Cameroon, Cuba, Ghana, Guinea, Guyana, Kenya, Mali, Madagascar, Myanmar, Namibia, Niger, Philippines, Republic of Moldova, Romania, South Africa, Sudan, United Republic of Tanzania, Togo, Trinidad and Tobago, Uganda, Zimbabwe.

their wild relatives, as well as for minor crops and WFP. A number of tools and practices that facilitate germplasm management have been adopted (see Engels and Ebert, 2021a). The development and application of genebank conservation standards help promote best practices. The *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (FAO, 2014) and three practical guides on their application, respectively covering conservation of orthodox seed in genebanks (FAO, 2022c), conservation in field genebanks (FAO, 2022d) and conservation via *in vitro* culture (FAO 2022e), have been published to support countries and genebanks in their conservation efforts.

The increasing use of barcoding technology greatly facilitates the effective, efficient and safe management of accessions in genebanks (Avagyan *et al*., 2020). Molecular tools, such as next-generation sequencing and genotyping-by-sequencing, combined with informatics have enabled scientists to enhance the quality, efficiency and cost-effectiveness of genebank operations and to deepen scientific knowledge of genebank holdings. Genomic information provides a rationale for reducing redundancies within and across crop collections, thus limiting the size of collections and making long-term conservation more cost effective (Singh *et al*., 2019). It can also facilitate genetic gap analyses to guide future collecting missions and acquisitions. Experiments with the seeds of several vegetable crops have shown that RNA integrity declines with storage time in dry seeds (Fleming *et al*., 2019), and assessment of RNA integrity can thus be used to predict the onset of viability decline. New developments in seed storage, such as initial high-temperature drying (Whitehouse *et al*., 2018), will help enhance seed longevity and thus make conservation more effective.

In recent years, the CGIAR Genebank Platform under the coordination of the Crop Trust implemented several quality-management mechanisms that enhanced effective online reporting, performance and quality management and included a periodic audit, external review and validation (Lusty *et al*., 2021). These mechanisms helped genebanks manage regeneration backlogs, avoid mistakes in the handling of accessions, minimize losses and reduce duplication of efforts, facilitating continuous improvements and compliance with the FAO Genebank Standards and other relevant best practices. As a result, in the past ten years, CGIAR (CGIAR Genebank Platform, 2021) and other genebanks that adopted these quality-management tools, for instance CePaCT in the South Pacific, WorldVeg and SPGRC, have significantly improved their performance and the conservation status of their collections.

3.4.11 Summary assessment

A total of 5 830 175 accessions are conserved under medium- and long-term storage conditions in 846 national, regional and international genebanks. These include 4 872 408 accessions conserved in 115 countries, representing 50 959 species from 394 families. This global total is almost 20 percent lower than that reported in the SoW2. The main explanation for this difference is that the SoW2 figures for *ex situ* collections included not only base collections but also active collections. The current figures include base collections only. Other reasons for the decrease include losses from collections because of loss of viability or problems during handling, and rationalization of collections.

It is also striking that the proportion of breeding/research materials in the total number of accessions was much higher 2021 than in 2009, an increase from 11 percent to 23 percent. The inclusion of more than 680 000 *Arabidopsis* accessions is an important factor in this increase. The proportions of wild species, farmers' varieties/landraces and advanced cultivars among the total number of accessions did not change significantly between the two reporting periods.

Crop groups that contain species with a strong breeding and research focus generally have the highest number of accessions, illustrating the impact that germplasm users have on the priorities of genebanks. The changes in the composition of *ex situ* collections in terms of biological types over the past decade are relatively small, even with an increase of almost 1 million accessions across the various crop groups. There have been no dramatic changes in the ranking and status of the 50 major food and other crop genepools of importance to the global food security.

In most countries, field genebanks are mainly used to conserve recalcitrant-seeded species and vegetatively propagated crops and are the only way in which these species can be conserved over the long term. As field genebanks are highly vulnerable to abiotic and biotic stresses and require year-around attention, including cultivation management, the need to reliably back up these collections through *in vitro* culture and/or cryopreservation is clear. It should be noted, however, that reliable *in vitro* and cryopreservation protocols have not yet been established for many crop species. Encouragingly, countries report increasing use of these techniques. More countries are recognizing that they are feasible, and many genebanks have started to install facilities and/or seek collaboration with partners at country level that will allow them to benefit from the advantages they provide.

The increasing use of molecular tools in germplasm management and the adoption of standardized information-management systems have increased capacity to rationalize conservation activities. There has therefore been some progress in terms of eliminating unwanted duplication within collections. The use of data documentation and the publication of data on web-based portals contribute to the rationalization of redundancies among collections. The significant increase in the estimated uniqueness in global germplasm holdings since the time of the SoW2 is also probably driven by efforts made at national level to increase efficiency as well as by the more focused coverage of SDG Indicator 2.5.1a, which now excludes active collections.

Although there was an overall increase in financial, technical and human-resource capacities for conservation of PGRFA at the global level between 2010 and 2019, the difficulties that many countries report with regard to sustaining conservation activities is a cause of concern. Reporting countries note the benefits of regional/international collaboration and coordination of conservation efforts, sharing of long-term conservation facilities, rationalization of collections and better collaboration among stakeholders

The importance of standards, practical guides and standardized operational procedures and of sharing knowledge and experience among members of the genebank community is increasingly being recognized. Adhering to such standards increases transparency and accountability and makes it easier to build trust among curators and other members of the genebank community and thus to promote collaboration and cooperation. It is, however, important to ensure that as many genebanks and collections as possible are enabled to take part in such developments.

3.5 Safety duplication of stored material

The safety duplication of accessions is an essential security measure for genebanks. The FAO Genebank Standards recommend that a sample of every original accession should be stored in a geographically distant area under equivalent or better conditions than those in the original genebank and that the duplicated sample should be accompanied by relevant associated information (FAO, 2014). For species producing orthodox seeds, safety duplication at other genebank facilities is relatively straightforward. For clonal species and species producing recalcitrant seeds, genebanks are increasingly backing up field genebank accessions via *in vitro* culture or cryopreservation (see Section 3.4.5). Several countries regard accessions collected within their territories as part of international collecting projects (e.g. the Crop Trust's Crop Wild Relatives Project) or kept in international collection (e.g. CGIAR Centres and MSB) as being under a form of safety duplication. The arrangements among the SADC member countries to deposit their germplasm collections at the regional genebank SPGRC offer a strategic form of safety duplication.

For orthodox seeds, the Svalbard Global Seed Vault (SGSV)[79] serves as an additional backup that provides genebanks with safe, free and long-term storage of safety duplicates. A global cryopreservation facility providing similar services for vegetatively reproducing species or species producing recalcitrant seeds has been proposed (Acker *et al*., 2017).

[79] https://www.seedvault.no/

As reported for Indicator SDG 2.5.1a at the end of 2021, 2 032 595 accessions – comprising 35 percent of all *ex situ* holdings of 286 genebanks in 86 out of 115 countries and 15 out of 17 regional and international centres[80] – were safety duplicated in other genebanks, including the SGSV. This represents a significant increase relative to the situation in early 2015, when 544 240 accessions, or 10 percent of the total, were reported to be safety duplicated by the respective countries and centres. The percentage of safety duplication is relatively high among international centres (77 percent) and regional centres (59 percent), while it is below 15 percent in the case of national collections.[81] Across regions, the level of safety duplication varies significantly: lowest in Africa and Asia, and highest in Oceania, Northern America and Europe (Table 3.22).

Table 3.22. Percentage of total *ex situ* holdings safety duplicated, by region

Region	Total accessions	Accessions safety duplicated (%)
Northern Africa	130 391	4
Sub-Saharan Africa	202 168	11
Northern America	699 909	22
Latin America and the Caribbean	454 668	13
Asia	1 033 859	7
Europe	1 379 212	18
Oceania	287 706	22

Overall, almost 64 percent of all accessions safety duplicated are conserved at the origin as seed, 2 percent in field collections, less than 1 percent *in vitro.* The remaining 34 percent are mainly represented by the collection at the Nottingham Arabidopsis Stock Centre, where they are held under cryopreservation. Cereals are the most represented crop group among safety-duplicated accessions (34 percent), followed by pulses (11 percent), forages (7 percent) and vegetables (5 percent). In taxonomic terms, safety-duplicated diversity includes 2 030 genera and 8 839 species. Safety duplicates are held by 325 genebanks in 71 countries, 15 regional and international centres and the SGSV.

At end of 2021, 126 genebanks from 46 countries, three regional centres and 11 international centres had deposited 1 125 597 samples at SGSV. These include 984 682 accessions, which represent 17 percent of the 5.8 million *ex situ* accessions reported for SG 2.5.1a and 73 percent of all accessions safety duplicated, excluding the collection at the Nottingham Arabidopsis Stock Centre. It is noteworthy that there are an additional 496 466 accessions that are reportedly not safety duplicated externally but are conserved in different storage collections in the same genebank. A list of the 15 largest depositors at the SGSV, each with more than 20 000 samples deposited, is presented in Table 3.23.

[80] The *ex situ* collections held by CePaCT and ICBA reportedly have no accessions safety duplicated.
[81] The Nottingham Arabidopsis Stock Centre, which is almost entirely safety duplicated at the Ohio State University, is excluded.

Table. 2.23. The 15 largest depositors at the Svalbard Global Seed Vault

Depositor institute	Number of samples	Number of taxa
International Maize and Wheat Improvement Center	177 830	42
National Plant Germplasm System, United States of America	135 237	2 084
International Rice Research Institute	126 447	67
International Crop Research Institute for the Semi-Arid Tropics	117 713	40
International Center for Agricultural Research in Dry Areas	71 229	347
Leibniz Institute of Plant Genetics and Crop Plant Research, Germany	64 231	4 629
International Center for Tropical Agriculture	57 534	708
Australian Pastures Genebank	34 735	1 196
International Center for Agricultural Research in Dry Areas	32 190	284
Plant Gene Resources of Canada	31 955	456
The World Vegetable Center	29 147	271
Nordic Genetic Resource Center	28 170	646
National Institute of Agricultural Sciences. Rural Development Genebank, Republic of Korea	26 880	57
International Institute of Tropical Agriculture	23 333	72
Centre for Genetic Resources, Kingdom of the Netherlands	21 703	448

Source: www.seedvault.nordgen.org cited 10 June 2022.

3.5.1 Situation in the regions

Sub-Saharan Africa

Fourteen countries provided information on the status of the safety duplication of their collections. Niger and Zimbabwe reported that they have been able to maintain or even to improve the level of their safety duplication. Benin, Ghana, Kenya, Mali and Uganda mention duplication at one or more of the CGIAR centres. Botswana and South Africa mention safety duplication of part of their collections at SPGRC Kenya, and Uganda report safety duplication at the SGSV. Kenya and Mali also mention safety duplicating germplasm at the MSB and at the University of Copenhagen, respectively. Ethiopia reports that it has no functional safety duplication facility in place. Madagascar reports safety duplicating part of its collections elsewhere in the country in response to climate change.

Northern Africa

Egypt reports that it is waiting to start systematic safety duplication; its national genebank stores duplicates of the Egyptian Desert Bank in Sheikh Zuweid, Sinai. Tunisia reports the creation of national collections of different species and that its national genebank ensures safety duplicates of its field genebank collections.

Latin America and the Caribbean

Several countries report various levels of safety duplication activities, including Chile, Ecuador, Guyana Mexico, Trinidad and Tobago and Uruguay. Brazil reports that it stores safety duplicates from other Brazilian and international genebanks at its national genebank. Colombia mentions that has developed new strategies and undertaken research on the development of new conservation techniques to ensure safe and viable safety duplication in the long term. Cuba reports that has no safety duplication strategy in place and that its biggest constraint is a lack of sufficient and adequate storage capacity.

Northern America

Canada reports that more than 30 percent of its seed collection is safety duplicated outside the country, including at Fort Collins and at the SGSV.

Asia

Bangladesh, Indonesia, Jordan, Lebanon, Mongolia, Philippines, Tajikistan and Yemen report safety duplication of accessions of the respective mandate crops at CGIAR centres. Jordan and Lebanon report that they also store duplicates at the MSB. Lebanon, Mongolia and Tajikistan report duplication of materials at the SGSV. Azerbaijan, Indonesia, Japan, Mongolia and the Philippines mention that they store safety duplicates from genebanks at their national genebanks. Tajikistan reports that it has safety duplicated germplasm accessions in the genebank of VIR. Japan reports that it regards the storage of medium-term storage accessions in long-term storage as a form of safety duplication. Armenia and Nepal mention that they have very low levels of safety duplication, especially for vegetables and grain-legume species. Malaysia reports that has no monitoring of safety duplication in place. Myanmar indicates that it recognizes the need for safety duplication at a safer genebank.

Europe

Fifteen European countries report on aspects of safety duplication. Albania reports a very low level of safety duplication. Belarus reports safety duplication of accessions of the respective mandate crops at CGIAR centres. Czechia mentions that it duplicates its accessions in Slovakia and at the SGSV. Estonia indicates that it still needs to resolve its safety duplication of fruit trees and *in vitro* materials. Finland reports that has started to develop a safety collection network for its national PGRFA collections and for valuable private collections. France reports that it duplicates materials under the auspices of a cooperation network. Germany mentions has duplicated 36 percent of its accessions at the SGSV and that its field genebank accessions are backed up in cryopreservation. The Republic of Moldova indicates that it has no safety duplication of its collections in place. The Nordic countries report that they keep their national field genebank collections at least two sites within the respective country. Poland mentions that it is in the process of establishing its national base collection and that it is simultaneously arranging for its safety duplication. Portugal indicates that it regards the storage of medium-term storage accessions in long-term storage as a form of safety duplication and is testing the cryopreservation of vegetatively propagated plants. Romania reports that it has started safety duplicating its field genebank collections *in vitro*. Serbia reports that it stores duplicates of accessions at its national genebank. Sweden reports that it has increased its clonal archives for the duplication of field genebank accessions significantly. Switzerland mentions that it intends to duplicate as many accessions as possible within the country, especially those from field-genebank collections. The United Kingdom reports that it uses cryopreservation of fruit trees and wild taxa for safety duplication.

3.5.2 Situation in the international and regional genebanks

The status of safety duplication of the mandate crops maintained by the CGIAR genebanks and WorldVeg is presented in Table 3.24.

NordGen reports that 25 805 accessions (80 percent of its entire holdings) are safety duplicated; 50 percent of its total holdings are in long-term seed storage at the Department of Food Sciences at Aarhus University, Denmark, and 71 percent in black-box storage at SGSV. The duplicated accessions include 169 genera and 345 species; 18 percent of all duplicated accessions are wild populations, 13 percent are farmers' varieties/landraces, 15 percent advanced cultivars and 52 percent are research materials.

CATIE reports that about 1 250 accessions, or 22 percent of total of its seed holdings, are safety duplicated. This includes 21 percent at SGSV and 7 percent in long-term seed storage at WorldVeg. The duplicated accessions include 19 genera and 40 species; 5 percent are samples of wild populations, and 95 percent are farmers' varieties/landraces.

SPGRC serves as a long-term seed storage backup for the national holdings of SADC countries. It reports that 60 percent of its total germplasm, constituted almost entirely of farmers' varieties/landraces of 19 genera and 23 species of staple food crops, is also conserved as a black box at SGSV.

Table 3.24. Safety-duplication levels of the CGIAR and WorldVeg crop collections in December 2021

Centre	Crop	Safety duplication (%)
AfricaRice	Rice	82
Bioversity International	*Musa* (banana)	73
CIAT	Pulses	98
	Forages	91
	Cassava	62
CIMMYT	Maize	88
	Wheat	74
	Triticale	91
	Barley	57
CIP	Potato	90
	Sweet potato	85
	Andean root and tuber crops	71
ICARDA	Barley	80
	Wheat	88
	Chickpea	81
	Lentil	77
	Broad bean	67
	Grass pea	84
	Forage and range species	68
ICRAF	Multipurpose trees	20
ICRISAT	Cowpea	95
	Finger millet	86
	Kodo millet	98
	Pearl millet	79
	Sorghum	86
IITA*	*Musa* (banana and plantain)	30
	Cassava	50
	Cowpea	97
	Maize	51
	Yam	35
	Legumes	60
ILRI	Forages	69
IRRI	Rice	93
WorldVeg	Vegetable crops	65

* As of December 2019 (direct communication).

3.5.3 Summary assessment

Safety duplication of *ex situ* stored or maintained accessions is an essential part of genebank management. It is clear from the narrative reports that the importance of safety duplication is well understood and recognized. This is further evident from the increasing number of countries (66) that have deposited accessions at SGSV. In spite of these gains, many genebanks still have no, or only limited, safety duplication. Many genebanks have difficulties regenerating or multiplying their collections adequately. They store accessions with low numbers of seed or plants and consequently do not have the materials needed to safety duplicate them. In other genebanks, materials are duplicated between active and base collections or between field genebanks and *in vitro* genebanks – and are thus regarded as safety duplicated. Overall, the reported figures are low, a situation that clearly indicates the need to accord more attention and higher priority to safety duplication.

The SGSV is playing an important role in the backup safety duplication of seed collections. The numbers are impressive, both in terms of the quantity of samples deposited and in terms of their diversity. While the SGSV is providing this important service for orthodox seed collections, no similar mechanism yet exists for species that produce recalcitrant seeds or propagate vegetatively.

3.6 Germplasm health

Germplasm-health issues are becoming increasingly important in the conservation, distribution and use of PGRFA. The increased movement of germplasm within and between countries and continents also increases the potential spread of pests and diseases. In response, a number of efforts have been made to minimize and mitigate such problems, especially via improvements to phytosanitary and plant-quarantine measures. Box 3.3 describes some of the activities carried out by CGIAR Germplasm Health Units (GHUs).

3.6.1 Situation in the regions

Sub-Saharan Africa
Eritrea, Ethiopia, Kenya and Nigeria report a lack of the technical facilities and trained personnel needed to conduct the health tests and activities required for germplasm distribution. Madagascar mentions problems with pests and diseases in its field genebank collections. Namibia reports that it has insufficient capacity to identify and manage storage pests and diseases.

Latin America and the Caribbean
Chile reports the need to determine the phytosanitary status of regenerated material before proceeding with its long-term conservation and distribution. Colombia and Costa Rica report that germplasm health activities are part of their overall germplasm management. Cuba and Ecuador report that establishing pathogen-free collections is a high priority.

Box 3.3 Germplasm health activities in CGIAR genebanks to promote safe global germplasm exchange and prevent the transboundary spread of pests

The germplasm health units (GHUs) of the CGIAR use comprehensive phytosanitary testing procedures to assess the heath of accessions and hence their suitability for safe conservation or distribution (Kumar *et al*., 2021). The GHUs pursue six strategic objectives: (i) to ensure that the transboundary movement of germplasm and non-seed biological materials complies with the regulatory guidelines of the importing and exporting countries and that the materials are free from quarantine pests; (ii) to develop and adopt phytosanitary procedures that generate pest-free germplasm; (iii) to develop diagnostic tools for seed-health monitoring and pest surveillance; (iv) to conduct pest-risk assessments of germplasm activities, including conservation, seed increase and transfers; (v) to contribute to the development of phytosanitary capacity around the globe; and (vi) to organize a GHU community of practice that forms a network of centres for transboundary pest prevention.

The GHUs closely collaborate with national and regional plant-quarantine organizations to export and distribute germplasm samples to partners. Between 2012 and 2020, the CGIAR GHUs tested 538 053 accessions for pests and diseases, and cleaned 102 593 accessions (https://www.genebanks.org/resources/genebanks-in-numbers/genebank-operations-data/). The GHUs applied uniform standards to all seed exports and imports to ensure pest-free germplasm transfers. In 2018 and 2019, GHUs facilitated 1 300 germplasm transfers from genebanks and 2 600 from breeding programmes to a total of 150 countries. In 2018 and 2019, extensive testing resulted in the detection and rejection of 7 percent of 335 928 genebank samples and 3 percent of 118 044 breeding samples.

The GHUs use new technologies that provide more accurate and rapid detection of existing and newly diagnosed pests. They strive to maintain a balance in terms of adopting technologies that offer the best cost and time efficiency, meet regulatory requirements and comply with ISO quality-management systems. However, specific phytosanitary standards for the international exchange of germplasm have not been developed, and requirements for germplasm shipments often vary from country to country. GHUs have recently begun developing a CGIAR GreenPass Phytosanitary Protocol (GreenPass) for assuring phytosanitary compliance (https://www.genebanks.org/news-activities/news/greenpass/). The protocol details best procedures to follow in germplasm regeneration and health assurance while maintaining transparency in risk assessment and mitigation strategies. The intention is that the initiative will allow national plant protection officers to expedite the clearance of plant germplasm material originating from GreenPass-accredited facilities by the eliminating redundant checks or reducing the processing time for material received from accredited facilities.

Asia

Azerbaijan reports that it uses molecular techniques to monitor germplasm health. Japan indicates that it applies stringent plant quarantine regulations to protect itself against the introduction of pests and diseases and that this impedes regional collaboration and the introduction of breeding materials from abroad. Malaysia mentions problems with pests and diseases during regeneration activities. Papua New Guinea reports that a recent outbreak of a new coconut disease threatens the regional coconut collection.

Europe

France reports that the transition of regeneration responsibilities from experimental stations to sites that practise agroecological approaches has made regeneration work more complex, especially in terms of pest management. Germany reports that targeted efforts are being made to identify viruses in national fruit accessions and where applicable to eliminate these and maintain pathogen-free accessions. This procedure is also required by AEGIS (A European Genebank Integrated System for PGRFA) for the inclusion of accessions in the European collection. Virus-infected grapevine accessions are a significant problem, as no techniques for curing infected plants are available. Because of quarantine issues with grapevine germplasm from outside EU, access is limited. Norway reports regular monitoring of the health of accessions in its clonal collection and that issues have been reported for several fruit-crop collections, including the appearance of two diseases in the apple and pear field collections. Romania indicates an interest in strengthening regional and international collaboration on germplasm health, possibly on a cost-sharing basis.

3.6.2 Situation in the international and regional genebanks

CePaCT has established a health-testing unit to support the safe exchange of crop and tree germplasm and carries out research on plant-pathogen diagnostics. It plans to provide diagnostic services to the Pacific region. Similar germplasm-health testing procedures are in place at WorldVeg.

All 11 CGIAR genebanks have well-functioning GHUs that use a multidisciplinary approach to ensure phytosanitary protection that allows the safe conservation and global movement of germplasm and breeding lines for agricultural research and food security (see Box 3.3). To promote capacity development in diagnostics, seed-health testing and seed treatment, the CGIAR GHUs organize at least ten workshops each year for staff from national and regional organizations.

3.6.3 Summary assessment

The impact of germplasm-health issues on the management and distribution of materials has increased overall during the reporting period. This is particularly the case for the CGIAR centres. However, several national genebanks do not have the human and/or technical capacity to address germplasm-health issues adequately. There is an obvious need to jointly build such capacities and train staff to ensure the availability and exchange of disease-free germplasm. Regional cooperation, especially with respect to infrastructure and the sharing of specialized knowledge, would greatly facilitate this process.

3.7 Characterization for *ex situ* conservation

Characterization is a key activity in genebank management. Characterization procedures based on standardized and calibrated measuring formats and categories ideally follow internationally agreed descriptor lists. A wide range of crop-descriptor lists have been developed, including by Bioversity International (2018), the International Union for the Protection of New Varieties of Plants (UPOV, 2011) and the National Plant Germplasm System (NPGS) of the United States of America (USDA-ARS, 2022). Bioversity International has also published *Guidelines for developing crop descriptor lists* (Bioversity International, 2007). The use of molecular characterization is becoming more widespread because the technologies required are becoming more affordable and opportunities for outsourcing within countries and for international collaboration are becoming more mainstream. More on characterization is discussed in Chapter 4.

3.7.1 Situation in the regions

Sub-Saharan Africa
Guinea reports on-station characterization of yam, rice and groundnut after collecting. Madagascar reports the characterization of well-performing clones and their testing for disease resistance. Uganda reports that the national genebank lacks the permanent nursery and screen houses needed for perform characterization activities.

Northern Africa
Egypt reports that it has characterized collected germplasm materials with the objective of integrating them into breeding programmes.

Latin America and the Caribbean
Guyana reports that outstanding progress has been made in the extensive characterization of more than 65 cassava landrace varieties.

Asia
Kyrgyzstan reports that it characterized 100 wheat varieties as part of a multiplication project. Türkiye reports that the characterization of its germplasm are major priorities. Yemen indicates that it lacks the staff to characterize its collections.

Europe
Czechia reports that a high proportion of its national collection has been characterized. Finland reports that it has characterized its national apple collection using morphological, phenological and genetic analyses. France mentions that 16 cooperation networks are responsible for the characterization of its PGRFA collections. Norway reports that many of the PGFA conserved in its *ex situ* collections have not been adequately characterized and identified, and that these activities will be given due priority. Spain reports that it has had difficulties assessing the state of characterization activities, as different institutions responded to the first and second national surveys and the overall response rate was low.

3.7.2 Situation in the international and regional genebanks

The CGIAR genebanks report that at the end of 2020 a total of 721 578 accessions (88 percent of their total holdings) had passport and characterization data available online (CGIAR Genebank Platform, 2022). Based on separate reports to FAO from ten CGIAR centres and WorldVeg, accessions have been characterized for an overall average of 20 traits for the ten-year period (an average of 24.5 traits ranging from 2 to 85 traits during the first reporting period and 18 traits ranging from 2 to 59 traits during the second reporting period). In addition to morphological characterization, these ten CGIAR centres report that 128 712 accessions have associated sequence data. Overall, the centres report 508 publications on characterization in refereed journals and 179 in non-refereed journals between 2012 and 2019. In addition, 308 further publications were produced by germplasm recipients.

NordGen reports that 3 859 accessions, including 13 species representing six genera (*Brassica*, *Daucus*, *Hordeum*, *Pisum*, *Trifolium* and *Vicia*), were characterized for a range of between 2 and 22 morphological traits. In addition, morphological and molecular data were used to assess diversity (Solberg *et al*., 2015; Geoffriau, 2019) and support genebank management (Solberg *et al*, 2017a, 2018; Yndgaard *et al*., 2016.

3.7.3 Summary assessment

Some countries report progress in the characterization of their collections. However, comprehensive characterization of the germplasm collections of many national genebanks are still lacking or incomplete. It appears from country reports that, international descriptors are used sporadically. At the international level, the CGIAR genebanks have characterization information for the majority of their collections.NorgGen was the only regional centre to provide information on characterization efforts. They reported that characterization data have been used to assess diversity of collections as well as enhance genebank management.

3.8 Regeneration

Regeneration of accessions to address low viability and/or decreased inventory are among the most complex and difficult routine activities undertaken by genebanks. Genebanks aim to maintain the genetic integrity of accessions during regeneration, taking into account sample size during the regeneration process and ensuring careful handling throughout the process. Determining the priority of the accessions to be regenerated requires a functional information management system and routine viability and stock monitoring.
Over the reporting period, 85 countries regenerated a total of 780 375 accessions (or 32 percent of all the 2 424 234 accessions reported). The countries with the highest reported number of regenerated accessions were Germany (111 479, or 65 percent of the total), Brazil (98 825, or 59 percent), India (59 139, or 14 percent), France (40 599, or 39 percent) and Bangladesh (34 110, or 127 percent). Twenty-three countries[82] report severe and/or specific difficulties with their regeneration activities, especially in the case of CWR and vegetatively propagated crops, and several report considerable backlogs.

[82] Sub-Saharan Africa: Eritrea, Ethiopia, Ghana, Kenya, Madagascar, Namibia, Niger, Sudan (CWR), Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe. Northern Africa: Egypt, Tunisia. South America: Argentina, Brazil, Colombia, Mexico, Uruguay. Asia: Armenia, Azerbaijan (CWR), Indonesia, Mongolia, Myanmar, Nepal, Philippines, Yemen. Europe: Albania, Republic of Moldova, Spain.

A regional comparison (see Table 3.25 and Figure 3.7) indicates that Northern Africa had the highest percentage of regenerated accessions (71 percent), followed by Latin America and the Caribbean (56 percent), Europe (36 percent), Asia (26 percent), sub-Saharan Africa (25 percent) and Oceania (6 percent).

Almost 600 000 accessions (24 percent) are in need of regeneration. Northern Africa (45 percent), sub-Saharan Africa (42 percent) and Latin America and the Caribbean (39 percent) are the regions with the highest percentage of accessions needing regeneration. All regions report insufficient funds to regenerate all the accessions requiring regeneration. Oceania reports insufficient funds to regenerate 94 percent of the accessions requiring regeneration (25 percent of total germplasm holdings). The equivalent figures for other regions were as follows: 67 percent (20 percent of total holdings) in North America; 63 percent (27 percent of total holdings) in sub-Saharan Africa; 60 percent (4 percent of total holdings) in Latin America; and 58 percent (12 percent of total holdings) in Europe.

Table 3.25. Regeneration activities between 2012 and 2019 and regeneration status at the end of 2019, by region

Region (number of reporting countries)	Accessions holdings	Accessions regenerated (%)	Accessions in need of regeneration (%)	Accessions in need of regeneration with no budget (% of accessions in need of regeneration)	Accessions in need of regeneration with no budget (% of accession holdings)
Northern Africa (5)	64 454	71	45	50	22
Sub-Saharan Africa (20)	169 610	25	42	63	27
Northern America (1)	110 363	-	30	67	20
Latin America & Caribbean (15)	328 356	56	39	60	24
Asia (20)	898 859	26	17	30	5
Europe (22)	760 873	36	20	58	12
Oceania (2)	91 719	6	27	94	25
Total (85)	**2 424 234**	**32**	**24**	**54**	**13**

Figure 3.7. Percentages of regenerated accessions and accessions in need of regeneration, by region

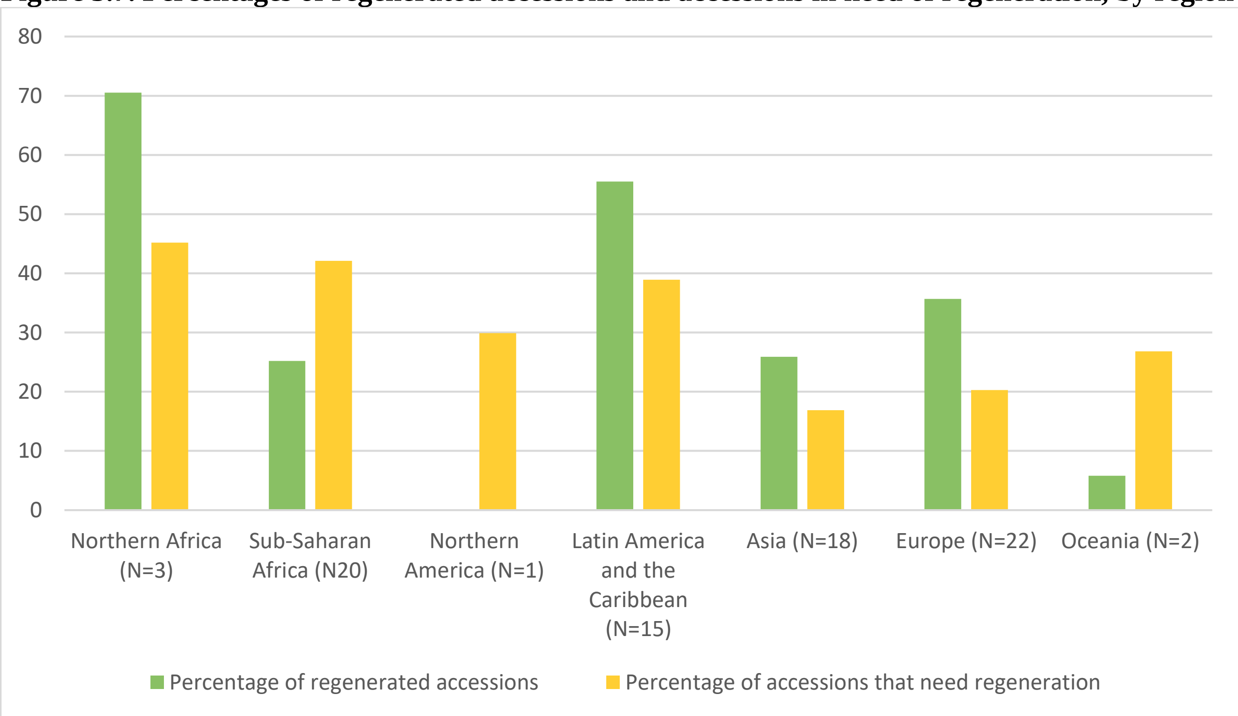


Table 3.26 summarizes regeneration activities and results for the period 2012 to 2019 by crop group. At the global scale, cereals are the crop group for which the largest number of accessions were regenerated (27 percent of total cereals holdings as of 2019), followed by pulses (33 percent), oil plants (51 percent), vegetables (32 percent) and roots and tubers (155 percent). Cereals (21 percent total holdings), pulses (31 percent) and vegetables (28 percent) are also the groups that have the most accessions requiring regeneration. With the exception of oil plants, these are the three crop groups that have the largest number of accessions in national genebanks overall. The other crop groups with high a percentage of overall accessions requiring regeneration are nuts (42 percent), fibre plants (41 percent), material plants (40 percent), forages (36 percent), stimulants (31 percent), medicinal plants (31 percent) and ornamentals (28 percent).

Table 3.26. Number and percentage of accessions regenerated and requiring regeneration by crop group for the period 2012 to 2019

Crop group	Number of accessions in national genebanks (2019)	Number of regenerated accessions	Percentage of regenerated accessions	Number of accessions requiring regeneration	Percentage of accessions requiring regeneration
Cereals	1 059 780	281 715	26.6	223 060	21
Pulses	301 299	97 815	32.5	93 180	31
Oil plants	158 618	80 152	50.5	13 329	8
Vegetables	246 672	79 625	32.3	69 098	28
Roots and tubers	44 286	68 492	154.7	9 408	21
Fruit plants	72 620	35 919	49.5	18 624	26
Fibre plants	66 626	31 326	47	27 129	41
Forages	169 921	19 296	11.4	61 160	36
Medicinal plants	27 519	13 742	49.9	8 191	30
Sugar crops	9 343	8 910	95.4	479	5
Stimulants	15 909	7 736	48.6	4 846	31
Pseudo cereals	14 765	5 534	37.5	2 740	19
Ornamentals	20 952	4 981	23.8	5 538	26
Herbs and spices	18 243	4 836	26.5	4 104	23
Nuts	3 494	1 617	46.3	1 464	42
Material plants	6 371	1 268	19.9	2 516	40
Other	187 816	37 411	19.9	47 710	25
Total	**2 424 234**	**780 375**	**32.2**	**592 576**	**24**

Note: Based on data from 85 countries.

3.8.1 Situation in the regions

Sub-Saharan Africa

Fifteen sub-Saharan African countries report difficulties with regeneration activities. Constraints included those related to human-resources capacity (Botswana, Kenya, Mali, Uganda, Zimbabwe), lack of infrastructure (Eritrea, Zimbabwe), difficulties with specific crops or type of crops (Kenya, Nigeria, Sudan, Uganda), lack of knowledge (Uganda), ecological problems (Botswana), lack of financial resources (Madagascar, Mali), lack of an adequate documentation system (Togo, Uganda) and difficulty keeping up with regeneration needs because of a lack of a reliable electricity supply was affecting longevity (Zambia). Ethiopia reports that it increased its regeneration by more than 300 percent over the reporting period. South Africa mentions the involvement of farmers in regeneration activities.

Northern Africa
Egypt and Tunisia report a lack of financial and human resources, especially for the regeneration of cross-pollinating crops.

Latin America and the Caribbean
Eleven countries provided information on regeneration activities. A number of constraints are mentioned, including limited financial resources (Argentina, Brazil, Cuba, Mexico), problems with cross-pollinated species and perennial crops such as coconut (Brazil, Cuba, Guatemala), the need to improve infrastructure (Colombia) and the lack of a monitoring system for seed viability and inventory that can flag accessions requiring regeneration (Peru). Costa Rica, Guatemala, Mexico and Uruguay report backlogs in their regeneration efforts. Chile reports prioritizing the regeneration of food crops that are of interest to plant-breeding programmes. Colombia mentions the need to develop more economical protocols for species that require special regeneration conditions. Trinidad and Tobago mention that it cultivates its accessions annually and suffers significant losses. Ecuador reports the use of the monitoring system CARDEX to identify accessions with low inventory and/or low viability. Guatemala reports the regeneration of part of its bean collection through the Mesoamerican Network on Plant Genetic Resources (REMERFI) with financial assistance from the Crop Trust. Guyana mentions significant improvements in its regeneration activities.

Asia
Nineteen Asian countries provided information on regeneration. Papua New Guinea reports that it replants its annual vegetatively propagated crops regularly, at least once a year. Philippines reports a lack of viability monitoring in many of its genebanks and that it uses the quantity of seed and the initial storage date as criteria for setting priorities. Several countries report well-functioning regeneration activities (Bangladesh, Japan, Türkiye and Uzbekistan). Azerbaijan reports the rejuvenation of old fruit and nut trees. Japan reports an operational cooperative project with the private sector for the regeneration of problematic vegetable species. Jordan and Lebanon report that they carry out regeneration in collaboration with other genebanks.

Constraints to successful regeneration are also reported by a number of countries and included the following: lack of adequate funding (Armenia); lack of a functional database management system (Armenia); problems with specific crops and species such as CWR sand cross-pollinated species (Azerbaijan, Myanmar); lack of specific guidelines and experience (Belarus); limited capacity (Indonesia, Kyrgyzstan); lack of adequate facilities (Malaysia, Myanmar, Tajikistan); and the need for more ecologically diverse regeneration sites (Mongolia, Nepal, Tajikistan). Yemen reports that it has not been able to conduct viability tests or regenerate materials since the start of the war in 2013.

Europe
Albania reports that approximately half of its accessions are cross-pollinated and have never been regenerated. Czechia mentions that as part of its GRIN-Global Czech documentation system, it has installed a new automatic monitoring system to monitor seed inventory and viability for identifying accessions needing regeneration. France reports that it operates a complex network that does not have funds for regeneration. Germany reports that the average rate of regeneration of its fruit-tree accessions is currently 75 percent, that CWR accessions have not been regenerated or multiplied and that its grapevine collection is continuously replanted by segments as viability and health status are checked annually. The Kingdom of the Netherlands reports that most regeneration of material held by its Centre for Genetic Resources is done by seed companies, usually at company locations in the Netherlands but at locations in other countries if there are ecological or climatic constraints, with this particularly being done in Spain or Morocco for landraces and CWR. Poland reports that some orphan crops have no curator assigned to them to coordinate regeneration, storage or maintenance. Portugal reports challenges associated with cross-pollinated species, especially those related to special infrastructural requirements. Romania reports that young scientists have been assigned to specialize in regeneration/multiplication of individual crops or crop groups and that accordingly partnerships with vegetable research institutes have been established. Switzerland reports that for some crop groups (e.g. fruit accessions maintained in field genebanks), regeneration is organized by a national coordinator.

3.8.2 Situation in the international and regional genebanks

Regeneration/multiplication activities at the CGIAR centres during the period between 2012 and 2020, as reported by the CGIAR Genebank Platform, are summarized in Table 3.27. The CGIAR genebanks have a multiplication rate that is almost four times the rate of regeneration, illustrating that the level of distribution is high and that viability is relatively stable overall, at least for accessions that are in high demand. Based on separate reports to FAO by 11 CGIAR centres and WorldVeg, over 900 000 accessions were regenerated during the entire reporting period. At the end of 2019, just under 180 000 accessions were in need of regeneration, and the budget to regenerate just over 28 500 accessions was lacking.

NordGen reports the development of a strategy for mitigating the challenge of increasing regeneration backlogs. A total of 5 568 accessions were regenerated over the reporting period (17 percent of the total holdings), including 69 genera and 224 species. The number of accessions in need of regeneration at the end of the reporting period totalled 4 391 accessions (14 percent), including 139 genera and 276 species. Budget was lacking to regenerate 2 110 accessions (7 percent).

Table 3.27. CGIAR regeneration and multiplication operations, 2012 to 2020

Indicator	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number accessions regenerated	15 815	12 670	16 674	11 641	25 290	19 023	21 220	15 193	11 414
Number accessions multiplied	54 153	45 425	56 804	58 168	74 873	72 612	85 594	75 799	68 616
Total number of accessions	710 001	725 244	738 215	750 604	757 767	768 576	773 402	760 467	736 210
Number accessions immediately available	465 358	492 654	525 410	559 053	580 706	608 751	621 915	592 118	601 811
Percentage of accessions available	66	68	71	74	77	79	80	78	82

Source: CGIAR Genebank Platform, 2022.

3.8.3 Summary assessment

Although over 32 percent of accessions in national holdings are reported to have been regenerated over the reporting period, regeneration remains one of the main challenges for many countries and genebanks. Technical constraints, lack of properly trained staff, insufficient funding and poor infrastructural are reported, Regeneration of CWR and out-crossing species are problematic for many genebanks. Many genebanks are unable to monitor viability and inventory adequately and are thus unable to establish priorities or use practical criteria to decide which accessions to regenerate/multiply. This is a significant constraint given the wide array of crop groups represented in national collections. Many of these groups require specialized regeneration techniques or are assigned lower priority by genebanks, especially in terms of the allocation of already-limited budgets. Additionally, very limited cooperation at the regional or global level is reported, including cooperation with regional and international genebanks. Collaboration with private breeding companies with solid technical knowledge is mentioned by a few countries.

3.9 Documentation

Documentation is an essential aspect of genebank management. A unique and permanent accession number is a key element of proper documentation. The voluntary use of Digital Object Identifiers (DOIs) (FAO, 2021) is an additional option for information sharing across different information systems. A genebank should manage all the data and information generated relating to all aspects of the conservation and use of the germplasm it conserves, including passport (Alercia, Diulgheroff and Mackay, 2015; Alercia *et al.*, 2020), characterization, evaluation, inventory and collection-management data and metadata. The use of a genebank information management system is the most efficient and effective means of managing such data. If possible, the system should include built-in automated tools for checking inventory and viability and flagging accessions requiring regeneration. Recent years have seen the development of a number of systems, including the German Genebank Information System (GBIS) (GBIS/I, 2022) and Alelo, developed by the Brazilian Agricultural Research Corporation (Embrapa) (Embrapa, 2022). Regional systems include the NORDIC Baltic Genebanks Information System (GeNBIS) (GeNBIS, 2022), the SADC Plant Genetic Resources Documentation System (SDIS) (SADC, 2022) and EURISCO) (ECP/GR, 2022).

At the global level, GRIN-Global was developed by the United States Department of Agriculture – Agricultural Research Service, the Crop Trust and Bioversity International to enable genebanks to store, manage and publish information associated with PGRFA, GRIN-Global is freely available (GRIN-Global, 2022). The recent development of GRIN-Global Community Edition (GG-CE), which builds on GRIN-Global and addresses some gaps in functionality, presents a major opportunity for genebanks to adopt a free-access, easy-to-use system (Crop Trust 2022c).

Genesys is an international global portal managed by the Crop Trust (Crop Trust, 2022b). Genesys allows accession data to be shared and facilitates the ordering of germplasm. It includes accession-level passport, characterization and evaluation data as well as ecogeographical information associated with accession collecting sites. Institutions can also utilize Embedded Genesys, an addition that allows the integration of their genebank accession data with their institutional/corporate websites (Crop Trust, 2020). Another option for making the passport data of genebank accessions publicly available is WIEWS (FAO, 2022b). Serving as the data repository for the plant indicator of SDG Target 2.5 (United Nations, 2022), WIEWS stores and publishes accession-level passport data for the largest global inventory of *ex situ* collections. Finally, the Treaty's Global Information System for PGRFA integrates and augments existing systems, creating a global entry point for access to information and knowledge related to strengthening capacity for PGRFA conservation, management and utilization (FAO, 2023c).

3.9.1 Situation in the regions

Northern Africa

Tunisia reports that it is in the process of fully adopting GRIN-Global Community Edition.

Sub-Saharan Africa

Three countries (Eritrea, Niger and the United Republic of Tanzania) report that they have an independent documentation system. Five countries (Botswana, South Africa, the United Republic of Tanzania, Zambia and Zimbabwe) report using SDIS. Six countries (Guinea, Madagascar, Mali, Namibia, Togo and Uganda) report the need to adopt a documentation system. Ethiopia, Ghana, Kenya, Nigeria and Zambia report being in the process of adopting GG-CE. A number of countries report that they have experienced problems with their current systems.

Latin America and the Caribbean

Three countries (Brazil, Mexico and Peru) report that they have an independent documentation system. Three countries (Costa Rica, Cuba and Guatemala) report the need to install a national documentation system. The Plurinational State of Bolivia, Chile and Uruguay report using GRIN-Global, and Ecuador and Mexico report that they are in the process of adopting it. Argentina and Colombia report that they are in the process of adopting GG-CE.

Northern America

Canada and the United States of America use GRIN-Global.

Asia

Four countries (Indonesia, Malaysia, the Philippines and Türkiye) report having an independent documentation system. Six countries (Bangladesh, Mongolia, Nepal, Papua New Guinea, Uzbekistan and Yemen) report the need for a functional documentation system. Four countries (Jordan, Lebanon, Oman and Pakistan) report using GRIN-Global, Armenia and Belarus indicate that they are planning to install it, and Azerbaijan and Viet Nam that they are currently evaluating it. Three countries regularly update their data in

EURISCO as members of ECPGR (Armenia, Azerbaijan and Belarus). Uzbekistan reports that it plans to collaborate with EURISCO.

Europe
Three countries (France, the Republic of Moldova and Romania) report having an independent documentation system. Finland and Norway reported that it uses GeNBIS, Czechia that it uses GRIN-Global and Portugal that its system is supported by GRIN-Global. The United Kingdom reports using GG-CE. Five countries report regularly publishing their national data through EURISCO (France, Romania, Serbia, Switzerland and United Kingdom). Serbia reports the need to install a proper documentation system, such as GRIN-Global.

Oceania
Australia reports using GRIN Global and. New Zealand that it is in the process of evaluating it.

3.9.2 Situation in the international and regional centres

The CGIAR Center Genebanks Bioversity International, CIMMYT, CIAT and CIP have adopted GG-CE, and AfricaRice, CIP, IRRI, ILRI, IITA and ICARDA are in the process of adopting it. WorldVeg has adopted GG-CE, while ICBA, ICRAF and ICRISAT are evaluating it. As of May 2019, over 784 000 accessions have DOIs assigned. The CGIAR centres (CGIAR Genebank Platform, 2019) and ICBA together have 829 293 accessions with DOIs assigned.

Among regional centres, CATIE uses its own databases for its seed and field collections. CePaCT uses its own genebank documentation and information system (PACGEN) but is in discussions about adopting GG-CE. NordGen uses GeNBIS, which is a customized version of GRIN-Global. SPGRC uses SDIS. At the end of 2021, 12 927 accessions from regional genebanks had been assigned DOIs.

3.9.3 Summary assessment

Although documentation has for many years been highlighted as an essential part of genebank management, and despite support provided by the international community, little overall progress has been made in this regard. Many countries still struggle to document passport and other genebank-management data. The recent development of GG-CE and technical support provided by the Crop Trust will hopefully encourage national genebanks to adopt it. Encouragingly, the CGIAR and other international centre genebanks, as well as the majority of regional centres, are either using or in the process of adopting GG-CE. The increasing use of DOIs improves not only collection management but also capacity to refer to specific germplasm in published papers and breeding pedigrees. The availability of web portals such as EURISCO, Genesys and WIEWS allows the global community to know what germplasm is conserved in which genebank collections. The option of Embedded Genesys makes it possible for institutes to provide their genebank inventories on their institution websites without the need to develop their own interfaces.

3.10 Multilateral System

In accordance with Article 11.2 of the Treaty, the Treaty's Governing Body periodically invites contracting parties to report on the PGRFA under their management and control that are in the public domain and are in the Multilateral System of Access and Benefit Sharing (MLS). A summary of the materials from national, regional and international genebanks placed under the MLS is presented in Table 3.28. As of 31 December 2021, materials under the MLS totalled over 2.3 million accessions reported by 76 contracting parties and 15 regional and international centres (Article 15 bodies).[83] This does not include 23 249 accessions from six countries that are not contracting parties but have nonetheless included part of their collections under the MLS.[84]

[83] Article 15 Bodies are International Agricultural Research Centres of the CGIAR and other international institutions with *ex situ* collections of PGRFA placed under the MLS of the Treaty.
[84] Azerbaijan (8 386 accessions placed under the MLS), Belarus (6), Bosnia and Herzegovina (6), Tajikistan (3 782), Uzbekistan (189), Viet Nam (10 880).

The MLS materials of the contracting parties and Article 15 bodies account for about 54 percent of their total *ex situ* holdings as reported for SDG Indicator 2.5.1a. While there is scope for improving the national average of 43 percent over time, it is noteworthy that about one-third of contracting parties have over 70 percent of their collections under the MLS. As might be expected given that they mainly cover Annex 1 crops,[85] the international centres and regional centres have almost their entire collections available under the MLS.

Table 3.28. Number of accessions conserved *ex situ* and percentage placed under the Multilateral System, by regions and subregions

	Number of accession		
Regions (number of countries or genebanks)	Genebanks	MLS	Percentage
Northern Africa (4)	128 046	34 131	27
Northern Africa (4)	128 046	34 131	27
Sub-Saharan Africa (13)	164 023	103 745	63
Eastern Africa (7)	153 506	95 663	62
Western Africa (6)	10 517	8 082	77
Northern America (2)	699 909	585 029	84
Northern America (2)	699 909	585 029	84
Latin America and the Caribbean (8)	299 021	30 742	10
Central America (3)	3 945	619	16
South America (5)	295 076	30 123	10
Asia (18)	855 076	133 571	16
Central Asia (1)	2 638	1 382	52
Eastern Asia (2)	246 645	40 149	16
South-eastern Asia (4)	39 938	14 648	37
Southern Asia (6)	510 720	71 077	14
Western Asia (5)	55 135	6 315	12
Europe (29)	1 024 599	454 714	44
Northern Europe (9)	175 882	28 445	16
Eastern Europe (6)	324 144	135 570	42
Southern Europe (8)	218 917	97 067	44
Western Europe (6)	305 656	193 632	63
Oceania (2)	251 562	111 636	44
Melanesia (1)	2 506	2 110	84
Australia and New Zealand (1)	249 056	109 526	44
National total (76)	3 422 236	1 453 568	43
Regional genebanks (3)*	57 852	40 781	88
International genebanks (12) **	834 967	820 273	98
Grand total	4 303 729	2 314 622	54

Note: MLS = Multilateral System of the Treaty. The materials under the MLS as reported by Burkina Faso (16 479), Burundi (188), the Lao People's Democratic Republic (440) and Luxemburg (12) are not included, as these countries did not report to FAO on their national *ex situ* holdings under SDG Indicator 2.5.1a.
* CATIE, CePaCT, NORDGEN.
** AfricaRice, Bioversity-ITC, CIAT, CIMMYT, CIP, ICARDA, ICBA, ICRAF, ICRISAT, IITA, ILRI, IRRI.

[85] International Treaty on Plant Genetic Resources for Food and Agriculture, Annex I, List of crops covered under the Multilateral System.

3.11 Germplasm movement (distribution/exchange)

3.11.1 Global germplasm exchange

A thematic study on global germplasm exchange (Khoury *et al*., 202X) was undertaken based on an analysis of two complementary information sources, WIEWS and the Data Store of the MLS, covering the period 2012 to 2019 in both cases. The WIEWs datasets primarily related to distributions of germplasm from national genebanks. Provider countries, provider institutions, types of recipient (optionally), crops and total numbers of accessions and samples distributed were reported for two periods (2012 to 2014 and 2014 to 2019). The Treaty data included all distributions made under the Standard Material Transfer Agreement (SMTA) reported to the Treaty's Governing Body and included distributions made by genebanks and by breeding programmes and other types of organization. The data primarily referred to distributions made by CGIAR genebanks and breeding programmes and included information on countries where providers and recipients were located, crop names and numbers of samples distributed between 2012 and 2019.

According to the WIEWS dataset, national genebanks in 87 countries distributed 1 269 818 accessions (an average of approximately 159 000 per year) and 4 182 582 million samples (about 523 000 per year) between 2012 and 2019, with well over 90 percent of distributions made within the respective country. Approximately 70 percent of accessions and 86 percent of samples were distributed by providers located in countries that were contracting parties to the Treaty, while 37 percent of accessions and 36 percent of samples were distributed by providers located in countries that were contracting parties to the Nagoya Protocol. The main recipients included national agricultural research centres (NARCs), farmers, NGOs, the private sector, others and unknown recipient types. The Treaty data covered the distribution of over 3.9 million samples (approximately 497 000 per year) from genebanks, breeding programmes and other organizational types using the SMTA. The germplasm distribution pattern differs from that indicated by the WIEWS data, with three-quarters (77 percent) of distributions occurring across international borders and only a quarter (24 percent) occurring within individual countries. The number of such distributions is considerably higher than the equivalent numbers documented in the first report on *The State of the World's Plant Genetic Resources for Food and Agriculture* (FAO 1998) and the SoW2 (FAO 2010).

Approximately 56 percent of all distributed accessions and 38 percent of distributed samples reported in the WIEWS dataset were of crops listed in Annex 1 of the Treaty. The non-Annex 1 crops comprising the other 44 percent of accessions distributed were soybean, cotton, tomato, tobacco, *Capsicum*, *Acacia*, pear, sesame, cocoa, okra, teff, flax, tea, beets, and cucumber and melon, each with over 5 000 accessions distributed. The non-Annex 1 crops among the other 62 percent of samples distributed were dragon fruit, pistachio, soybean, cocoa, avocado, coffee, mango, rubber, tomato, *Acacia*, grape, *Annona*, coconut, *Capsicum*, sugar cane, fig, pear, cotton, cucumber and melon, lettuce, guava, tobacco, okra, flax, sapote and papaya, each with over 10 000 samples distributed. This high level of demand for germplasm of non-Annex 1 crops underscores the importance of giving attention to ways and means of further facilitating access to their genetic resources while also ensuring the fair and equitable sharing of any benefits arising from such access.

Approximately 89 percent all the samples reported in the Treaty dataset were distributed by the CGIAR. In line with expectations, approximately 95 percent of the samples were of crops listed in Annex 1, with food-crop germplasm comprising 97 percent of all the samples reported distributed, and cereals, food legumes, vegetables, roots and tubers, forages and oil plants among those most distributed. Crops with the highest total numbers of samples distributed included wheat, maize, rice, barley, chickpea, lentil, bean, sorghum, pearl millet, Brassicaceae crops, broad bean and vetch, pigeonpea, cowpea, potato, groundnut, oat, lettuce, grasspea and other *Lathyrus*, soybean and pea, all with over 10 000 samples distributed.

3.11.2 Situation in the regions

Sub-Saharan Africa

Kenya reports that germplasm users have shown increased interest in dryland cereals and legumes but notes that its national genebank lacks the capacity to undertake the seed-health testing necessary for the distribution of pathogen-free germplasm. Nigeria reports a significant increase in requests for materials and in distribution to users. Uganda reports multiplication activities for cereal, root and tuber, and fruit-tree accessions/varieties, as well for as vegetatively propagated crops such as coffee, ornamentals and medicinal species, for subsequent distribution to farmers.

Latin America and the Caribbean
Chile reports a significant increase in demand from public and private entities and individuals for seeds of traditional varieties. It notes, however, that a lack phytosanitary support to determine the health status of regenerated material prior to distribution meant that these demands could not be addressed. Guatemala reports that the genebank of its Institute of Agricultural Science and Technology mainly distributes seeds from conserved native vegetables to local groups, as well as aromatic, condiment and medicinal plants to local communities. Peru reports that many accessions in its genebanks are not managed/conserved optimally, noting that the seed numbers per accession are therefore frequently low and that these accessions are consequently not available for distribution. Trinidad and Tobago reports the distribution of conserved germplasm to several research institutions and growers during the reporting period.

Asia
Armenia reports that the accessibility of germplasm in its national genebank needs to be improved by establishing a web-based national catalogue and increasing public knowledge. Malaysia reports an 80 percent increase in seed requests in 2019, largely due to improved availability of information on individual accessions. Nepal reports only very few seed germplasm requests during the reporting period.

Europe
Norway reports the need to better facilitate access to the vegetative planting material in the clonal archives, including access to associated documentation, and to identify responsible entities and procedures. The national genebank of Serbia reports the distribution of maize and pumpkin accessions to farmers in 2019.

3.11.3 Situation in regional and international genebanks

NordGen distributed 30 303 samples (9 165 accessions) of 162 genera and 358 species. Over 900 samples were distributed for *Hordeum* (4 740 samples), *Brassica* (2 144 samples and four species), *Pisum* (1 772 samples and two species), *Triticum* (1 484 samples), *Solanum* (1 229 samples of tomato), *Daucus* (1103 samples) and *Avena* (907 samples).

WorldVeg reports distribution data for 53 different vegetable crops during the first reporting period. A total of 39 902 samples and 21 384 accessions were distributed to 87 countries as well as for internal use at the organization’s headquarters.

Data provided by the Treaty show that 3 534 349 samples (89 percent of the reported total) were distributed by CGIAR centres during the eight-year period, which equates to approximately 440 000 samples per year. A total of 680 067 samples (19 percent) distributed by CGIAR centres went to recipients in the country where the respective centre is located, while 2 854 282 samples (81 percent) were sent to recipients outside the country. This equates to an annual average of 85 008 samples distributed by international centres within the countries where they are located and 546 785 to recipients in other countries across the entire period. The number of annual distributions from CGIAR centres to recipients within the country where the centre is located grew on average over the eight-year period, while the number of international distributions declined slightly.

3.11.4 Summary assessment

National genebanks in 87 countries distributed over 1.2 million accessions over the eight-year period, the majority of which were to recipients within the national borders of the respective country. Several countries report increasing demands for germplasm during this time, especially for local crops. Many national genebanks, however, also report decreased capacity to carry out regeneration, viability testing and testing for pathogens – all of which are needed in order to ensure the distribution of sufficient, healthy and viable germplasm. The lack of a searchable web-based documentation system is also reported. This limitation hinders the ability of researchers to know what is available and therefore to request materials. The international genebanks of the CGIAR and WorldVeg distributed over 3.5 million samples of germplasm over the reporting period. Over 80 percent of distributions by the CGIAR centres were across international borders. This is in line with expectations given the widespread importance of the mandate crops of the CGIAR, the size and comprehensiveness of their *ex situ* collections and the relative ease with which they can be accessed.

3.12 Botanic gardens

There are over 3 000 botanic gardens in the world (BGCI, 2022a) – an increase of around 500 since 2009. These gardens collectively conserve more than 640 000 taxa. Botanic gardens maintain germplasm in living collections, in seed banks, in *in vitro* culture and under cryopreservation. Many also maintain large herbaria and other collections, such as ethnobotanical and carpological collections. At least 470 botanic gardens around the world have associated herbaria, which together hold more than 250 million specimens. An increasing number of botanic gardens are establishing seedbanks to conserve the genetic diversity of the species in their collections. The expansion of seed banks in botanic gardens has led to an increase in research on the seed physiology of wild species, an essential component of determining seed-storage protocols. The Seed Information Database of the Royal Botanic Gardens, Kew, United Kingdom (RGB, 2022), holds over 10 000 records on seed storage behaviour.

3.12.1 Seed banks associated with botanic gardens

A number of botanic gardens have large and sophisticated seed banks, including the MSB of the Royal Botanic Gardens, Kew and the Germplasm Bank for Wild Species in Kunming, China. At least 350 botanic gardens in 74 countries have associated seed banks (BGCI, 2022a). Table 3.29 lists the countries with the largest numbers of botanic gardens and the number botanical gardens with associated seed banks. Approximately 57 000 taxa, representing nearly 7 000 genera, are stored in botanic garden seed banks in 83 countries (BGCI, 2022b).

Table 3.29. Countries with the largest number of botanic gardens and the number of botanic gardens with associated seedbanks by country

Country	Number of botanic gardens	Number of botanic gardens with associated seed banks
United States of America	1 036	84
United Kingdom	211	18
China	173	13
Australia	149	24
India	138	15
Canada	122	9
Italy	115	20
Russian Federation	114	16
Germany	109	18
France	102	32
Mexico	65	10
Japan	65	2
Argentina	57	8
Republic of Korea	57	3
Brazil	49	9

Source: BGCI Advanced Garden Search database (BGCI, 2022a).

Botanic gardens exchange seed for a range of purposes, including for research, conservation and display. The exchange of seed material by botanic gardens is governed by the principles of the Convention on Biological Diversity and particularly the access and benefit-sharing (ABS) regulations of the Nagoya Protocol. The

International Plant Exchange Network (BCGI, 2022c) has been developed to provide a common framework for seed exchange for non-commercial use between participating botanic gardens, using a SMTA.

3.12.2 Conservation of plant genetic resources for food and agriculture in botanic gardens

Botanic gardens have historically focused on conserving plants of importance to humans. Their role in conserving PGRFA is increasingly being recognized. A number of countries report on the role of botanic gardens, particularly in relation to CWR, fruit and nut crops and medicinal plants. In Uganda, for example, two botanic gardens are involved in the conservation of indigenous fruit trees. The field genebank of the botanic gardens of the National Academy of Sciences of Tajikistan maintains 3 251 accessions of wild fruit-tree and berry species, 500 nut-bearing species and 650 *Allium* species as well as a pool of 4 278 hybrids of apple and plum.

Table 3.30 provides an overview of botanic gardens holding collections of CWR of selected crops listed in Annex 1 of the Treaty. Such collections include the breadfruit collection at the Breadfruit Institute of the National Tropical Botanic Garden in Hawaii and the mango collection at the Fairchild Tropical Botanic Garden in the United States of America, which maintains more than 600 mango cultivars.

Table 3.30. Botanic garden collections of selected crops listed in Annex 1 of the Treaty

Crop	Genus	No. of species recorded in botanic garden collections*	No. of gardens reporting species	Important collections
Breadfruit	*Artocarpus*	79	151	National Tropical Botanical Garden, Hawaii, United States of America
Asparagus	*Asparagus*	159	321	Millennium Seedbank (MSB), United Kingdom
Yams	*Dioscorea*	176	106	No specific major collections
Sunflower	*Helianthus*	78	26	Denver Botanic Garden; MSB
Sweet potato	*Ipomoea*	203	260	Singapore Botanical Garden; MSB
Apple	*Malus*	112	399	Many significant collections, including Arnold Arboretum of Harvard University, United States of America; Belmonte Arboretum, Kingdom of the Netherlands; Bergius Botanic Garden, Sweden
Mango	*Mangifera*	31	160	Fairchild Tropical Botanic Garden, United States of America; Preston B. Bird/Mary Heinlein Redland Fruit and Spice Park, United States of America
Grass pea	*Lathyrus*	129	251	Chelsea Physic Garden, United Kingdom; MSB; National Botanic Gardens, Glasnevin, Ireland

*Synonyms not removed.
Source: BCGI (2022b).

A study of the role of botanic gardens in the conservation of CWR by Meyer and Barton (2019) focused on a list of 1 103 CWR taxa identified as globally valuable for food security, income generation and sustainability by Castañeda-Álvarez *et al*. (2016), many of which were found to require further conservation action. The study found that 29 percent of global priority CWR taxa were represented in botanic gardens and that botanic gardens maintained 22 global priority CWR taxa not reported by crop genebanks.

In addition to conserving CWR, botanic gardens also play an important role in the conservation of socio-economically important species. A study by Hudson *et al*. (2021) looked at the number of socio-economically important plant taxa conserved in the living and seed collections held in botanic garden, as recorded in Botanic Gardens Conservation International's (BGCI's) PlantSearch database. Data were compared with a list of socio-economically important plant taxa published by Khoury *et al.* (2019). At least 6 017 of the 6 941 socio-economically important taxa (87 percent) were found in botanic garden collections, with 1 456 taxa (21 percent) being held in more than 40 collections.

3.12.3 Documentation

A range of documentation systems are used across the botanic gardens community, ranging from sophisticated systems, though a range of commercial data-management systems, to simple spreadsheets. These generally focus on tracking every accession maintained by the garden and compiling associated data gathered through the collecting, processing and/or growing activities of the garden. Typically, the data shared by botanic gardens relate to taxonomy, distribution, conservation status, uses and availability in gardens, and include brief descriptions of the plants. Incompatibility among the different data management systems across botanic gardens and seed banks means that data sharing can be challenging.

3.12.4 Capacity building and networking

Botanic gardens around the world are well connected through BGCI (BGCI, 2022d) and through national and regional networks. Botanic gardens involved in seed banking are further linked through BGCI's Global Seed Conservation Challenge (BCGI, 2022e), an initiative that aims to build capacity in botanic garden seed banking. The Seed Conservation Specialist Group[86] and the Directory of Seed Conservation Experts developed within the framework of the IUCN Species Survival Commission also facilitate networking.

The taxonomic and horticultural expertise of botanic gardens is a useful resource for PGRFA conservation. An example of this is provided by Meise Botanic Garden in Belgium, where staff have been studying the genetic diversity of wild *Coffea* diversity of Central and West Africa for almost 25 years. They are now working in collaboration with partners in the Democratic Republic of the Congo to build capacity to conserve *Coffea* genetic resources locally (Piet *et al*., 2019).

3.12.5 Awareness raising

Botanic gardens, with their comprehensive educational programmes and large numbers of visitors, have the potential to play an important role in outreach and engaging the public in issues related to crop diversity conservation and the origin of food crops. The plants in their collections can play a valuable role in connecting people to food and the raising awareness of need to conserve potentially valuable traits. An example of this is the Food Forever campaign organized by the Crop Trust in collaboration with BGCI, the Royal Botanic Garden Edinburgh, the Royal Botanic Gardens Kew and the Leichtag Foundation, which calls upon the global community to protect the vast, colourful spectrum of diversity within our food system. Together, the partners have developed a toolkit and a series of Food Forever panels that are available free of charge for use by botanic gardens and other key sites to produce their own Food Forever exhibitions.[87]

3.12.6 Collaboration with plant genetic resources for food and agriculture genebanks

While the collections of botanic gardens and PGRFA genebanks are often complementary, collaboration between the two communities continues to be weak. In many countries, resources are duplicated and

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[86] https://seedconservationsg.org
[87] Food Forever Global Exhibition | Botanic Gardens Conservation International (bgci.org)

opportunities for sharing skills and expertise missed. With a few exceptions, the botanic garden community does not share its collection-level data with Genesys and the crop and forestry sectors. This is in part because the botanic garden sector has no equivalent data portal that enables the sharing of accession-level information. Instead, botanic gardens maintain their own accessions databases (in a variety of formats) and currently only share the names of those accessions via BGCI's PlantSearch database.[88]

The lack of collaboration may also be caused by differing institutional and reporting structures. However, the fact that a significant number of countries mention the work of botanic gardens in their country reports indicates that, in some countries at least, these barriers are being overcome. Another example is the involvement of botanic gardens in the recent development of an integrated genetic resources strategy for Europe through the GenRes Bridge project.[89]

Several countries, including Azerbaijan, Ethiopia and Lebanon, report the establishment of one or more new botanic gardens, In a number of countries, botanic gardens are reported to be an integral part of national PGRFA conservation efforts, sometimes with specific responsibilities, for example in Egypt, El Salvador, Estonia, Indonesia, Kyrgyzstan, Mexico, Nepal, Tajikistan, Tunisia, Uganda and Zimbabwe. Some other countries report the need to establish better collaboration between PGRFA genebanks and botanic gardens (e.g. Bangladesh, Brazil, Mexico and Nepal). Several countries (e.g. Armenia, Botswana, Tajikistan and Uganda) report that one or more botanic gardens focus on local or regional native flora. The conservation of CWR in botanic gardens is mentioned by Tajikistan and Zimbabwe. The maintenance of herbaria by botanic gardens is reported by Cuba, Kyrgyzstan, Romania, Türkiye and Zimbabwe. In El Salvador, the botanic garden assists the national PGRFA programme in the planning of collecting missions. In Romania collaboration between genebanks and botanic gardens focuses on research and assistance in education.

3.12.7 Summary assessment

Botanic gardens are numerous and widespread across the world. The enormous species diversity they conserve is without question a major contribution to global efforts to conserve plant species, including many PGRFA. The increasing focus on conserving species producing orthodox seeds, including in seed banks, means that there is incentive to seek much closer collaboration between PGRFA genebanks and botanic gardens. Botanic gardens possess considerable experience in the identification of plants and train people around the world in the skills needed to maintain and conserve plant diversity. They are very experienced in creating public awareness and showcasing interesting and important species. They also have a well-functioning global network.

3.13 Gaps and needs

3.13.1 Issues of relevance to *ex situ* conservation

Complementary conservation

It is generally agreed that *in situ* and *ex situ* conservation methods should be combined to achieve sustainable, secure, efficient and cost-effective long-term conservation of PGRFA. Farmers' varieties/landraces are often only cultivated by small-scale farmers in traditional production systems and are steadily disappearing. Securing them therefore requires combining on-farm conservation with *ex situ* conservation. CWR and WFP are threatened by the effects of climate change, including increasing biotic and abiotic challenges. Major efforts to secure the diversity of CWR *ex situ* and to enhance their availability to users are required. In addition, complementarity among different *ex situ* conservation methods such as field genebanks, *in vitro* conservation and cryopreservation needs to be considered.

Policy support

Following the adoption of the Treaty, the MLS was intended to play a central role with respect to ABS arrangements for germplasm that had been placed into the FAO global system of conservation and use, largely confined to the major food crops listed in Annex 1. The focus on a limited number of species may

[88] https://www.bgci.org/resources/bgci-databases/plantsearch
[89] http://www.genresbridge.eu/

have repercussions for the sustainability of crop production systems, as research tends to neglect other species that are important for nutrition. Additionally, current benefit-sharing arrangements tend to be complex and can delay implementation.

The Convention on Biological Diversity is of particular relevance in the context of the collection of material from farmers' fields/stores or community areas, including some natural habitats, as prior informed consent (PIC) and mutually agreed terms (MAT) may be required (CBD, 2018). The acquisition and exchange of germplasm is also governed by national and international phytosanitary regulations and quarantine laws. Safety-specific phytosanitary standards for the international exchange of germplasm have not yet been developed, and requirements for germplasm shipment often vary from country to country, necessitating collaboration with national and regional plant-quarantine organizations.

Financial support for *ex situ* conservation

Ex situ conservation is intended to be for the long-term, ideally in perpetuity, and therefore requires sustainable and adequate funding for infrastructure and equipment, sufficient numbers of well-trained staff and timely purchasing of perishable supplies. Inadequate or unsustainable funding, which affects many genebanks, may hamper conservation efforts and even result in the loss of germplasm. Furthermore, many routine conservation activities are funded predominantly through short-term projects. While these initiatives are commendable, more attention needs to be given to long-term financial stability in order to allow proper planning and adequate staffing of genebanks and other *ex situ* conservation activities.

Human capacity

Shortages of adequately trained staff cause severe constraints to the efficient and effective *ex situ* conservation of PGRFA. Gaps include a lack of expertise in critical subjects such as plant taxonomy, conservation and population genetics, physiology, pathology, statistics and informatics. Additionally, curricula in genetic resources science are declining globally. The appeal of molecular science has further affected the availability of the above-mentioned categories of expertise.

Networks, networking and collaboration

As many countries do not have sufficient human capacity, funds or facilities to adequately carry out germplasm management operations, many valuable collections are in jeopardy. There is therefore a need for greater cooperation among genebanks and institutions involved in the conservation and sustainable use of PGRFA at national, regional and international levels to strengthen human and technical capacity and share facilities and know-how. Such cooperation could also include the exploration of useful traits for use in breeding programmes. Collaboration with the private plant-breeding sector might also be worth expanding.

Furthermore, the need for adequate coordination of long-term conservation programmes at national level and better networking among the various stakeholders involved in the conservation of PGRFA is evident (Engels and Ebert, 2021b). Strong national PGRFA programmes that facilitate efficient and effective long-term conservation efforts are needed. Cooperative activities among botanic gardens and national, regional and international genebanks need strengthening through specific organizational arrangements, especially for the conservation of CWR and WFP.

Regional genebanks provide countries with an invaluable resource, especially in terms of maintaining their base collections. CePaCT ensures efficient long-term conservation of a broad range of genetic diversity of key food crops in the Pacific region, maintaining over 1 000 accessions of 23 species from 47 countries in long-term, slow-growth *in vitro* conditions. NordGen maintains over 33 000 accessions in long-term seed storage facilities, enabling countries in the Nordic region to focus on vegetatively propagated species. SPGRC coordinates with the national centres for PGRFA in the Southern African region, providing a safety backup of over 11 000 accessions deposited by 12 member countries.

The funding and coordination of regional efforts to conserve base collections needs to be improved, thus freeing up human resources at national level to conduct research on conservation and sustainable use. The regional centres should provide opportunities for training and secondment of national staff to undertake tasks at the centres on a rotational basis.

3.13.2 Overall gaps and needs

Overall gaps and needs were assessed based on the country summative narratives. Some countries report significant reductions in human capacity and that aging and/or damaged infrastructure such as cold storage facilities has resulted in partial or complete loss of germplasm collections.

The lack of a sustainable funding mechanism for conservation activities is by far the most commonly reported gap, especially with regard to viability testing, seed and plant health monitoring, regeneration and multiplication, characterization and safety duplication. Countries also indicate that financial limitations contributed to difficulties with (i) hiring sufficient staff; (ii) expanding and/or maintaining facilities such as cold storage, seed drying rooms and seed health laboratories; (iii) conserving germplasm in field genebanks; (iv) obtaining specialized facilities for molecular characterization, in *vitro* conservation or cryopreservation; and (v) purchasing state of the art equipment and the necessary consumables.

Several countries report a lack of policy support, for example the need for a national strategy for the conservation of PGRFA. The lack of technically qualified staff is also reported as an important gap, especially with respect to expertise in botany, taxonomy, general knowledge of CWR, pathology and database management. As such, better coordination within and between institutions at country level was regarded as necessary. For example, collection of CWR often requires coordination between the genebank, which is frequently under the country's agriculture ministry, and the environment ministry, which often oversees the areas where CWR are found. Other examples include the need for coordination between genebanks, research stations and academic institutions within countries, especially for activities such as collecting and safety duplication but also for outsourcing of regeneration and multiplication, viability testing, health screening and molecular characterization. The need for collaboration between national, regional and international genebanks and institutes is also reported.

3.14 Conclusions

Although some major achievements and advances have been made over the past ten years, many of the issues that impede the efficient and effective conservation of PGRFA remain to be addressed. Many countries still provide insufficient policy support to *ex situ* conservation, which often results in limited or sporadic funding for hiring qualified staff, building or maintaining infrastructure and buying equipment and supplies. In turn, there are still significant gaps in viability testing, characterization, regeneration and safety duplication, as these require sufficient and sustainable sources of funding. In addition, several national genebanks do not have the human and/or technical capacity to address germplasm-health issues adequately.

Acquisition of germplasm through collecting has improved, but many genebank holdings could still benefit from more targeted collecting, especially through the use of gap analyses. Despite renewed interest in the acquisition of CWR, collecting wild species requires staff specialized in topics such as taxonomy and phenology, which are not always available. Additionally, there are often difficulties with conserving CWR effectively once they have been added to collections. The collection and conservation of WFP are also often overlooked or limited for similar reasons. In the case of both CWR and WFP, *in situ* and *ex situ* conservation need to be better integrated.

Genebank information management systems that include built-in automated tools for checking inventory and viability and flagging accessions requiring regeneration are still only used by a limited number of countries and international centres. Although things are improving, a number of genebanks still rely on simple Excel spreadsheets. Greater efforts are needed to train data specialists and genebank managers to adopt and use available systems such as the new Grin-Global Community Edition. Passport data and DOIs are increasingly being used in documentation, for germplasm exchange and for cross-referencing germplasm in publications. However, there is plenty of room for greater use of barcoding and direct digitalization of data in all areas of genebanking activity. In addition, digitalization of old data from hard copies is still required for some genebanks and should be prioritized before the data are lost. Linking databases to global portals is enhancing germplasm exchange and use but also facilitates compliance with international reporting obligations such as those for SDG Indicator 2.5.1a.

The international community has made great strides in taking advantage of the SGSV as a long-term black-box storage facility, especially benefiting from increased coordination and financial support for packaging and shipment provided by the Crop Trust and the Government of Norway. As noted above, there is still a need to provide sustainable, long-term black-box storage for species that are vegetatively propagated or produce recalcitrant seeds. Although institutes cooperate to maintain duplicates in field collections and *in vitro*, these conservation methods have high costs and labour requirements and are vulnerable to pests, diseases and natural disasters. The proposed development an international cryopreservation facility would help overcome these obstacles. While this would require substantial initial expenditure on infrastructure and research into the methodologies needed at species level, the long-term running costs would be lower than maintenance in field collections or *in vitro*.

The success of existing regional genebanks could provide a model for similar regional initiatives to support national programmes by providing training, backup storage and collaboration in activities such as viability and germplasm-health testing, regeneration and characterization, including molecular characterization. Collaboration should also established or strengthened with universities, other research institutes and the private sector, both in terms of outsourcing activities and to fund mutually beneficial activities that enhance germplasm use.

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Chapter 4. The state of sustainable use

4.1 Introduction

Article 6 of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) commits its Contracting Parties to "*develop and maintain appropriate policy and legal measures that promote the sustainable use of plant genetic resources for food and agriculture*" (FAO, 2009). Though the Treaty does not explicitly define the concept of the sustainable use of plant genetic resources for food and agriculture (PGRFA), a set of measures, the implementations of which are within the remit of the Article, were identified. These measures, which encompass the direct utilization of PGRFA by farmers and other end-users and their indirect exploitation in research and development, include the development and maintenance of diverse farming systems; research on PGRFA; plant breeding; broadening the genetic base of crops; utilization of local and locally adapted crops, varieties and underutilized species; on-farm diversity; and the release of crop varieties and seed distribution.

Further underscoring the importance of this Article of the Treaty, one Target of the multi-year programme of work (MYPOW) of FAO's Commission on Genetic Resources for Food and Agriculture (Commission), under which auspices this report is prepared, is "*By 2020, there has been an increased use of plant genetic resources for food and agriculture to improve sustainable crop production intensification and livelihoods while reducing genetic vulnerability of crops and cropping systems*"[90]. This Target is instructive as it recognizes that the use of PGRFA should result, on one hand, in food security and nutrition from cropping systems and on the other, in enhanced genetic diversity of such systems, thereby underscoring the sustainability dimension to the use of PGRFA.

The Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA), the globally agreed framework for the conservation and sustainable use of PGRFA, is an implementing mechanism for the Treaty. Five of the 18 priority activities of the Second GPA stipulate the actions to be taken for attaining the sustainable use of PGRFA. These priority activities, which are aligned with the measures stipulated in Article 6 of the Treaty, relate to the characterization, evaluation and development of subsets of germplasm collections; plant breeding, genetic enhancement and base-broadening; the diversification of crop production systems; the development and commercialization of all varieties, especially farmers' varieties/landraces and underutilized species; and seed production and distribution, respectively.

Countries and other relevant stakeholders were required to report on progress towards the implementation of the priority activities of the Second GPA, for the period 2014 to 2020, using the Reporting Format for Monitoring the Implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Reporting Format)[91]. In order for the results to be comparable across countries and regions, the Reporting Format stipulated a uniform set of indicators and questions for the feedbacks on the respective priority activities. In addition to responses based on this template of indicators and questions, respondents also provided summative narratives as supplemental information. For the five priority activities pertaining to the sustainable use of PGRFA, there were 19 indicators and 16 associated questions. While the majority of the data used in preparing the Third Report were provided by countries, other information, which provide context, was obtained from literature, databases and other validated sources.

The progress towards achieving the sustainable use of PGRFA, as envisaged in the Treaty, the Second GPA and the MYPOW of the Commission, for the period 2014 to 2020, is presented according to the relevant five priority activities of the Second GPA in this chapter.

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[90] CGRFA-15/15/4.1 https://www.fao.org/3/mm172e/mm172e.pdf

[91] CGRFA-18/21/12.4/Inf.1 Rev.1 Annex I. Reporting Format for monitoring the implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture.

4.2 Germplasm characterization, evaluation and development of trait-specific sets

The utility of the large germplasm collections is typically constrained by the lack of knowledge about the traits that would be useful for the genetic improvement of crops. This is one reason why only less than one percent of all germplasm accessions are used in crop improvement. The mining of traits or gene alleles for breeding from large germplasm collections is both resource- and labour-intensive. The generation of, and facilitated access to reliable data from germplasm characterization and evaluation creation of trait-specific collection subsets, which would be more amenable to querying for, and isolating the particular germplasm accessions that harbour, heritable traits of interest. There is a need to improve the generation and quality of characterization and evaluation information, implement mechanisms for documentation and access to information, so the conserved PGRFA could be used in effectively plant breeding programs. Workable subsets of germplasms that captre sufficient genetic variation (core collections being 10 percent of all accessions and mini corecore being one percent) have been created for rice, maize soybean, common bean, chickpea, groundnut, pigeonpea, sorghum and millets (Guo *et al*. 2014, Kuzay *et al*. 2020).

The characterization and evaluation of plant germplasm, using standard descriptors – such as those published by Bioversity International and the International Union for the Protection of New Varieties of Plants (UPOV), are critically important to the efficient conservation and use of genebank collections. The standard descriptors consist of morphological traits with high heritabilities. In recent years, there was a significant increase in the number of accessions characterized and progress made in the development of thematic collections for characters of interest based on data generated from characterization and evaluation of genebank holdings. These facilitated the better understanding of the diversity amongst germplasm accessions and hence enhanced the potential for the use of these resources in plant breeding and/or other research activities.

4.2.1 Germplasm characterization

As at the end of 2019, a total of 685 281 germplasm accessions had been characterized in 62 countries, representing 32 percent of their total genebank holdings[92] (Table 4.1). Globally, the proportion of characterized germplasm to the total holdings was higher than 50 percent in 20 countries; between 20 and 50 percent in 10 countries; between 10 and 20 percent in 15 countries; and less than 10 percent in the remaining 17 countries, the majority of which were in Eastern Africa (5) and Western Asia (3). The regional averages for Western Africa, the Caribbean, Southern Asia and Western Europe were higher than 50 percent and ranged between 20 and 50 percent in Northern and Eastern Africa, Eastern Asia and Eastern Europe.

The accessions that constitute this 32 percent of the genebank holdings of the reporting 62 countries were characterized on the bases of about 25 traits per accession. Globally, the significantly lower average of eight traits were used for the characterization of the entire genebank holdings, indicating that a substantial number of germplasm accessions had been partially characterized to varying degrees. In fact, in 21 out of the 62 countries, the average number of traits used for the characterization of genebank accessions was more than eight.

[92] Genebank holdings as per 2019 SDG 2.5.1a report.

Table 4.1. Level of morphological characterization of *ex situ* collections by regions and sub-regions based on reports from 62 countries

Region	Sub-region	Number of countries	Number of accessions conserved *ex situ*	Number of accessions characterized	Percentage of accessions characterized	Average number of traits per accession characterized	Average number of traits per accession conserved *ex situ*
	Northern Africa	4	124 195	37 759	30	22	7
Northern Africa		**4**	**124 195**	**37 759**	**30**	**22**	**7**
	Eastern Africa	8	159 698	78 826	49	21	11
	Southern Africa	1	6 842	88	1	9	0
	Western Africa	4	8 751	4 424	51	15	7
Sub-Saharan Africa		**13**	**175 291**	**83 338**	**48**	**21**	**10**
	Central America	4	81 107	7 844	10	24	2
	Caribbean	2	20 050	14 315	71	36	26
	South America	8	331 018	60 962	18	30	6
Latin America and the Caribbean		**14**	**432 175**	**83 121**	**19**	**30**	**6**
	Central Asia	2	70 787	10 429	15	8	1
	Eastern Asia	2	243 900	94 441	39	20	8
	Southern Asia	4	112 858	65 870	58	18	11
	Western Asia	5	66 351	3 592	5	16	1
Asia		**13**	**493 896**	**174 332**	**35**	**19**	**7**
	Northern Europe	2	3 934	803	20	18	4
	Eastern Europe	6	290 061	87 718	30	12	4
	Southern Europe	4	76 010	7 010	9	49	5
	Western Europe	4	284 848	208 901	73	34	25
Europe		**16**	**654 850**	**304 430**	**47**	**28**	**13**
	Melanesia	1	1 567	225	14	49	7
	Australia and New Zealand	1	248 905	2 074	1	10	0
Oceania		**2**	**250 472**	**2 299**	**1**	**14**	**0**
Total		**62**	**2 116 027**	**685 281**	**32**	**25**	**8**

Table 4.2. Status of the germplasm characterization in 280 genebanks in 62 countries showing the holdings, proportion characterized and average number of traits per accession characterized by crop groups and genera

Crop group	Genus	Number of accessions	Characte-rization percent	Average traits	Crop group	Genus	Number of accessions	Characte-rization percent	Average traits
Cereals	*Triticum*	348 872	37	20	Oil plants	*Glycine*	50 590	28	20
	Hordeum	180 083	47	26		*Sesamum*	14 137	30	19
	Zea	100 537	21	21		*Helianthus*	13 426	27	7
	Oryza	99 837	43	28		*Brassica*	8 106	45	20
	Sorghum	51 686	45	29		*Carthamus*	4 603	25	21
	Avena	35 101	29	18		*Guizotia*	1 488	89	20
	Triticosecale	14 688	33	16	Pulses	*Phaseolus*	89 168	21	28
	Secale	10 354	58	17		*Lathyrus*	38 745	7	23
	Eleusine	9 203	49	16		*Vigna*	31 641	31	18
	Eragrostis	5 256	93	15		*Cicer*	26 575	29	14
Pseudo cereals	*Amaranthus*	8 258	27	23		*Vicia*	16 637	30	23
	Chenopodium	7 731	88	35		*Lupinus*	15 484	34	47
	Fagopyrum	2 495	43	18		*Lens*	14 972	18	17
Forages	*Medicago*	44 739	8	17		*Arachis*	14 098	27	22
	Trifolium	32 898	11	20		*Lablab*	1 996	40	26
	Festuca	13 781	47	29	Roots and Tubers	*Solanum*	28 674	63	33
	Dactylis	13 365	64	20		*Ipomoea*	8 725	30	36
	Lolium	12 839	57	39		*Manihot*	6 768	35	44
	Vicia	12 171	28	25		*Oxalis*	1 711	144	21
	Poa	5 331	72	25		*Dioscorea*	1 610	28	47
	Phleum	4 887	77	25		*Colocasia*	1 082	15	50
Fruit plants	*Vitis*	61 009	10	42	Sugar plants	*Saccharum*	8 509	60	27
	Malus	24 172	24	33		*Beta*	4 415	64	33
	Prunus	17 048	19	22	Vegetables	*Solanum*	37 766	33	27
	Pyrus	10 577	12	30		*Capsicum*	24 209	29	36
	Citrus	3 944	43	21		*Cucumis*	21 190	34	31
	Fragaria	2 499	42	20		*Cucurbita*	19 923	14	34
	Musa	2 401	41	92		*Brassica*	17 952	32	28
	Annona	1 583	52	38		*Allium*	11 924	46	15
	Persea	1 375	38	31		*Lactuca*	8 742	45	24
Herbs and Spices	*Brassica*	4 202	26	27		*Raphanus*	3 852	50	26
	Trigonella	1 760	41	13		*Daucus*	3 434	28	28

Cereals accounted for 49 percent of all the characterized germplasm accessions. About 38 percent of cereals germplasm accessions in the 62 countries were characterized based on an average of 23 traits. The most represented genus was *Triticum*, with 128 507 accessions or 37 percent of the total held by the reporting countries morphologically characterized on the bases of an average of 20 traits. The proportion of the characterized germplasm accessions of barley was 47 percent, rice 43 and maize 22. Of the 187 361 vegetable germplasm accessions from 255 genera in the genebanks of the reporting countries, 30 percent belonging to 135 genera were characterized using more than 25 traits. Tomatoes and eggplants accounted for 72 and 15 percent, respectively, of the *Solanum* species that were characterized while the remaining belonged to

45 species of crop wild relatives of the two crops. Over 267 999, or a quarter of the, accessions of the conserved pulses were characterized using more than 26 morphological traits. Similarly, 30 percent of the germplasm accessions of peas, i.e. *Vigna*, lupins, Indian peas and lablab bean, were characterized. The number of accessions in *ex situ* holdings, the proportion that were characterized and the average number of traits per characterized accession as reported by 280 genebanks from 62 countries are presented by main crop groups and genera in Table 4.2 above.

The highest proportions of germplasm accessions were characterized in Germany, Ethiopia, Iran, Poland and Japan with 100, 81, 58, 56 and 41 percent, respectively of the total germplasm collections in the national genebanks having been characterized. A few highlights of the status of germplasm characterization are presented by regions below.

Latin America and the Caribbean

Brazil reported the characterization of a total of 100 645 accessions belonging to 129 taxa. On the average, 19 traits was used for the characterization of an accession. For instance, the Embrapa soybean collection, totalling 55 000 accessions, was fully characterized on the basis of 15 characters.

North America

In Canada, the characterization and evaluation of several crop species, including pea, flax, wheat, oat, buckwheat, triticale, sunflower and several *Brassicaceae*, were conducted. This included collaborative efforts between plant pathologists and plant breeders to screen crop germplasm for resistance to fungal diseases. In this regard, 14 000 accessions of wheat were screened for stem rust, leaf rust, leaf spot and *Fusarium* head blight); 28 000 accessions of oat for crown rust and wilt; and 3 500 accessions of flax for pasmo. The similar screening of the germplasm of lentil, chickpea and canola resulted in the identification of accessions with improved resistance to important fungal pathogens, e.g. *Ascochyta* blight and clubroot. The digital passport data records of the accessions at the Plant Gene Resources of Canada were improved.

A summary of the status of characterization of *ex situ* collections is presented by regions and sub-regions in Table 4.1. The extent of improvement in the level of characterization of *ex situ* collections since the Second Report is not easily quantifiable and latest country data show less progress overall than those reported in 2008 (FAO, 2010). The discrepancy may be in part due to the different number of reporting countries, i.e. 42 in 2008 and 62 in 2019. A comparison between the status of germplasm characterization in 103 genebanks in 34 countries, in June 2014 and December 2019, showed a 48 percent increase, from 366 190 to 540 650 accessions out of over 1 052 000 *ex situ* accessions conserved. The average number of traits used for the characterization of an accession also increased from 21 in 2014 to 25 in 2019. Among these genebanks, 14 in 12 countries characterized more than 1 000 accessions during this 5-year period (Table 4.3). Notably, a number of genebanks further characterized accessions that had been previously characterized using additional traits. For example at the IPK, Gatersleben genebank in Germany, the number of the descriptor traits was increased by 67 percent. At IPK also, historical characterization data that had been collected in the genebank since 1946 were also digitized and analysed.

Table 4.3. Changes in the level of morphological characterization of *ex situ* collections during 2014-2019 for genebanks that characterized over 1 000 new accessions during the period

Country	Genebank	Number of accessions conserved	Percent of accessions characterized at		Average number of characterized traits per accession conserved	
			30-Jun-2014	31-Dec-2019	30-Jun-2014	31-Dec-2019
Czechia	CRI	45 895	57	62	9	10
Germany	IPK	129 815	100	100	21	36
	JKI-Grapevine	2 929	0	42	0	3
	JKI-Fruit	1 601	40	100	21	36
Ecuador	DENAREF	21 902	11	55	22	23
Iran Islamic Rep. of	HSRI	70 759	40	58	0	25
Japan	NARO	224 353	9	41	3	18
Morocco	INRA CRRAS	69 628	9	14	1	8
Mali	URG	2 137	29	100	1	1
Mongolia	IPAS	19 547	4	13	4	9
Nepal	NAGRC	6 470	43	68	1	2
Peru	INIA-EEA.DONOSO	1 899	44	100	5	8
Poland	IHAR	76 160	0	56	30	73
Sudan	ARC	17 177	2	65	0	3
	Total/Average	560 457	16	45	2	8

In Germany, the national evaluation program (EVA and EVA II) of cereals, operating in private public partnership (PPP) mode and involving 15 breeding companies and three scientific organizations resulted in the evaluation of 2 292 wheat and 1 865 barley accessions for resistance or tolerance to eight wheat and barley pathogens. The evaluation programme served as blueprint for the successful development of the ECPGR evaluation network EVA in 2018, which was implemented through a series of projects funded by the Federal Ministry of Food and Agriculture of Germany.

4.2.2 Molecular characterization

Advances in molecular biology, in particular DNA sequencing and genotyping technologies, provided a significant impetus for the use of plant genomics for germplasm characterization and evaluation and crop improvement. The second generation of DNA markers including simple sequence repeat (SSR) markers were still being used for molecular characterization of smaller PGRFA sets. Owing to their cost-efficiency and suitability for assaying large numbers of samples, next generation sequencing (NGS) methods, based on reduced representation, such as genotyping by sequencing (GBS), specific locus amplified fragment sequencing (SLAF-seq), restriction-site associated DNA (RAD) sequencing, etc. were particularly suitable for genetic profiling of genebank collections.

The use of molecular characterization approaches, in particular whole genome sequencing and other high-density genotyping techniques, such as whole genome re-sequencing (WGRS), genotyping by sequencing (GBS), SNP arrays, etc., which enabled in-depth genetic characterization of large crop germplasm collections, were increasingly enabled by international collaborations. These included the whole genome sequencing of hundreds of diverse accessions of rice (Wang *et al*. 2018); chickpea (Varshney *et al*., 2019, 2021c); wheat (Sansaloni *et al*. 2020); maize (Romay *et al*. 2013); soybean (Bandillo *et al*. 2015); sorghum (Girma *et al*. 2020); pepper (Tripodi *et al*. 2021); cassava (Bredeson *et al*., 2016, Ramu *et al*., 2017, Hu *et al*., 2021); sunflower (Hübner *et al*., 2019); common bean (Wu *et al*., 2020); pigeonpea (Varshney *et al*., 2017a); pearl millet (Varshney *et al*., 2017b) and lettuce (Wei *et al*., 2021). These underscored the potentials of “germplasm genomics” for plant genetics and improvement in the post-NGS era.

Over all, in 53 countries from five regions, there was an increased adoption of DNA marker technologies for the assessment of genetic variations. Countries like Ghana reported that characterization was only carried out agro-morphologically until this reporting period. Currently, molecular characterization has also been extended in addition to agro-morphological measurements. The use of DNA markers increased particularly in the assessment of diversity assessment, either as standalone method or in combination with pedigree studies or other methods.

Northern Africa
In Egypt, different molecular techniques, such as inter simple sequence repeat (ISSR), SSR and amplified fragment length polymorphism (AFLP), and DNA barcoding, was used for the characterization of some *Vicia* species, and for crops including cantaloupe, broad beans, clover, wheat, pomegranate, and grapes.

Sub-Saharan Africa
In Botswana, 30 accessions of sorghum were characterized using molecular techniques just like 33 cowpea accessions in Eritrea; 113 of cowpea and 80 of taro in Ghana; 30 of rice in Zambia; and 49 of sorghum in Mali. In Kenya, NGS was used to assay the genome of finger millet, leading to the identification of 10 327 SSR and 23 285 single nucleotide polymorphism (SNP) markers, which were polymorphic across wild and cultivated accessions.

Europe
At the Federal Genebank IPK, Gatersleben, Germany, the entire barley collection, of more than 20 000 accessions, and about 22 000 wheat accessions were assayed by genotyping by sequencing (GBS) technology. Additionally, yellow lupine accessions were characterized for traits relevant for breeding improved varieties. Genetic reference profiles for future validation of varieties were generated for 1 544 apple, 476 cherry and 192 strawberry varieties at the German fruit genebank. Underutilized native species were also characterized under the auspices of a series of innovative projects, which involved both phenotypic and genotypic characterization and evaluation of PGRFA. The German Federal Ministry of Education and Science (BMBF) funded research projects to genotype, phenotype and sequence the accessions conserved at the federal genebank IPK (e.g. GeneBank 2). Genome sequencing of wheat and barley accessions and the establishment of pan genomes were implemented through several projects, including Public-Private Partnership projects, which were funded by the Federal Ministry of Food and Agriculture (BMEL) and BMBF. Similar work on oats was ongoing by the end of 2019.

In the Netherlands, the molecular characterization of germplasm accessions was implemented through the ‘150 Tomato Genome Sequencing Project’, the ‘International Lactuca Genomics Consortium’, the ‘Capsicum Genome Initiative’, the NWO-funded project ‘Healthier lettuces for healthier food’ (lettuce metabolomics), the ‘LettuceKnow’ project (lettuce transcriptomics), and a cooperative project with the Beijing Genomics Institute (BGI) in Shenzhen, China.

At the Swiss National Genebank, 502 bread wheat (*Triticum aestivum)* and 293 spelt (*Triticum aestivum* subsp. *spelta*) accessions were analyzed using a 15K SNP array. This, importantly, demonstrated the importance of old landraces as sources of novel alleles for crop improvement (Müller *et al*. 2017).

In the United Kingdom, a large-scale and cost-efficient functional genomics platform was established for Targeting Induced Local Lesions in Genomes (TILLING) for Brassica rapa, Brassica napus, Brasica rapa and rice. The characterization of 1 779 accessions including landraces and elite lines was done using Wheat Breeders’ Array to design future wheat cultivars. Also, Kompetitive Allele-Specific PCR (KASP) markers were employed for the quality assurance of mapping populations of wheat. At the John Innes Centre, 712 pea accessions were sequenced with 20x coverage. Molecular characterization was applied to several subsets of PGRFA in Italy. At the Research Centre for Olive, Fruit and Citrus Crops (CREA OFA), about 400 peach accessions were analyzed with IPSC 9K SNP array (Micheletti *et al*. 2015, Verde *et al*. 2012). Moreover, the entire peach collection of about 900 accessions was characterized with SSR markers. Furthermore, about 400 apple accessions local to Central Italy were characterized with 20K SNP arrays. A subset of 200 bread wheat was analyzed by SNPs and phenotyped for relevant agronomic and qualitative traits (Lazzaro *et al*. 2019, Ormoli *et al*., 2015; Talini *et al*., 2020).

Northern America

At the Plant Gene Resources of Canada genebank in Saskatoon, genetic sequence data were generated on subsets of germplasm of oat (including wild oat species), barley (including wild barley species), wheat, flax, maize, soybean, and oilseed Brassica species in Canada. The DNA analysis and digital recording of the germplasm collections, which over 19 million specimens of insects, plants, fungi, bacteria and nematodes, included the sequence data for 20 000 PGRFA accessions.

Asia

High-resolution multiple-SNP (mSNP) arrays, which were developed through genotyping by target sequencing with capture-in-solution (liquid chip) (GBTS-LC), 40K mSNPs, 251K SNPs and 690K haplotypes and validated by genetic diversity detection, linkage disequilibrium decay analysis, and genome-wide association studies, were used to genotype 647 maize inbred lines in China (Guo *et al*. 2021).

Development of trait-specific subsets of germplasm collections

During the reporting period, trait-specific sub-sets of germplasm accessions, which were tailored to breeding goals, were created on the bases of data generated from the characterization and evaluation of the resources.

Europe

In Sweden, the following trait-specific sub-sets of germplasm accessions of crops were developed: barley – growth habit and row type; wheat – growth habit; hop –morphological, chemical, sensory characteristics for brewing beer; asparagus –morphological, sex traits; potato and onion – morphological and storage properties; garlic – morphological and sensory traits; horse radish – morphological and chemical (sinigrin) traits; rhubarb – morphological and chemical (oxalic acid) traits; and Jerusalem artichoke – morphological and sensory traits.

In the Netherlands (Kingdom of), there were a total of 512 trait-specific collection subsets while there were 68 in Belarus.

Northern Africa

In Egypt, germplasm accessions of crops with tolerance to abiotic stresses were identified, thus: lentil – high temperature; alfalfa – drought and salinity; and wheat – drought and heat.

Sub-Saharan Africa

A core collection of 350 accessions of *Oryza glaberrima*, which captured 97 percent of the molecular variation for amylose content (AC), was developed from the whole set of germplasm accessions of the species held in the genebank of AfricaRice. This was achieved using genome-wide association studies (GWAS). Further work was ongoing on the evaluation of the core collection for diverse agronomic and biotic stresses tolerance traits.

4.2.3 Predictive characterization

Characterization and evaluation data are not always available for constructing trait-specific sub-sets of germplasm collections. The focused identification of the germplasm strategy (FIGS) is a predictive characterization method, which makes use of ecogeographical information of the sites from where the accessions were collected to determine with a high probability whether they harbor the traits of interest. FIGS has therefore been used reliably to construct sub-sets of germplasm accessions. In wheat, for instance, Bhullar *et al*. (2009) successfully identified alleles for powdery mildew resistance gene *Pm3* in a subset of 1 320 landraces that was created from a large genebank collection of 16 089 accessions using the FIGS approach. FIGS was also used to create sub-sets of wheat germplasm for other traits such as resistances to Russian wheat aphid (El Bouhssini *et al*. 2010), stem rust (Endresen *et al*. 2012), yellow or stripe rust (Bari *et al*. 2014). Similarly, FIGS facilitated the identification of sources for resistance to net blotch in barley (Endresen *et al*. 2011) and drought adaptation in broad bean (Khazaei *et al*. 2013). Haupt and Schmid (2020) also applied FIGS to over 17 000 soybean accessions from the USDA Soybean Germplasm Collection and identified two diversity panels of 183 and 366 accessions each for abiotic stress adaptation in the crop.

Still, as indicated by several countries including Eritrea, Ethiopia, Sweden, Indonesia, Norway, Türkiye, more efforts and resources are needed for the development of trait-specific collections, core or mini-core collections. One of the major constraints to achieving this aim was the poor level of feedback by the germplasm recipients and lack of sharing of results/publications originating from the use of the received germplasm.

The information on several of these subsets were available from online platforms that store PGRFA data, e.g. Genesys[93], which showed the availability of 262 subsets of different crops including, core and mini-core collections and the accessions having specific traits. Core collections were available for sorghum (2 246 accessions); pearl millet (2 094 accessions); soybean (small seeded: 1 466 accessions; large seeded: 111 accessions); subterranean clover (97 accessions); and cassava (629 accessions). Also accessible from Genesys were mini core collections for rice (600 accessions); *Oryza glaberrima* (350 accessions)*; Triticum timopheevii* (92 accessions); *Aegilops tauschii* (40 accessions); and cowpea (376 accessions). As demonstrated in rice (Kumar *et al*. 2020), wheat (Pascual *et al*. 2020) and common bean (Kuzay *et al*. 2020), the generation of large-scale sequencing and genotyping data in recent years facilitated more detailed investigations of the existing diversity panels, which in turn allowed the optimization of these subsets to have better representations of the genetic diversity of the crop species.

4.3 Pre-breeding and germplasm enhancement

Pre-breeding, i.e. the introgression of novel traits from non-adapted germplasm into parental lines in order to generate intermediate materials that could be used subsequently in breeding improved crop varieties, is a means to both introduce novel desirable traits and to broaden the genetic base of crops. In pre-breeding, these desirable traits are typically sourced from crop wild relatives (CWR), exotic materials and landraces. Pre-breeding requires collaboration between genebank personnel, who maintain the germplasm accessions, and plant breeders.

Table 4.4. Overview of 18 crops that were the most frequent target of pre-breeding activities between 2014 and 2019

Crop	Number of		
	Pre-breeding activities	Species	Countries
Wheat	106	5	34
Maize	87	3	37
Tomato/Eggplant	67	6	37
Barley	56	3	28
Capsicum pepper	51	5	21
Rice	46	5	29
Potato	45	3	37
Cowpea	45	7	23
Beans	45	5	21
Prunus	35	9	14
Brassica	34	9	16
Soybean	33	2	19
Chickpea	29	2	14
Onions	28	6	14
Cucumber and cantaloupe	25	4	15
Pea	25	5	12
Cotton	25	6	11
Sorghum	25	3	21

[93] https://www.genesys-pgr.org/subsets

Over 350 national research organization from 76 countries implemented pre-breeding activities for 322 crop species, viz: fruit plants (20 percent), vegetables (18), forages (12), cereals (8), herbs and spices (7), pulses (7), ornamentals (5), and roots and tubers (5 percent). Overall, wheat, maize, tomato, barley, sweet pepper, rice, potato, cowpea and common bean were the nine most common crops for which pre-breeding activities were conducted (Table 4.4).

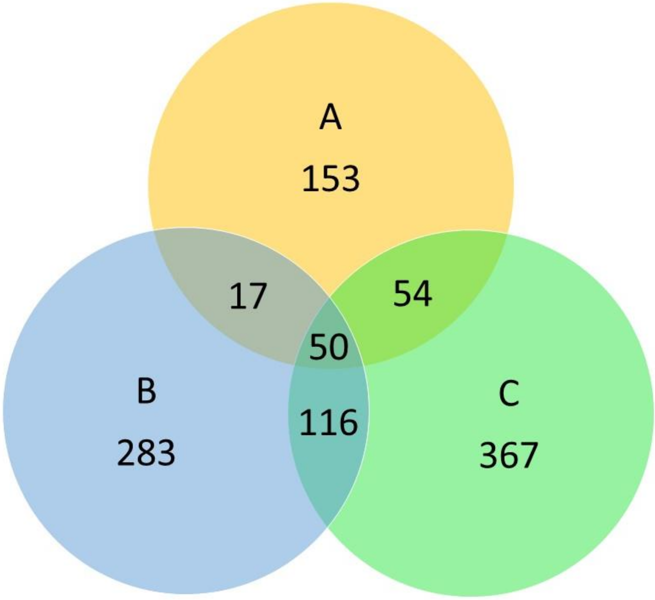
Table 4.5 provides a non-exhaustive list of the key taxa/crops used in plant breeding, genetic enhancement and base-broadening efforts. The most frequent rationale for embarking on pre-breeding was the unavailability of the specific trait in current breeding materials, sub-optimal genetic gains from breeding programmes and evidence of narrow genetic base (Figure 4.1). Nearly 23 percent respondents, who provided data for the Third Report, reported a combination of two or all three reasons as rationale pre-breeding. Few of the notable success stories of enhanced use of CWR in pre-breeding are shown in Box 4.1.

Table 4.5. Main crops addressed in plant breeding, genetic enhancement and base-broadening efforts

Country	Main crops addressed
Argentina	Cereals, oilseeds, vegetables, and fruit trees
Armenia	Wheat, tomato, triticale, peas, chickpea, basil, kohlrabi, clover, tall oat-grass, onion, garlic, vegetable marrow, vegetable soybean, and summer squash
Azerbaijan	Legumes, apple, lemon, grapes, wheat, barley, and cotton
Belarus	Cereals, legumes, oilseeds, vegetables, berry, nut crops, perennial cereals and legume grasses
Botswana	Jatropha, cowpea, sorghum, tepary beans, sorghum, and jatropha
Brazil	Gossypium, forages, fruits, pulses, black pepper, oilseeds, cassava, coffee, guarana, yerba mate, sugarcane, vegetables, *Araucaria* and *Hevea*
Cameroon	Cocoa
Colombia	Cocoa, fruit trees (gooseberry, cashew, soursop, guava), tubers (arracacha, yam, cassava, sweet potato), cereals (corn, oats, rice) and vegetables (beans, peas and vine onions)
Costa Rica	Rice, oil palm, sugar cane, tomato, coffee, cocoa, corn, beans, grass and forage legumes
Cuba	Phaseolus vulgaris, Capsicum annuum
Ecuador	Potato, corn, cocoa, cereals, and Andean fruit trees
Egypt	Broad bean
El Salvador	Cocoa and sorghum
Eritrea	Wheat, barley, sorghum, pearl millet, maize, beans, rapeseed, pepper and onion
Ethiopia	Wheat, maize, barley, sorghum, lentil, chickpea, common bean/Haricot bean, enset, avocado, mango, citrus, banana, papaya, noug, linseed, Ethiopian mustard, safflower, sunflower, tef
Finland	Barley and apple
France	Wheat, rapeseed, peas, corn, and sunflower
Germany	Wheat, barley, and lupin
Ghana	Maize, millet, rice, common bean, cowpea, groundnut, soyabean, cassava, cocoyam, frafra potato, sweet potato, yam, and taro
Guatemala	Beans and maize
Guinea	Rice, groundnut, and maize
Guyana	Sugarcane, cassava, sweet potato, watermelon, tomato, chili pepper, breadfruit, quinoa, onion, and potato
Hungary	Soybean
India	Rice, wheat, chickpea, pigeonpea, green gram, black gram, lentil, brassica, barley, and sesame
Indonesia	Rice, soybean, sweet potato, beans, coconut, ginger, cloves, and nutmeg
Italy	Lucerne, field pea, white lupin, and broad bean
Japan	Barley, maize, soybean, ryegrass, and sugarcane
Jordan	Wheat and barely
Kenya	Pigeonpea, sorghum, finger millet, and rice

Kyrgyzstan	Wheat, barley, apple, chickpea, alfalfa, soybean, plum, pear, cotton, garlic, corn, and barley
Latvia	Barley
Lebanon	Wheat, barley, lentil, chickpea, and broad bean
Madagascar	Rice, cassava, potato, beans, sweet potato, wheat and cocoa
Malaysia	Rice, cassava, watermelon, starfruit, and rambutan
Mali	Sorghum, maize, and millet
Mexico	Maize and chili
Mongolia	Wheat, barley, triticale, potato, tomato, pea, cabbage, seabuckthorn, strawberry, and alfalfa
Namibia	Cowpea, sorghum, pearl millet, maize, groundnut and Bambara groundnut
Netherlands	Tomato, potato, and Brassica spp.
Nicaragua	Beans, sorghum, tomato, corn, cocoa, *Colocasia* and *Xanthosoma*
Niger	Voandzou, sesame, fonio, maize, groundnut, sweet potato, millet, sorghum, cowpea, rice, and potato
Norway	Barley, wheat, oat, potato, timothy grass, red clover, white clover, rye grass, festuca grass, plum, strawberries, lucerne, apple, and forages
Papua New Guinea	Sweet potato and coconut
Peru	Cotton, grapevine, corn, rice, beans, and potato
Philippines	Rice and maize
Poland	Oat
Portugal	Cereals, grain legumes, fruits, vegetables, forages and medicinal and aromatic plants
Romania	Wheat, tomato, and pepper
Serbia	Wheat, maize, forage (alfalfa and red clover) and grain legumes (pea, broad bean and soybean)
South Africa	Amaranthus, hemp, medicinal cannabis, essential oil crops, cowpea, and soybean
Sudan	Wheat, sorghum, pearl millet, and cotton
Sweden	Wheat, triticale, barley, oat, oilseed rape, forage grasses, legumes, potato, Salix, turnip rape, perennial ryegrass, and apple
Switzerland	Wheat, forage legumes and grasses, apple, soybean and grape, apricot, spelt, pear, aromatic and medicinal plants
Tajikistan	Wheat, barley, rye, oat, chickpea, bean, broad bean, lathyrus, and lentil
Togo	Cassava, yam, rice, maize, coffee, cocoa, sorghum, sesame, groundnut, and soybean
Trinidad and Tobago	*Lablab purpureus, Cucurbita moschata, Cajanus cajan* and *Theobroma cacao*
Tunisia	Wheat, barley, chickpea, broad bean, field bean, and lentil
Türkiye	Wheat, barley, and tobacco
Uganda	Sorghum, common bean and finger millet
United Kingdom	Cereals, sugar beet, oilseeds, grasses, potatoes, Brassicas, lettuce, onion, and carrot
United Republic of Tanzania	Maize, tomato, finger millet, cowpea, and common bean
Uruguay	Wheat, barley, rice, potato, sweet potato, tomato, deciduous fruit trees (Citrus, peach, apple, pear and vine), Tinopiro (Thinopyrum intermedium) and perennial sunflower (Silphium sp.).
Uzbekistan	Green gram, groundnut, safflower, sesame, Jerusalem artichoke, sweet corn, tomato, sweet pepper, hot pepper, eggplant, sweet potato, pumpkin, and vegetable marrow
Yemen	Wheat, maize, sorghum, and peas
Zambia	Sunflower, castor, sesame, maize, sorghum, common bean, pigeonpea, groundnut, soybean, cotton, rice, cowpea, cassava, sweet potato, and potato
Zimbabwe	Maize, soybean, groundnut, rice, sunflower, potato, cowpea, Bambara groundnut, beans, sorghum, pearl millet, and finger millet

Figure 4.1. **Number of countries reporting rationales for undertaking base-broadening activities during the reporting period.** A) Evidence of narrow genetic base; B) Poor gain in breeding programme; and C) Specific trait not available in current breeding materials. The distribution is based on reports from 353 stakeholders in 74 countries.



Box 4.1. Base-broadening and crop variety development

Adequately conserved and well-characterized and documented germplasm collections, including CWR, are repositories of valuable traits and alleles of genes. The genetic variation in these collections are critically important for plant breeding programs. The use of CWR in pre-breeding increased during the reporting period and resulted in, for instance trait introgression from CWR that conferred tolerance to biotic and abiotic stresses in a set of rice introgression lines derived from the wild relative Oryza rufipogon by CREA-CI (Italy). The Nordic pre-breeding project in apple (Malus domestica) delivered pre-bred lines with resistance to certain diseases like European fruit tree cancer and fruit storage rots (https://sites.google.com/a/nordgen.org/ppp-apples/). The developed genetic resources have been used for genomic prediction and markers validation. Crosses between rice variety IR 64 and Oryza rufipogon resulted in the development and release of a red rice variety ‘Pamelen’ with resistance to tungro and blast in Indonesia in 2019. The variety widely adopted by farmers in the country.

Several interspecific mapping populations of sorghum and millet were produced from pre-breeding activities undertaken in Kenya under the auspices of the Crop Trust funded Crop Wild Relatives project on. In sorghum, the target was breeding for adaptation to drought, and the superior lines identified through farmer participatory evaluation had high tillering ability, good sorghum taste, and lodging resistance besides earliness, panicle characteristics and adaptation. Pre-breeding activities in millet targeted improving tolerance levels against striga and blast.

In Lebanon, the International Center for Agricultural Research in the Dry Areas (ICARDA), in collaboration with Lebanese Agricultural Research Institute (LARI) created new pre-breeding materials for six species, Aegilops caudata, Aegilops speltoides, Triticum dicoccoides, Triticum urartu, Hordeum vulgare spontaneum and Lens culinaris orientalis. Participatory evaluation by breeders and farmers of the resulting lines under field conditions in target environments following the integration of the promising materials into breeding pipelines led to the release of two new durum wheat varieties, Zagharin 2 and Margherita in 2017 and 2020, respectively in Ethiopia and Lebanon. In addition, one barley variety, Kfardan 1 (ACSAD 176), with high productivity and drought tolerance was registered and released by the end of 2019.

Latin America and the Caribbean

In Brazil, the intensive pre-breeding work at Embrapa led to the release of various crop varieties for specific needs. The introgression of desirable traits from wild relatives of passion fruit resulted in the development of improved cultivars such as BRS Rubi do Cerrado (*Passiflora edulis*), BRS Pérola do Cerrado (*P. setacea*), BRS Céu do Cerrado (*P. incarnata* X *P. edulis*) and BRS Rosea Púrpura [*P. incarnata* X (*P. quadrifaria* X *P. setacea*)], BRS Sertão Forte (*P. cincinnata*) and BRS Mel do Cerrado (*P. alata*). Similarly, a wheat cultivar BRS 404, with significantly enhanced tolerance to drought and heat stress and hence highly suitable for the Cerrado region of Brazil, was bred using an intermediate material developed using pre-breeding strategies.

Europe

Notable among several pre-breeding initiatives in Europe was the "Public-Private Partnership (PPP) project on Pre-breeding" in the Nordic region that included projects such as 'Pre-breeding for Future Challenges in Nordic Apples' (Sweden, Finland, Norway), 'Combining Knowledge from Field and from Laboratory for Pre-breeding in Barley II' (Denmark, Finland, Iceland, Sweden), 'PPP for Pre-breeding in Perennial Ryegrass' (Norway, Finland, Denmark, Lithuania, Iceland). In apple, the target traits were resistance to fruit tree canker (caused by *Neonectria ditissima*) and storage rots (caused by *Neofabraea* spp. and *Penicillium expansum*). The project on barley screened the spring barley germplasm for resistance to biotic stresses including diseases like scald, powdery mildew, leaf rust and *Fusarium* head blight. The identified lines were used for the generation of multi-parent populations for the identification of genes for stress tolerance.

The pre-breeding activities in perennial ryegrass involved the development of a broad-based population accompanied by high-density genotyping and multi-location phenotyping of the resulting population to train genomic selection models to obtain accurate prediction of phenotypes associated with wider adaptation. These PPP projects aimed to deliver "easy-to-use" DNA markers to hasten the development of new crop cultivars.[94] In Sweden, the routine use of CWR in commercial breeding programmes was deemed unaffordable and as requiring long-term funding. In Poland, pre-breeding was conducted as part of genebank activities, particularly for widening the genetic base of winter oats by using the wild species *Avena macrostachya*. In Italy, wild relatives were being targeted for improving crops for biotic and abiotic stresses. For example, CREA-CI created a set of introgression lines in rice from the wild relative, *Oryza rufipogon*.

Sub-Saharan Africa

In Sub-Saharan Africa, pre-breeding activities were undertaken in Kenya under the auspices of the Crop Trust-funded Crop Wild Relatives project. This involved various national and international partners: ICRISAT, Rongo University, KALRO-Kisii and Maseno University[95]. The pre-breeding activities targeted the improvement of adaptation to drought in sorghum and tolerance to striga and blast in finger millet. The activities resulted in the development of several interspecific mapping populations and promising genotypes of sorghum carrying superior traits for earliness, panicle characteristics and adaptation. The activities also led to the identification of promising lines using a farmer participatory approach.

Breeding programs in Ethiopia were attempting to integrate alleles from the wild to the cultivated genetic backgrounds in chickpea and teff. In Cameroon, wild maize (teosintes from CIMMYT) and local varieties were used to transfer genes for high yields and adaptability genes into improved varieties. For improving adaptability of cocoa, the Ethiopian national programme used CWR of cocoa from the Amazon rainforest. Pre-breeding activities in Mali were carried out for cowpea and sorghum with collaborations with the Cinzana biotechnology laboratory and CIRAD.

Asia

In the Philippines, traditional varieties and wild relatives of rice and maize were being used to introgress desirable traits into breeding lines. In Lebanon, wild relatives of durum wheat were incorporated into the crop's breeding programmes, through which two new improved varieties were ultimately released (Box 4.1). In Malaysia, white rice varieties UKMRC-2 and UKMRC-8, which have low starch were bred by crossing

[94] https://norden.diva-portal.org/smash/get/diva2:944842/FULLTEXT02.pdf
[95] https://www.croptrust.org/pgrfa-hub/crops-countries-and-genebanks/countries/kenya/

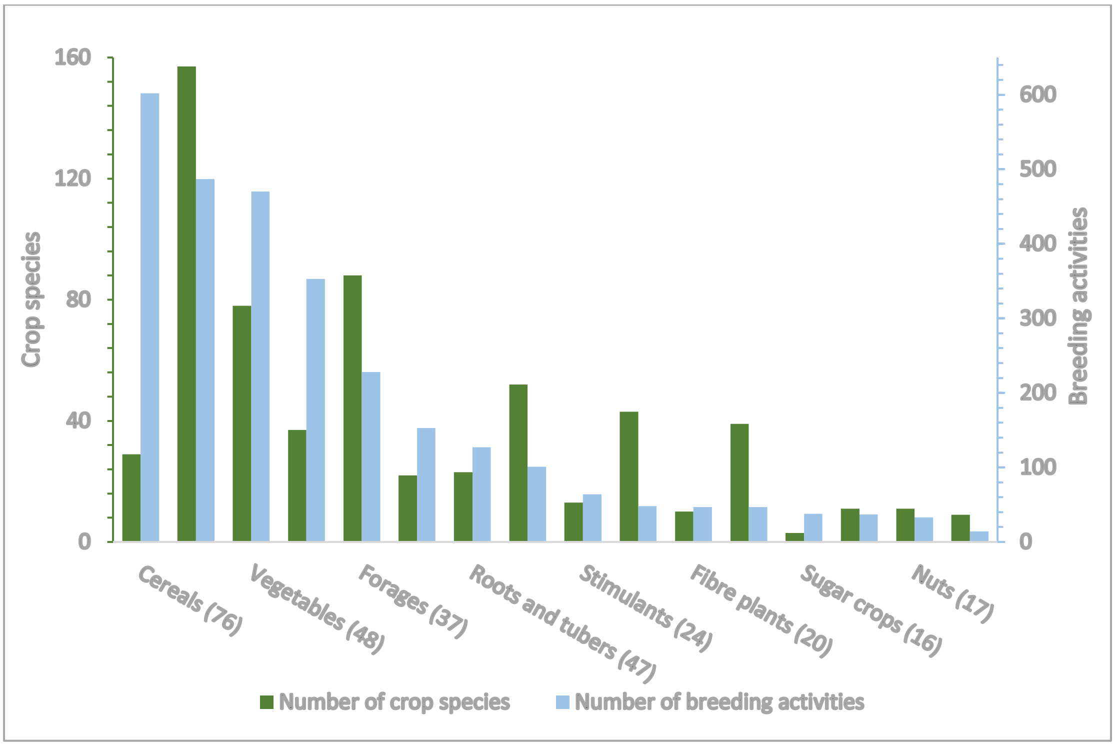
Oryza sativa and wild rice *O. rufipogon*. An accession of the wild groundnut, *Arachis cardenasii*, GKP 10017, contributed to the development of 251 elite lines and cultivars in 30 countries in Africa, Asia, Oceania and the Americas. It was used to improve the tolerance levels of the groundnut lines and varieties to various diseases and pests, including root knot nematode, late leaf spot and rust (Bertioli *et al*. 2021).

The inadequacy of human capacities was identified as a major constraint to pre-breeding, in particular involving the extensive use of wild relatives, by some countries. For example, this limitation led to the discontinuation of some pre-breeding activities in Armenia, which were previously reported in 2012 as aiming to introduce new traits from wild wheat species and goat grass into improved wheat varieties.

4.4 Crop varietal development

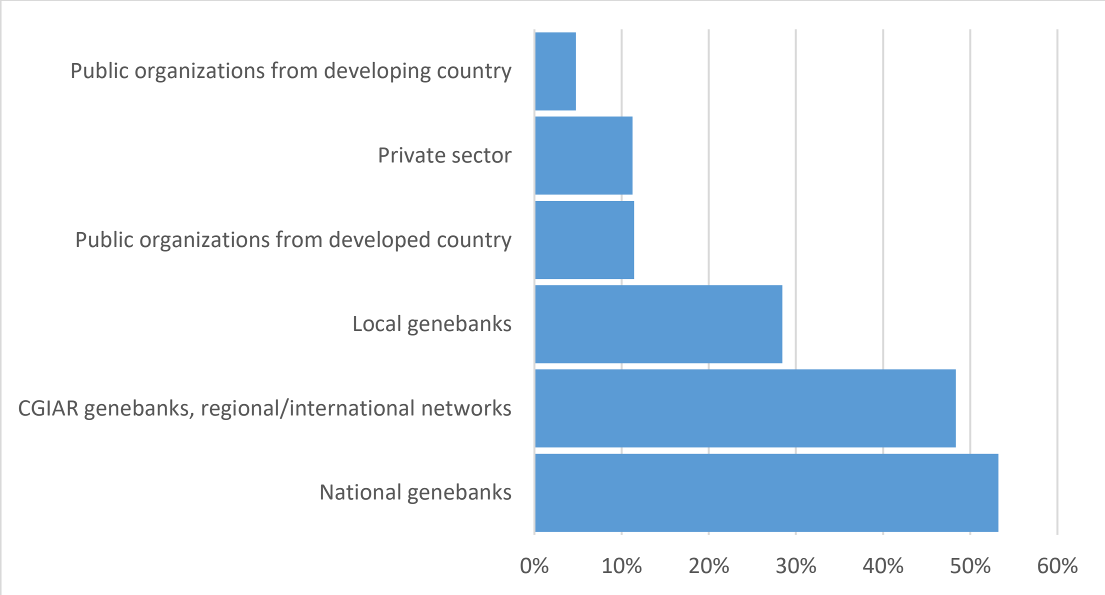
Plant breeding, the art and science of deliberately altering the traits of plants in order to produce progeny with desired characteristics, was implemented globally over the reporting period. With 602 plant breeding activities undertaken in 76 countries on 29 crop species of cereals, this was the crop group for which most countries had active crop improvement programmes over the reporting period (Figure 4.2). While a fewer number of countries (45) had a fewer number (487) of genetic improvement programmes for fruit plants, the breeding activities were conducted on more than three times more species (157). There were also 470 breeding programmes in 48 countries, which addressed the improvement of 78 vegetable species. Significant efforts and resources were also invested in the genetic improvement of both pulses and forages. With 69 countries having active breeding programmes for pulses, the crop group was second only to cereals on this index. Similarly for forages, the 88 species that were the subjects of genetic improvement placed the crop group second only to fruit plants for this measure.

Figure 4.2. Number of crop species and breeding activities in 87 countries by crop groups between 2014 and 2019. Number of countries are shown in parenthesis after each crop group



A majority of the plant breeding activities, totalling 2171 or 76 percent, was implemented in publicly funded research institutions. Comparable proportions of the plant breeding activities were implemented by private entities and by public-private partnerships, which had 304 and 320 active programmes, respectively, or approximately 11 percent of the activities apiece. The majority of germplasm accessions used in plant breeding were sourced from national genebanks followed by CGIAR genebanks and international and regional networks (Figure 4.3).

Figure 4.3. Germplasm sources for plant breeding activities



Overall, 50 997 improved crop varieties and 523 farmers' varieties/landraces were registered and released in 82 countries during the reporting period. These spanned a total of 749 plant species of which 745 were improved varieties and 76 farmers' varieties/landraces. Ornamentals was the crop group with released varieties from the highest number of species (173); followed by forages (151); fruit plants (132) and vegetables (85) (Table 4.6). Combined, cereals, with 27 species reported, and vegetables accounted for more than half of the released varieties, with 29 percent and 28 percent, respectively, followed by oil and fruit plants (9 percent each). The two regions with the largest number of the registered and released varieties of cereals were Latin America and the Caribbean, and Europe, accounting for 39 and 33 percent, respectively. Most releases of vegetable varieties, 39 percent, occurred in Europe, with the Netherlands (Kingdom of the) having the highest number (over 440 varieties); 32 percent in Latin America and the Caribbean, with Brazil leading; and 21 percent, in Asian countries, including Türkiye and Iran (Islamic Rep. of).

Registration and release of new fruit plant varieties was mostly reported in two regions, Europe (63 percent) and Latin America and the Caribbean (31 percent). Three regions, Latin America and the Caribbean, Northern America and Europe accounted for most of the released oil plant varieties with 44 percent, 19 and 17 percent, respectively. Forage varieties releases were mainly reported in Europe (39 percent) and Asia (28 percent). Finally, a relatively large number of ornamental varieties were reported by countries from Latin America and the Caribbean.

Overall, these numbers were lower than those provided by seed associations, likely due to incomplete reporting by countries to FAO.

Table 4.6. Number of species, improved varieties (CV) and farmers' varieties/landraces (FV) registered and released per region and crop group during 2012-2019. The number of reporting countries are in parenthesis after each region.

	Total (82 countries)			Northern Africa (4)			Sub-Saharan Africa (20)			Northern America (1)			Latin America and the Caribbean (15)			Asia (20)			Europe (20)			Oceania (2)		
Crop group	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV	Species	CVs	FV
Cereals	27	15 026	92	10	202	5	15	1 863	35	6	295	0	15	6 727	5	18	2 155	6	16	3 734	41	7	50	0
Vegetables	85	14 251	68	14	616	0	27	581	4				54	4 471	2	51	2 970	12	45	5 601	50	4	12	0
Oil plants	15	4 862	11	5	44	0	6	384	0	3	877	0	10	2 045	0	13	473	2	6	1 002	9	2	37	0
Fruit plants	132	4 544	231	7	30	0	7	27	0				85	1 485	0	39	103	11	64	2 792	220	18	107	0
Forages	151	3 174	7	8	106	0	29	193	1	15	212	0	88	766	0	42	378	3	57	1 484	3	18	35	0
Ornamentals	173	2 578	0				1	3	0				154	2 540	0	6	9	0	18	23	0	1	3	0
Pulses	32	2 177	20	5	46	0	18	400	4	4	122	0	13	362	0	18	539	4	15	669	12	7	39	0
Roots and tubers	15	1 669	77	2	108	0	12	188	34	1	248	0	8	322	34	5	161	2	2	631	7	1	7	0
Fibre plants	14	556	5	2	5	0	4	65	0	1	17	0	6	150	0	11	202	3	4	110	2	2	7	0
Sugar crops	4	542	0	2	29	0	1	20	0				2	111	0	3	102	0	2	270	0	1	10	0
Stimulants	9	526	0				5	54	0	1	2	0	8	420	0	4	24	0	1	25	0	1	1	0
Herbs & spices	45	488	6	1	37	0	13	34	0	2	7	0	21	166	0	23	133	3	17	110	3	1	1	0
Material plants	25	275	2				2	3	2				19	259	0	3	10	0	3	3	0			
Nuts	10	198	1				1	41	0				9	41	0	1	1	0	4	114	1	1	1	0
Medicinal plants	29	74	0				6	10	0				13	31	0	8	20	0	7	8	0	1	5	0
Pseudo cereals	9	56	3				3	8	0	1	2	0	4	23	0	6	18	2	2	5	1			
Other	1	1	0																1	1	0			
Total	749	50 997	523	52	1 223	5	149	3 874	80	33	1 782	0	493	19 919	41	245	7 298	48	259	16 582	349	65	315	0

4.5 Advances that facilitated crop improvement

A ready access to a wide spectrum of well-characterized and documented PGRFA, including CWR and landraces that contain valuable heritable genetic variation, is of vital importance to breeding the progressively superior crop varieties, which are needed to underwrite food security and nutrition of the burgeoning population, especially under worsening climate change scenarios. The significant advances in genomics and phenotyping have greatly enhanced the scale and efficiency with which germplasm collections are characterized and otherwise used for trait discovery and crop varietal development. Table 7 shows the applications of plant biotechnologies in breeding programmes of countries. Some of the more commonly used methods and which have the potentials to enhance the scale and efficiencies for conserving, characterizing, evaluating and exploiting the inherent hereditary potentials of PGRFA include the following:

4.5.1 Genomics-guided development of broad-base populations

The advanced backcross QTL method (AB-QTL) combines the identification of a QTL with its introgression into a breeding material (Tanksley and Nelson 1996). AB-QTL method has been applied for the genetic dissection of complex traits and the development of superior lines in several crops including tomato (Fulop *et al*. 2016), rice (Nagata *et al*. 2015, Xia *et al*. 2017), wheat (Naz *et al*. 2018, Sayed *et al*. 2021), barley (Bauer *et al*. 2009, Mora *et al*. 2016), common bean (Blair and Izquierdo 2012), groundnut (Alyr *et al*. 2020, Essandoh *et al*. 2022), and pigeonpea (Saxena *et al*. 2020).

Genetic stocks that serve as the complete library of the donor genome (CWR or landrace) are enabled by methodologies that track the inheritance of specific genomic regions in the recipient background. Chromosome segment substitution lines (CSSLs), for instance, constitute genetic stocks that harbour the entire genome of the exotic, i.e. donor, accession in the genetic background of the recipient. The development and analysis of CSSLs has enabled the genetic dissection of complex traits in several crops including rice, wheat, maize, pearl millet, barley, soybean, peanut, pea, rapeseed and cabbage (see Balakrishnan *et al*. 2020).

However, the use of such base-broadening strategies has been limited during the reporting period. With the costs for genotyping, in particular genome sequencing, becoming progressively cheaper, the use of these populations should be promoted as advanced populations confer higher probabilities for the detection of QTLs, even those that exert only small effects on the phenotype (Tanksley and Nelson 1996).

4.5.2 Multi-parent populations

The development of multi-parent populations (MPPs), whereby the genomes of multiple founders are mixed and recombined to generate populations with high genetic diversity, has become an efficient means to leverage broad genetic variation for crop improvement and the elucidation of the heredity of complex traits. The two most common designs are nested association mapping (NAM) and multi-parent advanced generation inter-cross (MAGIC) (Varshney *et al*. 2021a, Bohra *et al*. 2020).

Table 4.7. The extent of application of plant biotechnology by breeding programmes

Country	Response
Armenia	Biotechnological techniques have gradually evolved in the country, and application of tissue culture and micropropagation in crop improvement is reported for vegetable crops (peppers, tomatoes, cucumber). However, so far the progress is not considerable.
Azerbaijan	The use of biotechnology in breeding activities work has become widespread in recent years. This is one of the main scientific directions of the Department of Biotechnology at the Genetic Resources Institute. In recent years, relevant departments have also been established at the Research Institute of Vegetable Growing, Research Institute of Fruits and Tea Growing and equipped with modern equipment. However, in these institutes, biotechnology methods are more focused on the rapid multiplication of existing germplasms. These departments are planned to contribute to the selection work.

Belarus	Methods of plant biotechnology are applied in breeding in the framework of implementation of the state programme for research “Biotechnologies” for 2016-2020, subprogramme “Structural and Functional Genomics”.
Bostwana	Molecular characterization of *Sorghum bicolor* and *Jatropha carcus* accessions was carried out.
Brazil	Biotechnological solutions are playing an important role in the search for greater efficiency in breeding programs. Biotechnology techniques have been used for the identification, selection and introgression of new genes. During the reporting period, 56 pre-breeding programs (28 percent) mentioned the use of molecular markers to estimate genetic diversity in the programs. This approach was adopted in 32 crops (passion fruit, peanut, potato, maize, banana, cassava, melon, aroeirinha, plum, forage palm, camu camu, tucumã, coffee, pepper, black pepper, beans, cane sugar, papaya, Heliconia, Spondias, tomato, coconut, rice, Paspalum, soybean, cotton, sorghum, apple, açaí, sesame, castor and citrus and the like). More recently, genomic selection, as well as genomic editing, have stood out as strategies with a high potential to impact the development of new cultivars. It is likely that these techniques will be gradually incorporated into the breeding routine, being used in a practical and applied way, contributing to the development of new technological products. Embrapa's project portfolio currently has genomic editing projects in rice, soybean, maize, wheat, sugar cane, apples, grapes and coffee, among others.
Cameroon	The use of plant biotechnology by breeding programs in Cameroon is slow to produce the first results due to a lack of capacity, especially human capacity, in this area. An upgrade of the technical platform and human capacities is necessary. This technology would greatly shorten selection times compared to the traditional method.
Canada	Research in genomics-based characterization of PGRC germplasm collections has involved several research projects associated with collections of wheat, oat, barley, flax, yellow mustard, Jerusalem artichoke and four native grass species. These research efforts have generated many innovative characterization tools, advanced knowledge of crop genetic diversity, molecular make-up of gene pools and contribute to germplasm conservation and utilization. Marker-assisted and genomic selections have been applied in several programs including flax.
Colombia	Many biotechnological tools are used in different institutions. This is how you can find many research and pre-breeding projects that involve the use of molecular markers, identification and isolation of genes, molecular mapping, transformation and gene editing. However, during the evaluated period, the use of these tools in plant breeding programs, measured as the obtaining or development of cultivars registered in the national registry of varieties of the competent authority, is very low.
Costa Rica	Biotechnology is playing an increasingly important role in genetic improvement and seed production activities in the country. From seed multiplication, health diagnosis, conservation, characterization, to gene editing, with greater progress in some areas than others.
Cuba	The Centre for Genetic Engineering and Biotechnology (CIGB) develops research aimed at obtaining Genetically Modified Organisms and introducing them into agricultural production as an alternative. In each variety or line obtained, it takes into account its agronomic attributes; the potential increase in agricultural yield; its adaptation to limiting edaphoclimatic factors; and the technology in its use, in order to increase the country's food productivity. It works mainly in soybeans and corn.
Eritrea	Assessment of genetic diversity was made through molecular markers for sorghum striga resistance
Ethiopia	Use of biotechnology in Ethiopia includes: • Molecular phenology and protoplast fusion • Tissue culture and double haploid breeding • Characterization of indigenous accessions of various crops using isozyme markers • Haplotype analysis of resistant genes using linked markers • Identification of new resistance source from landraces • Genetic engineering (transformation)
Finland	The domestic plant breeding in Finland has a strong market share, and Finland is not dependent of the foreign breeding programs of the major field crops. Finland relies on the regional genebank “NordGen”, which is actively involved in the Nordic pre-breeding programme PPP and thus provides germplasm and the platform for genetic enhancement of the some of the major field crops. For widening the genetic base, the local breeding programme utilizes occasionally gene material mainly for improving resistance traits. In horticultural crops, the pre-breeding has been started especially in strawberry, by utilizing genetic resources of the parental species to reconstruct hybrid species, for integrating new variation to breeding programs. To enhance breeding, genomic tools and in vitro cultivation

	techniques are used in the field crop breeding. To define breeding goals for field crops in Finland, active communication with the various actors of food chain is carried out regularly.
France	The use of molecular markers is widespread in pre-selection or selection programs (75 percent), most of the time supplemented by phenotypic studies in the context of work in association genetics. As part of future investment projects (AMAIZING, BREEDWHEAT), sections on genomic selection have also been developed.
Guatemala	The number of molecular techniques (microsatellites, SSR, SCAR, INDEL and STARP) was increased to assist the genetic improvement of beans, and they were applied to maize families with high protein quality (QPM), to identify the presence of gene (Opaque -2). The germplasm used in the studies came from the ICTA Breeding Programs, stored in the Germplasm Bank (ICTA, 2019). The ICTA Biotechnology laboratory works with the maize and bean improvement programs, in assisted breeding with molecular markers. This is a new activity, which was not previously reported.
Guinea	The Republic of Guinea does not have the laboratories to carry out selection assisted by molecular marker (biotechnology).
Indonesia	Extent of application of plant biotechnology by breeding programmes in your country. The use of biotechnology in breeding in Indonesia has been carried out since 1997 until now. This approach has been used for various commodities. High-yielding varieties have been produced through this biotechnological approach, especially through MAS (rice, maize) and mutation breeding (sorghum, soybeans and rice). Meanwhile, the use of genetic engineering techniques has resulted in transgenic sugarcane and potato varieties that have obtained food, feed and environmental safety. Currently the transgenic potato variety is in the process of release.
Italy	In Italy, the use of biotechnologies in agriculture in the last decade has suffered from the ban to the commercialization and field experimental trials for biotech varieties. The situation is even worst since 2018 after the judgement of Court of Justice of the European Union (CJEU) on New Breeding Techniques (NBT) approach. At the research level the Italian flag project BIOTECH funded by the Ministry of Agriculture has given an important impulse. In this project, 13 sub projects are trying to apply genome editing and cisgenesis to several agricultural crops (wheat, apple tree, citrus, tomato) addressing several important traits controlling quality, yield and resistance to biotic and abiotic stresses. At CREA CI some interesting QTLs were identified through GWAS that can be potentially used by breeders.
Japan	Public acceptance of GM crops has not progressed in Japan, and no GM field crops varieties have been put into domestic crop production. In major crops, selective breeding using DNA markers derived from genomic information is widespread.
Jordan	Still in the beginning but taking over more and more now.
Kenya	The country has made advances in the use of biotechnology in breeding. Genetically modified Bt maize and Bt cotton is currently being tested by KALRO, KEPHIS, and other partners. Conditional approval has been given by the National Biosafety Authority (NBA) for the commercialization of Bt Cotton. Similarly, conditional approval was made for Bt Maize but trials had not yet been conducted by the end of the reporting period.
Lebanon	The plant biotechnology is not yet applied by breeding programmes in Lebanon.
Madagascar	Application of plant biotechnology still weak.
Malaysia	Research on transgenic papaya, delayed ripening papaya through molecular manipulation; development of hermaphrodite papaya through vegetative propagation
Mali	Biotechnology is used on sorghum and cowpea.
Mexico	The application of biotechnology for plant genetic improvement is little used in the generation of new varieties by public institutions, which mainly use classical genetic improvement. In the period covered by this report, there is little link between the different actors to establish improvement priorities, however, in programs financed by the public sector, some general criteria are established, such as attention to crops with a center of origin and diversity in Mexico, of cultural, gastronomic and economic importance, among the main ones. Currently, we work with a value chain approach, to link the actors, from the plant breeders to the consumers and processors of the raw material. This also seeks to establish pyramids of genetic improvement and facilitate the generation of varieties.
Namibia	The Ministry of Agriculture Water and Land Reform has a biotechnology lab and has just started finger printing newly improved crop varieties. Furthermore, the University of Namibia through the Department of Biology in the Faculty of Science also conducts biotechnology

	research emphasizing on genetic characterization and marker assisted selection of pearl millet, sorghum and other leguminous crops.
Nepal	Application of biotechnology in breeding programme is very poor. Major work using biotech is to assess genetic diversity
Niger	The degree of application of plant biotechnology by breeding programs is at its beginning, notably with fairly well-equipped laboratories run by highly competent researchers. There is a good development of *in vitro* culture for the acceleration of certain phases of selection.
Nigeria	Moderately carried out.
Peru	The application of plant biotechnology in plant breeding in the country has been relatively limited. Peru has a moratorium on the entry of transgenic crops from 2011 to 2021, which has probably also limited the participation of the private sector in genetic improvement through biotechnology. Although it is true that research on the use of biotechnology in genetic improvement is not prohibited, there have been relatively few efforts from the public sector for its application. Plant breeding programs use conventional techniques for the most part. On the other hand, more human resources capable of applying biotechnology for genetic improvement are required.
Philippines	Plant biotechnology is employed in crop improvement to address specific breeding objectives in *Zea mays, Oryza sativa, Solanum melongena, Musa textilis* and *Mangifera indica*.
Poland	Application of molecular markers linked to disease resistance for selection in the breeding programs.
Republic of Moldova	Several institutes reported the use of plant tissue culture technique in tomato, wheat, triticale, barley, potatoes, grapes breeding. The progress is not considerable.
Serbia	Biotechnology is a part of every breeding programme at IFVCNS. Starting from prebreeding, through marker assisted selection (lines with desired traits) and even estimation of general and specific combining abilities.
Sweden	Commonly used, in particular marker-assisted selection, genomic selection, haploid techniques, etc.
Trinidad and Tobago	The Research Division has played an important role in the testing, evaluation and breeding crop plants for the benefit of farmers. The genetic improvement and selection programme included the selection of appropriate root crops, *Cocos nucifera* and *Cucurbita moschata* varieties for value added and export. The Cocoa Research Section evaluated Theobroma cocoa varieties for disease tolerance to witches' broom, black pod diseases and evaluations for flavor profiles, cocoa butter fat content and productivity characteristics. The Research Division currently has limited technical capacity to engage in plant breeding and genetic enhancement work due to staff limitations and financial resources.
Tunisia	The degree of involvement of biotechnology in breeding programs remains low and is limited to a few crops, notably cereals and legumes and market garden crops. The main cereal crops affected by genetic improvement are durum wheat, soft wheat and barley; for food legumes the main crops are broad beans, chickpeas and lentils. These programs aim to develop varieties that are more efficient, more adapted and more tolerant to the various biotic and abiotic constraints. This is done by using classic selection methods (pedigree selection, bulk selection) and by integrating the use of molecular tools such as molecular markers such as SCAR markers, diagnostic markers and microsatellite markers for marker-assisted selection (MAS).
United Kingdom	The UK is a signatory of the International Plant Treaty, so therefore its government funded genebankssupport distribution of material through the MLS. The Germplasm Resource Unit at the John Innes Centre recently entered into a collaboration with the Chinese Academy of Agricultural Sciences to obtain resequencing information for ~700 accessions from the JI Pisum collection. Together they aim to generate a world leading resource for gene discovery and forward breeding in pea. To represent the best possible diversity snapshot of the collection, 500 accessions from the JI Pisum germplasm collection were chosen using the core-collection novel analysis. An additional 114 accessions were included following a request from PCGIN management team. The John Innes Centre also contribute internationally to the work done by EVA- the European Wheat and Barley Evaluation Network. On a national level they are involved in the PCGIN. The UKVGB work closely with the Vegetable Genetic Improvement Network and their material is also being used by the Oilseed Rape Genetic Improvement Network. Pre-breeding activities that have been facilitated through the aforementioned GINs are central to activities of both the John Innes Centre and the UKVGB.
United Republic of Tanzania	The extent of plant biotechnology in the Country is gaining more attractions and attention, but more technical and financial supports may be required to enhance its use.

Uruguay	Regarding the degree of application of biotechnology in programs, the following stand out: Soybean, transgenesis, adaptation for resistance to drought; development of haploids in potato; Speed breeding in wheat.
Uzbekistan	Biotechnology methods are widely used in plant breeding, especially in the propagation of the resulting hybrids. The breeder, before starting work on the development of new varieties, carefully examines the needs of the future variety by consumers. Therefore, the breeder carefully selects the source material for breeding. The new variety must meet the needs of all consumers.
Yemen	The use of biotechnology is still weak due to poor physical and technical capabilities.
Zambia	The extent of application of plant biotechnology by breeding programmes in Zambia was equally very low in the private sector, and virtually non-existent in the public sector.
Zimbabwe	Current projects in agricultural biotechnology are mainly carried out at universities and public research institutes and are aimed at improving disease, herbicide, drought and insect resistance and for plant propagation. Zimbabwe is being involved in industrial biotechnology at a low level, through research and use of her biological resources as sources of potential industrial enzymes. For example, the Harare Institute of Technology (HIT) is currently using tissue culture techniques to develop oyster mushroom for commercial purposes. Biotechnology is also being used in food processing e.g., in food and beverages, biotechnological research is focused on microbiology and biochemical processes and use of starter cultures during fermentation of traditional foods such a– Mahewu - a nonalcoholic beverage made form malt and sour milk.

The NAM design was originally proposed in maize as a community mapping resource with enhanced statistical power. The maize NAM design was based on the crossing of B73, an inbred line used as parent in several maize hybrids, to 25 diverse inbred lines, thus generating a set of 5 000 recombinant inbred lines corresponding to 25 ‘interconnected’ populations (Yu *et al*. 2008). The enormous potential of NAM design for understanding complex trait architectures was demonstrated in maize by genetic analysis of various traits including flowering time, Southern leaf blight and Northern leaf blight, leaf architecture, kernel composition, drought tolerance and so forth. In recent years, the NAM design has been further extended to several other crops for high-resolution genetic dissection of a variety of agriculturally important traits such as leaf rust resistance, flowering time, salinity tolerance, net blotch, and yield related traits in barley; days to heading, recombination events, and segregation distortion in rice; adaptive traits in sorghum; yield and agronomic traits in soybean and common bean; resistance to rust and powdery mildew in wheat and seed and pod weights in peanut (see Gireesh *et al*. 2021).

Inspired by the collaborative cross (CC) panel of mouse derived from eight founder parents[96], the MAGIC is another, though more complex, MPP design adopted in plants that incorporates broad genetic diversity in the resulting mapping populations. The MAGIC design involving 19 accessions was first used in Arabidopsis (Scarcelli *et al*. 2007, Kover *et al*. 2009), and with adjustments to minimize crossing later adopted in several crop plants including maize, rice, barley, wheat, sorghum, tomato, Chinese mustard, cotton, cowpea, broad bean (see Scott *et al*. 2020). More recently, Novakazi *et al*. (2020) developed four MAGIC populations in barley by using 17 founder parents that included the cultivars Lavrans, RGT Planet, Iron, Chevron, Olve, Brage, Krasnodarskij 35 and Fairytale; breeding lines GN 06075, GN 09096, SJ 111998 and GN 09005; and landraces Ylitornion, MBR 1012, JLB06-034 and Gaffelbyg. The GWAS on the MAGIC populations provided QTL, candidate genes and haplotypes for improving resistance to important diseases, such as powdery mildew (Novakazi *et al*. 2020) and scald (Hautsalo *et al*. 2021).

Genomic selection (GS) has become a promising method to improve the rate of genetic gain in plant breeding populations. The acquisition of large-scale genotype and phenotype information on germplasm sets and breeding populations helps develop genomic selection (GS)/prediction models to quickly determine the accurate genetic worth of PGRFAs for use in breeding. Based on genome-wide marker information, GS helped to optimize the selection strategies for choosing worthy genotypes in the absence of phenotypic information. For example, by generating GBS data on 962 sorghum accessions, Yu *et al*. (2016) demonstrated the efficacy of genomic prediction as a novel and cost-

[96] https://csbio.unc.edu/CCstatus/CCGenomes/

effective strategy for mining traits from genebank accessions‘ In the 'Seeds of discovery' project[97], the use of genomic predictions helped enhance the frequency of favourable alleles detected in CWR populations and helped shorten the length of the breeding cycles. In the reporting period, only a limited number of countries documented the use of genomic selection for pre-breeding.

4.5.3 Modern phenotyping platforms

The rapid advancements in the development of non-invasive and digital technologies have facilitated remarkable increases in the throughput and accuracy of plant phenotyping over the last decade. Advances in sensor and imaging techniques operating at different scales and levels (leaf, canopy and airborne) enabled the assaying of large population sizes and the concomitant generation of high numbers of data, thereby relieving the so-called "phenotyping bottleneck" that has been a major hindrance to plant breeding programs (Varshney *et al*. 2021b). The constant refinements of plant phenotyping platforms for mobility, affordability, throughput, accuracy, scalability, and data storage and analytics enhance the ability to bridge the gap between genetic information and the phenotypic manifestations (Zhu *et al*. 2021).

The International Plant Phenotyping Network[98] (IPPN) is constituted by Australian Plant Phenotyping Facility[99] (APPF); EMPHASIS[100]; the European Plant Phenotyping Network[101] (EPPN); North American Plant Phenotyping Network[102] (NAPPN); Nordic Plant Phenotyping Network[103] (NPPN); PhenomUK[104]; German Plant Phenotyping Network (DPPN), PHENOME etc.
Crop phenomics or high-throughput crop phenotyping was successfully used to enhance the generation of phenotypic data for different species, including wheat, rice, maize, Arabidopsis and barley (Yang *et al*., 2020). The leading countries in the application of phenomics were the USA, followed by Australia, Germany, China and France.

4.5.5. Genome-editing

Genome editing, also known as genome engineering or gene editing is the term used for a set of relatively recently described molecular techniques that are used to induce site-specific mutations in living organisms. This is achieved through the insertion, deletion, modification or replacement of DNA in the genome of the organism. Zinc finger nucleases (ZFNs), Transcription activator-like effector nucleases (TALENs) and more recently, the CRISPR-Cas9 clustered regularly interspaced short palindromic repeats (CRISPR-Cas9) represent the three most commonly used genome editing techniques. For the development of a method for genome diting, Emmanuelle Charpentier (Max Planck Unit for the Science of Pathogens, Berlin, Germany) and Jennifer Doudna (University of California, Berkeley, USA) jointly won the Nobel Prize for Chemistry 2020.

The proof of concept for the potential use of gene editing to improve disease resistance was demonstrated for rice (Brown plant hopper, *rice tungro spherical virus*, blast, bacterial blight); wheat (rust, powdery mildew); maize (Lethal necrosis); banana (Fusarium wilt, banana streak virus); tomato (Fusarium wilt, powdery mildew, bacterial speck, *Botrytis cinerea*, *Pseudomonas syringae*, *Phytophthora capsici*, and *Xanthomonas* spp.); potato (Late blight, potato virus Y); grape (Powdery mildew, citrus canker, *Botrytis cinerea*); and apple (Fire blight). The potential use of the techniques for engineering abiotic stress tolerance was also remonstrated, in particular, for drought tolerance in rice and maize; salinity tolerance in rice; semi-draft trait for lodging resistance in banana). The examples of their use in improving traits include for rice, increase amylose and carotenoids, prevented cadmium uptake; wheat, low gluten; maize, reduced starch, reduced phytic acid; potato, reduced

97 https://seedsofdiscovery.org/
98 https://www.plant-phenotyping.org/
99 https://www.plantphenomics.org.au/
100 https://emphasis.plant-phenotyping.eu/
101 https://eppn2020.plant-phenotyping.eu/
102 https://www.plantphenotyping.org/
103 https://nordicphenotyping.org/
104 https://www.phenomuk.net/

starch; peanut, increased oleic acid content; tomato, increased anthocyanin levels; sorghum, reduced kafirins; and soybean, altered oil levels.

Gene editing was also applied to so-called orphan crops, such as cassava – for improved disease resistance (African cassava mosaic virus, bacterial blight, cassava brown streak) and quality traits (waxy starch, cyanide free) (Karavolias *et al*. 2021, Pixley *et al*. 2022, Zaidi *et al*. 2020).

Canada regulated the products of genome editing based on the presence of the novel traits regardless of the procedure and the evaluation of the products was on a case-by-case basis. In the US, gene edited crops lacking foreign DNA and having no food safety concerns were not subjected to regulation. Countries like Colombia, Brazil, Argentina, Ecuador, Chile, Paraguay, Uruguay, Nigeria, Kenya, Israel, Japan and Australia followed the principle that if no foreign DNA had been introduced, then no regulations akin to GMOs was warranted.

In several countries, gene-edited crops/products were assessed on a case-by-case basis by respective agencies such as National Commission on Agricultural and Forestry Biosafety in Paraguay; Canadian Food Inspection Agency (CFIA) in Canada; Colombian Agricultural Institute (ICA) in Colombia; the Ministry of Agriculture's Agricultural and Livestock Services (SAG) in Chile. Genome-edited plants were regulated as GMOs in European Union and New Zealand whereas discussions were ongoing in the UK and Norway. There remained therefore the need to develop an internationally agreed regulatory framework for the products of genome editing, as was done through the Cartagena Protocol on Biosafety to the Convention on Biological Diversity for GMOs. Additionally, it would seem that the main hindrance to a widespread application of genome editing to crop improvement in developing countries would be the intellectual rights regime.

4.6 Diversification of crop production systems

The on-farm diversity of crops is critical to sustainable crop production systems. Crop production systems that are characterized by more intra- and interspecific diversity tend to be more resilient, especially with regard to biotic and abiotic stressors, and generate more nutrition outcomes than those with less diversity.

4.6.1 Increasing diversity within crop production systems

The negative impacts of the continually declining number of species in crop rotations included an increase in spread of weeds and harmful organisms and the development of resistances to active ingredients of pesticides, as was observed in Germany. During the reporting period, almost 300 stakeholders in 73 countries carried out programs/projects/activities aimed at the increases diversity within crop production systems in different crops and taxa. These initiatives were typically carried out as collaborations between various organizations and with farmers and addressed the assessment and/or monitoring and the increasing of intra-specific diversity in crops; increasing intra-specific diversity in agricultural production systems.

In Ethiopia, drought tolerant durum wheat varieties developed from farmers' varieties were released as means to enhance on-farm diversity and hence the resilience of the systems. The African Orphan Crops Consortium (AOCC) aimed at developing next-generation genomics resources for genetic improved in order to inject new improved, adapted and productive varieties. In Southeast Asia, the Southeast Asia Regional Initiatives for Community Empowerment[105] (SEARICE) initiated several programmes, which aims encompassed enhanced on-farm diversity and informed polices in five countries – Bhutan, Laos, the Philippines, Thailand and Viet Nam). These included 'Democratizing Agricultural Research and Extension' (DARE, 2011); 'Putting Lessons into Practice: Scaling-up People's Biodiversity Management for Food Security' (2012); 'Building Resilient Community Managed Seed Systems towards Climate Change Adaptation' (2013); 'Sowing Diversity = Harvesting Security' (SD=HS, 2014); 'Policy Research and Awareness Improvement on Seeds (PRAISE, 2017)';

[105] https://www.searice.org.ph/

and 'Rights to Seeds (RISE, 2018)'. The cultural practices that were promoted included crop mixtures – involving multiple crops, crop rotations, intercropping, and cover crops.

The Soils, Food and Health and Communities (SFHC) project supported small holder farmers in Malawi to use the 'doubled-up' legume technology as intercrop or rotation with the main cash crop maize[106]. This exploited the complementary growth habits of two different legume crops, pigeonpea and groundnut. The demonstrated outcomes were improved nutrition, especially of children; increased soil fertility and land productivity; and reduced incidence of pest and diseases. The project also led to the establishment of Agriculture and Nutrition Discussion Groups (ANDGs) as a platform for informal exchange of agricultural knowledge and resources. The ecological principles, which were validated through the project were later adopted and scaled out by Malawi government agricultural extension system, the Feed the Future[107] and Africa RISING[108], both funded by the U.S. Agency for International Development.

Indigenous African leafy vegetables (ALVs), such as amaranth (*Amaranthus* spp.), cleome (*Cleome gynandra*), *African nightshades (Solanum spp) and cowpea (Vigna unguiculata), which* were rich in minerals and vitamins, were re-introduced into cultivation and diets following collaborative initiatives involving research institutes including Bioversity international, farmer associations, women's empowerment groups in the five sub-Saharan African countries Botswana, Cameroon, Kenya, Senegal and Zimbabwe. Improved cultivation, which practised in combination with adequate seed systems, awareness raising and marketing campaigns, led to an increase in dietary diversity, farming system adaptability and household incomes, with women being the major beneficiaries.

There were several instances of the public sector collaborating with NGOs to promote on-farm diversity, such as "Garden of Moldova" in the Republic of Moldova. In the initiative, different agroecological practices were promoted along with crop rotation. In Mongolia, where the wheat monoculture was dominant and occupied over 85 percent of total cultivation area, the new pea variety, Bayalag, was widely cultivated for animal feed as well as for green manure for soil improvement in wheat rotation systems in the Central and Eastern cropping zones of the country. Well-adapted extra early varieties of soybean and maize were also introduced into the cropping systems of the country. In Malaysia, government focused on a few priority crops for agrifood such as coconut, pineapple, durian and corn, which not only diversified crop but also helped to generate more income for the farmers.

Intercropping was used to enhance crop diversification in agricultural systems, for instance in Italy, where CREA-ZA selected the field pea cultivar 'Pifor' for this specific purpose. Intercropping of sorghum and pearl millet with grain legumes was promoted in Eritrea. The strip cropping of arable and vegetable crops in the Netherlands resulted in comparable yields with monocultures in addition to reduced pest and disease pressures and a higher biodiversity. Community-supported agriculture, for example the 96 projects, including "Cooperative agriculture" by Organic Norway, was a means to enhance on-farm diversity.

4.6.2 Introduction of new crops, re-introduction of crops and domestication of wild species

Several instances of the successful introduction of new crop species into a country's cropping systems were documented in recent years. During the reporting period, 95 wild species were domesticated in 71 countries, 347 crops newly introduced from abroad, and 104 crops reintroduced in certain areas of countries using seeds sourced from the genebank. Overall, the majority of the species that were newly introduced were fruit plants (22 percent), followed by vegetables (17), pulses (8), cereals and forages (7 percent each) (Table 4.8). The newly introduced crops were from Europe (38 percent), Asia (18 percent), Latin America and the Caribbean (18 percent) and Oceania (16 percent). In Europe, vegetables constituted the largest crop group and among them *Brassica* was the most commonly introduced. Among the fruit plants, the genus *Prunus* was the most frequently introduced new crop in Asia, Europe and Latin America and the Caribbean. *Ziziphus* was newly introduced in some areas of

[106] https://soilandfood.org/
[107] https://www.feedthefuture.gov/
[108] https://africa-rising.net/

Greece and Jordan.

Table 4.8. Number of species by crop group introduced from abroad, reintroduced from a genebank collection and wild species newly domesticated as reported by 71 countries

Crop group	Number of: Newly introduced crops	Reintroduced crops	Wild species domesticated
Fruit plants	78	17	17
Vegetables	62	20	9
Pulses	29	20	6
Herbs and spices	21	5	19
Cereals	26	15	3
Forages	26	9	7
Medicinal plants	21	1	17
Ornamentals	25		6
Fruit	15	2	2
Oil plants	11	6	1
Material plants	10		1
Roots and tubers	5	5	1
Stimulants	6	2	3
Fibre plants	7		1
Nuts	7		1
Pseudo cereals	4	2	
Sugar crops	2	1	1
Other			2
Total	355	105	95

Typically, the ensuing enhanced on-farm diversity resulted in diversified diets and also translated to improved livelihoods for smallholder farmers. For instance, collaborative research endeavors paved the way for introducing into various countries quinoa, a pseudo-cereal, which originated in the Andean region. The seeds are rich in proteins, B vitamins and micro nutrients and it is mostly cultivated in Peru and Bolivia. Starting in the late 1990s, it was introduced and cultivated in several countries, including Canada, China, the Netherlands, UK, USA (Bazile *et al*. 2016).

The introduction of varieties of date palm, Irish potato, and green gram; the expanded cultivation of emmer wheat; and the reintroduction of sweet potato were undertaken in Eritrea. In Ethiopia, farmers' varieties of sorghum, haricot bean and maize, the cultivation of which had been discontinued in the past were reintroduced in Ethiopia. Similarly, 200 sorghum and finger millet accessions were introduced into cultivation in Kenya. Also, a number of new crop species such as triticale, soybean, pea, maize, camelina, sweet sorghum, flax and cultivated strawberry, leafy vegetable species, apple and blue honeysuckle berry were successfully introduced in different areas of Mongolia. In addition, the area under cultivation to new berry varieties collected from Canada, Japan and the Russian Federation increased in different cropping zones of the country.

In Kenya, nearly two million seedlings of underutilized nutrient-dense fruit species, including guava, jackfruit, pomegranate, custard apple, loquat, gooseberry, blackberry, raspberry, tree tomato, tamarind and java plum, were distributed to farmers. Orange-fleshed sweet potato (OFSP), a biofortified crop variety, which was developed to combat vitamin A deficiency (VAD) among children and women, a significant public health concern in Sub-Saharan Africa, was introduced into the cropping systems of many African countries, a development that was termed "a disruptive innovation" (Girard *et al*. 2021). The programmes for the promotion of the OFSP included the Sweet potato for Profit and Health Initiative (SPHI) (2010–2014), which was followed by an expanded dissemination of OFSP

(2015-mid-2019). OFSP reached approximately 10 million African households by 2020, and helped to both address malnutrition and increase economic returns to the families.[109] The other projects that sought to promote OFSP were: Mama SASHA in Kenya, VISTA in the United Republic of Tanzania and Nutritious Diets for Niassa, Mozambique and Quality Diets for Better Health Sidama and Gedeo zones SNNPR in Ethiopia (Girard *et al*. 2021). *To match the* new OFSP varieties with the consumer preference, *CIP started a breeding program 'Breed in Africa for Africa' to develop* OFSP varieties with better taste and adaptation. More than 100 OFSP varieties were released by 16 countries in the region (Girard *et al*. 2021).

Introductions of new and 'forgotten' crops contributed to reduced reliance on imports from foreign countries. The "Better products, new crops" initiative at Wageningen University and Research (WUR), which was implemented in collaboration with relevant partners from the business community, led to the successful introduction of new crops like quinoa, tagetes, hemp in the Kingdom of the Netherlands[110]. Another project on diversification of cropping systems, 'DiverIMPACTS', was aimed at improving productivity, delivery of ecosystem services and resource-efficient and sustainable value chains in Europe.[111] Similarly, the projects 'ReMIX'[112] and 'Diversifood'[113], were aimed at developing diverse and resilient arable cropping systems through species mixtures and increasing diversity in crop production and food supply, respectively, in Europe.

Instances of the new introduction of pulses included pigeon pea in Jordan and Mali. Among the pseudo cereals, the introduction of quinoa was reported in all regions apart from Oceania, while amaranth and buckwheat were the other 2 pseudo cereals that were introduced in different regions. Among the cereals, the genera *Triticum* and *Sorghum* were the most frequently introduced. Examples included the introduction of wheat into sub-Saharan Africa. To a lesser extent, pearl millet was introduced in Jordan and Kyrgyzstan. In Greece, vegetables, pulses, fruit plants and herbs and spices were newly introduced. In Australia, 74 new introductions, covering almost all crop groups but with a majority being fruit plants (26), forages (20) and cereals (8), were implemented.

The reintroduction of crops from genebanks was more prevalent in Latin America and the Caribbean (49 percent), and to a lesser extent in Europe (23 percent) and Asia (16 percent). In Cuba, 25 crops were introduced from genebanks, for instance. They included fruit plants (8), forages and vegetables (6 each). Other countries where the reintroduction of crops was frequently done were Romania (19), Nicaragua (14) and Mexico (13). The introduction of domesticated wild species was mostly done in Asia (52 percent) and included mostly herbs and spices and medicinal plants, which were introduced the most in Lebanon. Bangladesh was the country with the second highest number of wild species introduced for domestication; the majority was wild pulses, six of which were introduced.

4.7 Development and commercialization of farmers' varieties/landraces and underutilized species

High-input crop production systems, which are based on a few varieties of a small number of major crops are prevalent in many parts of the world – underscoring therefore the vulnerability of food systems to shocks and their inability to provide enough nutrients to those who depend on them. These shortcomings persist in spite of the evident abundance of many more crops, including the so-called neglected and underutilized species, and varieties, including farmers' varieties and landraces that could easily be used to enhance the intra- and inter-specific diversity of the systems. The constraints to the diversification of cropping systems through the routine introduction of new crops and varieties include the absence of suitable varieties for prevailing dietary preferences; the lack of information on their existence and/or availability; weak value chains and markets and sub-optimal enabling

[109] https://www.sweetpotatoknowledge.org/topics/sweetpotato-for-profit-and-health-initiative-sphi/
[110] https://www.wur.nl/en/research-results/research-institutes/plant-research/field-crops/better-products-new-crops.htm
[111] https://www.diverimpacts.net/
[112] https://www.cropdiversification.eu/projects-involved/remix.html
[113] https://diversifood.eu/project/

environment.

4.7.1 Farmers' varieties/landraces

Twenty-nine countries[114] from 5 regions[115] reported the registration and release of 523 farmers' varieties/landraces, 49 percent of which were during the last two years of the reporting period, i.e. 2018 and 2019 (Table 4.6)**.** These farmers' varieties/landraces were mostly fruit plants species (231), roots & tubers (77), cereals (92) and vegetables (68). Over 95 percent of the registered farmers' varieties of fruit plants were in Europe. They were mainly apples and vines in Finland and France. Regarding roots and tubers, farmers' varieties/landraces of sweet potatoes and potatoes were released in Guyana and Peru; cassava, sweet potato, taro, coleus potato and yams in Ghana. Few yams were also released in Nigeria and potatoes in Germany, France and Norway. The most numbers of the release and registration of cereal farmers' varieties/landraces was in Europe (45 percent). These were mainly in Germany (wheat, barley, maize) and in Finland (barley and rye). In the second place, about 38 percent of the releases and registrations were Sub-Saharan Africa (38 percent) with the most frequent crops being rice in Niger, maize in Ghana and sorghum in Mali and Nigeria. Finally, vegetable farmers' varieties/landraces were mostly registered in Europe (75 percent) with two countries (Croatia and Germany) accounting the majority with *Brassica*, tomato, onion and garlic. Table 4.9 summarizes by year, crops, number of registered and released varieties, and countries.

Nearly 1 400 programs were implemented by 283 stakeholders in 75 countries on farmers' varieties/landraces and underutilized crops or species. These interventions pertained to research, crop improvement, improved processing, public awareness, seed distribution, market development, and policy changes. Of these, 412 programs were specific to farmers' varieties/landraces, 159 specifically targeted underutilized crops or species while 108 addressed both farmers' varieties/landraces and underutilized crops or species.

In Germany, old Bavarian landraces, including varieties of the German red list of endangered indigenous crop, were characterized. Based on the generated data and those from the participatory variety assessment by stakeholders from agricultural value chain, varieties with high potential for further cultivation were identified. A limited amount of seeds from these activities was then made available to interested farmers as well as regional initiatives and institutions - the so-called treasure keepers - for trial cultivation. Selected varieties were then submitted for approval as conservation varieties, thereby ensuring their continued availability.

Supportive measures for the cultivation of local plant varieties, such as the Estonian Rural Development Plan in Estonia, contributed to promoting the development, cultivation and commercialization of farmers' varieties/landraces and underutilized species. Seventy countries reported the existence of national policies to promote the development and commercialization of farmers' varieties/landraces or underutilized species.

[114] Armenia, Azerbaijan, Bangladesh, Bhutan, Costa Rica, Croatia, Estonia, Ethiopia, Finland, France, Germany, Ghana, Guatemala, Guyana, Jordan, Latvia, Malawi, Mali, Nepal, Niger, Nigeria, Norway, Panama, Peru, Philippines, Portugal, Serbia, Sri Lanka, Sudan.

[115] Asia, Europe, Latin America and the Caribbean, Northern Africa, Sub-Saharan Africa.

Table 4.9. Number of the farmers' variety/landraces (FV/LR) of different crops released and registered over the period 2012-2019

Year	Crops	Number of FV/LR	Country
2012	Barley, cauliflower, cabbage, garlic, horseradish, frafra, pearl millet, potato, plum, sorghum, maize, rice, rye, tomato	33	Azerbaijan, Bhutan, Croatia, Germany, Ghana, Niger, Norway, Sudan, Serbia
2013	Amaranth, bread wheat, cabbage, chickpea, canistel, common bean, maize, muskmelon, onion, parsley, pepper, oat, parsnip, radish, rice, rye, spelt wheat, sugar beet, tomato	45	Armenia Croatia, Germany, Malawi, Panama, Portugal, Sri Lanka, Sudan
2014	Common bean, cucumber, garlic, flax, maize, mustard, pear, pumpkin, oat, tomato, watermelon, white mustard	17	Germany, Croatia, Philippines, Serbia
2015	Bread wheat, buckwheat, cassava, cebada, cowpea, cocoyam, lettuce, onion, malanga, maize, pearl millet, pepper, potato, sorghum, tef,	51	Croatia, Ghana, Ethiopia, Finland, Germany Mali, Peru
2016	Barley, bread wheat, cowpea, rice, rye	9	Costa Rica, Finland, Germany, Ghana
2017	Barley, blackcurrant, bread wheat, common bean, garlic, longan, mango, Manila hemp, pea, pear, plum, red clover, red currant, red raspberry, sour cherry, spelt wheat, white currant, yam	35	Finland, Germany, Ghana, Philippines, Portugal,
2018	Apple, barley, bread wheat, common bean, cucumber, hemp, lettuce, mango, pear, plum, potato, sorghum, sour cherry, sweet cherry	145	Colombia, Finland, Germany Mali, Nigeria, Peru, Philippines
2019	Apple, blackcurrant, bread wheat, cassava, castor, frafra potato, gooseberry, hemp, mango, mustard, pea, pear, potato, red currant, red raspberry, rye, sour cherry, sweet potato, white currant, yam	235	Colombia, Finland, Ghana, Germany Nigeria, Philippines

Nonetheless, the utilization and commercialization of farmer's varieties remained challenging in some cases due to a lack of the relevant laws and policies as was observed in 15 countries[116]. For example, in the Czechia, no farmer's varieties had been registered and commercialized up to December 2019.

4.7.2 Underutilized species with potential for commercialization

A total of 577 underutilized crop species with potentials for commercialization were identified in 62 countries (Table 4.10) and prioritized (Figure 4.4). Fruit plants were the most represented group (25 percent), followed by vegetables (20 percent), pulses (9 percent), cereals (8 percent) and roots and tubers (7 percent). In all, 127 of the underutilized crop species were considered to be of high priority, the six most represented crop groups being vegetables (24 percent), fruit plants (15 percent), herbs and spices (10 percent), roots and tubers (9 percent), pulses (8 percent) and pseudo cereals (6 percent). High priority underutilized crop species identified in Asia totaled 66 or 52 percent of the total, with significant representations of vegetables (e.g. eggplants, cucurbits, okra) and pulses (e.g. lentils in Bangladesh and Jordan; broad bean in India). Thirty-one percent of the high priority crop species were in countries from Latin America and the Caribbean, with about 16 species being roots and tubers, among them yam and cocoyam in Cuba and El Salvador, and cassava in Costa Rica, Cuba and Guyana. Figures 4.5.a to 4.5.d show the identified underutilized species with potentials for commercialization ranked in terms of progress on crop improvement, marketing, multiplication of seeds and planting materials, and geographical distribution.

[116] Australia, Belarus, El Salvador, Ghana, Guatemala, Moldova, Netherlands, Nigeria, Papua New Guinea, Philippines, Senegal, South Africa, Trinidad and Tobago, Tunisia, and Zimbabwe.

Figure 4.4. Number of underutilized species with potential for commercialization identified and ranked in terms of priority (53 country).

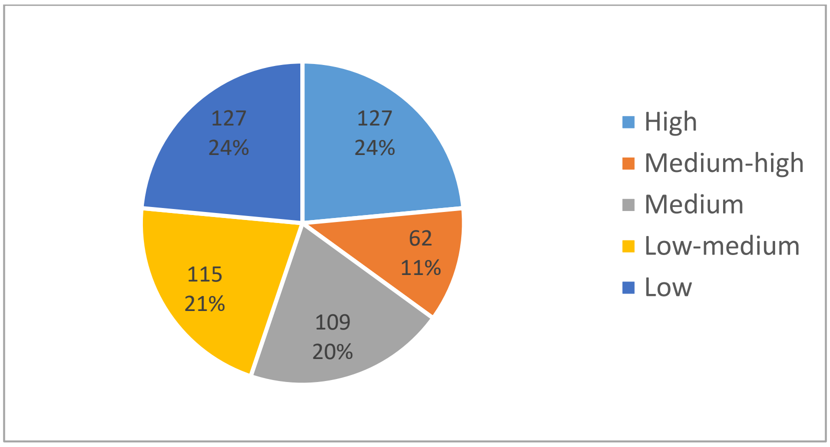


Table 4.10. Number of underutilized crop species with potential for commercialization for different crop groups and regions

Crop group	Number of crop species						Total
	Northern Africa	Sub-Saharan Africa	Latin America and the Caribbean	Asia	Europe	Oceania	
Fruit plants	1	20	131	18	13	2	171
Vegetables	5	20	37	41	26	2	97
Roots and tubers		13	28	1	1		37
Herbs & spices	1	1	7	18	12		36
Medicinal plants		5	10	10	13	1	36
Ornamentals		5	28	1	3		37
Forages	15		10	4	3	1	32
Pulses	1	4	12	18	15		32
Cereals	10	7	2	13	7	1	28
Oil plants	1	4	4	10	4		14
Pseudo cereals		4	4	4	4		13
Material plants		3	6	2	1		12
Nuts		3	5	3	3		12
Stimulants			9			1	9
Fibre plants			5	1	1		6
Other	1		5	1	1		9
Total	35	88	303	145	107	8	577

Figure 4.5a. Number of underutilized species with potential for commercialization identified and ranked in terms of status of crop improvement (53 countries).

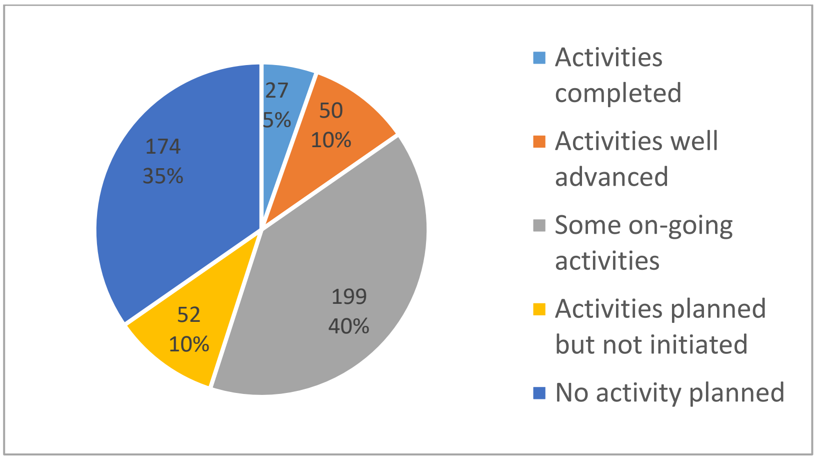


Figure 4.5b. Number of underutilized species with potential for commercialization identified and ranked in terms of status of marketing (49 countries).

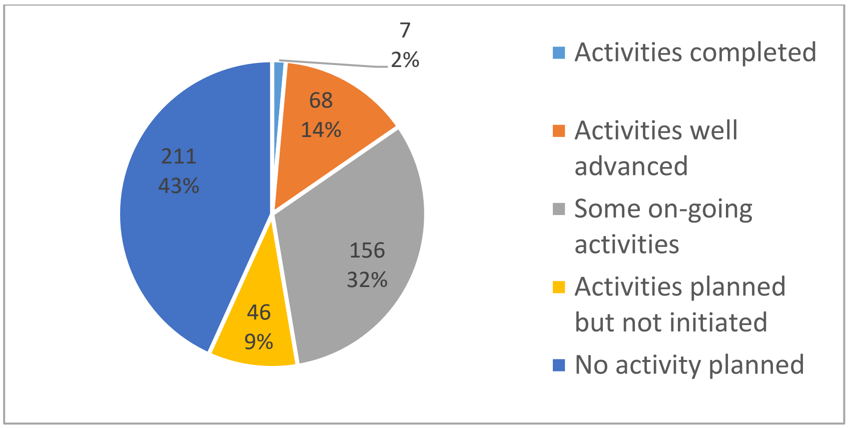


Figure 4.5c. Number of underutilized species with potential for commercialization identified and ranked in terms of status of seed/planting materials multiplication (53 countries).

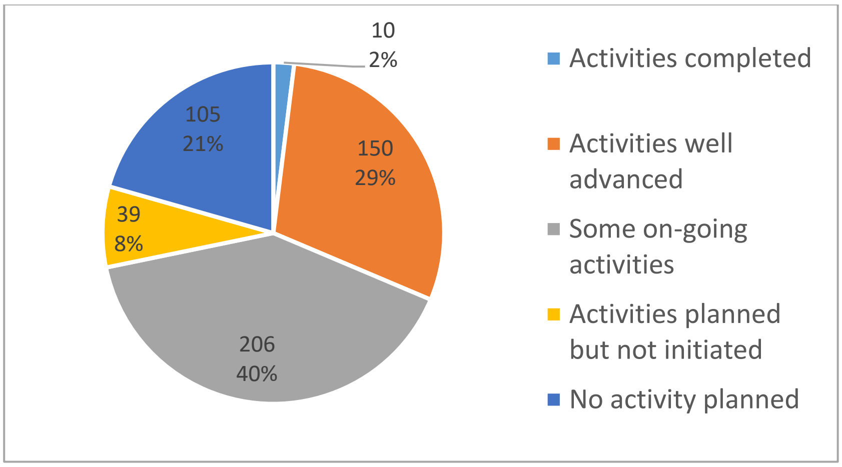
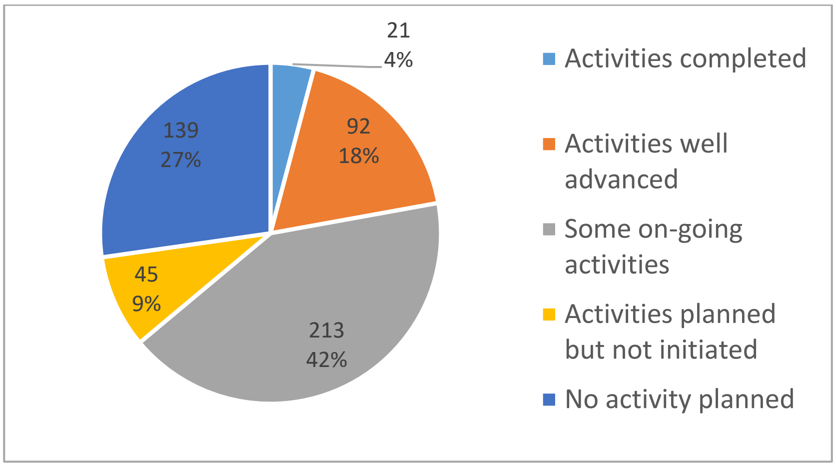


Figure 4.5d. Number of underutilized species with potential for commercialization identified and ranked in terms of status of geographical distribution mapping (54 countries).



There were crop improvement activities, to varying degrees, in 23 countries for about two-thirds of the 178 underutilized crop species with high and medium-high priority (Table 4.11). For those crops, varying degrees of characterization and/or evaluation and seed multiplication activities. The countries with the most high or medium-high priority underutilized crops were Bangladesh (34 species), El Salvador (19), Mexico (18), Albania and Lebanon (17), Cuba (16), Uganda (12), and Iran, the Islamic Republic of (10 species).

Table 4.11. Number of underutilized crops with potential for commercialization of high or medium-high priority for different crop groups and regions.

	Number of crop species				
Crop group	Sub-Saharan Africa	Latin America and the Caribbean	Asia	Europe	Total
Vegetables	7	6	22	8	38
Fruit plants	3	18	6	4	30
Roots and tubers	2	17			18
Herbs & spices	1	2	9	4	16
Pulses	1	3	12	3	16
Cereals	6	2	9		12
Ornamentals		9	1		10
Pseudo cereals	3	3	3	1	9
Medicinal plants	2	2	3	1	8
Oil plants	1		6		7
Forages		4	1		5
Nuts		1	3		4
Stimulants		2			2
Material plants		1			1
Other		1	1		2
Total	26	71	76	21	178

Some success stories on the development and commercialization of farmers’ varieties/landraces and underutilized species have been reported by several countries (Box 4.2).

Box 4.2. Development and commercialization of farmers' varieties/landraces and underutilized species

The renewed interest in the development and commercialization of products from previously neglected and underutilized species yielded dividends. There was a growing desire by Ugandan emerging middle class for more health products and healthy diets, for instance. In Uganda, the neglected and underutilized species, which were targeted for product development and commercialization included Tamarindus indica, Telfairia occidentalis, Mondia whitei, psorospermum, Persea americana seeds, Abelmoschus esculentus, Artocarpus heterophyllus, Hibiscus rosa-sinensis, Zingiber officinale, Cucurbita seeds, Cymbopogon citratus, Serenoa repens, Dioscorea species and mushrooms.

In Indonesia, several varieties of durian and rice were registered as improved local varieties. In several areas, the development and commercialization of commodities was accomplished via the release of improved local varieties and registration under geographical indication. The two notable examples of such varieties were Kopyol coffee (Kintamani), a type of local coffee from Bali released in 2010 by the Bali Provincial Plantation Service, and Malikka Black Soybean, a local soybean variety released in 2007 that is used by multinational companies as raw material for making soy sauce.

The 'Heritage seeds project' was initiated in October 2015 in Netherlands by the Oerakker foundation (https://www.seeds4all.eu/seed-operators/netherlands/de-oerakker/) and the Zaadgoed foundation, with the support of the Centre for Genetic Resources with the aim to produce the seeds of heritage varieties (such as the old bitter Brussels sprouts, tomato, pea, bean and wheat). The Oerakker foundation aimed to safeguard traditional Dutch agricultural and horticultural crops and varieties. The Zaadgoed foundation supported farmer and community-based plant breeding and the conservation of traditional varieties for organic agriculture.

In Germany, the Common EU Agricultural Policy from 2014 to 2020 (CAP 2014–2020) required that farmers having less than 30 hectares of arable land to grow at least two different crops while those who had more than this threshold were required to grow three (https://www.gov.ie/en/organisation/department-of-agriculture-food-and-the-marine/). This measure was implemented by numerous farmers in several federal states.

4.8 Strengthening seed delivery and distribution systems

Effective seed delivery and distribution systems, which ensure that farmers have timely access to sufficient quantities of the quality seeds and their planting materials, are crucial for the realization of the full benefits of the potentials that are encoded in the blueprints of crops and their varieties. The formal and informal seed systems co-existed in nearly all countries. The exchange of traditional varieties and landraces among farmers pertained to the informal seed system while the government-regulated production and distribution of quality assured seeds, typically with the involvement of private sector seed companies and nurseries that may produce seeds and seedlings locally or import and multiply them constituted the formal variant. Non-government organizations (NGOs) that work in close collaboration with smallholders to produce and distribute seeds also operated within the informal system.

There were considerable improvements in the seed systems of many countries between 2012 and 2019, enabling therefore the facilitated adoption of the most suitable varieties by farmers. There was an unprecedented growth in the value of the global seed market, which increased from US$ 36 billion in 2007 to over US $50 billion in 2020. The United States ranked first, followed by China, France, Brazil and Canada in descending order of the share of the global seed market. Some of the countries with most marked growth in the sizes of the national seed sector in recent years included China and Türkiye. In China, a total of 6 393 seed companies were registered in 2020 as compared to 730 companies in 2018. Türkiye produced a total of 1.32 million tons of certified seed in 2021 doubling the amount of 2011. Also, the seed market in Asia-Pacific region grew at a phenomenal rate with a market value of USD 22.91 billion in 2021 (APSA, 2022).

In Sweden, for instance, a country-wide network for agricultural advisory services was instrumental to making farmers aware of the continuous development of new crop varieties, including through information on variety testing.[117]
The Organization for Economic Co-operation and Development (OECD) Seed Schemes engaged with the National Designated Authorities (NDAs) of its 61 member countries to ensure the adherence to certification standards and procedures and thereby facilitated the movement of quality seed across borders. The total volume of seeds certified by the OECD Seed Schemes doubled over the last ten years. A total of 69 643 plant varieties belonging to 204 species were registered in the 2019 and 2020 period, with maize varieties being 49 percent of them, followed by other cereals and crucifers and other oil or fibre species. OECD certified 1 035 million kg of seeds in 2019 – 2020, with an estimated worth of 1.6 billion USD. In 2019 – 2020 period, Iran, France, Italy and the USA were the largest producers of OCED certified seeds, collectively contributing 741 million kg seeds.[118]

The harmonized seed regulatory system (HSRS) was implemented in the Southern African Development Community (SADC), which is made up of 16 countries, in order to facilitate enhanced access to quality seeds in the sub-region, in particular through cross-border trades. The functioning of the SADC Seed Security Network (SSSN) was further enabled in 2015 to 2016 by the USAID-funded 'Feed the Future Southern Africa Seed Trade Project'. For instance, the project contributed to the production and exportation of nearly 200 metric tonnes of maize seeds by the Seed Co Zambia Limited to the Democratic Republic of Congo (DRC). The success motivated other seed companies e.g. Lake Agriculture, Zambia; Zimbabwe Super Seeds (ZSS) Cooperative, Zimbabwe; and Peacock Seeds, Malawi to join the Seed Trade project for producing and exporting the quality seeds of maize and beans to Mozambique. In all, the four seed companies produced 700 metric tonnes of quality seeds, which were exported to the DRC and Mozambique and also sold domestically in the respective producing countries.

The CGIAR Research Programme – Grain Legumes and Dryland Cereals (GLDC) facilitated the establishment of viable seed systems in sub-Saharan Africa and Asia, leading to an enhanced adoption of improved crop varieties. As discussed by Ojiewo *et al*. (2020), a total of 397 050 tonnes of certified and quality declared seeds (QDS) of three legume crops was produced in the United Republic of Tanzania (groundnut), Nigeria (cowpea) and Uganda (common beans) under the Tropical Legumes (TL) Projects funded by the Bill and Melinda Gates Foundation. Both crop area and productivity increased following the planting of the quality seeds in the target regions over the project period, 2007 to 2019. For instance, the harvested area of groundnut increased from 40 000 to 1.6 million hectares and yields increased from 0.6 to 1.2 tonnes per hectare in the United Republic of Tanzania, whereas cowpea yields rose from less than 0.5 to 1.1 tonnes per hectare in Nigeria. The TL projects were led by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with the International Center for Tropical Agriculture (CIAT), International Institute of Tropical Agriculture (IITA) and other national agricultural research systems partners (NARS) in Africa and India.

Similarly, from 1998 to 2018, remarkable improvement was made in chickpea production in Myanmar under MyPulses project (2014 to 2017), which was funded by the Australian Centre for International Agricultural Research (ACIAR) and involved ICRISAT and Myanmar's Department of Agriculture Research (DAR) and the Department of Agriculture (DOA). The unprecedented rise in chickpea seed quality achieved through Village Seed Bank (VSB) resulted in increases in area under cultivation from 101 172 to 368 390 hectares and yield from 668 to 1 384 kilograms per hectare in the country (Ojiewo *et al*. 2020).

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[117] https://uniseco-project.eu/case-study/sweden
[118] https://www.oecd.org/agriculture/seeds/

Notable among similar initiatives aimed at developing economically sustainable seed systems for small holder farmers in developing countries was the ‘Building an Economically Sustainable and Integrated Cassava Seed System, Phase 2 (BASICS-II)’, which was funded by the Bill & Melinda Gates Foundation.[119] The BASICS-II project, which was led by IITA, involved the collaborating partners Go Seed, Tanzania Official Seed Certification Institute (TOSCI), National Root Crops Research Institute (NRCRI)-Nigeria and Mennonite Economic Development Agency (MEDA). The project resulted in enhanced production of early generation seed (EGS) of cassava via strengthened public-private partnerships and linkages between seed entrepreneurs and processors. The BASICS-II project led to the establishment of seamless links with other complementary schemes in sub-Saharan Africa, such as ‘Building an Economically Sustainable Seed System for Cassava in Tanzania (BEST)’, to enhance the availability of quality seeds of improved and disease-resistant varieties to farmers and seed entrepreneurs. [120]

The increasing number of crop varieties that were released and registered during the reporting period complemented the considerable improvement in the seed production capacity of different countries. In the United Republic of Tanzania the capacity to produce quality seeds increased 110 percent from 2015/2016 to 2019/2020, resulting in 53 percent reduction in seed import over the same period of time. Similarly, in Nigeria, the production of certified seeds increased from 14 788 metric tonnes in 2011 to 170 692 in 2014. Similarly, the number of accredited seed entrepreneurs rose from 71 in 2012 to 314 in 2018. The Growth Enhancement Support (GES) scheme was introduced in Nigeria to deliver government subsidized farm inputs, including certified seeds, directly to farmers. In some cases, such as reported from Botswana, the level of the adoption of released varieties was not readily quantifiable as farmers could exchange seeds between themselves without records being kept. In the country, the number of registered seed enterprises also increased from two in 2014 to 517 in 2019. The regular inspection of the enterprises contributed to seed quality assurance.

The spread of the varieties and their adoption by farmers could be boosted by the establishment of commercial agreements such as the one in Italy between the Council for Agricultural Research and Economics (CREA) and national and international seed companies to allow companies to multiply and commercialize crop varieties selected and registered by CREA.

The adherence to the guidelines established by the International Seed Testing Association (ISTA) for seed testing enhanced the overall quality of seeds, for instance in Estonia. In Egypt, the Central Administration for Seed Production (CASP) administered the quality assurance and production of foundation seeds and other seed classes in the country, resulting in the continued availability of quality seeds to farmers.

The enhanced availability of quality seeds of new high-yielding varieties (less than 10 years old) of pulse crops to small holder farmers in India led to a significant increase in pulses production from 14.76 million tonnes in 2007 and 2008 to 24.42 million tonnes in 2020 and 2021. This followed the implementation of the project, “Creation of seed hubs for increasing indigenous production of pulses in India”.[121] The project was initiated in 2016-17 by the Ministry of Agriculture and Farmers Welfare, the Government of India and implemented through the Indian Council of Agriculture Research (ICAR), India).[122] The production targets of different pulse crops (chickpea, pigeonpea, lentil, pea, mungbean, urdbean, lathyrus, horsegram, mothbean, common bean, cowpea) were achieved through 150 seed hubs located in 24 states that engaged 46 All India Coordinated Research Project Centres (AICRP Centers) in different State/Central Agricultural Universities; and seven ICAR Institutes), and 97 Krishi Vigyan Kendras (KVKs i.e. Agriculture Science Centres) (Rubyogo *et al*. 2019). The ICAR-Agricultural Technology Application Research Institutes (ICAR-ATARIs) played an important role in the facilitated farmer access to quality seeds under the auspices of the project.

[119](https://cassavamatters.org/basics-ii/)
[120] https://www.meda.org/projects/best-cassava/
[121] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1716492
[122] https://iipr.icar.gov.in/seedHub.html

4.9 Changes since the second State of the World reports were published

In the last decade, crop improvement programmes accorded high priorities to breeding for adaptation to the effects of climate change on crops and to reduce negative impacts of crop production systems, which exacerbate climate change. Also, compared to the previous reporting cycle, there was increased awareness of the importance of underutilized species in diversifying smallholder production systems. This is because the efforts to achieve food security and nutrition targets are constrained by the over-reliance on a limited number of food crops. The constraints to the use of PGRFA, which were described in the First and Second Reports, including inadequate human resources, funding and facilities (FAO 2010), were still evident in this reporting cycle.

Great advances were observed for the characterization and evaluation of germplasm in national collections and more especially in major national genebanks, for species of outstanding economic importance. Still, countries reported the non-implementation of molecular characterization of germplasm in their genebanks – as was the case with the National Plant Genetic Resources Centre (NPGRC) in South Africa.

In crop breeding programs, yield still remained the most sought-after trait, however resistance to biotic and abiotic stresses, adaptability and quality traits also attracted significant attention. Compared to Second Report that mentioned examples of participatory plant breeding (PPB) in 28 countries, PPB has been reported from a total 66 countries (Table 12).

Table 4.12. Countries reporting participatory plant breeding activities over the reporting period

Regions	Number of countries	Name of countries
Asia	19	Armenia, Azerbaijan, Bangladesh, Bhutan, India, Indonesia, Japan, Jordan, Lebanon, Malaysia, Mongolia, Nepal, Philippines, Tajikistan, Sri Lanka, Türkiye, Uzbekistan, Yemen
Europe	12	Albania, Bulgaria, Croatia, Czechia, France, Germany, Greece, Poland, Portugal, the Republic Moldova, Serbia, United Kingdom
Latin America and the Caribbean	12	Argentina, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Guyana, Mexico, Nicaragua, Uruguay
Northern Africa	3	Morocco, Sudan, Tunisia
Oceania	2	Australia, Papua New Guinea
Sub-Saharan Africa	18	Cameroon, Chad, Ethiopia, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Namibia, Nigeria, Senegal, South Africa, Togo, the United Republic of Tanzania, Uganda, Zambia, Zimbabwe

Tremendous advances have been seen in the field of high-throughput genotyping, phenotyping and modern breeding techniques like genomic selection. The projects involving international organizations like CGIAR, in collaboration with NARS partners, were crucial in the development and exchange of genetic resources and technologies. The routine application of these novel techniques in addressing identified problems require the possession of specialized skill sets, in particular by younger generations of breeders and scientists in the developing world. Therefore, the training of a new generation of plant breeders in developing countries in modern biotechnologies is of paramount importance. This may be achieved by the establishment of training centers and collaborative programs such as the West Africa Centre for Crop Improvement (WACCI; https://wacci.ug.edu.gh/).

The growing realization of the vulnerability of cropping systems to abiotic and biotic stresses, which may result from climate change has fueled a renewed interest in the diversification of the systems. Considerable progress was made towards the production of high-quality seeds of crops and making these available to the farmers at affordable prices. For instance, the seed hubs that were established by the Indian Council of Agricultural Research (ICAR), and which produced and distributed quality seeds to farmers, were instrumental to achieving the record volumes of harvests of pulses in India in recent years.

4.10 Gaps and needs

Several factors continued to constrain both the conservation and sustainable use of PGRFA. The following are the most important:

4.9.1 Gaps

- Modern biotechnologies and molecular genetic tools remained too costly for routine use in crop breeding programmes, of especially developing countries. Some countries reported a lack of funding for the national programme for the molecular characterization of PGRFA. The number of funded projects for PGRFA decreased at national levels.
- Due to the lack of characterization and evaluation data, the targeted selection of accessions possessing specific traits or characters remained challenging, especially for the genebank managers. Most of the existing characterization and evaluation data were not publicly available. The lack of trait specific subsets of crop germplasm also limited the use of PGRFA.
- The lack of standardisation in the collection and curation of phenotypic data from different sources impeded the comparisons and analyses of datasets. The standardization of data generated from the recent “omics” disciplines was also problematic.
- The use of high-throughput plant phenotyping platforms was restricted to the developed world and a handful of emerging economies like Brazil, China and India.
- The continued disappearance of indigenous varieties due to a declining farmer population and the erosion of CWR will limit access to valuable sources of traits for breeding progressively superior crop varieties.
- The paucity of special-purpose policies for the promotion of the commercialization of farmers’ varieties/landraces and underutilized species undermined efforts to enhance on-farm diversity and diversify diets.
- The lack of sufficient awareness of the importance and potentials of diverse, typically nutrient-rich underutilized crops and local varieties detracted from envisaged nutrition outcomes from the management of PGRFA.
- Quality seeds seemed too costly for many resource-poor smallholder farmers in developing countries.
- The limited involvement of the private sector in pre-breeding and germplasm enhancement may be constraining the injection of resources to leverage validated innovative technologies for harnessing the potentials of PGRFA.
- The lack of national strategies for plant breeding in some countries limit the implementation of solution-oriented crop improvement programmes.

4.9.2 Needs

- The standardization of characterization and evaluation of germplasm to ensure better interoperability of databases and facilitated exchange of information.
- Establish linkages between the physical germplasm (accessions) and various types of data (e.g. digital sequence information and other similar molecular data) generated by genebanks and their clients.
- Strengthen seed quality assurance mechanisms, especially based on internationally agreed standards and guidelines, in order to both enhance the availability of quality seeds and to prevent the sale of counterfeit non-quality assured seeds and planting materials
- Develop national programmes for under-utilized crops with especial emphasis on their identification for large-scale cultivation, marketing and consumption.

- Strengthen institutional and human capacities in novel efficiency-enhancing technologies, especially in the emerging areas such as gene editing, genomic selection and high-throughput phenotyping.
- Implement long-term investment and research plans on pre-breeding for a greater utilization of PGRFA, particularly CWR and landraces.
- Develop and implement national seed policies and regulations that are suitable for the participation of a multiplicity of stakeholders along the value chain and enable the co-existence as necessary of diverse seed systems.

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Chapter 5. The state of human and institutional capacities

5.1 Introduction

The conservation and sustainable use of PGRFA entail more than the immediate management of germplasm. It depends on the state of in range of fields, including policies, legislation, infrastructure, education and networking. These capacities constitute the subject of this chapter.

Since the publication of *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoW2), a number of global changes have significantly shaped the context in which the management of PGRFA is embedded. Chief among these is that an increase in the frequency of disruptive and catastrophic weather events has meant that climate change has become more palpable for many. The need for urgent action to address climate change is now fundamentally anchored in the international community and reflected in widespread discourses about "net zero", decarbonization, mitigation and adaptation. While this awareness has not yet universally translated into the action needed, addressing climate change has moved to the forefront of the international agenda, which since 2015 has been framed by the Sustainable Development Goals (SDG). Similarly, even if the years since 2020 have been dominated by the COVID-19 pandemic, the decade since the publication of the SoW2 has also been characterized by concerns regarding the loss of biodiversity, declines in soil health and the need for agroecological transformation of food and farming systems. Against this background, awareness of the importance of PGRFA has grown. Their crucial role in food security and nutrition, smallholder farmers' livelihoods and the sustainability of agriculture in the face of climatic uncertainty and biodiversity loss is increasingly recognized, and this in turn has encouraged greater attention to, and investments in, their conservation. As this chapter outlines, while there remain significant gaps in human and institutional capacities for the management of PGRFA, this enhanced attention has also enabled noticeable progress since the SoW2 was published.

The international governance framework for genetic resources has also seen noteworthy development, specifically with the entering into force in 2014 of the 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 (Nagoya Protocol), the adoption in 2021 by FAO of the Framework for Action on Biodiversity for Food and Agriculture and the Global Plan of Action for the Conservation, Sustainable Use and Development of Aquatic Genetic Resources for Food and Agriculture, and the adoption of the Kunming-Montreal Global Biodiversity Framework in December 2022. These international agreements are intended to be implemented in a mutually supportive manner and will support the implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture (Second GPA) and the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty). However, implementing them also places greater demands on strengthening human and institutional capacities, to ensure harmonization.

The developing governance framework for genetic resources has increasingly emphasized the rights of smallholder and peasant farmers, Indigenous Peoples and local communities, and specifically women and youth, and their participation in decision-making. While this focus has existed since before adoption of the first Global Plan of Action for Plant Genetic Resources for Food and Agriculture, it has found renewed emphasis over the last decade, as the farmers and Indigenous Peoples have gradually been better integrated in international negotiations. Examples include such mechanisms as the Permanent Forum on Indigenous Issues under the UN's Economic and Social Council established in 2000,[123] the Civil Society and Indigenous Peoples Mechanism for Relations with the UN Committee on World Food Security established in 2010,[124] and the process under the 2017 UN Resolution on Enhancing the Participation of Indigenous Peoples' Representatives and Institutions in Meetings of Relevant United Nation Bodies on Issues Affecting Them.[125]

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[123] https://www.un.org/development/desa/indigenouspeoples/about-us/permanent-forum-on-indigenous-issues.html
[124] https://www.csm4cfs.org/
[125] See Resolution adopted by the General Assembly A/RES/71/321 http://www.undocs.org/A/RES/71/321

Crucially, over the last decade, digital technologies and biotechnologies have seen remarkable development. New molecular techniques led to a drastic reduction in the costs and time involved in generating DNA and RNA sequence data. These developments are increasing the efficiency of the characterization of PGRFA and speeding up the development of new crop varieties through such techniques as marker-assisted selection, genomics-assisted breeding and gene editing. However, the technical capacity to generate and manage this information and utilize these technologies is unevenly distributed across regions and institutions, mirroring wider economic and geopolitical asymmetries, and constraining equitable access to the benefits arising from PGRFA use. Advances in these fields have also led to discussions at the international level with regard to the distribution of benefits arising from the use of digital sequence information (DSI). Similarly, developments in genomics-assisted breeding have led to a steady growth in the number of patents and other exclusive intellectual property rights over germplasm and related technologies, leading to further concerns about benefit-sharing and market control.

Especially since the COVID-19 pandemic, social media and other online communication tools greatly transformed the ways in which the wider public, as well as professional communities, share information. This has also had an impact on the delivery of education, including in the context of PGFRA, often facilitating participation and increasing training opportunities. However, the amount of information available online today can be overwhelming and requires improved skills to assess and evaluate its credibility and reliability, as well as continuous capacity building to keep pace with technological and informational developments.

This chapter is based on a literature review and an analysis of country responses to assessment indicators and country reports submitted in the context of reporting requirements for the Second GPA. Country reports were mined for PGRFA key aspects pertaining to Priority Activity Areas 13 to 18 of the Second GPA.[126] Sections 2 to 6 document achievements and remaining gaps and needs in these priority areas. The country reports were also used to analyse differences between regions for each priority area. This analysis is thus based on countries' own assessments. Moreover, each component of the analysis only covers the countries that reported on their actions and needs in the respective priority area. As not all countries responded to all questions, the total numbers of respondents vary, and this hinders precise comparisons. The chapter also draws on information available from the Treaty on ongoing work under its ambit. Given that almost two decades have passed since the Treaty came into force in 2004, the chapter highlights the critical role it has played so far, outlining some key developments and reviewing some of the major achievements and lacunae in its implementation.

[126] Priority Activity Areas (PAAs) 13 to 18 are covered in this chapter: PAA 13 Building and strengthening national programmes; PAA 14 Promoting and strengthening networks for PGRFA; PAA 15 Constructing and strengthening comprehensive information systems for PGRFA; PAA 16 Developing and strengthening systems for monitoring and safeguarding genetic diversity and minimizing genetic erosion of PGRFA; PAA 17 Building and strengthening human resource capacity; PAA 18 Promoting and strengthening public awareness of the importance of PGRFA.

Key findings of the chapter

National programmes for the management of PGRFA have increasingly been put in place but lack adequate implementation in most countries. A lot of PGRFA work is done through time-bound projects and ad hoc activities, not all of which is recognized and supported, especially when driven by civil society organizations, and individual initiatives are still inadequately connected and coordinated.

Training and education opportunities in the field of PGRFA management have increased, but knowledge transfer to a younger generation of professionals needed to replace those that are retiring is still a significant challenge in many country contexts.

International collaboration in PGRFA management brings important benefits but is still patchy and not equally accessible to all, especially where funding is inconsistent. Lack of funding is a key constraint to all PGRFA activities across all regions. In many cases this means that gaps are being plugged with project funding rather than dedicated budget streams. Innovative approaches to resource mobilization may increasingly be necessary for key PGRFA institutions and this will require new capacities and levels of preparedness.

Information systems on PGRFA have expanded, proliferated and begun to be integrated. However, important gaps remain in their geographical and thematic coverage, especially in the case of crop wild relatives and farmers' varieties/landraces. Asymmetries in technological capacities constitute significant hurdles to equal access to and adequate management of PGRFA-related information.

Monitoring mechanisms for genetic erosion, especially in the context of *in situ* conservation and on-farm management, still urgently need to be improved and better implemented in most national and regional contexts.

Significant progress has been made in the development of access to PGRFA at the international level. However, concomitant benefit-sharing is relatively underdeveloped, and existing mechanisms need to be enhanced.

Farmers' Rights have seen substantial development over the last decade, with the Treaty having played a key role. However, crucial contradictions between the implementation of Farmers' Rights and seed laws reman to be resolved in many countries.

Participation of smallholder farmers, Indigenous Peoples, local communities and the wider public, especially women and youth, in the development of solutions to PGRFA challenges and decision-making in this domain has been advancing but is still far from reaching its full potential.

Public awareness of the importance of PGRFA and understanding of challenges in their management are greater than ever before. Nonetheless, there is still scope to improve understanding and awareness, especially among professionals and policymakers in other sectors – such as environment, trade and health – in order to maximize synergies and catalyse changes in an integrated way.

5.2 National programmes, legislation and education

A national programme for the conservation and sustainable use of PGRFA is an agreed set of objectives, activities and measures, associated with particular institutions or other structures, to be undertaken at the national level. Four main elements make up an effective national programme: (1) a governmental policy framework and/or strategy for PGRFA conservation and use that provides clear guidance on priorities and implementation actions; (2) governance or coordination by a national entity (e.g. a committee, commission, council or board) to provide coherence and efficiency; (3) at least one officially appointed national focal point for PGRFA to coordinate PGRFA activity in the country; (4) a strong and functioning national information-sharing mechanism for PGRFA that enables the programme to monitor and evaluate progress in the implementation of the Second GPA and share best practices and lessons learned among national actors. Well-designed and implemented national programmes enable countries to set clear goals and priorities and to effectively allocate resources, assign roles and responsibilities, and identify and strengthen linkages between relevant actors. They promote the implementation of international instruments such as the Second GPA, the Treaty and the Convention on Biological Diversity (CBD) by translating global commitments into action at national and local levels. Effective national programmes integrate and unite the diverse actors working with PGRFA in ways that synergize their efforts. Building and strengthening national programmes is a priority activity area of the Second GPA.

Effective and efficient conservation and use of PGRFA also depend on human-resource capacity. Building and strengthening human-resource capacity is another priority activity area of the Second GPA. Critical components of human-resource capacity include curators, plant breeders, geneticists, field and laboratory technicians working in genebanks, botanical gardens and research institutes, as well as farmers and their cooperatives, NGOs, extension workers, policymakers and academics.

This section provides an overview of the state of national programmes and supporting legislation and of education and training provision across the world. Section 2.1 presents an analysis of achievements since the publication of the SOW2 across the various elements of national programmes, followed by a more detailed account of differences between regions, including gaps and needs. Section 2.2 provides an overview of achievements in the field of training and education at national level and then presents regional differences.

5.2.1 National programmes and supporting legislation for the conservation and sustainable use of PGRFA

Achievements in the implementation of the Second GPA in the context of national programmes are mentioned in country reports from all regions. Key achievements are summarized in Table 5.1.

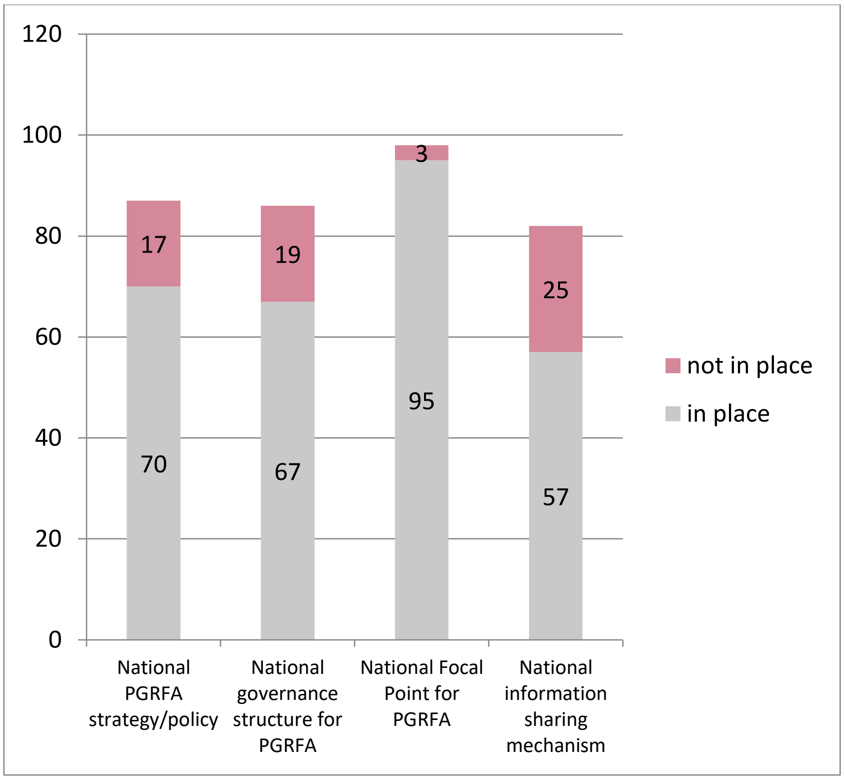
Table 5.1. Reported achievements with respect to national PGRFA programmes

Type of achievement	Number of countries reporting achievements in this area (out of a total of 79 reporting countries)
PGRFA strategies and legislation	37 countries report some progress in developing PGRFA-specific strategies or relevant legislation – however, the development of strategies and legislation was also highlighted as a crucial gap for many countries
National coordinating entities	21 countries report achievements in establishing or strengthening governance entities to coordinate PGRFA activities at national level
Coherence in national programmes	14 countries report progress in improving the coherence of their national programmes more broadly

National policy framework

As illustrated in Figure 5.1, most reporting countries (70 of a total of 87 respondents or 86 percent) indicate that they have a national policy framework or strategy for PGRFA in place. However, only 47 percent of these frameworks have titles that specifically refer to PGRFA or related keywords (e.g. Switzerland's National Plan of Action for PGRFA from 1999), leaving some uncertainty regarding the extent to which the reported strategies target PGRFA specifically. Most of the reported instruments whose titles do not refer to PGRFA are policies that are relevant to PGRFA (e.g. national biodiversity strategies and action plans [NBSAP] or seed certification laws) but may not necessarily address PGRFA conservation and use specifically, or if they do may not identify clear pathways for strategy implementation or for the monitoring and evaluation of impacts. Details are not available on how exactly NBSAPs (national instruments required under Article 6 of the Convention on Biological Diversity)[127] embed PGRFA-specific actions and priorities. A 2016 study of 119 NBSAPs found that only 30 percent included concrete actions on the conservation and sustainable use of PGRFA and that many fewer included plans for the implementation of the Treaty (Lapena, Halewood and Hunter, 2016).

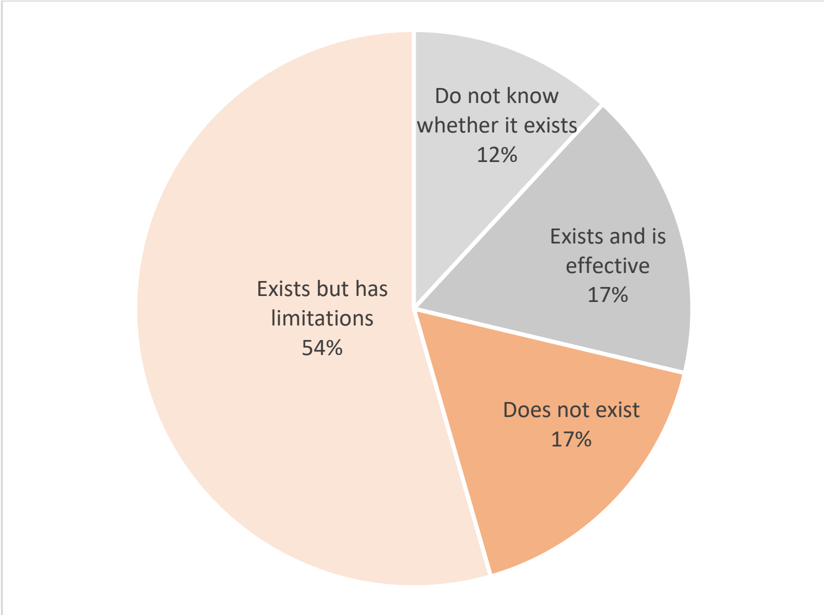
Figure 5.1. Number of countries with elements of national PGRFA programmes in place



This tendency for policies to exist without necessarily addressing all PGRFA-relevant dimensions in a comprehensive manner was also reflected in a global survey conducted by the Secretariat of the Treaty (Kell, Marino and Maxted, 2017). More than half of 271 respondents indicated that national policy supporting the sustainable use of PGRFA is in place in the country(ies) where they work but that it does not cover all elements of sustainable use and/or that there are problems with its implementation (Figure 5.2).

[127] https://www.cbd.int/nbsap/

Figure 2.1.2. Stakeholder responses on national PGRFA policy



Note: The chart summarizes responses to a question answered by 271 respondents to a survey undertaken by the Secretariat of the Treaty on Plant Genetic Resources for Food and Agriculture in 2015.
Source: adapted from Kell *et al*. (2017)

National governance structure

Most (81 percent) of the 86 countries that provided information for the current round of reporting (Figure 5.1) indicate that they have at least one national entity coordinating PGRFA activities. These include specially constituted committees and already existing institutes, genebanks, statutory bodies and departments within ministries. Occasionally, the role is fulfilled by public–private boards (e.g. the Public–Private Roundtable on Genetic Resources for Food and Agriculture in Chile). Most of these entities meet annually or more frequently.

National focal point

Almost all countries (95 of 98 or 97 percent) that participated in the current round of reporting had a national focal point (NFP) for PGRFA in place at the time (see Figure 5.1). While not all the reports provide information on gender, it is promising to note that in all regions NFPs include both women and men. NFPs are based at a variety of organizations with relevance to PGRFA – from genebanks and genetic resources or biodiversity institutes to agricultural research centres, agricultural or environmental ministries and seed-industry management units (including phytosanitary agencies).

National Information Sharing Mechanism

The 150 countries that adopted the first GPA in 1996, at the Fourth International Technical Conference on PGR held in Leipzig, Germany, under the auspices of the Commission on Genetic Resources for Food and Agriculture, agreed that its implementation would be monitored and guided by governments and recommended the establishment of a transparent and effective monitoring system. National Information Sharing Mechanisms (NISMs) were one tool for monitoring the implementation of the first GPA, with roles also in improving countries' capacity in exchanging and analysing PGRFA information for future planning and in supporting the coordination of diverse national stakeholders. While the NISMs established for reporting on the Second GPA have mostly fallen into disuse, information sharing mechanisms are nonetheless needed to support national programmes and enable reporting. Almost three-quarters of reporting countries (57 of 82, or 74 percent) indicate that they have established some sort of information-sharing mechanism for PGRFA (see Figure 5.1). Most of these consist of genebank databases, inventories and Biodiversity Clearing House Mechanisms – many of which are also cited by countries in the context of information systems (see Section 5.4.1). Even though the content of such information outlets is relevant to PGRFA, they may not on their own be sufficient to enhance the coordination and development of national PGRFA activities. Nonetheless, there has been progress in establishing information outlets of relevance to PGRFA since the publication of the SOW2 in 2011.

The data indicate that countries have made some progress over the last decade in developing their national PGRFA programmes. However, major shortcomings remain in terms of the quality, implementation and impact of these programmes. There is little evidence that national programmes are enhancing and strengthening conservation and sustainable use of PGRFA to the extent that is necessary in times of climate chaos and biodiversity collapse. Programmes often still lack certain key elements (e.g. appropriate coordination or a dedicated PGRFA strategy) and are generally under-resourced, in terms of both budgets and human capacity. In many countries, “national programmes” are more like “institutional programmes” implemented by individual institutions and do not integrate all relevant stakeholders.

Regional differences

Northern Africa
Sudan and Tunisia report that they are either developing or revising their NBSAPs. PGRFA-relevant units have been strengthened, and research and development projects with a focus on PGRFA have been developed, as have proposals for national legislation, including biosafety laws. Of the three reporting Northern African countries, two cite the lack of a national strategy and the lack of implementation of PGRFA-related legislation as constraints. Gaps in human and technical capacity are also underlined.

Sub-Saharan Africa
One-third of reporting countries across sub-Saharan Africa report that they have revived non-functioning coordinating entities, established new ones or reinforced existing ones. As further detailed in Chapter 3, genebanks have been strengthened in several countries, and PGR units have been set up or upgraded, including in Kenya, Nigeria, Mali and Zimbabwe. Several countries, including Botswana, Madagascar and South Africa, report that they have drafted PGRFA-specific strategies, and others mention having developed or revised their NBSAPs. Some countries specifically mention strategies focusing on crop wild relatives (CWR). Uganda highlights that its new PGRFA-related strategies and policies have increased institutional harmonization.

Crucially, more than half the reporting countries in sub-Saharan Africa (58 percent) note that funding shortages need to be addressed before progress can be made in the implementation of the Second GPA. Similarly, 47 percent of reporting countries cite shortcomings in the development, finalization or full implementation of a PGRFA strategy or related policies, and some underline the need for technical assistance to overcome these weaknesses, including assistance with implementing existing conflicting policies in harmonized ways. A few countries highlight failure to address Farmers’ Rights. The need to overcome fragmentation and strengthen collaboration is also stressed, particularly collaboration between different government entities but also between government and farmers and breeders. Countries also note the need to address gaps in human and technological capacities and to upgrade infrastructure. Information sharing is reportedly also often poor and in many cases no information-sharing mechanisms exist at all. A few countries mention the need to strengthen or even establish competent authorities. It is also stressed that changes of government and volatile politics jeopardize the continuity of programmes even where they are in place.

Northern America
The only North American country that reported in detail on the state of its national programme was Canada. It notes that its Biodiversity and Bioresources Science Strategy has three PGRFA-related objectives. It also mentions the need to reinstate its Expert Committee on Plant and Microbial Genetic Resources.

Latin America and the Caribbean
The achievement most frequently reported by countries in this region is that they have drafted or adopted PGRFA-relevant policies and legislation or incorporated PGRFA-related priorities into NBSAPs (reported, for example, by Brazil, Costa Rica, Cuba and Nicaragua). The next most frequently reported achievement is the establishment, renewal or strengthening of the respective country's coordinating or key advisory entity. Collaboration between stakeholders are reported also to have been strengthened. Fewer countries report that they have developed a PGRFA-specific strategy or action plan. A few countries indicate that they have appointed an NFP where one did not previously exist.

A few countries (Brazil, Chile and Mexico) report that they have upgraded or developed their genebank infrastructures or technologies, for example introducing cryopreservation or improving software. Other countries emphasize that public awareness of PGRFA has increased and that the participation and capacity of their rural populations – including of Indigenous Peoples and women – has increased. They mention that community seed banks have been central to this (notably in Guatemala). The collection, conservation and distribution of PGRFA have reportedly been able to continue even in a few countries that cite serious financial difficulties. Two countries (Argentina and Costa Rica) specifically mention achievements related to the Treaty – ratification and progress in its implementation.

The most urgent need across the region is reported to be that of addressing the lack of funding or lack of consistent funding (mentioned by two-thirds of reporting countries), followed by that of developing national programmes and developing or implementing PGRFA-related legislation. Information-sharing mechanisms also need to be set up or strengthened. Capacity building is cited as another significant requirement across the region. Also reportedly important across countries is the need to establish or strengthen national coordinating entities for PGRFA and to improve collaboration among diverse stakeholders. Some countries also report the need to improve infrastructure and technology. Some also stress the importance of incorporating farmers' varieties/landraces into legislation, setting priorities for underutilized species and ensuring the inclusion of smallholder and peasant farmers as key actors in PGRFA management.

Asia
In Asia, while only India reports having a strong policy framework in place, many other countries report that they have drafted, revised, developed or adopted a PGRFA-specific strategy or PGRFA-related legislation. Some countries report having improved their NBSAPs, in some cases (including in Armenia, Jordan, Malaysia) by adding a specific strategy for PGRFA or indicators for CWR. Several countries also report having established a governing or coordinating entity for PGRFA-related activities or a new institutional structure supporting PGRFA – for example, the Biodiversity Thematic Research Group in Jordan. Two countries report appointing focal points for PGRFA, where they did not previously exist. Japan and Mongolia note accession to the Treaty among their achievements.

Most reporting countries in Asia (11 of 18, or 61 percent) indicate weaknesses in the development, finalization or full implementation of a PGRFA strategy or related policies. The need to harmonize conflicting policies is also mentioned in this context, as is the need to overcome fragmentation and strengthen collaboration between diverse stakeholders. Lack of sufficient funding ranks as the next most frequently reported constraint, alongside the need to establish or strengthen coordinating entities and to build human capacity. A smaller number of countries also mention gaps in information sharing, including a lack of publicly accessible databases, and inadequate infrastructure and technology more broadly.

Europe
Half the European reporting countries note that they have implemented, renewed or drafted specific national PGRFA programmes since the time of the SOW2. Several note having drafted, approved or implemented PGRFA strategies and action plans (including Belarus, France, Hungary and Norway). A few mention that PGRFA-related legislation has been adopted or guidelines published. One country (Hungary) notes that its NBSAP includes an objective related to genetic resources for food and

agriculture. A small number of countries (Hungary, Poland, Portugal, Switzerland) report having increased budgets for PGRFA management, something that is not been reported in any other region. Several countries (including Estonia, France, Germany and the Nordic countries) report having strengthened coordination among stakeholders.

Genetic Resources Strategy for Europe
In November 2021, an overarching Genetic Resources Strategy for Europe was launched. Developed by 17 partners through the GenRes Bridge project[128] to secure genetic resources and enable Europe to meet its commitments under global policy frameworks, the strategy is bolstered by individual strategies for plant, animal and forest genetic resources. The plant genetic resources strategy was produced by the European Cooperative Programme for Plant Genetic Resources.

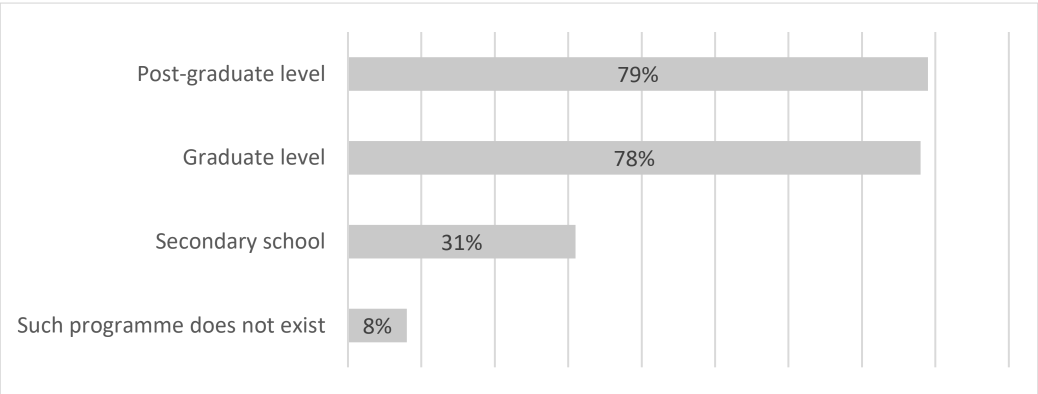
Funding is at the top of the list of gaps and needs in the region (reported by six countries). However, in contrast to other regions, the challenge is less an absolute shortage of funding than a lack of funding that is sufficiently consistent, stable or long-term to allow PGRFA-related objectives to be achieved. Six countries also report the need to strengthen collaboration and coordination among stakeholders. Several countries report gaps in the development of their national programmes and related legislation: some are non-existent, others need approval or implementation. Similarly, several countries report the need to develop or implement PGRFA strategies and action plans. It is notable that no European countries cite human capacities or infrastructure and technology as gaps or needs.

Oceania
Papua New Guinea reports that commodity institutes have their own national programmes for particular crops. It also indicates that it needs to develop a policy framework for PGRFA, establish a national coordination entity and strengthen human capacities in technology.

5.2.2 Training and education

Most reporting countries indicate that human-resource capacity has increased during the reporting period. As illustrated in Figure 5.3, most countries report that they have some kind of educational or training programme that covers aspects of the management of PGRFA, mainly at graduate and postgraduate levels. However, while PGRFA seem to be increasingly included in educational provision, very few countries have adopted a capacity-building programme specifically dedicated to PGRFA conservation and use, and shortcomings remain in the quality of educational provision. In some countries, programmes and objectives for strengthening technical and institutional capacities in PGRFA conservation and use are developed and implemented in the context of the NBSAPs, for instance in Ecuador, Indonesia, the Republic of Moldova and Sri Lanka.

Figure 5.3. Percentage of countries with different levels of PGRFA-related educational programmes



Note: Based on responses from 90 countries.

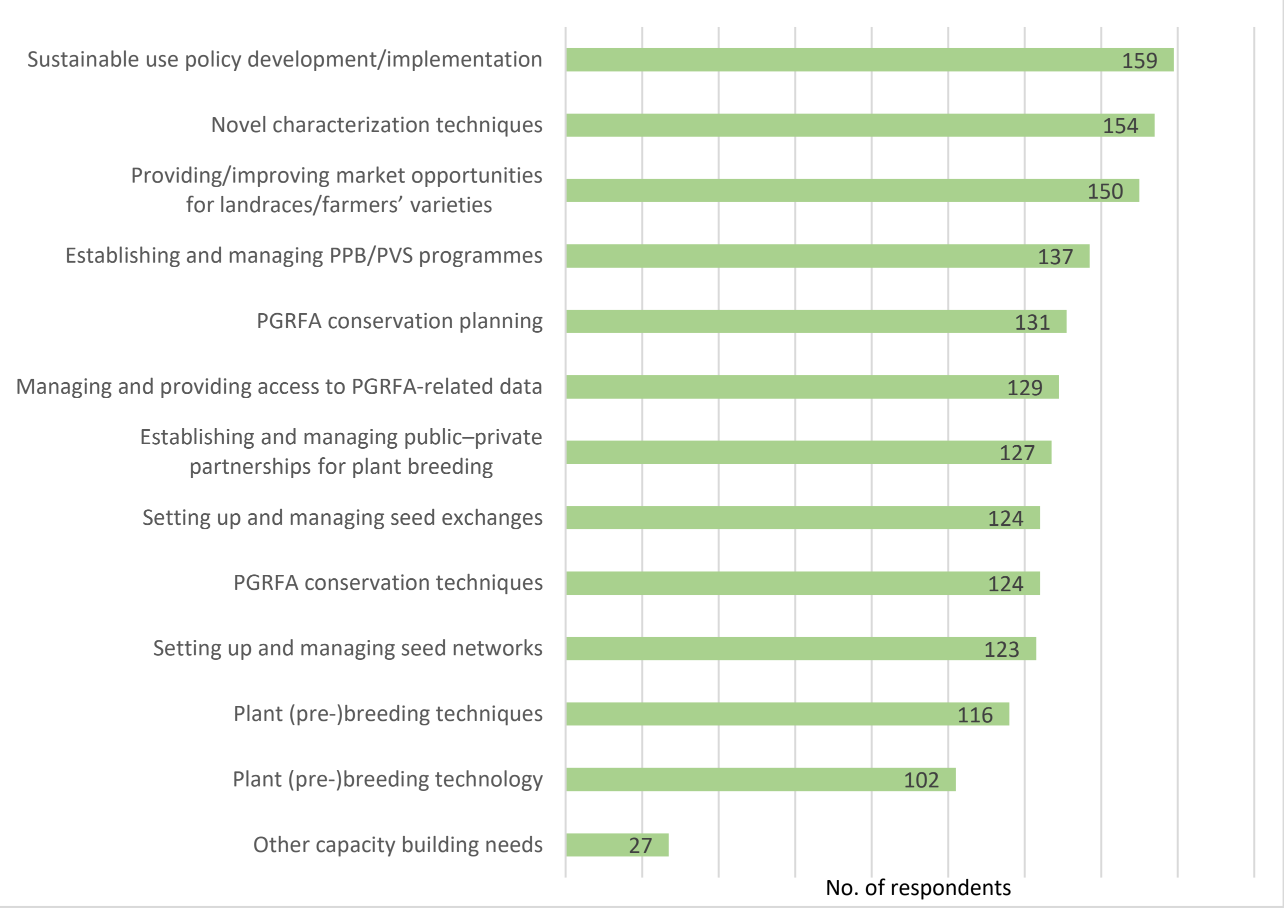
[128] http://www.genresbridge.eu/

Generally speaking, countries indicate that the diversity of actors involved in training and education has been greater during the current reporting period than it was during the reporting period for the SOW2. Universities continue to play a pivotal role in developing and strengthening human-resource capacities, conducting research and development projects on PGRFA conservation and use, and operating vocational agricultural schools that provide practical and hands-on approaches to agricultural studies. In addition to academic and educational institutions, an ever-widening array of actors, including botanic gardens, genebanks, seed networks, research centres and institutes, regional and international organizations, NGOs, foundations, associations and museums, also contribute to the development and strengthening human-resource capacity by offering courses, organizing workshops, events and exhibitions, and promoting the exchange of information and experiences.

Thirty-four out of 79 reporting countries (43 percent) report that greater cooperation among and between academic and educational institutions, seed networks, research centres and institutes, especially with FAO, the CGIAR Centres and regional and international genebanks, has led to the implementation of joint and targeted educational, training and research projects, the organization of scientific and practical seminars and conferences and/or the development of exchange programmes for students and teaching staff. For example, many educational institutions offer a greater range of capacity-building opportunities specifically designed for staff of the national programme and for farmers, local communities, civil servants and extension agents. However, limited financial resources continue to be an important bottleneck in many countries, hindering access to educational and capacity-building programmes. At the same time, the increasing number of online workshops and remote participation in seminars and conferences has contributed to wider distribution of some training opportunities. Additionally, innovative teaching materials, including educational videos and online courses and learning resources, have been developed by a range of actors. For instance, the Secretariat of the Treaty, Bioversity International and UPOV have all developed distance learning courses and training and educational modules.

Reporting countries note there is still a need for greater capacity in education and training and for more professional staff specialized in the different areas of PGRFA conservation and use, and that some important gaps and needs remain to be addressed in educational curricula and training programmes. Some countries also express concern about limited financial support and a lack of facilities for training, including a lack of access to updated technologies and information. Figure 5.4 shows the most important capacity-building needs identified across all regions by a global survey conducted in 2015 by the Secretariat of the Treaty (Kell *et al*., 2017).

Figure 5.4. Capacity-building needs reported by respondents to a survey by the Treaty



Notes: Total number of respondents = 245.
Source: adapted from Kell *et al*. (2017).

Regional differences

Northern Africa
Graduate and/or post-graduate education programmes on subjects that are relevant to PGRFA conservation and use are reported to be in place in Egypt, Morocco, Sudan and Tunisia. Egypt and Sudan report that staff from genebanks and research centres have been trained in various aspects of the conservation and sustainable use of PGRFA, including through workshops organized by the Secretariat of the Treaty between 2014 and 2019 on the use of genetic markers in characterization and plant breeding, information networks and exchange, and the registration of digital object identifiers (DOIs) for information systems. Overall, however, countries' report that undergraduate and general educational programmes need to be improved and that more training is needed on a variety of topics, especially on advanced technologies.

Sub-Saharan Africa
A large majority of reporting countries from sub-Saharan African indicate that their universities offer graduate and/or postgraduate educational programmes in subjects related to genetic resources, with some having introduced these subjects in the past decade, for instance Botswana, Eritrea and Niger. Many countries, including Benin, Ethiopia, Ghana, Madagascar, Mali, South Africa, Zambia and Zimbabwe, mention that these topics are also taught in secondary schools.

A number of countries, including Botswana, Ethiopia, Ghana, Kenya, Nigeria, Togo, Uganda, Zambia and Zimbabwe, report that the number of newly trained graduates in relevant topics at MSc and PhD levels has increased, including among the staff of genebanks and research institutes, and that collaboration among universities, genebanks and research centres has increased. Some report active institutional support for university study, in some cases with international funding (Botswana, Ethiopia, Kenya).

The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM)
As a network of 157 African universities operating in 40 countries, RUFORUM provides a platform for supporting academic exchanges and collaboration partnerships, for promoting linkages with NARS, the private sector and rural communities, and for enhancing postgraduate training and research. In 2012, RUFORUM and the Centre for Agriculture and Bioscience International (CABI) entered into strategic collaboration to strengthen tertiary agricultural education in Africa. Since 2015, RUFORUM has been implementing the Graduate Teaching Assistantship Programme, which aims *inter alia* to: improve the quality of higher education and increase the pool of PhD-level academic staff in African universities; provide opportunities for doctoral research to contribute more directly to African development; strengthen inter-university collaboration in the field of higher education in Africa; and promote staff mobility among RUFORUM member universities and across Africa. In addition, with funding from Carnegie Cooperation of New York, RUFORUM-Carnegie supports doctoral alumni for 24-month postdoctoral fellowships based at member universities in Africa. In the past decade, 334 early-career scientists were supported this way. As of 2021, RUFORUM had supported the training of 2 857 students (608 PhD, 2 010 MSc and 239 undergraduate) and the release of over 300 technologies.

In-house training and participation in short-term training courses on PGRFA issues, including varieties improvement, biosafety and sustainable use, are reported also to have increased in many countries, for instance in Cameroon, Ethiopia, Guinea, Kenya, Madagascar, Mali, Namibia, Senegal, Togo and Zimbabwe.

In Ethiopia, 223 PGRFA professionals had a PhD and 726 had MSc degrees at the end of the reporting period, up from only, two and five, respectively at the beginning. The numbers of Ethiopian PGRFA professionals who had completed short-term training increased from four to 815.

Regional plant breeding and biotechnological capacity was boosted by means of a partnership between research centres at different universities across the region and Cornell University (United States of America), with funding from the Alliance for a Green Revolution in Africa (AGRA). Since its launch in 2013, the African Plant Breeding Academy (AfPBA), an initiative of the African Orphan Crops Consortium (AOCC), has helped 152 plant breeders from 28 African countries to use genomics-assisted approaches in the development of improved crop varieties. The fifth cohort of this intensive six-week course for scientists managing plant breeding programmes finishes in May 2023. Of the 152 scientists trained, 90 percent have PhDs and nearly 40 percent are women. Collectively they are working to improve 125 different crops, 60 of which are African orphan crops. The course is delivered by the University of California, Davis (UC Davis) at the World Agroforestry Centre in Kenya (CIFOR-ICRAF). In January 2023, AfPBA introduced a new course on genome editing in agriculture to fast track the engineering of special traits in food crops.

Despite these developments, important gaps and needs in human-resource capacity remain. Gaps are created, *inter alia*, by shortages of skilled professional and by staff turnover and difficulties in recruiting young people to replace retiring staff. In several countries, no strategy, policy or national programme for building human capacity is in place. A few countries indicate that they have no academic programme with a PGRFA component in place, in some cases because a programme of this kind was discontinued during the reporting period. Where they exist, the PGRFA curricula of educational institutions need to be updated on a continuous basis in the light of new challenges. Lack of financial resources is a key barrier to accessing training and capacity-building programmes in the region.

Northern America

Canada reports that increased interaction between genebanks and research centres has helped to increase the sharing of knowledge and information. The location of one genebank, Plant Gene Resources of Canada, on the campus of the University of Saskatchewan has facilitated regular training of its staff. In-person and remote participation in regional and international meetings and conferences have also strengthened human capacities.

Even though the United States of America did not report on its activities in the field of education and training, its education and training programmes in conservation and use of plant genetic diversity have global outreach. The Plant Breeding Academy at UC Davis, which offers classes in Africa, Asia and Europe, is a postgraduate programme teaching the fundamentals of plant breeding, genetics and statistics. The Distance Education Program in Plant Breeding at the University of Texas A&M is a fully online graduate degree programme in plant breeding that also aims to train future plant breeders worldwide with streamed videos and teleconferencing. Moreover, the GRIN-U collaborative project, developed by the Germplasm Resources Information Network (GRIN) in partnership with the Agricultural Research Service, Colorado State University, Iowa State University and a private contractor, with funding from the USDA National Institute of Food and Agriculture, aims to provide free and open access to educational and training content on PGRFA conservation and use, including visual (videos, virtual tours, podcasts) and printed (e-books, infographics, manuals) materials.[129]

Latin America and the Caribbean

Latin American and the Caribbean reporting countries indicate that, overall, educational and research opportunities in biology and agronomy in the region have greatly increased. New universities and other educational institutions, greater collaboration within and between universities, research centres and extension agencies, at both national and regional levels, and expansion of research activities have reportedly resulted in a greater number of newly trained graduates in relevant topics. Specialized programmes in biodiversity and PGRFA-related topics are reported to have been established at MSc and PhD levels in Brazil, Cuba, Ecuador, Guyana, Mexico and Nicaragua. Vocational schools are also reported to play an important role in the region, for instance in Guyana, where PGRFA-related subjects are taught at the Guyana School of Agriculture, and in Guatemala, where an agrobiodiversity school was established by the Participatory Plant Breeding Program of Mesoamerica in 2016.

Many countries, including Argentina, Brazil, Colombia, Costa Rica, Guatemala, Guyana, Mexico, Nicaragua, Peru, Uruguay and Trinidad and Tobago, report that capacity has been strengthened and/or that the number of qualified personnel involved in PGRFA work has increased over the reporting period. As well as providing in-house training, universities, research institutes, NGOs and other extension services are reported to have given courses and workshops for researchers, managers of community seed banks, producers, farmers, local communities, students, civil servants and NGOs on a broad range of topics, ranging from phenotypic characterization and cryopreservation to participatory plant breeding, seed processing and storage, and legal aspects of the exchange and use of PGRFA. Remote participation has enhanced these training opportunities of this kind.

> **In Costa Rica,** a National Centre Specialized in Organic Agriculture was created by the National Training Institute with the aim of promote organic agriculture. The centre has developed didactic projects and eco-productive systems, including the "Peasant Seed Rescue Classroom" and the Dynamic Bank of Organic Seeds, which runs the House of Seeds project. This project promotes organic agriculture and conserves traditional and ancestral crops, including through the promotion of indigenous and peasant seeds.

Reporting countries from this region also indicate that, alongside formal education, informal institutions such as networks, foundations and social movements have become increasingly important in building and strengthening capacity through exchange of information, workshops, symposia,

[129] https://grin-u.org/

technical meetings and debates. Reported examples include the “Sementes da Paixão” (Seeds of Passion) programme in Brazil and the Salomón Foundation in Costa Rica. A few countries, report that they have no strategy, policy or other type of plan in place at national level for capacity building or that their national policy has not been implemented. Two countries report that they have no PGRFA-related educational programmes. Many countries report that the number of qualified staff at MSc and PhD levels and trained professionals is insufficient and inadequate in a range of areas of PGRFA management. Difficulties in promoting agricultural careers and attracting young professionals are highlighted, as is a lack of financial resources to support education and training.

Asia

All reporting countries in Asia indicate that they have graduate and/or postgraduate educational programmes in subjects related to PGRFA. PGRFA-related subjects are reported to be taught at secondary-school level in Armenia, Azerbaijan, Jordan, Kyrgyzstan and Sri Lanka. Azerbaijan reports that an MSc programme specifically dedicated to the management of PGRFA was established in 2015 at its Genetic Resources Institute (AGRI) and that agreements on joint research activities and staff training were concluded between AGRI and universities . Armenia mentions that modules on agrobiodiversity, PGFRA conservation and other related subjects are included in the agricultural sciences curricula of several of its universities, at both undergraduate and postgraduate levels, with support from the German Agency for International Cooperation. Capacity-building for the conservation and sustainable use of PGRFA is a strategic axis of the country’s National Strategy and Action Plan on Conservation, Protection, Reproduction and Use of Biological Diversity.

Since the Second GPA was adopted, the number staff members at genebanks and research institutions qualified at Bsc, MSc and PhD levels has increased in many of the region’s reporting countries, including Indonesia, Jordan, Lebanon, Mongolia, Nepal, the Philippines, Türkiye, Uzbekistan and Yemen. Countries also report a variety of local and regional training courses and workshops, including online, often organized with the support and collaboration of national, regional and international institutions and other partners. Capacity building in documentation and information systems has been the focus of specific courses, especially upon upgrading to GRIN-Global Community Edition in 2019. Staff members of genebanks and research centres in several reporting countries, including Jordan, Mongolia, the Philippines and Yemen, received training in these areas. However, lack of resources and limited knowledge and expertise among key actors are still challenges in most countries. More staff and higher capacities are needed in many areas of PGRFA management, especially in those involving advanced technologies and those related to policies and legislation. Countries identify the replacement of retiring senior staff and attracting and training young specialists as particularly challenging. The lack of adequate facilities to support research activities is identified as an additional bottleneck. The PGRFA curricula of educational institutions at all levels need to be further developed and updated.

The Genebank Operation Advanced Learning Master Class (GOAL Master Class)[130]

The first GOAL Master Class took place in 2015 in India and gathered participants from national genebanks across Asia Pacific to improve their knowledge and skills in information management, quality control and standard genebank operating procedures. The fifth (and last to date) GOAL Master Class was held in 2019 in Viet Nam and placed particular emphasis on information technology and data management in genebanks. GOAL is supported, *inter alia*, by the Global Crop Diversity Trust (Crop Trust, Bioversity International and the Indian Council of Agricultural Research.

Europe

Many European countries report a significant increase in the number of students studying PGRFA-related topics and personnel working on PGRFA management and that their levels of qualification have increased. Courses and modules specifically dedicated to PGR conservation and use already existed at the beginning of the reporting period and have continued to be taught in a number of

[130] https://www.crawfordfund.org/news/news-genebank-operations-and-advanced-learning-goal-master-class-november-2015/

countries, for instance in Finland, France, Italy, the Netherlands, Norway, Spain, Sweden and Switzerland, with new ones having been established in several countries, including in Albania and the Republic of Moldova. A few countries, including Belarus, France, Spain and Switzerland, report vocational agricultural schools at the secondary level. These schools are reported to train students in a variety of topics including agronomic botany, plant physiology, crop production, seed production and horticulture and to enhance their practical skills at training sites. A few countries also report education on PGRFA-related topics at the primary level, for instance in Belarus where 19 ecological centres for schoolchildren have been established.

In Sweden, the Grogrund Centre created in 2018 at the Swedish University of Agricultural Sciences acts as a knowledge hub for plant breeding. The centre brings together academia and industry to develop the skills needed to ensure access to plant varieties for agricultural and horticultural production throughout the country in accordance with the objectives of the national food strategy. The Grogrund Centre includes a school that promotes research-based education for plant breeding and food-related disciplines.

Countries report that a broader range of online learning materials that offer rich educational resources has been developed. For example, in Finland the Natural Resources Institute has produced innovative teaching and training material freely available on virtual platforms. In France, a Massive Open Online Course (MOOC)[131] with a strong component on PGRFA conservation was created in 2019. In the Kingdom of the Netherlands, Wageningen University's MSc programme on Plant Breeding and Organic Agriculture and its tailor-made professional development courses on PGR conservation and use are available online.

About half the reporting countries from Europe indicate that greater collaboration among national universities and research institutes – often the result of the strategic orientation of national plans and strategies and the institutionalization of capacity building – has enabled students to engage in hands-on activities including, for example, practical studies in botanical gardens and national parks, and to undertake internships at genebanks and other scientific and research institutions. For instance, in the Republic of Moldova, where the NBSAP for 2015 to 2020 aimed, *inter alia*, to "develop programs and on-the-job vocational training in public and private sectors in biodiversity conservation", master's students are directly involved in *in situ* and *ex situ* conservation activities as part of their training programmes. In Belarus, university students take part in field trips to conduct research on species diversity in botanical gardens, national parks and scientific centres. This aligns with Belarus's National Strategy for Conservation and Sustainable Use of PGRFA for 2020–2035 and its Concept of the National Strategy for Sustainable Development for the Period up to 2035, which both stress the need for practice-oriented education and strong cooperation between universities and scientific and research institutions. In some countries, technical and managerial staff of genebanks and research centres are reported to be involved in teaching at various levels, and welcome students in their research projects and activities through internships or graduation education programmes. Countries also report that a variety of training courses and seminars have also taken place with the support of regional and international organizations including FAO and ECPGR. They note that important areas for training include plant breeding, database management and information systems such as GRIN-Global. The role of networks in building human capacities has also become increasingly important, for instance in Spain with the Network of Cultivated Universities.[132]

Despite the positive achievements, countries note that continuous training in all aspects of PGRFA management continues to be needed. Collaboration among the educational, scientific and research institutes that offer training opportunities needs to be developed to improve visibility and better promote such opportunities. Countries also indicate that knowledge transfer at all levels and in all areas related to conservation and use of PGRFA, including in the context of generational turnover, remains an important issue. The loss of knowledge of cultivation practices due to the aging of

[131] https://www.mooc.org
[132] http://universidadescultivadas.org/

knowledgeable producers and professionals and the rural-to-urban migration of young people are reported to require special attention. Countries note that traditional knowledge associated with the conservation and management of PGRFA is particularly at risk with the extinction of locally adapted agricultural landraces and varieties. Opportunities for the staff of agricultural research institutes to pursue further training, including postgraduate education, reportedly still need to be improved. Countries also mention the need to improve informal exchange of information, experiences and expertise, for instance through the organization of yearly multistakeholder seminars. Several countries mention the need for additional funding to enhance training opportunities.

Oceania
Australia reports that educational programmes in subjects related to PGRFA are available at undergraduate and post-graduate levels as well as in secondary schools. Papua New Guinea mentions that the number of staff working at its National Agricultural Research Institute has decreased. Opportunities for the staff of the country's national programme to participate in postgraduate training only exist

5.3 International collaboration

International collaboration is fundamental to achieving the aims and objectives of the Second GPA and other PGRFA-related international instruments, such as the Treaty, not least because of the interdependence of countries with respect to crop germplasm. International collaboration takes different forms, including through PGRFA networks. These networks facilitate the exchange of PGRFA and provide platforms for synergistic collaborations and partnerships that enable the sharing of information, technology transfer, research collaboration, priority setting and the pooling of resources. Promoting and strengthening PGRFA networks is a priority activity area of the Second GPA. Other forms of international collaboration on PGRFA conservation and use include international agreements that set parameters and guide policy, other international initiatives that direct and galvanize action, and funding arrangements that which foster and undergird activity in the PGRFA context. This section considers the state of these various forms of international collaboration.

5.3.1 PGRFA networks

Networks can exist at all scales, can be formal or informal and can provide a wide range of different benefits to their members. Regional or international networks are of particular relevance, as they promote learning across country borders and reflect the high level of interdependence among all countries with respect to PGRFA. However, many countries also report on their intranational networks (local and for subnational regions), indicating the importance that these more local networks play for diverse stakeholders.

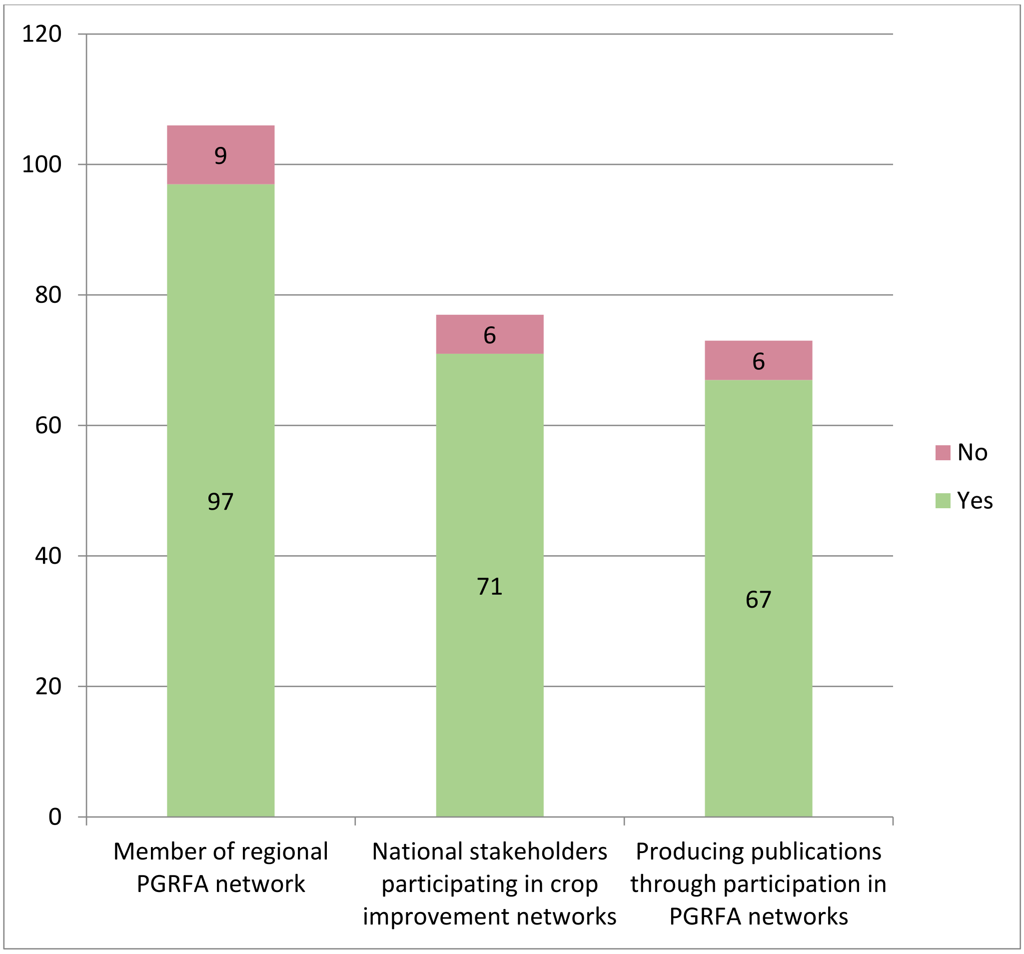
The Second GPA urges countries to participate in regional networks and to assist their national stakeholders to participate in crop-improvement networks at any scale. Networks have remained important hubs of activity and promotion with respect to PGRFA conservation and sustainable use since the publication of the SoW2. While some important regional networks, such as the East African Genetic Resources Network, (EAPGREN), the Genetic Resources Network for West and Central Africa (GRENEWECA), the Cooperative Program on Research and Technology Transfer for the South American Tropics (PROCITROPICOS), the Mesoamerican Network of Plant Genetic Resources (REMERFI) and the Caribbean Plant Genetic Resources Network (CAPGERNET), have had to pause or cease their activities, including due to a lack of financial resources, others have renewed their efforts, for example the Near East and North Africa Plant Genetic Resources Network (NENAPGRN) and the Arab Center for the Studies of Arid Zones and Dry Lands, (ACSAD). Overall, there is consensus that networks of different kinds provide important benefits to members and participants (Box 5.1). However, weakened networks in a number of regions have meant that these important benefits have not been able to be realised for all countries.

Box 5.1. Key benefits of PGRFA networks as reported by countries
The following list presents the benefits reported across all regions in order of the number of mentions received:

(1) knowledge exchange and access to information;
(2) capacity building;
(3) development of new and/or improved varieties;
(4) technology transfer and improved data management;
(5) access to and exchange of genetic materials;
(6) research partnerships and joint project proposals and funding bids;
(7) international collaboration, networking and synergies;
(8) characterization and evaluation work;
(9) increased publications and dissemination;
(10) financial support or savings due to cost effectiveness or resource pooling;
(11) farmer exposure and training;
(12) better project design;
(13) improved strategy development;
(14) enhanced conservation.

The great majority of countries (97 of 106 or 92 percent, see Figure 5.5) report being part of a network. Apart from specific regional PGRFA networks of the kind listed above, countries report being part of, for example, community seed networks and university networks as well as the CGIAR, the Commission on Genetic Resources for Food and Agriculture, the Global Crop Diversity Trust (Crop Trust), the Treaty and the CBD. These latter international organizations and agreements are not usually understood as the kind of research and conservation networks that support crop-specific development and knowledge and are important to the implementation of the Second GPA. However, from the country reports it is clear that membership of, or engagement with, these organizations provides benefits that are considered important.

Figure 5.5. Number of countries participating in international PGRFA networks in different ways



Similar figures hold for the participation of countries' national stakeholders in crop-improvement networks. Ninety-four percent of reporting countries state that at least some of their stakeholders are part of crop-improvement networks – only six out of 77 countries report no network membership among their national stakeholders (see Figure 5.5). Information is reported for a total of 224 stakeholders across 77 countries, with a total of 488 crop-improvement networks cited. Networks are not always named – sometimes reference is just made to individual crops or particular organizations (e.g. CGIAR and the International Union for the Protection of New Varieties of Plants [UPOV]). Botanical Gardens are also mentioned, as are civil society and farmers' seed networks, such as Let's Liberate Diversity and the Peasant Seed Network (Réseau Semences Paysannes). Named networks included, the East and Central Africa Bean Research Network (ECABREN), the International Network for the Genetic Evaluation of Rice (INGER), the Inter-American Citrus Network (IACNET) and many more. The specific stakeholders that were mentioned in country reports include research institutes, sometimes crop-specific institutes, genebanks, universities, ministries or research units within ministries, private-sector companies, and foundations (e.g. ProSpecieRara and SAVE Foundation).

Over 3 730 publications documenting collaborative activities carried out in the context of PGRFA-related networks were reported by at least one stakeholder in 92 percent of reporting countries (67 of 73 countries, see Figure 5.5). Information is reported for a total of 220 stakeholders, 215 of which produced at least one publication of this kind. Even though many scientific publications are cited by reporting countries, not all of them are fully referenced.

Achievements in terms of the promotion and strengthening of networks were reported across all regions. The main achievements are summarized in Table 5.2.

Table 5.2. Achievements reported in the context of strengthening PGRFA networks

Achievement area	Number of countries reporting achievements in this area (out of a total of 79 reporting countries)
Increased participation in networks overall	40 countries report increasing or maintaining their or their stakeholders' participation in international or regional networks, including for crop improvement; a further 7 countries report participating in network-specific working groups or committees; and a further 4 countries report consolidating their national networks
Establishment or support of networks focusing on farmers' varieties/landraces or *in situ* work	8 countries report achievements with respect to supporting networks focused on farmers' varieties/landraces or *in situ* work, often involving the establishment of community seed banks
Development of technology and infrastructure	7 countries reported developing databases, software integration or research infrastructure as contributions to or as a result of their participation in networks

Regional differences

Northern Africa
Egypt, Sudan and Tunisia report achievements with regard to an increase or maintenance of participation in crop improvement networks and PGRFA collaborations.

Sub-Saharan Africa
While the network of Plant Genetic Resources Centres of the Southern African Development Community (SADC) has been active and strengthened since the publication of the SOW2, some regional networks ceased operations over the reporting period (e.g. EAPGREN and GRENEWECA), leaving gaps in the promotion of PGRFA research and conservation activities. Germplasm exchange was not affected by these developments and continued through crop-specific networks.

Many countries in sub-Saharan Africa (including Botswana, Madagascar, Mali, Niger, Zambia, Zimbabwe) report that they increased or maintained their participation in crop-improvement networks during the reporting period. They indicate that they improved their germplasm, their knowledge or their techniques through their involvement in networks, as well as increasing the amount of germplasm conserved *ex situ* and the number of new varieties registered. Countries note that funding for networks is lacking and also report significant shortfalls in human capacity, especially among government staff and in in terms of capacity to write funding proposals. Some countries indicate that crop-specific networks and collaborations need to be established or improved and some explicitly state that the lack of implementation of their PGRFA strategy has hindered progress in the development of networks. A few countries reported that publications produced in the context of networks needed to be increased and improved.

Northern America
Canada reports continued participation in international networks, cooperation with other countries' genebanks and involvement in PGRFA activities at the global scale. It highlights the need for better procedures for reachng international agreements on PGRFA-related matters.

Latin America and the Caribbean
Most countries in this region report that they participate in international or regional networks and that their national networks have been consolidated. Regional networks within countries are also reported to have been further developed – here the Semi-Arid Articulation in Brazil (a grouping of more than 3 000 civil society organization), the Agrobiodiversity Alliance in Colombia, which organizes knowledge and germplasm-exchange events for native and farmers' varieties/landraces, and the network of Meso-American community seed banks stand out as a non-institutional seed-exchange networks.

However, several regional networks are reported to have declined or ceased their activities (e.g. PROCITROPICOS, REMERFI, CAPGERNET), in some cases because of a lack of finances. Consolidation and strengthening of networks at all scales is hence needed. The lack of public funding requires alternative ways of operating, including working with private sector, which presents its own challenges. Weak national systems and a lack of leadership are reported to be bottlenecks constraining improvements to the coordination of existing national networks. Moreover, failures in information sharing mean that there is still a lack of information on national stakeholders' participation in networks. Finally, some countries report that networking is significantly constrained by deficiencies in information technology and internet access.

Asia
Countries across the Asia region report that participation in international networks, involving cooperation with CGIAR Centres and other organisations or countries has increased or remained steady during the reporting period. Several countries (including Bangladesh, Indonesia and Tajikistan) report that the number of publications increased, that databases were created and that infrastructure improved as result of participation in networks. Crop-specific networks or projects are reported to have led to the creation of new varieties. In some cases, countries report that they have revived networks. Attendance of meetings at FAO and the Treaty are highlighted as achievements.

However, countries note that it remains important to further strengthen collaboration between stakeholders in the management of national and international networks, especially for specific needs (e.g. emerging diseases, particular crops, advanced technology). Many countries also mention that a lack of funding is a constraint to participation, specifically high costs for membership of networks. Human-resource capacity is low and information systems and technological infrastructure are inadequate for knowledge exchange.

Europe
Countries across Europe report steady or increased participation in networks during the reporting period, mostly those under the umbrella of the European Cooperative Programme for Plant Genetic

Resources (ECPGR). Several countries (including Albania, Switzerland, Germany, Estonia, Finland, France, Latvia, the Kingdom of the Netherlands and Portugal) stress their membership in network-specific working groups or committees and the development of software integration or research infrastructure as a result of networking activities over the last decade. Networking have also led to the establishment of CWR reserves and to the strengthening of *in situ* conservation work, community seed banks and specially curated genebank collections. Generally, national networks have been promoted and strengthened and funding has been provided.

Despite the progress that has been made, countries note that there is a need to strengthen regional coordination and increase financial support for networking. They point out that because networks are generally based on voluntary work, they tend to be fragile and dependent on project funds. They also note that information sharing needs to be improved and more stakeholders need to be involved. The lack of a regional network on CWR is highlighted as is the lack of a coordinating organization at regional level.

Oceania

Papua New Guinea reports continued participation in international networks and accession to the Treaty as key achievements. The Pacific Agricultural Plant Genetic Resources Network (PAPGREN) continues to support its 27 member countries.

5.3.2 Intergovernmental agreements and initiatives

The importance of crop diversity, CWR and wild food plants to sustainable production, nutritious and sustainable diets, the livelihoods of smallholder farmers and the resilience of agricultural systems' to climate change is increasingly recognized at the international scale. The Treaty (see Section 5) remains the central international agreement providing a framework for the management and exchange of PGRFA. Since the publication of the SoW2, the conservation and sustainable use of PGRFA, along with access and benefit-sharing, have been prioritized by several other international agreements and initiatives (IPBES, 2019). However, many global goals and targets related to safeguarding biodiversity, have not been met within their timeframes, and worries about the state of the world's total biodiversity are mounting (IPBES, 2019).

In this context, a crucial question is how to effectively turn the international agreements into action. Apart from political will, this will require effective institutional support and inclusive processes for devising actionable strategies. Similarly, actors on the ground need to be strengthened, including local governments, civil society organizations, Indigenous Peoples and local communities and their networks, all of which have been at the forefront of crucial and often neglected aspects of GPA implementation.[133] The present section identifies key international agreements and initiatives that have been developed or gained in significance alongside the Treaty since the publication of the SoW2.

Convention on Biological Diversity, biodiversity plans and Aichi Targets

2011 to 2020 was the UN Decade on Biodiversity. The CBD's Strategic Plan for Biodiversity 2011–2020 and its Aichi Targets[134] as well as the Global Strategy for Plant Conservation 2011–2020[135] cemented their focus on cultivated and wild food plants and on CWR.

Aichi Target 13 focused on the maintenance of the genetic diversity of cultivated plants, farmed and domesticated animals and wild relatives. Indicators for assessment included the number of PGRFA conserved *ex situ* and expenditure in the context of genetic conservation. The Global Biodiversity Outlook (GBO) 2020[136] – a periodic report on the state of the world's biodiversity prepared under the CBD – demonstrated that while 74 percent of countries' NBSAPs contained targets related to Aichi Biodiversity Target 13, less than a fifth of countries had set targets similar to (18 percent) or exceeding (1 percent) the scope and level of ambition of the global target. The majority of national targets

[133] https://www.usgs.gov/publications/ipbes-global-assessment-pathways-action
[134] https://www.cbd.int/sp/targets/
[135] https://www.bgci.org/files/Plants2020/GSPCbrochure/gspc_english.pdf
[136] https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf

referred to the conservation of genetic diversity in general but did not consider the specific elements set out in Aichi Target 13. In particular, the conservation of CWR and strategies to minimize their genetic erosion were not included in countries' national targets. While about a third of countries reporting on progress towards their targets to the CBD stated that their national targets were on track to be met (30 percent) or exceeded (5 percent), the majority (49 percent) had made insufficient progress and targets were therefore not met in time. Moreover, almost a fifth (17 percent) reported that they had made no progress at all. Only 8 percent of reporting countries had national targets of similar scope and ambition to Aichi Biodiversity Target 13 and were on track to meet them. According to the GBO 2020, countries reported that the key constraints to reaching this target were biases towards conservation programmes for targeted crop species and a lack of financial and human resources for conservation.

Nagoya Protocol

Having been adopted in 2010, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biodiversity (Nagoya Protocol) entered into force in 2014. While the objectives of both the CBD and the International Treaty are the conservation and sustainable use of genetic resources and the equitable sharing of benefits arising from their use, the access and benefit-sharing (ABS) systems established under these agreements are different: The Treaty establishes a Multilateral System of Access and Benefit-sharing (presented in more detail in Section 5 below), while the Nagoya Protocol creates bilateral mechanisms. Over recent years, cooperation between the secretariat of the two instruments increased and various stakeholders have taken action to support countries in their efforts to improve and harmonize their ABS-related measures.

Harmonious implementation of the Treaty and the Nagoya Protocol has been supported chiefly through the following initiatives developed since the publication of *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*:

- joint capacity building workshops conducted by the secretariats of both international instruments under the Global Environment Facility-funded project for the early entry into force of the Nagoya Protocol (2011–2012);
- a series of "tandem" workshops (2014–2018) that paired focal points of the two international instruments from individual countries to work together on the challenge of ensuring coherence and mutual support;
- a Darwin Initiative-funded project (2015–2018) for mutually supportive implementation in Benin and Madagascar; and
- a "tandem" workshop organized under the UNDP-GEF Global Access and Benefit-sharing Project (2016–2021).

2030 Agenda for Sustainable Development and the Sustainable Development Goals

In 2015 the UN General Assembly adopted the 2030 Agenda for Sustainable Development (Agenda 2030), with its 17 SDG and 169 associated targets. The conservation and sustainable use of PGRFA are addressed under Target 2.5 and Target 15.6.

Target 2.5 (under SDG 2 Zero Hunger) specifically concerns the conservation of genetic diversity, including PGRFA. The plant component of Target 2.5 is monitored by Indicator 2.5.1a, "Number of plant genetic resources for food and agriculture secured in either medium or long-term conservation facilities." SDG 2.5.1.a, which is part of the global indicator framework adopted by the United Nations General Assembly in July 2017[137] to monitor the implementation of the SDG, is a Tier I indicator, i.e. an indicator with an internationally agreed methodology and a global reporting rate equal to or higher than 50 percent. Monitoring of country reporting on SDG 2.5.1a started in 2014 as part of the monitoring of the implementation of the Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture, and since 2016 it has been done on an annual basis. The geographical coverage of the indicator increased from 71 countries in 2014 to 115 in 2021.

Target 15.6 (under SDG 15 Life on Land) concerns the promotion of access to genetic resources and benefit-sharing arising from their use, a key indicator of which is the number of countries that have adopted legislative frameworks to ensure fair and equitable benefit-sharing. The data-collection methods for the indicators refer to countries' efforts in implementing the Treaty and the Nagoya Protocol.[138] In 2021, 67 countries had reported to the Access and Benefit-Sharing Clearing-House of the CBD that they had put in place legislative, administrative and policy frameworks or measures to ensure the fair and equitable sharing of benefits.

According to the *Sustainable Development Report 2022*,[139] cascading and interlinked crises are putting Agenda 2030 in grave danger, along with the very survival of humanity. It notes that there are severe challenges ahead associated with a confluence of crises, dominated by COVID-19, climate change and conflicts. This is creating impacts on PGRFA-relevant matters.

Kunming-Montreal Global Biodiversity Framework

The goals and targets of the Kunming-Montreal Global Biodiversity Framework[140] adopted at the 15th Conference of the Parties to the CBD, held in Montreal, Canada, in December 2022, undergird increased PGRFA-relevant action. The framework is intended to go beyond the CBD and its protocols and to be of relevance to all biodiversity-related international agreements. As shown in Table 5.3, eight targets are associated particularly closely with implementation of the Second GPA.

[137] A/RES/71/313 https://documents-dds-ny.un.org/doc/UNDOC/GEN/N17/207/63/PDF/N1720763.pdf
[138] https://unstats.un.org/SDG/metadata/files/Metadata-15-06-01.pdf
[139] https://unstats.un.org/SDG/report/2022/
[140] https://prod.drupal.www.infra.cbd.int/sites/default/files/2022-12/221222-CBD-PressRelease-COP15-Final.pdf

Table 5.3. Kunming-Montreal Global Biodiversity Framework targets with special relevance to PGRFA

Target	Relevance to PGRFA
4	Target 4 concerns conservation and restoration of genetic diversity, including through *in situ* and *ex situ* conservation and sustainable management practices.
10	Target 10 concerns the sustainable management of areas under agriculture, aquaculture, fisheries and forestry, in particular through the sustainable use of biodiversity.
13	Target 13 concerns facilitated access to genetic resources and associated traditional knowledge and equitable sharing of benefits arising from their use, as well as the use of digital sequence information on genetic resources.
14	Target 14 concerns the integration of biodiversity values into all policies and regulations across all sectors and levels of government and into financial flows.
19	Target 19 concerns increasing financial resources to meet implementation needs.
20	Target 20 concerns strengthening capacity and access to technologies and innovations for biodiversity management.
21	Target 21 concerns the promotion of awareness, education and research to ensure that biodiversity management is guided by relevant knowledge, including the traditional knowledge of Indigenous Peoples and local communities when provided with their free consent.
22	Target 22 concerns full participation in decision-making on biodiversity by Indigenous Peoples and local communities as well as by women and youth and persons with disabilities.

5.3.3 Other international initiatives

Svalbard Global Seed Vault

In 2008, the Government of Norway established the Svalbard Global Seed Vault (SGSV)[141] in Svalbard, in the Arctic Circle, which provides a secure and controlled environment (-18 °C) as a safety backup for *ex situ* collections. The Treaty provides the international legal framework for the seed vault, which is managed by a partnership between the Norwegian Ministry of Agriculture and Food, NordGen and the Crop Trust. As of December 2022, almost 1.2 million seed samples from 93 genebanks located in 70 different countries, and representing about 6 000 plant species, were stored in Svalbard,. Twelve of the current 93 depositors are International Agricultural Research Institutes (IARCs) including CGIAR centres, 73 are national genebanks and universities, two are regional genebanks and five are NGO genebank collections. One of the depositors is a private company that has deposited seeds in cooperation with the Government of Singapore.[142]

CGIAR

Eleven CGIAR centres signed Article 15 agreements with the Governing Body of the Treaty in 2006. Taken together, CGIAR genebanks represent the largest and most widely used collections of crop diversity in the world. As of 31 December 2021, these centres – sometimes referred to as Article 15 institutions – conserved and made available, using the Treaty's standard material transfer agreement (SMTA), a total of 722 525 accessions of crop, tree and forage germplasm. In addition, the centres maintain approximately 17 000 accessions that are not available under the Treaty's multilateral system, as they are maintained under blackbox or other legal conditions that do not allow their distribution with the SMTA. During 15 years of operation within the framework the Internatonal Treaty (January 2007 to December 2021, inclusive), CGIAR centre genebanks and breeding programmes distributed over 6 million PGRFA samples under 61 000 SMTAs.[143]

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[141] https://www.seedvault.no/

[142] Information on depositors obtained via email exchange with NordGen.

[143] Figures on accessions held and distributed are taken from the 2022 CGIAR Report Concerning Centers' Implementation of their Article 15 Agreements, available at https://www.fao.org/3/ni851en/ni851en.pdf

From 2017 to 2021, the CGIAR Genebank Platform, coordinated by the Crop Trust, supported the core activities of the CGIAR genebanks: conserving and making available crop and tree genetic resources by ensuring that the genebanks meet international standards in compliance with the Treaty. In 2019, the CGIAR embarked on a system-wide reform (towards "One CGIAR") with a view to increasing efficiency and effectiveness in response to evolving global challenges. One CGIAR brings all CGIAR centres together under a single, cohesive structure intended to make better use of the centres' capabilities.[144] In the context of this reform, the CGIAR Genebank Initiative, which arose from the former CGIAR Genebank Platform, aims to implement technological advances and institutional measures to continue to improve the *ex situ* conservation of PGRFA globally. Aside from conservation, CGIAR centres also engage in breeding programmes on some of the world's most widely cultivated crops.

Other international agricultural research networks

Alongside the CGIAR, other international agricultural research and innovation networks have made crucial contributions to global efforts to conserve and sustainably use PGRFA. They cannot all be listed herel, but some examples can be provided.

The Association of International Research and Development Centres for Agriculture (AIRCA) groups seven key international agricultural research centres in an alliance focused on increasing global food security through climate-resilient food systems and enhancing the work of individual centres.

Jointly established by FAO, the International Fund for Agricultural Development, the World Bank and the CGIAR in 1996, the Global Forum on Agricultural Research and Innovation (GFAR) unites over 600 partner organizations across several sectors, bringing together scientific research organizations, educational organizations, extension services, development agencies, private sector, and representatives of farmers and civil society. With the aim of enhancing the contribution that agrifood research makes to the achievement of the SDG, GFAR partners advocate for and catalyse multistakeholder programmes of work that include producers and focus on women and youth. GFAR has co-organized three iterations of the Global Conference on Agricultural Research for Development (GCARD) (2010, 2012 and 2015–2016).

Regional agricultural research networks also play crucial roles in advancing knowledge and action in the field of PGRFA conservation and use. The Forum for Agricultural Research in Africa (FARA), which serving as the technical arm of the African Union Commission, coordinates and advocates for agricultural research for development across the Africa and brings together regional associations such as the West and Central African Council for Agricultural Research and Development (CORAF/WECARD), the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA). Since 2010, the African Union programme ABNE (African Biosafety Network of Expertise) has been working with regulators and policymakers across Africa to enhance countries' regulatory systems in the field of biosafety. It also provides technical services to African Union member countries with respect to international agreements, including the Treaty and other agreements discussed above.

Since 1990, the Asia–Pacific Association of Agricultural Research Institutions (APAARI) has been working to catalyse collaborations that strengthen agrifood research and innovation systems for sustainable development in the Asia–Pacific region. APAARI brings together countries, universities, national and international agricultural research centres, civil society organizations and subregional and regional fora – including FARA and the Asia and Pacific Seed Association (APSA).

The Biotechnology Network in Latin America and the Caribbean (REDBIO) promotes the development and use of biotechnology in the region. Founded in 1990 at an FAO meeting, it has been working independently of FAO since 2011 to disseminate knowledge and promote regional cooperation and projects, with a special focus on agricultural innovations. Every three years, REDBIO

[144] https://cgspace.cgiar.org/bitstream/handle/10568/110918/OneCGIAR-Strategy.pdf

organizes scientific conferences, which have gained considerable visibility and consolidated biotechnological research in the region. Moreover, several of the Cooperative Programmes on Research and Technology Transfer under the Interamerican Institute for Cooperation on Agriculture continue to provide considerable support for their members, most notably the Cooperative Program in Research and Technology for the Southern Cone (PROCISUR), the Cooperative Program in Research and Technology for the Northern Region (PROCINORTE), and the Cooperative Program in Research and Technology for the Caribbean (PROCICARIBE).

Non-governmental and civil society organizations and networks at international level

Organizations and networks in the civil society sector have also increased in number and influence since the publication of the SoW2. The Gene Campaign, the ETC Group and GRAIN, all of which were mentioned in the SoW2, have continued and strengthened their PGRFA-related activities over the last decade. Several new actors can be added to this list, as their influence has increased significantly over the last ten years. For example, the international peasant movement La Via Campesina, which is celebrating “30 years of struggle”, has become an increasingly strong voice in international fora, representing its large constituency of smallholder associations, Indigenous Peoples’ organizations and other food-producers’ networks. It has put forward demands for food and seed sovereignty as crucial elements of the realization of Farmers’ Rights and has made the plight of famers’ varieties/landraces more visible. International seed saver networks have also gathered strength and expanded their member bases and work programmes. Notable examples include the Seed Guardians’ Network (Red de Guardianes de Semillas), African Seed Savers, the Peasant Seed Network (Réseau Semences Paysannes) and the Gaia Foundation’s International Seed Network Exchanges initiative, all of which focus on conserving locally adapted and often ancestral or culturally significant crop diversity in farmers’ fields and in community seed banks. The Global Movement for Seed Freedom brings together 67 networks of organizations internationally with a focus on conserving PGRFA for the benefit of all, free from intellectual property restrictions.

Launched at the 2002 World Summit on Sustainable Development in Johannesburg, the programme on Globally Important Agricultural Heritage Systems (GIAHS) covered 67 sites in 22 countries in 2022, with applications for further designations growing. Promoting policies and incentives to support the conservation and sustainable development of GIAHS and their associated landscapes, local cultures and traditional knowledge, the programme aims to enhance the resilience of these important sites, including through a focus on locally adapted PGRFA. It was officially endorsed as a FAO regular programme in 2015.

5.3.4 International funding mechanisms

In 2019, a study commissioned by the Treaty indicated that if funding made available through multilateral organizations, bilateral agreements, public institutions at national level and the private sector is taken into account, global investments in PGRFA activity dimensions (see Table X) range from USD 12 billion to USD 14billion per year. The same study developed a number of scenarios for the successful implementation of the Second GPA and calculated the funding gaps that would need to be covered in order to achieve them were USD 600-700 million per annum approximately (Caracciolo, 2019). A 2015 study by FAO, IFAD and the World Food Programme similarly indicated that USD 977 million (at 2017 prices) in additional rural investment in developing areas would be required per year for activities related to the preservation and improvement of crop genetic resources within a set of activities required in order to sustainably end hunger by 2030 (FAO, IFAD and WFP, 2015). Yet public spending in the context of genetic resources has steadily decreased over the last few decades (Smyth *et al*., 2021), and while private foundations and private-public partnerships have to some extent filled this gap, both national and international initiatives increasingly depend on finding innovative ways of mobilizing resources.

The Crop Trust, established in 2004, remains the pivotal mechanism for providing long-term sustainable funding for the conservation of PGRFA. Its endowment fund has grew from the USD 150 million cited in the SOW2 to USD 340 million at the end of 2022, a considerable achievement that has also led to an increase in the number of genebanks supported by the Crop Trust. Since 2018, the Crop Trust has been funding the International Rice Research Institute (IRRI) in perpetuity through a long-term partnership agreement. Its long-term grants also cover, in perpetuity, a proportion of the conservation costs of 20 internationally important PGRFA collections. Over the last decade, the Crop Trust has also successfully attracted new funding from sources that have not previously been available for work on PGRFA and has placed greater emphasis on supporting national genebanks. However, Crop Trust calculations show that despite the growth of the endowment fund, another USD 500 million are needed to safeguard PGRFA diversity *ex situ* in perpetuity. In order to raise these additional funds, the Crop Trust has since 2021 been working on developing a new financing strategy to increase its income from traditional donors such as national governments and foundations as well as to establish innovative finance mechanisms to attract greater contributions from the private sector and individuals.

Emergency Reserve for Genebanks

Recognizing that genebanks are not indestructible and are just as prone to disasters and catastrophes as other vital infrastructure, the Global Crop Diversity Trust (Crop Trust) and the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture jointly launched the Emergency Reserve for Genebanks in November 2021. While the Crop Trust had previously supported genebanks in emergency situations, for example by contributing to the safeguarding of seeds threatened by the civil war in the Syrian Arab Republic in 2011, providing finance to restore the seed-drying facility of the genebank of the Philippines after it had been damaged by flooding in 2019 and replacing the generator of the genebank of Yemen, the new Emergency Reserve will be the world's first dedicated fund for urgent provision of financial support to genebanks that are under imminent threat from natural disasters, political conflict, pest and disease outbreaks, technological failure or other emergencies. The Governments of Italy and Norway were initial donors.

In 2017, the Governing Body of the Treaty decided to update its Funding Strategy with a view to adopting a programmatic approach that would strengthen linkages between different funding sources and partners relevant to the Treaty by pursuing collaborative planning and co-spending opportunities and identifying and using appropriate channels to make such linkages. The Funding Strategy's overarching aim is to mobilize funds "for priority activities, plans and programmes, in particular in developing countries and countries with economies in transition, and taking the Global Plan of Action into account" (Art 18.3), especially in order to assist farmers to conserve and sustainably use PGRFA. Importantly, since the publication of the SoW2, a funding target of USD 1 billion per year has been established with the objective of ensuring adequate financing for the implementation of the International Treaty and generating funding for its various mechanisms, including its Benefit-sharing Fund. The Benefit-sharing Fund is discussed in more detail in Section 5.5.1. The funding target is intended to allow a high level of implementation to be achieved for all the priority actions of the Second GPA by 2030, and the methodology used to determine the target (Caracciolo, 2019), drew on the monitoring process for the Second GPA, thus strengthening the mutual interrelation between the Treaty and the Second GPA. The Treaty's Funding Strategy furthermore foresees the development of monitoring processes that would involve periodic reviews of financial flows to areas of Treaty implementation. Information derived from such monitoring processes could inform future iterations of *The State of the World's Plant Genetic Resources for Food and Agriculture*.

While quantitative figures were impossible to obtain, the information presented in Table 5.4 indicates the key funding channels and mechanisms that support different areas of PGRFA-related activity.

Table 5.4. Key funding channels and mechanisms supporting different areas of PGRFA activity

Area of activity	Key funding channels and mechanisms
Ex situ conservation	The two international institutions leading efforts in funding *ex situ* conservation are the Crop Trust and the CGIAR. These institutions ensure funding to genebanks at the global level. The World Bank and the Bill and Melinda Gates Foundation are among the key donors to the CGIAR Centres. The Crop Trust is the only institution that has reported specific funding for CGIAR collections and that has a long-term programmatic approach to support these collections. These collections also receive funding from bilateral or regional programmes on a more ad hoc basis. Core funding for national *ex situ* collections comes from national budgets. While there appears to be no leading multilateral channel for the provision of support to national *ex situ* collections, these collections receive funding, on an ad hoc basis, under individual projects through multilateral and bilateral channels.
In situ conservation/ on farm management	There is strong indication that the main multilateral channel through which support flows specifically to *in situ* conservation efforts and crop wild relatives is the Global Environment Facility (GEF). Other actors such as the International Fund for Agricultural Development (IFAD) and the CGIAR contribute to some extent to *in situ* conservation, specifically to research in this field. A wide range of players interface in on-farm management of PGRFA. On-farm management is one of the main priorities of the Treaty's Benefit-sharing Fund, and there are specific GEF programmes supporting this area of activity. GEF projects on biodiversity conservation also promote the *in situ* and on-farm conservation of crop diversity, through awareness raising and capacity building among farmers, Indigenous communities, and local and national institutions. Many IFAD grants focus on on-farm management coupled with crop diversification and market value chains, and the same holds for projects funded by the Green Climate Fund. While the CGIAR may often be seen as a leader in *ex situ* conservation and breeding, a considerable amount of funding has also been channelled through the CGIAR to support on-farm management, especially through aspects of their research programmes (CRPs), which were part of the 2017–2022 portfolio.
Breeding/sustainable use	The CGIAR channels considerable amounts of funding towards the breeding of the crops listed in Annex I of the Treaty. Many regional breeding initiatives have been funded by bilateral programmes or foundations. The World Bank and the regional development banks play significant roles in this context, as does the private sector. Where support for other areas of sustainable use is concerned, crop diversification, markets and seed delivery are frequently included in projects funded by the GEF, the Green Climate Fund, IFAD and the Treaty's Benefit-sharing Fund. The sixth and seventh GEF replenishment cycles included specific objectives for sustainable use. FAO has a long tradition of support for projects focused on seed systems and seed policies,.

Information systems	The main resource partners for PGRFA information systems are FAO, the Crop Trust, the CGIAR, the United States Department of Agriculture and certain donors to the Fund for Agreed Purposes of the Treaty. These are the key entities that contribute financially to maintaining the global information infrastructure, including the systems detailed in Section 5.4.1. The national and regional programmes that contribute data to global systems and manage their own information systems receive funding mainly from national sources. Resource partners for biodiversity information, including information on wild PGRFA occurring *in situ,* are the Global Biodiversity Information Facility (GBIF) and the International Union for Conservation of Nature (IUCN).
Access and benefit-sharing	Funding to support the Treaty's Multilateral System is channelled primarily through (i) the funding provided to the global, regional, and national genebanks that sustain the System, that is mainly through the Crop Trust, the CGIAR and national sources, and (ii) the policy and capacity-building programmes that the CGIAR and the Treaty's Fund for Agreed Purposes support to facilitate developing countries' participation in the Multilateral System. The GEF has financially supported the implementation of the Nagoya Protocol in harmony with the Treaty, as has the United Kingdom's Darwin Initiative. The Treaty's Benefit-sharing Fund is a key channel for sharing monetary benefits arising from the use of materials in the Multilateral System (see Section 5.5.1 for more details).
Farmers' Rights	There are no known funding mechanisms that specifically prioritize Farmers' Rights (Farmers' Rights are discussed in more detail in Section 5.5.2). However, while very limited ad hoc funding is provided by some donors through the Treaty's Fund for Agreed Purposes, on-farm management projects regularly have policy and capacity building components that relate to the implementation of Farmers' Rights.

Note: The information presented draws heavily on a background study conducted in two iterations between 2018 and 2019 by the Secretariat of the International Treaty to inform the process of updating its Funding Strategy.[145]

5.4 Information systems and monitoring mechanisms

For PGRFA diversity to be of use to plant breeders and farmers, information about their characterization and subsequent evaluation is essential. The Second GPA envisions effective information systems for managing data on *ex situ* collections, and on CWR and farmers' varieties conserved *in situ* and on farm, and making these data publicly available, along with as much relevant associated information as possible. New varieties released nationally are also meant to be documented and the data made publicly available. The more stakeholders participate in these information systems by contributing, accessing and exchanging data, the stronger the systems become. Priority Activity Area 15 of the Second GPA focuses on constructing and strengthening comprehensive information systems. Exchange of information is also a key element of the Treaty's Article 17, which requires that contracting parties "cooperate to develop and strengthen a global information system to facilitate the exchange of information."

[145] Appendix 1 of the Report of the Ad Hoc Advisory Committee on the Funding Strategy and Resource Mobilization to the 8th Session of the International Treaty's Governing Body https://www.fao.org/3/na359en/na359en.pdf

The importance of genetic diversity is increasingly being recognised, as is fact that systematic monitoring of this diversity is key to its conservation and sustainable use (Thormann and Engels, 2015). Genetic erosion occurs in farmers' fields and in the wild, as well as in *ex situ* collections.[146] The SoW2 concluded that better techniques and indicators for establishing baselines and monitor trends in genetic diversity were needed. A key objective of the Second GPA is to minimize genetic erosion and its impact on sustainable agriculture through effective monitoring of genetic diversity, the drivers of genetic erosion and the implementation of remedial or preventive actions. Similarly, the need to monitoring genetic diversity has been reflected in the negotiation of the Kunming-Montreal Global Biodiversity Framework.

This section first presents findings on the state of information systems documenting PGRFA *ex situ* and *in situ* and then discusses the state of monitoring mechanisms for genetic erosion.

5.4.1 Information systems for PGRFA

The SoW2 noted that there had been an overall improvement in the accessibility of information since the publication of the first state of the world report. However, there was a significant imbalance between regions and even between countries within regions. Overall, the documentation and characterization of many collections was still inadequate, and in the cases where information did exist it was often difficult to access. The SOW2 concluded that greater efforts to build a functional global system of *ex situ* collections were needed and that this, in turn, required stronger regional and international trust and cooperation. The need for greater standardization of data and data management was also acknowledged.

Since the publication of the SoW2, digital object identifiers (DOIs) and Multi-crop Passport Descriptors (MCPDs) have been adopted and have improved interoperability between different information systems, and this has contributed to a significant increase in data availability. These standards capacity-building activities to promote their use have helped improve the documentation of *ex situ* collections, facilitating access to PGRFA and improving their management and use.

Today, a panoply of PGRFA information systems exist across the world, ranging from pen and paper collection catalogues to web-based platforms that offer (i) digital inventory and management systems for gene banks and (ii) tools that provide interfaces between information systems, whether internal management systems or externally facing platforms for specific users or the public at large. Some of these systems overlap, potentially creating redundancies, while others are converging organically and through structured efforts arising from Article 17 of the Treaty. This section introduces some of the key international information systems for PGRFA.

The Treaty's Global Information System on PGRFA (GLIS)

Following the entry into force of the Treaty in 2004, work has been carried out to implement GLIS[147] under Article 17, which, based on existing information systems, aims to facilitate the exchange of information on scientific, technical and environmental matters related to PGRFA. GLIS provides, in line with its entry-point or platform concept, links to a whole range of different sources of information.

[146] The two previous state of the world reports (FAO, 1998, 2010) defined genetic erosion as "the loss of individual genes and the loss of particular combinations of genes (i.e. of gene complexes) such as those maintained in locally adapted landraces."
[147] https://ssl.fao.org/glis/

Box 5.2. Number of countries participating in international PGRFA Seven objectives of GLIS

1. To create a web-based platform with use-oriented entry points to PGRFA information;
2. To provide a comprehensive overview and facilitate access to sources of PGRFA and associated information;
3. To promote and facilitate interoperability among existing systems by providing clear principles, technical standards and appropriate tools to support their operations in accordance to the principles and rules of the Treaty;
4. To promote transparency on the rights and obligations of users for accessing, sharing and using PGRFA associated information and to establish ways to exercise those rights and obligations within the Global Information System;
5. To create and enhance opportunities for communication and international and multidisciplinary collaboration to increase knowledge about and add value to PGRFA;
6. To provide capacity development and technology transfer opportunities for the conservation, management and use of PGRFA and associated information and knowledge paying special attention to the needs of developing countries;
7. To create a mechanism to assess progress and monitor effectiveness of the Global Information System.[148]

Increasingly, partnerships and connections have been developed between GLIS and the World Information and Early Warning System (WIEWS), Genesys, GRIN-Global, and the European Search Catalogue for Plant Genetic Resources (EURISCO). Linkages with the Convention on Biological Diversity's Clearing House Mechanism and the South African Development Community Plant Genetic Resources Centre's Information System (Web-SDIS) have been strengthened since 2020. Cooperation with the DivSeek International Network, the Global Open Data for Agriculture and Nutrition (GODAN), the CGIAR Platform, as well as the Global Biodiversity Information Facility (GBIF) has also been enhanced.[149]

In addition, easy access to information on seeds and other crop materials for research, training and plant breeding is provided through the development and promotion of the use of DOIs. The first version of the GLIS Portal went online in 2017, allowing users to share information on their PGRFA holdings and to point to information and knowledge available in referenced databases and systems. DOIs were implemented as central elements of GLIS. In May 2022, a total of 1 228 000 accessions had been identified and linked to related datasets in other systems through registration of DOIs on the GLIS Portal. By the end of 2021, DOIs had been assigned to 99 percent of accessions conserved by CGIAR genebanks. In addition, DOIs were increasingly referenced in publications and papers. Further efforts focussed on automated data exchange between Genesys and GLIS databases, and the development, implementation and promotion of standards for the documentation of PGRFA[150]. Examples of these include the MCPD, six strategic sets of characterization and evaluation descriptors for multipurpose tropical fruit tree species conserved *in situ,* and a globally agreed list of Descriptors for CWR conserved *in situ* (CWRI v.1.1).[151]

World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)

WIEWS,[152] established by FAO in 1993 for the preparation of periodic, country-driven global assessments of the status of conservation and use of PGRFA, collects accession-specific data primarily for the purpose of monitoring national, regional and international *ex situ* germplasm collections over defined periods of time. In addition to accession-level data on *ex situ* collections, WIEWS collects and provides detailed information as well as metadata on many matters, such as *in situ* conservation and on

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[148] Governing Body Resolution 3/2015, available at https://www.fao.org/3/a-bl140e.pdf
[149] See also https://www.fao.org/plant-treaty/areas-of-work/global-information-system/en/
[150] https://www.fao.org/3/ni831en/ni831en.pdf
[151] https://www.fao.org/publications/card/en/c/CB0681EN/
[152] https://www.fao.org/wiews/en/

farm management of PGRFA, sustainable use, and the building of institutional and human capacities. It currently constitutes the largest source of data for monitoring the status of the global diversity of PGRFA conserved in genebanks. Since the adoption of the Second GPA, WIEWS provides the platform for the GPA's monitoring and reporting framework. In addition, since December 2016, it serves as platform for reporting annually on the plant component of SDG2, Target 2.5, having, therefore, acquired a new role in the implementation of the 2030 Agenda for Sustainable Development. At the time of writing, WIEWS made available passport information of 5 830 175 accessions conserved *ex situ* by 846 genebanks in 115 countries and 12 international and 5 regional research centres.

Genesys

Genesys[153], a global web platform that provides information on the world's crop diversity conserved in genebanks, has been integrated by GLIS as one of its core services. Genesys publishes passport, characterization and evaluation data, and images of the accessions conserved in genebanks from around the world. It also provides guidance and assistance to genebanks in documenting the data, to make it suitable for publication following agreed standards. Since 2013, Genesys is managed and maintained by the Crop Trust. It continues to evolve as the main PGRFA accession-specific information database, comprising information from both national and CGIAR genebanks. At the end of 2022, it held information from more than 450 genebanks, on more than 4 million accessions, which is estimated to represent around half of all accessions conserved worldwide[154]. Ongoing efforts include increasing the number of genebanks that feed information into the dababase.

Germplasm Resources Information Network (GRIN-Global)

Alongside developments to facilitate data sharing between existing PGRFA information systems, by creating platforms and interfaces between databases within the auspices of the Treaty's Article 17, an Open Source tool called GRIN-Global,[155] continues to be developed. A freely downloadable data management system originally developed by the United States Department of Agriculture and the Crop Trust to improve standardization among genebanks globally, GRIN-Global enables genebanks to store and manage information associated with germplasm and deliver that information globally. The first version of GRIN-Global, released at the end of 2011, was replaced by an improved version 1.9 in November 2015. In 2019, the next generation of the system, GRIN-Global Community Edition, started development, with the aim to bring the community of users together to improve database usability and functionality. As Open Source tool, GRIN-Global has open-ended potential for further development and collective design.

The Global Biodiversity Information Facility (GBIF)

GBIF[156] is an international network and data infrastructure aimed at providing open access to data about all types of life on Earth, established by members of the Organization for Economic Cooperation and Development (OECD). It provides data-holding institutions around the world with common standards, best practices and open-source tools enabling them to share information about where and when species have been recorded. This information derives from different sources, from museum specimens collected in the 18th and 19th century, to DNA barcodes and smartphone photos recorded in recent times. In the context of PGRFA, GBIF is contributing in particular to the documentation of CWR and wild food plants *in situ*.

National implementation of information systems

While progress has been made with regard to the existing global information systems, there has been less improvement of national information systems across the world. In 2022, the Secretariat of the Treaty published a study about bottlenecks and challenges to the implementation of Articles 5 and 6 of the Treaty.[157] Difficulties in obtaining information associated with materials was identified in the study

[153] https://www.genesys-pgr.org/
[154] https://www.croptrust.org/pgrfa-hub/data-and-information-systems/genesys/
[155] https://www.grin-global.org/
[156] https://www.gbif.org/
[157] https://www.fao.org/3/cc2057en/cc2057en.pdf

as an important challenge in all regions, with differences depending on the type of information concerned. As in the SoW2, lack of characterization and evaluation data, especially for minor crops, landraces and CWR was identified as a significant obstacle for PGRFA use. In line with these findings, the present analysis concludes that significant gaps in documentation and information sharing on PGRFA still persist in many countries. Significant differences still exist between regions, and between countries within regions, with regard to their ability to access, manage and disseminate information. Most countries report not having put in place comprehensive information systems for PGRFA. Moreover, in most of the regions there were countries where much of the existing data is still not electronically accessible, and not all existing digital information systems were publicly available. Where multiple information systems existed, there were no single entry points to facilitate access and use of the information. Time and resources were often lacking to maintain and update the existing databases and to keep pace with technological developments, and data standardization remained a major challenge, although the progressive adoption of DOIs promises improvement in this area. Traditional/Indigenous knowledge on PGRFA seemed to be rarely documented and included in the information systems, where they existed.

The rest of this section presents the state of information systems with respect to different kinds of PGRFA data documented.

Ex situ *accession records in information systems*

The increasing number of countries reporting MCPD standardized accession-level data on SDG indicator 2.5.1a (see section 3.2. Intergovernmental agreements and initiatives) reflect progress at country level in documenting and making publicly accessible *ex situ* germplasm holdings. SDG 2.5.1a reporting[158] highlighted that the growth rate of global *ex situ* holdings of PGRFA resumed after a significant abeyance during the COVID-19 pandemic in 2020, which affected genebanks' operations, including germplasm acquisition. At the end of 2021, 5.8 million PGRFA accessions were reportedly conserved in 846 genebanks by 115 countries and 17 regional and international research centres, an increase of 2 percent on the previous year. 321 of these genebanks conserved samples from over 1 815 species listed in the IUCN categories of global major concern.

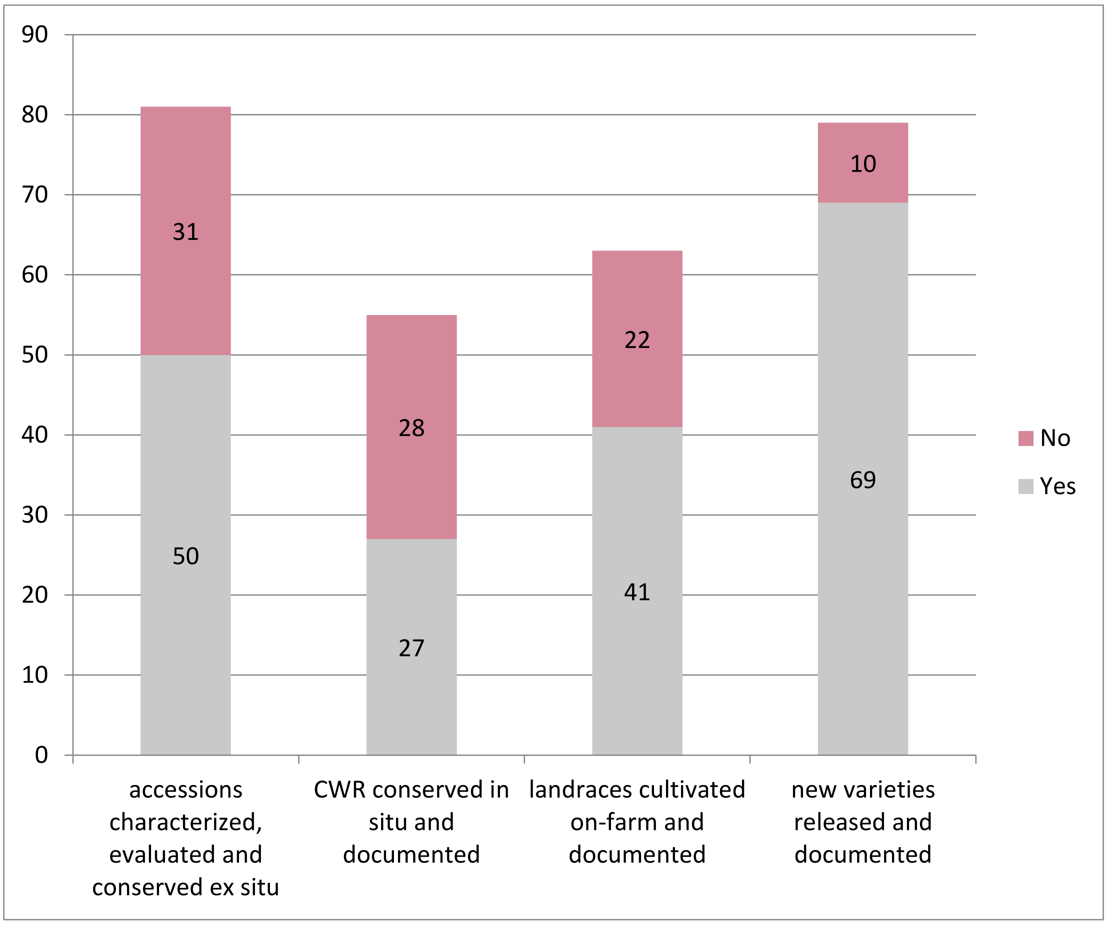
According to the 2021 FAO's progress report on SDG indicators under FAO custodianship[159], and in agreement with the fifth Global Biodiversity Outlook (GBO-5)[160], the diversity of CWR, wild food plants, and neglected and underutilized crop species continued to be under-represented in *ex situ* collections. In line with these findings, the application of an indicator developed to assess the conservation status of nearly 7 000 useful wild plant species found that less than 3 percent of the assessed taxa were sufficiently conserved either through protected areas (*in situ*), or in genebanks or botanic gardens (*ex situ*)[161]. Given that information on the holdings of CWR and wild plant species is likely to be stored in a variety of mechanisms, such as online databases, off-line datasets, or repositories that may not yet be digitized, estimations based exclusively on the reporting of *ex situ* collections, may contribute to an overestimation of gaps. This underlines the importance of comprehensive data sharing beyond digital systems. Nonetheless, even if overestimated, the gaps are of serious concern considering the increasing pressure faced by these species. Moreover, despite the moderate success in increasing the numbers of species and varieties held in genebanks since the publication of the SoW2, accessions could still be at risk of technical failure in *ex situ* settings and require regular regeneration and renewal (IPBES, 2019). Preserving wild populations of food plants *in situ* was, therefore, still considered pivotally important. Farmers, who have developed and maintained crop diversity for millennia, are indispensable partners in the conservation of these PGRFA in particular, as well as in the identification of cultivars adapted to unpredictable climatic conditions.

[158] https://unstats.un.org/SDG/report/2021/extended-report/Goal%20(2)_final.pdf
[159] https://www.fao.org/sdg-progress-report/en/
[160] https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf
[161] https://www.sciencedirect.com/science/article/pii/S1470160X18308781

Duplication of accessions held in genebanks
It is widely recognized that the existence of poor information systems or inconsistent documentation of germplasm results in unintentionally duplicated accessions. In fact, the SoW2 estimated that less than 30 percent of the 7.4 million total number of accessions that existed in *ex situ* conservation facilities worldwide were distinct. A remaining challenge for genebanks around the world is to identify these duplicates while making sure that the duplicates really are identical to prevent genetic diversity loss (Palmé, *et al*., 2020). However, recent developments such as digitalization, next generation sequencing tools, molecular techniques, genomics, and bioinformatics to obtain genotypic information from these accessions may contribute to both help to rationalize the long-term conservation of accessions and the facilitation of its use (Singh *et al*., 2019 ; Engels and Ebert, 2021).
An interesting collective effort to tackle this issue is the European Genebank Integrated System (AEGIS), created under the auspices of ECPGR, which aims at establishing and operating a European collection of unique and important germplasm and to increase conservation efficiency and quality while continuing to facilitate the use of these genetic resources.

Although progress has been achieved since the SoW2, a significant portion of *ex situ* conserved accessions had not been characterized and evaluated for morphological and agronomic traits, or this information had not been properly documented. Where this information existed, it was frequently not available in publicly available databases. In fact, although 81 countries reported having PGRFA documented and to have made that information available in public information systems (see Figure 5.6), the vast majority of the reported information systems were inaccessible when tested in the preparation of this chapter. 31 of 81 countries (38 percent) reported that no characterization and evaluation data of their nationally held accessions were published through an accessible on-line system. Lack of standardization in data collection, storage and dissemination, capacity development on information systems and data management, and lack of coordination among leading stakeholders, were identified as major constraints.

Figure 5.6. Number of countries documenting different types of PGRFA in public information systems



In situ *conservation and documentation of CWR*

Less has been achieved with regard to the geographical distribution of CWR and farmers' varieties/landraces found *in situ*, for which the realisation of systematic *in situ* inventory is particularly needed. This was often constrained by lack of funding, human resources, knowledge and awareness among stakeholders. CWR as well as farmers' varieties/landraces conserved *in situ* were at the time of writing still poorly documented in most reporting countries and, consequently, there were almost no information systems in place for them. As shown in Figure 5.7, 28 of the 55 reporting countries stated that neither did they have any CRW populations conserved *in situ* nor documented in a publicly available information system. In addition, only 18 indicated the percentage of their CWR populations that had been characterized. Of these 18 countries, five stated that none of the CWR populations held by national stakeholders had been characterized, six countries reported percentages under 35 percent, and only the remaining seven countries reported that percentages over 60 percent of these populations had been characterized.

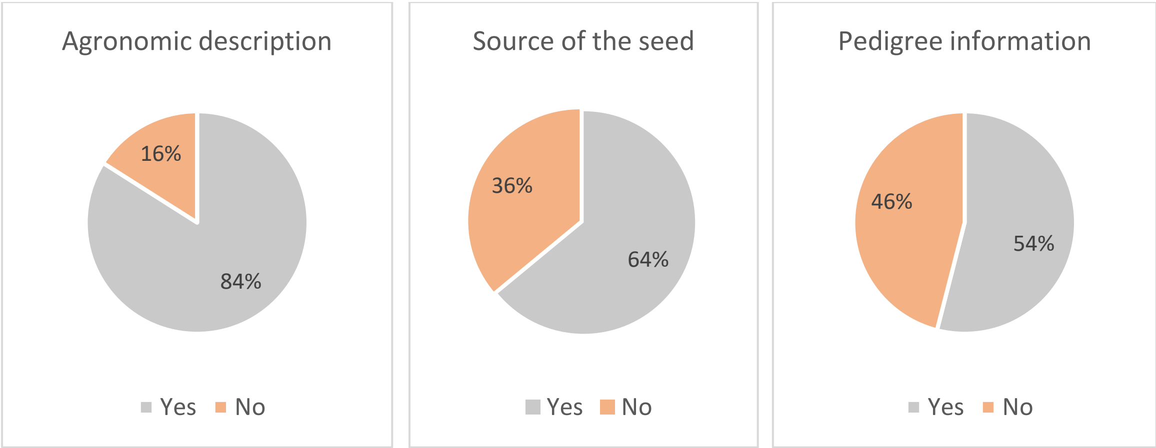
On-farm conservation and documentation of farmers' varieties/landraces

Similarly, as visualised in Figure 5.7, 22 of 63 countries stated that they did not have any farmers' varieties/ landraces cultivated on farm or documented in a publicly available information system. Of the 41 countries which reported to have documentation information of on-farm varieties, only ten stated that 100 percent of these varieties were documented with morphological, agronomic and geographic distribution data.

Documentation of new varieties released

Information made publicly available by countries on varieties released in their jurisdictions differed significantly. While 69 countries reported having released and documented varieties through a formal process, ten countries reported not having done so in the last decade. 54 of the reporting countries provided further details on the kind of information that was published for these varieties: in 84 percent of the cases, released varieties had documentation of their agronomic description, 64 percent documented the source of the seed, with over half of them (54 percent) also including pedigree information (Figure5.7).

Figure 5.7. Percentage of new, released varieties for which different kinds of information was documented



Obtaining and documenting pedigree and other descriptive information of released varieties was reportedly made difficult due to constrains such as lack of regulations; lack of a public information system to document and describe cultivars; insufficient capacity and technical equipment; poor documentation of the released varieties; and insufficient financial and human resources. Pedigree data was also reported to be generally unknown for the varieties received from the nurseries of CGIAR centres or for the materials obtained from other countries. In the case of conventional breeding, information on pedigree was often not shared with database managers. Other major constraints mentioned were lack of integration between conservation and utilization programmes, i.e. between genebanks and breeding programmes, lack of coordination between relevant stakeholders, as well as the challenge to get breeders and scientists to share their pedigree related data and descriptive information of the released varieties.

Contribution of national stakeholders to information systems

Regarding the contribution of national stakeholders to international or regional PGRFA information systems, 78 of 85 countries reported that at least one of their stakeholders had contributed to an international information system, such as ECPGR databases, GBIF (particularly with regard to the monitoring/registration of CWR), and smaller information systems such as the West Indies Sugarcane Breeding and Evaluation Network, although not all of them were publicly available.

Regional differences

Northern Africa
Based on the information provided by the two reporting countries from this region, increased efforts to strengthen the national PGRFA documentation and information systems and to export data to international systems were needed. However, progress was made by the two reporting countries regarding the transfer of data from their, previously offline, national information systems to international information systems, such as Genesys or the *Musa* Genetic Resources Information System. Further efforts to improve the national information systems included, for example, the realization of capacity building trainings on the Agricultural Plant Genetic Resources Conservation and Research Center of Sudan to facilitate access to PGRFA-related information through institutional and international PGRFA information platforms.

Sub-Saharan Africa
Main achievements since the SoW2 in this region included the computerization of existing information systems in countries such as Eritrea, Ethiopia, Ghana, Guinea, Namibia, Nigeria, South Africa and Zambia; an increased number of documented registered varieties (e.g. Kenya); installation of database systems, such as SESTO,[162] BRAHMS[163] or GRIN-Global, or use of Genesys or GBIF (e.g. in Ghana, Kenya and Nigeria); the publication of information via WIEWS; the employment of more staff to support information systems (e.g. Nigeria), and the training of relevant staff (e.g. South Africa). However, none of the 18 reporting countries reported having a comprehensive information system in place for PGRFA. No country reported having an information system in place for CWR or for farmers' varieties/landraces conserved *in situ*. In general, public availability of the information was not the rule. Capacities of stakeholders with regard to PGRFA information systems and data management also needed further strengthening. Consequently, improved coordination on PGRFA information management, financial support and reliable access to internet was considered key needs by several countries.

Northern America
The implementation of a customized version of GRIN-Global, efforts to analyze genetic sequence data and uploading it to public databases and the development of DNA libraries associated molecular catalogues for PGRFA collections were some of the main achievements made by Canada in the last decade. There were no major gaps and needs identified. However, improving the availability of the genetic sequence data and other molecular information related to accessions generated by the PGRFA users was considered of high importance, and the standardization for data from recent "-omics" disciplines was considered an emerging issue. The United States of America did not report on their use of information systems. However, it is worth mentioning here that its Agriculture Research Service has used GRIN-Global to manage its plant germplasm collections, the U.S. National Plant Germplasm System, since November 2015. Indeed, GRIN-Global is an extension of the Germplasm Resources Information Network (GRIN) information management system, which was first developed by the USDA's Agriculture Research Service beginning in the mid-1980s.

Latin America and the Caribbean
As in the other regions, the information systems that existed were mainly focused on PGRFA conserved *ex situ*. Progress made by countries of this region was uneven. Information systems, where they existed, ranged from very basic documentation in spreadsheet tables, to very advanced information systems, such as GRIN-Global. The computerization, development or update of information systems to make the PGRFA related information publicly available were identified as main priorities in the region (e.g. in countries such as Brazil, Colombia and Peru). Data standardization, capacity building and financial support were considered key in this regard. As in other regions, the documentation and monitoring of CRW and farmers' varieties/landraces conserved *in situ* were a precondition for their inclusion in information systems and needed to be strengthened.

[162] The SESTO database system, previously in use by NordGen and the Nordic Baltic Genebanks has now been replaced by GeNBIS, which uses GRIN-Global, see Europe section below.
[163] https://herbaria.plants.ox.ac.uk/bol/

Asia
The progress experienced in the region differed importantly depending on the country. Overall, main achievements since the SoW2 included the digitalization of the existing information systems in countries such as Malaysia and Yemen; the further inclusion of characterization and evaluation data in databases in Azerbaijan; the increased use of modern technologies for PGRFA management by scientists, researchers, curators and genebank managers in Indonesia; the development of web based and mobile applications to facilitate the access to PGRFA-related information in India; the development of databases for CWR and wild food plants in Nepal; and the increased contribution to regional and international information systems such as GRIN Global (e.g. Jordan) or the European Search Catalogue for Plant Genetic Resources (EURISCO) (e.g. Armenia and Azerbaijan). Despite this progress, the need to further strengthen existing systems and to develop information systems for CWR and farmers' varieties/landraces conserved *in situ* was recognized by several countries, for which financial resources, capacity building on information systems management, improved cooperation between stakeholders and standardization of data and characterization and evaluation activities, were identified as major needs.

Europe
In general, most countries had information systems for *ex situ* conservation holdings and, in all but three of the 20 reporting countries, the information was publicly available. However, at the time of reporting, two countries still did not have electronic databases. Specific examples of some of the key achievements experienced in the region included the development of an updated information system (GRIN-Czech) in Czechia for documentation of PGRFA conserved *ex situ*, *in situ* and on farm, the update of the national inventory of PGRFA in Germany, where the database structure was improved and descriptors for the *in situ* and on farm data were developed, and the establishment of a yearly national reporting procedure in Norway, which allows to assess the status and trends on genetic resources for food and agriculture (i.e. animal, forest and plants).

Nordic Baltic Genebanks Information System (GeNBIS)
GeNBIS[38], a database tool gathering all information belonging to the plant genetic resources of the genebanks in the Nordic and Baltic countries (Denmark, Finland, Iceland, Norway, Sweden, Estonia, Latvia and Lithuania), was established in 2020 in replacement of the former database system SESTO. This undertaking represents a major step towards harmonizing documentation of genebank accessions in the Nordic and Baltic regions, as well as globally, as a result of acceding to the 'GRIN-Global community'.

The transfer of information to EURISCO was widespread in the region, and the membership of the countries of the region to the European Cooperative Programme for Plant Genetic Resources (ECPGR) contributed to a certain standardization of the documentation and conservation practices of their genebanks. The ECPGR crop-specific databases provided data about conservation, characterization and use of accessions of specific crops. Most of these databases, however, were not regularly updated.

In the Kingdom of the Netherlands, the CWRnl website (www.cwrnl.nl) was established in 2014. It includes information about 214 taxa, organized in fact sheets, including data on crop relationship, conservation status and distribution. For the 53 CWR included in the Dutch Red List of Threatened Species, expected distribution maps are presented for the year 2070 based on climate change scenarios. In addition, for these CWR, CWRnl presents the occurrence in protected nature reserves and the presence of seed samples in genebanks.
The 'Orange List'[164] list contains around 6 600 agricultural and horticultural varieties (of 63 crops) that were grown from 1850 until the Second World War in the Kingdom of the Netherlands. Since August 2019, Dutch heritage breeds have been earmarked in the Orange List, which also shows where varieties are still commercially available and/or in which genebank they are conserved. About 900 of the varieties included are still commercially available and 1 000 of them are being conserved in genebanks.

While web pages and sites dedicated to CWR had increasingly been developed, there remained significant gaps with regard to the development of information systems for CWR conserved *in situ*. Even greater gaps remained with respect to the documentation and creation of information systems for farmers' varieties/landraces. Main challenges, therefore, continue to be the development of information systems for CWR and farmers' varieties/landraces conserved *in situ*, which, as in the other regions, implies the need to strengthen efforts to document and monitor their occurrence. Improving the coordination between stakeholders, as well as data standardization also remained key needs.

Oceania
No achievement was reported by the only reporting country from this region. Major constraints highlighted were the need to develop a comprehensive information system, to make the information on PGRFA publicly available and to export information to global information systems.

5.4.2 Systems for monitoring and safeguarding genetic diversity and minimizing genetic erosion

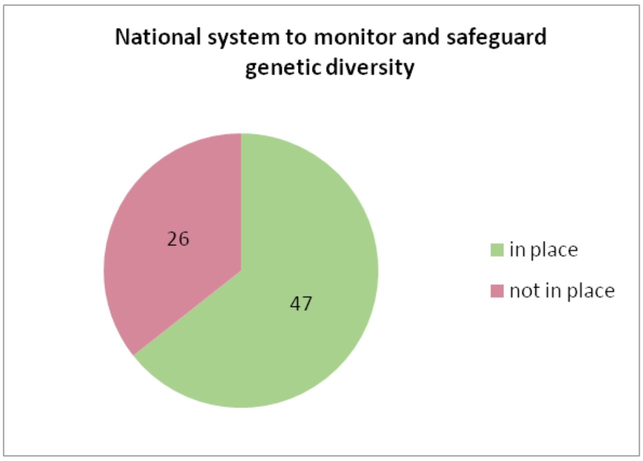
Loss of crop diversity has been discussed for more than a century. At the time of publication of the SoW2, the development of new molecular techniques had already led to an increase of the amount of data available on genetic diversity, which in turn allowed achieving an improved understanding of issues such as domestication, genetic erosion and genetic vulnerability. The SoW2 highlighted that despite the already growing public awareness with regard to the importance of genetic diversity, many country reports expressed continuing concern over the extent of genetic vulnerability and the need for a greater deployment of diversity. Along the same lines, a study published in 2022 reveals that over 95 percent of analyzed scientific papers on PGRFA genetic erosion (published between 1939 and 2021) reported diversity change, and almost 80 percent found evidence of genetic loss (Khoury *et al*., 2022). However, the magnitude, trends, drivers and importance of genetic erosion are not yet sufficiently understood, which constitutes a major constraint for designing measures for effective conservation (Khoury *et al*., 2021). This lack of knowledge has constrained the establishment of baselines, which are required for assessing changes in diversity over time to inform conservation priorities (Thormann *et al*., 2015). In this context, PGRFA monitoring is not only necessary to be able to assess the underlying mechanisms and drivers of genetic erosion, but also to measure their consequences (Leroy *et al*., 2017).

Traditionally, efforts to avoid genetic erosion were mainly focused on surveying and inventorying PGRFA *in situ* and on-farm, collecting and conserving them in *ex situ* facilities, which implies conserving once the damage in the field has already been done. Since the publication of the SoW2, recognition of the benefits of combining *ex situ* and *in situ* conservation efforts have further increased, as has awareness of the need to monitor genetic status and trends of PGRFA diversity to inform policy decisions and PGRFA management. At the end of 2019, almost two thirds of the reporting countries (47 of 73, or 64 percent, see Figure 4.2.1) had in place some sort of national system or mechanism for monitoring and safeguarding genetic diversity and minimizing genetic erosion. National genebanks were mentioned as key players of these mechanisms with their *ex situ* collections and established

[164] http://www.oranjelijst.nl

protocols to monitor sample viability and regenerate the samples when inventory or viability are low. Protected areas and their management also played an important role in safeguarding genetic diversity and minimizing genetic erosion being part of the national system or mechanism. The overall expansion of protected areas observed in the majority of countries has therefore also contributed to enhance conservation of CWR and WFP *in situ*, although most of these protected areas lack specific management plans for these important plant groups.

Figure 4.2.1 Number of countries with systems to monitor and safeguard genetic diversity in place



Nonetheless, despite the efforts conducted worldwide to conserve crop diversity, the State of the World's Biodiversity for Food and Agriculture (FAO, 2019) and the IPBES' Global Assessment Report (2019) clearly showed that the situation for the world's biodiversity, including that of food and agriculture, was still far from optimal. Many diverse local crop varieties have been lost, as has the knowledge associated with their cultivation and use.

Developing biodiversity indicators and other tools to monitor genetic erosion

Several international organizations are working on the development of indicators to enable comparison of current, recent and future biodiversity at the genetic, species and ecosystem levels. Some of these are internationally agreed, like the indicators developed under the FAO's Commission on Genetic Resources, the CBD, the SDG or the IUCN. The Biodiversity Indicators Partnership, which, bringing together 60 organizations, has been working since 2007 to promote and coordinate the development and delivery of biodiversity indicators[165], originally developed under the Commission, for use by the CBD and other biodiversity-related conventions, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the SDG and national and regional agencies. Moreover, the IUCN Red List of Threatened Species is set to increase in importance as a tool to measure progress towards the reduction of genetic erosion of CWR and wild food plants. In 2017, under the IUCN's 'Plants for People' initiative, two species of wild wheat, three species of wild rice, and 17 species of wild yam were added to the list documenting species under threat of extinction (IUCN, 2017). In addition, although not internationally agreed, the Alliance of Bioversity International and CIAT developed an Agrobiodiversity Index[166] that assists measuring genetic diversity, *in situ* and *ex situ*, in production systems, and in markets and people's diets. Moreover, the Group on Earth Observations Biodiversity Observation Network (GEO BON) developed the Essential Biodiversity Variables as a metrics to help aggregate, harmonize, and interpret biodiversity observation data from diverse sources (Hoban *et al*., 2022).

[165] https://ciat.cgiar.org/usefulplants-indicator/
[166] https://www.agrobiodiversityindex.org/

Tools for monitoring and assessing genetic diversity using molecular data are now available to be used for monitoring genetic diversity. Examples of the use of recent advances in molecular technologies include the use of molecular markers to assess diversity and genetic erosion in *ex situ* collections, or analysis of genome-wide genotyping of genebank accessions. However, these technologies are still not affordable and easy enough, so their use is far from widespread (Stephenson, 2020).

Generally, then, in safeguarding the genetic diversity of plants and their wild relatives insufficient progress is noted since the publication of the SoW2. Based on the country reports, countries did monitor, with differences within and between regions, the state of conservation of their PGRFA conserved *ex situ* and, to a lesser extent, *in situ*. However, often, these activities were just part of individual research projects or activities, surveys conducted by individual researchers, or efforts made by NGOs, education or research institutions to monitor the crops being grown in farmers' fields, and did not form part of wider, more comprehensive programmes. Other initiatives undertaken to support monitoring efforts include the development of laws, national strategies and action plans, specific monitoring programmes, establishment of government departments or working groups, improvement and standardization of genebanks' conservation procedures, and the development of catalogues and scientific publications. However, according to the information received in the country reports, the implementation of the GPA objective to minimize genetic erosion through effective monitoring of genetic diversity remained far from being achieved. What is needed, therefore, is greater effort to document the patterns of this diversity, with concomitantly greater participation of local actors, including smallholder and peasant farmers and Indigenous Peoples, who are important agents of *in situ* conservation (IPBES, 2019).

Regional differences

Northern Africa
An example of the achievements made in the region during the reporting period was the development in Tunisia (the only reporting country) of the national register of wild species, called REGNES, which constituted a first nucleus of the Tunisian red list. However, the country did not have a specific system in place for monitoring and safeguarding genetic diversity and minimising genetic erosion. Limited financial and human resources were identified as main constraints.

Sub-Saharan Africa
Similar to the situation during the SoW2, no systematic monitoring of genetic diversity was overall undertaken in the region. However, some of the major achievements experienced by the reporting countries included the organization of more, and more targeted, collecting missions (e.g. Botswana, Ethiopia and Kenya), more and improved documentation, characterization and monitoring of the *ex situ* collections (e.g. Botswana and Ethiopia), endowment of genebanks with the development of biodiversity registers (e.g. Mali), and the development of safety duplicates of new released varieties and the shipment of safety duplicates to the Svalbard Seed Vault (e.g. Nigeria). With respect to crop diversity at farmers' fields, new community seedbanks were established, those that already existed strengthened (e.g. Ethiopia, Mali) and local communities were trained to manage them (Zambia). Seed fairs were organized in countries such as Ethiopia, Kenya, Mali, and Zambia. In Kenya, smallholder farmers were supported with seeds of different plant varieties, and in Mali awareness on the risks of genetic erosion was raised through radio broadcasts in local languages and TV. Moreover, the need to monitor and safeguard genetic diversity and minimizing genetic erosion of PGRFA was included in the draft PGRFA policy and PGRFA National Strategy of Uganda. However, while the awareness of the importance of CWR and wild food plants had overall increased within the region, little collection and characterization work of these species appeared to be done. Major constraints to establish a formal monitoring system for PGRFA and to conduct comprehensive country-wide PGRFA surveys in the region included lack of financial resources, lack of coordination among stakeholders, and lack of comprehensive and harmonized policy and legal frameworks for PGRFA conservation and use, as well as limited capacities and staff.

Northern America
In Canada, tools for monitoring and assessing genetic diversity evolved from classical taxonomy and agri-botanical characterization to molecular assessments. The management of diverse genebank

collections with considerable inter- and intra-accession diversity was reported to be a challenge, and the need to be strategic - when making new material acquisition decisions – was highlighted.

Latin America and the Caribbean
Overall, reporting countries did not have national systems in place for monitoring and safeguarding genetic diversity and minimizing genetic erosion. Still, achievements were reported. For example, in Chile, increased selection, domestication and improvement of CWR and farmers' varieties/landraces had led to the increase of their use and value. In addition, there seemed to be a tendency to innovate with wild food plant species. Cuba reported that the annual SDG2 compliance monitoring of PGRFA and the commitment to submit information to WIEWS had incentivised centres involved in *ex situ* conservation of PGRFA to better monitor the status and viability of their collections.

The majority of reporting countries recognized the need to develop a national monitoring system for PGRFA, as well as the urgency of conducting comprehensive country-wide PGRFA surveys, particularly with regard to CWR. Weak PGRFA coordination structure and lack of indicators for identifying genetic vulnerability in order to develop early warning systems were identified as major constraints.

Asia
Similar to the other regions, none of the 17 reporting countries from Asia, had in place a system for monitoring and safeguarding PGRFA and their wild relatives and for minimizing genetic erosion. However, progress was made in the region to move forward in this regard. For example, Azerbaijan reported the development of a national system to monitor and protect PGRFA diversity and their wild relatives. Also in Azerbaijan, there were improvements in storage condition of *ex situ* collections. In Myanmar, safety duplicates were sent to other genebanks, and in Indonesia, genebanks were established at the local and national levels and the crop breeding programmes were strengthened. Exchange of PGRFA with international/regional partners and/or genebanks to increase crop diversity was reported by countries such as Indonesia and Kyrgyzstan; and in Malaysia and Myanmar, awareness was raised on the importance of genetic diversity among farmers and local communities during collecting missions. In Nepal, at on-farm level, baseline reports were developed for monitoring status of landraces. Similarly, in Türkiye, national inventory studies related to landraces, CWR and other wild plants were conducted.

In situ monitoring, *ex situ* storage of CWR and wild food plants and their inclusion in information systems in the region remained generally limited, although some countries reported to have made significant progress, including the establishment of national parks (e.g. Azerbaijan); increased collection, conservation and availability for use of these resources by farmers and in breeding programs (e.g. Lebanon); development of projects and activities focused on *in situ* conservation and sustainable harvesting; and use, domestication and cultivation of edible and aromatic wild food plants (e.g. Lebanon).

Major gaps and needs in the region included financial resources; development of comprehensive country-wide PGRFA surveys; and indicators for PGRFA monitoring and early warning systems. Absence of national breeding programs that made use of CWR, wild food plants or farmers' varieties/landraces and the inexistence of national regulation encouraging their use posed particular constraints; where these did exist, they were inadequately implemented.

Europe
Two out of the 16 reporting countries reported to consider to have national systems in place for monitoring and safeguarding genetic diversity, yet both of them reported difficulties in effectively implementing them, due to lack of coordination of activities at the national level, limited exchange of information between the relevant institutions, lack of data integration, and insufficient monitoring.

German Network of Genetic Reserves
Established in 2019, under the Federal Office for Agriculture and Food, the German Network of Genetic Reserves coordinates existing and future CWR conservation

measures. It consists of sub-networks for priority CWR, such as wild celery, wild grapevine and grasslands, which are coordinated by specialist agencies. The network facilitates regular and targeted monitoring of CWR.

Progress made in the region included improved reporting of field collections (e.g. Norway); strengthened capacity for long term storage in *ex situ* collections (Poland); improved coordination and information sharing between stakeholders; and publication of catalogues and/or inventories of farmers' varieties/landraces, and/or of accessions conserved *ex situ* (Switzerland). Yet, major needs remain, particularly in terms of strengthening monitoring efforts and conducting country-wide PGRFA surveys. Insufficient financial resources were a constraint.

European Search Catalogue for Plant Genetic Resources (EURISCO) for CWR
In 2021, initial discussions regarding a possible extension of EURISCO for CWR *in situ* data commenced within the framework of ECPGR. It was expected that such extension would adopt the Descriptors for Crop Wild Relatives (CWRI v.1.1),[167] published in 2021. If accomplished, this development would contribute to the harmonization and systematization of the monitoring and information sharing with regard to CWR in the region.

Oceania
No achievements or changes were experienced by the only reporting country of this region. The major constraint identified was the lack of a national policy and strategic framework to coordinate the conservation, management and use of PGRFA across sectors, organizations, and government agencies.

5.5 Multilateral access to plant genetic resources, the sharing of benefits arising out of their utilization and the realization of Farmers' Rights

Access to germplasm for enhanced conservation and sustainable use is fundamental to the achievement of the objectives of the Second GPA. Yet for considerations of justice and equity, such access to genetic resources also needs to lead to the sharing of benefits arising from their use.

The Treaty on PGRFA remains the central international instrument governing the conservation and sustainable use of PGR germplasm, as well as access and benefit-sharing in this context. As of 1 January 2023 the Treaty counts with 150 Contracting Parties including the European Union, up from 127 in 2011, when the last State of the World was published. Of particular note in this context are the ratifications by the United States of America, Japan and Argentina, all of which boast important PGRFA collections. Contracting Parties are still unevenly distributed across the regions. It not only promotes and facilitates the conservation and sustainable use of PGRFA (Articles 5 and 6), but also recognizes the "enormous contribution" of farmers to the diversity of crops that feed the world (Article 9), and it establishes a global system that provides facilitated access to plant genetic materials, and simultaneously ensures that recipients share the benefits they derive from the use of these (Articles 10-13). The Treaty's Funding Strategy (Article 18) has been described under section 3.4 above.

The Treaty and the GPA are closely interrelated and mutually reinforcing.[168] Article 14 of the Treaty recognizes the importance of the rolling GPA and calls upon Contracting Parties to "promote its effective implementation". Furthermore, Article 17.3 of the Treaty provides that "Contracting Parties shall cooperate with the Commission on Genetic Resources for Food and Agriculture of the FAO in its periodic reassessment of the state of the world's PGRFA in order to facilitate the updating of the rolling GPA". In its turn, the GPA is an important mechanism for the effective implementation of the Treaty's objectives.

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[167] https://www.fao.org/3/cb3256en/cb3256en.pdf
[168] The FAO's CGRFA counts with 179 Members and the EU. 145 of these are also Contracting Parties of the International Treaty.

Assessing achievements in the implementation of the Treaty is an important aspect of assessing the state of the world's PGRFA. This section focuses on two aspects of pivotal relevance to the achievement of the objectives of the GPA: the Treaty's Multilateral System of Access and Benefit-sharing and Farmers' Rights, from the point of view of human and institutional capacities.

5.5.1 Access and Benefit-sharing

Although the Treaty applies to the access to, and conservation and use of all PGRFA, it has established the Multilateral System, a special regime of facilitated access for currently 35 food crops and 29 forages which are listed in its Annex 1. The Multilateral System considers the materials in Annex 1 as part of a common pool shared by Contracting Parties and the entities under their jurisdiction, and makes these available without any other condition for access apart from those included in the Standard Material Transfer Agreement (SMTA). The Multilateral System and its SMTA facilitate the exchange of the genetic resources of these crops without the need for complex bilateral negotiations, as is currently still the case under the CBD's Nagoya Protocol (see also section 3.2 above). It also provides for benefits arising from the use of these common pool resources to be shared, including via the Treaty's Benefit-sharing Fund, not least as a form of compensation of the intergenerational work of farmers in creating crop diversity (Girard, and Frison, eds., 2018; Halewood and Nnadozie, 2008; Moeller, 2021).

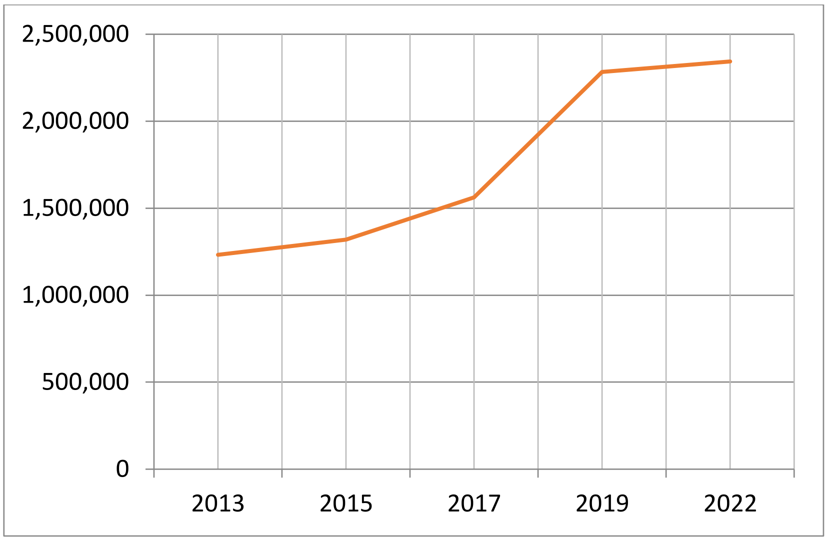
Facilitated access to *ex situ* collections

The Multilateral System, and the facilitated access to crop germplasm which it provides, are understood by the Treaty as a benefit in itself that is shared between all Contracting Parties, user organizations under their jurisdiction, and beyond. Since the coming into force of the Treaty in 2004, and increasingly since the publication of the SoW2, more and more non-Annex 1 accessions have been released under SMTAs. Several Contracting Parties to the Treaty have as an independent policy decision issued non-*Annex 1* accessions in their holdings under SMTAs. Many national and regional genebanks now make all their PGRFA available under the terms and conditions of the SMTA, indicating that, overall, access has been enhanced in the decade since the publication of the last SoW. In 2017, the United States of America also decided to add approximately 500 000 samples of 15 000 varieties of PGRFA into the Multilateral System, available under an SMTA, significantly increasing the pool of shared germplasm that is accessible via the rules of the Multilateral System. The development of the SMTA generation and reporting mechanism EasySMTA[169] has also facilitated access since the publication of the SoW2.

Data from 2022 shows that total materials available in the Multilateral System amounted to 2 343 549.[170] This represents an increase of almost 3 percent from 2019 figures, which amounted to a total of 2 283 001,[171] which in turn represented an increase of over 46 percent from data published in 2017 which amounted to a total of 1 561 638.[172] This is an increase of almost 18 percent from 2015 figures, which indicate that 1 319 099 accessions were available at that time,[173] representing an increase of over 7 percent from 2013 figures which indicate that 1 232 173 materials were available in the Multilateral System.[174] As shown in 5.9, The Multilateral System has grown significantly since publication of the SoW2. The reduced rate of growth of the last biennium is likely to have been caused, amongst other things, by the disruptions caused by the COVID pandemic. In some national contexts, pandemic restrictions also complicated distribution of germplasm from genebanks during 2020 and 2021.

[169] EasySMTA can be accessed via https://mls.planttreaty.org/itt/index.php
[170] See the Report on Implementation and Operations of the Multilateral System to the 9th Session of the Governing Body, available at https://www.fao.org/3/ni825en/ni825en.pdf
[171] Report to the 8th Session of the Governing Body: https://www.fao.org/3/na911en/na911en.pdf
[172] Report to 7th Session of the Governing Body: https://www.fao.org/3/bs796e/bs796e.pdf
[173] Report to the 6th Session of the Governing Body: https://www.fao.org/3/mo510e/mo510e.pdf
[174] Report to the 5th Session of the Governing Body: https://www.fao.org/3/be561e/be561e.pdf

Figure 5.9. Number of accessions available in the Multilateral System (by year)



However, having said this, it is also important to point out that the lack of availability of *Annex 1* material held by a number of Contracting Parties to the Treaty hampers the functioning of the Multilateral System.

Germplasm Exchange

Information on germplasm movement constitutes a good indicator of the extent to which PGRFA are being used and exchanged globally, and thereby helps evaluate how access to PGRFA is being promoted and facilitated. Germplasm movement involves exchange between genebanks, acquisitions by genebanks from research and breeding programs, and distributions to plant breeders, researchers and farmers. According to the Secretariat of the Treaty[175], there has been a steady increase in the reporting of SMTAs for the period 2007-2020, based on the total number of SMTAs reported per year. As of mid-June 2022, the total amount of Multilateral System material transferred since 2007 was 6 396 485, under a total of 90 688 SMTAs[176]. From the total amount of materials transferred under SMTAs, 11 percent was distributed by the Plant Treaty's Contracting Parties, 89 percent by Article 15 institutions (CGIAR Centres), and almost 25 500 items of PGRFA were distributed by providers in countries that are not Contracting Parties. These figures are indications of the extent to which users are accessing, and thereby benefiting from, PGRFA for research, breeding and training. For more information see the Thematic Background Study on Germplasm Exchange (Khoury, 2023) and the Chapter on *Ex situ* conservation.

National ABS legislation

Data from reporting to SDG Target 15.6[177] shows that 39 countries have measures on access and benefit-sharing in place for both the Nagoya Protocol and the Treaty. While this indicates moderate progress in terms of developing policy and legislative measures, it does not provide much evidence in terms of effective implementation or impact of such implementation. In this context, it is important to point out that new indicators for ABS are being developed in the context of the Kunming-Montreal Global Biodiversity Framework, which provides the opportunity to improve monitoring and evaluation of ABS activities and enhance the mutually supportive implementation of the two access and benefit-sharing instruments.

[175] https://www.fao.org/3/ni825en/ni825en.pdf
[176] https://www.fao.org/3/ni825en/ni825en.pdf
[177] Target 15.6: Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed. Indicator 15.6.1: Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits

Some countries have reported delays in legislative processes and in the implementation of other activities due to the COVID-19 pandemic, and this could have contributed to delays in progress towards SDG target 15.6 for these countries.[178]

With respect to national implementation of the Treaty and its Multilateral System, countries' efforts have continued during the last decade in the shape of coordination, networking and policy-making (FAO, 2021). It is not necessary to adopt new laws, regulations or policies at national level for the national implementation of the provisions of either the Treaty or of its MLS. One model for national implementation of the Treaty is hence to use or strengthen existing legislative and regulatory frameworks. This works particularly well in countries where existing institutions with well-defined mandates contribute to the Multilateral System by continuing their normal practices (e.g. genebanks with discretion to distribute PGRFA freely). Another model for implementation of the Treaty and its Multilateral System is to develop new or amend existing legal measures in order to establish clear procedures for their day-to-day implementation, to identify the corresponding competent national authorities and their respective responsibilities, and to ensure harmonious implementation of both the Treaty and the Nagoya Protocol.

Examples of legal measures or national legislation put in place during the last decade for implementation of the Treaty (FAO, 2021) include:
• the approval in Spain of the Decree 429/2020, of 3 March, that regulates access to PGRFA and cultivated plants taking into account the provisions of both the Treaty and the Nagoya Protocol;
• an implementation strategy and action plan for the implementation of the Treaty and its MLS between 2015–2020 in Nepal;
• a dedicated law to support implementation of the Treaty in Lebanon, and concomitant establishment of a National Plant Genetic Resources Committee under the Ministry of Agriculture (Decision 394, 12/05/2014).

The Access and Benefit-sharing Clearing-House (ABS Clearing-House) is a platform for exchanging information on access and benefit-sharing established by Article 14 of the Nagoya Protocol, as part of clearing-house mechanism under Article 18 of the CBD.[179] The ABS Clearing-House was designed with the objective to assist users in finding information on how to access genetic resources and associated traditional knowledge; as well as to providers in receiving information related to the utilization of their genetic resources once they leave the provider country's jurisdiction. As more countries ratify and implement the Nagoya Protocol and, as a consequence, as countries revise or replace their existing ABS laws to reflect their commitments under the Nagoya Protocol, the contribution of the ABS Clearing-House facilitating users information about the rules and regulations that are to apply to access to genetic resources in compliance with national regulations can only increase. When it comes to PGRFA, this is particularly important when accessing PGRFA that are not available through the Treaty's MLS.

Benefit-sharing

Under certain conditions of use – namely if Multilateral System materials are incorporated into a commercial plant variety as part of its parentage – monetary benefit-sharing obligations are triggered through the provisions of the SMTA. However, as long as the commercial plant variety remains available for further breeding (e.g. when its intellectual property protection allows for a breeders' exemption), monetary benefit-sharing remains voluntary. Since its inception, the Benefit-sharing Fund of the Treaty has only received few mandatory benefit-sharing payments, totalling over USD 390 000 as of February 2023. While it needs to be highlighted that all of these payments were made in the decade since the publication of the SoW2, the great majority of all finance to the Benefit-sharing Fund

[178] https://unstats.un.org/SDG/report/2022/extended-report/Extended-Report_Goal-15.pdf
[179] https://absch.cbd.int/en/

consists of voluntary contributions from Contracting Parties and international institutions, as well as the private sector. This is particularly significant given that it is estimated that more than 1 000 material transfers occur daily via SMTAs.[180] As of November 2022, 67 projects have been funded with the resources from the Benefit-sharing Fund over a total of four project cycles, translating into approximately USD30 million (mostly, as explained, from voluntary contributions, and including over USD 1 million by the private sector).

The compensatory function of the MLS – its monetary benefit-sharing provisions – has hence come increasingly under question since the publication of SoW2 (Frison, Lopez and Esquinas-Alcazar, 2011; Girard and Frison, 2018: Moeller and Stannard, 2013; Wynberg *et al*., 2021). Since 2013, a process to enhance the functioning of the Multilateral System has been conducted under the Treaty. The Working Group which was tasked with developing proposals to this end discussed different measures, until it was suspended in 2019. These measures included the expansion of Annex 1 to include more or even all PGRFA in the Multilateral System, as well as the revision of the SMTA to create a de facto subscription system, and to make all benefit-sharing payments mandatory. Due to a number of disagreements, including on the question of whether the use of digital sequence information (DSI) associated with MLS material should also trigger benefit-sharing obligations, no decisions on the enhancement of the MLS had been taken at the time of writing. However, with negotiations having been relaunched at the 9th session of the Governing Body in September 2022, renewed progress on the enhancement of the Multilateral System is possible.

Aside from providing for monetary benefit-sharing, the Treaty also urges the recipients of material from the Multilateral System to share non-monetary benefits resulting from research and development carried out on the material through "the exchange of information, access to and transfer of technology, [and] capacity-building" (Art 13.2).

Digital sequence information

Since the publication of the SoW2, DSI has increased exponentially in significance in the plant sciences and associated engineering and technologies, and specifically plant breeding.

> **Digital sequence information** (DSI) is an umbrella term that refers to digital information on genetic resources, such as genetic sequence data. DNA sequences, RNA sequences, and protein sequences, as well as metadata, annotations and related information can all come under the term DSI, all of which are held in databases around the world from which they can be downloaded. As its precise meaning and scope are still being debated, the term 'DSI' is currently used as a placeholder until agreement is reached.

The implications of DSI are currently being discussed in the context of the Treaty, the FAO's CGRFA, the CBD and its Nagoya Protocol and other fora. Positions diverge, sometimes sharply, on whether DSI should be included in the access and benefit-sharing provisions of these agreements. The main concern regarding DSI is that it represents information available online which, due to technological advances, can substitute the use of the physical, biological material it relates to. That is to say that certain research and development can be conducted, and commercially exploited, purely on the basis of accessing and processing DSI, thereby circumventing the need for accessing the physical material at all. Circumventing material access currently also means circumventing the benefit-sharing obligations which go hand in hand with this access.

While DSI is playing increasingly important roles in taxonomy, and thereby conservation management, the tracking of threatened species, and prevention of illegal trade, its chief use lies in genetic engineering and molecular recombination technologies. Given the economic value of these technological sciences, DSI is understood to potentially catalyse enormous monetary benefits for organizations with the capacity to exploit these sciences, whereas the societal and environmental

[180] See the report to the 8th Session of the Governing Body: https://www.fao.org/3/na911en/na911en.pdf

benefits created by them are heavily contested, and developments may increase existing power asymmetries.

Millions of genetic data sequences are submitted to open access databases every year, and can be easily shared and replicated. Therein lies the value of DSI, which is accrued through the processing of high volumes of digital data by multiple users in multiple iterations. Tracing its origin, uses and transformations along value chains is complex if not impossible. Because the absence of specific provisions relating to the use of DSI in the Treaty or the CBD could lead to a loss of monetary and non-monetary benefit-sharing potential in a world in which genetic information plays an increasingly pivotal economic role, the Kunming-Montreal Global Biodiversity Framework now clarifies the need to ensure the sharing of benefits that arise from the utilization of genetic resources and from DSI on genetic resources, in its Target 13.

However, it is also feared that new benefit sharing mechanisms may hinder crop research. Given that this data is commonly available via open access platforms, many crop researchers take this access for granted and have built their work on the premise of accessibility. It has hence been suggested that if not fully open, at least multilateral systems of exchange might retain the important benefits of DSI for scientists and managers of genetic resources (ITPGRFA, 2022; Brink and van Hintum, 2021; Cowell *et al*., 2021). However, crucially, the capacity to make use of and benefit from the growing and complicated datasets available varies significantly across institutions, countries and regions. Capacity building is hence critical to allow for the wide and equitable enjoyment of the benefits of DSI (ITPGRFA, 2022; Cowell *et al*., 2021. Rohden *et al*., 2020; De Jonge, Salazar, and Visser, 2021).

5.5.2 Realisation of Farmers' Rights

In addition to establishing the Multilateral System, the Treaty is the first legally binding international instrument to have promoted Farmers' Rights and recognizes the importance of farmers in conservation, selection and development of new crop varieties. As set out in its Article 9, the Treaty calls on its member countries to implement appropriate measures to recognize and protect Farmers' Rights through the protection of traditional knowledge, the right of farmers to equitably share in the benefits that result from the use of PGRFA and to participate in making decisions on matters related to the conservation and sustainable use of these resources.

Farmers' Rights, first brought onto the international agenda by civil society organizations in the 1980s (for example, see Mooney, 1983), have their origin in the asymmetric distribution of benefits between farmers as providers of PGRFA and commercial plant breeders who generate returns on the basis of such PGRFA. Central here is hence a question of recognition and economic compensation – which the Treaty aims to address through its system of benefit-sharing.

Another aspect of Farmers' Rights concerns traditional practices of saving, using, exchanging and selling farm-saved seed. Intellectual property rights can restrict these practices. In this sense, and since the 1991 revision of the International Convention for the Protection of New Varieties of Plants (UPOV Convention), breeders can restrict the use of the seed they develop, and prevent farmers from saving seed, unless an (optional) exception is established in national law. This means that farmers can face sanctions for practising traditional aspects of their work in countries that have adopted the 1991 version of the UPOV Convention (Dutfield, 2011).

Some progress with respect to global processes in the area of Farmers' Rights has been achieved since the publication of the SoW2. In 2016, the governments of Indonesia and Norway co-hosted the Global Consultation on Farmers' Rights, in Indonesia, as a response to the invitation of the Governing Body of the Treaty through Resolution 5/2015.[181] This consultation brought together 95 participants from 37 countries across the world.[182] In 2017, the Governing Body established the Ad Hoc Technical Expert Group on Farmers' Rights. This represented a milestone in the discussions on Farmers' Rights. The group was created with the mandate to produce an *inventory* of national measures, best practices and

[181] https://www.fao.org/3/bl144e/bl144e.pdf
[182] For proceedings, see https://www.fao.org/3/bt110e/bt110e.pdf

lessons learned from the realization of Farmers' Rights; and based on the inventory, to develop *options* for encouraging, guiding and promoting the realization of Farmers' Rights. The Inventory is based on the submissions received by Contracting Parties and relevant stakeholders, especially farmers' organizations. It reflects the range of measures and practices that have been submitted. The Inventory, to be updated on a regular basis, was first presented at the 8th meeting of the Governing Body in November 2019, when it was also decided to establish an online version of it.[183] The group was then reconvened to continue to work on the Options, which were finalised in 2022. Both the Inventory and the Options are organized using the same set of 11 categories (see Table 5.5). By the end of 2022, the Inventory contained a total of 232 records. Further work on this topic will include the organization of an international symposium on Farmers' Rights in India in September 2023.[184]

Table 5.5. Number of national measures on Farmers' Rights, by category, as documented in the Inventory

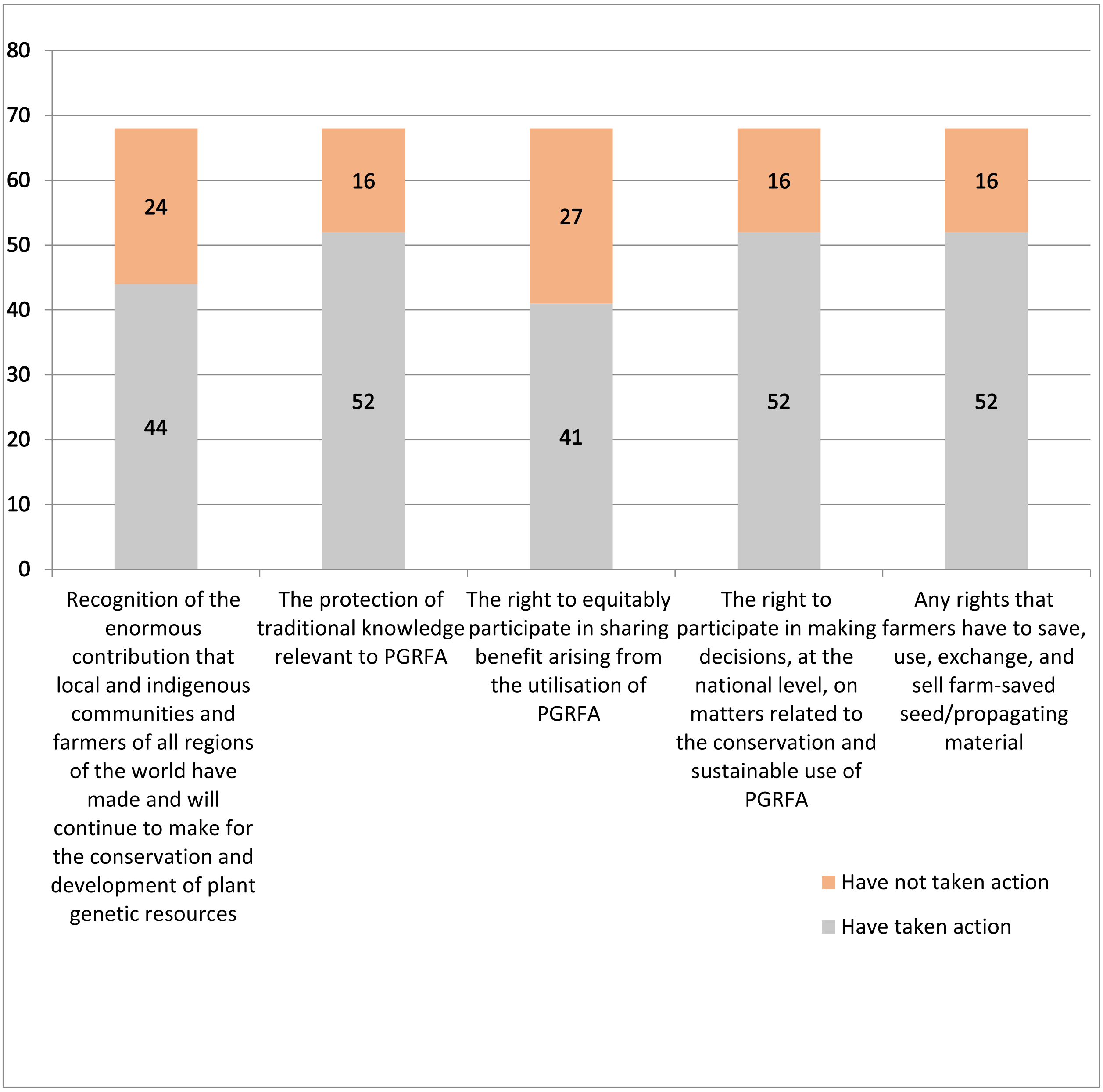
Category of measures for the implementation of Farmers' Rights	Records
1. Recognition of local and Indigenous communities', farmers' contributions to conservation and sustainable use of PGRFA, such as awards and recognition of custodian/guardian farmers	12
2. Financial contributions to support farmers' conservation and sustainable use of PGRFA, such as contributions to benefit-sharing funds	9
3. Approaches to encourage income-generating activities to support farmers' conservation and sustainable use of PGRFA	16
4. Catalogues, registries and other forms of documentation of PGRFA and protection of traditional knowledge	18
5. In-situ/on-farm conservation and management of PGRFA, such as social and cultural measures, community biodiversity management and conservation sites	10
6. Facilitation of farmers' access to a diversity of PGRFA through community seed banks, seed networks and other measures improving farmers' choices of a wider diversity of PGRFA	44
7. Participatory approaches to research on PGRFA, including characterization and evaluation, participatory plant breeding and variety selection	29
8. Farmers' participation in decision-making at local, national and sub-regional, regional and international levels	15
9. Training, capacity development and public awareness creation	22
10. Legal measures for the implementation of Farmers' Rights, such as legislative measures related to PGRFA	41
11. Other measures/practices	20

As of March 2023, 90 countries submitted reports on their implementation of the Treaty in accordance with the Compliance Procedures of the Treaty. Of these, 68 countries (76 percent) have stated to have taken some measures to protect and promote Farmers' Rights. Figure 5.10 visualises the proportion of these countries which have taken action with respect to specific elements of Farmers' Rights.

[183] The Inventory can be accessed at https://www.fao.org/plant-treaty/areas-of-work/farmers-rights/inventory-on-frs/en/

[184] The Options can be accessed at https://www.fao.org/3/cc4085en/cc4085en.pdf

Figure 5.10. Number of countries taking actions with respect to different elements of Farmers' Rights



In terms of regional differences with respect to the implementation of Farmers' Rights, the compliance reports to the Treaty reveal the figures summarised in Table 5.6 below.

Table 5.6. Number and percentage of countries who have taken measures with respect to Farmers' Rights

Region	Number of countries who reported on their implementation of the Treaty	Number of countries who have taken some measures to protect and promote Farmers' Rights	Percentage of reporting countries who have taken some measure to protect and promote Farmers' Rights
Northern Africa	2	2	100
Sub-Saharan Africa	22	15	68
Northern America	2	2	100
Latin America and the Caribbean	15	12	80
Asia	22	19	86
Europe	23	17	74
Oceania	4	1	25

Specific examples of efforts undertaken at the national level with respect to the realisation of Farmers' Rights during the last decade include:

- In 2010, Norway adjusted its seed regulation to be more accommodative to the approval and use of traditional varieties: the general DUS-criteria are applied in a less restrictive way and the registration fees for such varieties are reduced;
- In Zambia, the Indigenous knowledge associated with PGRFA has been protected through the Protection of Traditional Knowledge, Genetic Resources and Expressions of Folklore Act (2016);
- In the United States of America, several federal advisory committees provide opportunities for farmers to participate in making decisions relative to the conservation and sustainable use of PGRFA, including the Plant Variety Protection Board and the National Agricultural Research, Extension, Education, and Economics Advisory Board.
- In Rwanda, the Law N°005/2016, of 05 July 2016, on governing seeds and plant varieties in Rwanda, gives the rights to farmers to save, to use, to exchange and sell farmer-saved seed or propagated materials irrespective of their origin.
- In several regions in Yemen, through various projects, farmers have been encouraged to reuse, produce, and share the seeds produced in their own fields with the participation of researchers and extension workers, and to sell them to other farmers.

Another fundamental achievement in the context of Farmers' Rights since the publication of the SoW2 is the 2018 UN Declaration on the Rights of Peasants and other People Working in Rural Areas (UNDROP),[185] which refers to the Treaty in its Preamble and adopts text from the Treaty in its Article 19 on the Right to Seed (see Box 5.3).

[185] UNDROP official text: https://digitallibrary.un.org/record/1650694

Box 5.3: Declaration on Rights of Peasants and other People Working in Rural Areas adopted by HRC 2018

Article 19
1. Peasants and other people working in rural areas have the right to seeds,... including:
(a) The right to the protection of traditional knowledge relevant to plant genetic resources for food and agriculture;
(b) The right to equitably participate in sharing the benefits arising from the utilization of plant genetic resources for food and agriculture;
(c) The right to participate in the making of decisions on matters relating to the conservation and sustainable use of plant genetic resources for food and agriculture;
(d) The right to save, use, exchange and sell their farm-saved seed or propagating material.
...
3. States shall take measures to respect, protect and fulfil the right to seeds of peasants and other people working in rural areas.
...
8. States shall ensure that seed policies, plant variety protection and other intellectual property laws, certification schemes and seed marketing laws respect and take into account the rights, needs and realities of peasants and other people working in rural areas.

Seed laws in the context of Farmers' Rights

National seed laws have a significant impact on the functioning of smallholder seed systems (Dey, 2022). Seed laws and regulations determine who can produce and sell seeds, which varieties may be offered in the market, and which quality requirements have to be fulfilled for seed lots to be marketed. They can support or hinder the realisation of Farmers' Rights depending on their restrictiveness with respect to farmers' practices of saving, using, exchanging and selling farm-saved germplasm. In a survey conducted by the FAO, it appeared that commercial production and exchange of uncertified seed was permitted for only a limited group of crops in 25 per cent of the covered countries, while 29 per cent of countries explicitly banned the sale of all seed that had not been certified (FAO, 2018). Furthermore, an analysis of the seed laws and policies and regulations across 35 countries in Africa showed that in 23 countries seed laws forbid the trade in unregulated seed. Government policy and legislation may have negative impacts on farmers' abilities to engage in seed production and marketing (De Jonge *et al*., 2020; Gatto, *et al*., 2021). The 2022 study on bottlenecks and challenges published by the Secretariat of the Treaty confirmed that the informal seed supply system is placed under pressure due to agricultural modernization and increased emphasis on the use of improved crops and varieties. However, many countries in most regions have recognized the danger in this situation and stressed the need to adopt specific legislation to recognize and support informal seed systems and supportive regulations governing the certification and marketing of landraces/farmers' varieties.[186]

While guaranteeing the quality of seed in the market, seed laws with more flexible regulatory approaches and practices may allow for more equal opportunities of formal and informal seed systems, and the marketing of high-quality seed of traditional and farmer-adapted varieties (Kuhlmann and Dey, 2021). To boost the quality of smallholder produced seed and to increase the marketing of such seed, FAO developed the Quality Declared Seed (QDS) concept (FAO, 2016), which has been enacted in several countries in sub-Saharan Africa. Other countries introduced legislation based on the related concept of truthfully labelled seed. Both concepts aim at a shift of the burden of quality control from the government to the seed producer, assuming that the seed producer has an interest in brand and/or origin reputation and in keeping clients satisfied with the quality of the seed provided (Spielman and Kennedy, 2016). These approaches may also enhance the use of farmers' varieties/landraces, if they indeed facilitate the marketing of seed of such varieties (FAO, 2021).

[186] Secretariat of the International Treaty on PGRFA, Background Study on Bottlenecks and Challenges to the Implementation of Articles 5 and 6 of the International Treaty (2022), available at https://www.fao.org/3/cc2057en/cc2057en.pdf

5.6 Participation, community innovations and public awareness

Huge inequalities remain in the way food is produced and distributed, exacerbated by unequal and insecure tenure of land and the growing impact of climate change. Participation in decision-making regarding food systems in general, and the conservation and sustainable management of crop diversity in particular, by food producers, smallholders, Indigenous Peoples and local communities is a fundamental precondition for the just and equitable realization of the objectives of the Second GPA. As explained in Section 5.5.2 above, participation in decision-making is also a key contribution for the realization of Farmers' Rights as enshrined in Article 9 of the Treaty. Moreover, whenever farmer and community innovations are included, PGRFA conservation and use are further enhanced.

In this context, promoting and strengthening public awareness on the importance of PGRFA is key to mobilizing popular opinion and to galvanizing appropriate political action nationally, regionally and internationally. The Second GPA underlines the promotion of public awareness in its Priority Activity Area 18. An effective awareness raising programme requires adequate financial support, human resource capacity in communication, lobbying and awareness-raising, and well-designed activities targeting different audiences, with a view to increase understanding of the issues surrounding PGRFA.

This section considers first the state of participation and innovations by farmers and other communities. It then discusses the state of public awareness across the world.

5.6.1 Farmer and community innovations and participation

Country reports indicate, albeit unsystematically, that since the publication of the SoW2, countries, national stakeholders and international institutions are increasingly building mechanisms for participatory governance of genetic resource management. These could be further strengthened or new ones could be developed where they do not yet exist.

Civil society networks co-developing public policies in Brazil

In Brazil, the National Agroecology Articulation, a network of networks connecting thousands of organizations representing family farming, Indigenous Peoples and communities, carries out actions across all of Brazil's regions, combining a focus on cultural and biological diversity.[187] As part of its strategies, the network is dedicated to the development and improvement of public policies to strengthen agroecology, including seed systems. It works to support reciprocal connections between government and civil society. Noteworthy are the development of the National Policy on Agroecology and Organic Production in 2012 and the implementation of the Ecoforte Program.[188] Ecoforte (2015-2022) was developed in a participatory approach and is unique in its focus on territorial agroecology networks. By combining multiple perspectives, the strength and viability of the policy was successfully translated in each territory through a combination of federal and territorial resources, fostering seed houses, seed banks, and local markets, promoting income generation and the defense of biodiversity.

Multiple avenues exist for improving engagement with communities and other relevant actors who, in many cases, are at the forefront of conservation actions on the ground. Inclusion of traditional knowledge and participation of Indigenous Peoples, peasant farmers and citizens of all genders in general will become increasingly important as efforts under the Kunming-Montreal Global Biodiversity Framework begin to take shape, especially under its Target 22 on participation in decision-making and related aims (see Table 5.6 above). This also means that the increasing recognition of the particularly severe inequalities affecting Indigenous Peoples and other traditional communities including smallholder and peasant farmers, as well as the valuable contribution of their knowledge and practices in the context of conservation, will need to be reflected in more direct ways

[187] https://agroecologia.org.br/
[188] http://www.agroecologia.gov.br/plano

in all actions towards implementation of the GPA in harmony with the new Global Biodiversity Framework.

Community legal innovations: Open Source Seed Initiatives
Over the last ten years, a number of Open Source Seed initiatives have been developed, including through support from the third cycle of the Treaty's Benefit-sharing Fund.[189] These have grown into a global network of seed sharing groups, plant breeders, smallholder farmers and civil society organizations who are working to create seed commons. Notable examples include: the United States of America-based Open Source Seed Initiative (OSSI), Agrecol's OpenSourceSeeds in Germany, Bioleft in Argentina, as well as organizations and networks in India, Italy, Kenya, Mexico, Philippines, Thailand, Uganda and the United Republic of Tanzania, many of which are connected through the Global Coalition of Open Source Seed Initiatives (GOSSI).[190] Together they support actors who are committed to developing, sharing and distributing seeds that are unencumbered by intellectual property rights or other restrictions on use, through knowledge exchange, training, advocacy and fundraising. Open Source approaches in the context of PGRFA are based on legal innovations that ensure the freedom to save, share and access seeds in perpetuity – for example through the use of contracts and licenses that prohibit the privatization of seed or its progeny distributed as Open Source.

Farmer seed production

Smallholder seed production requires diverse capacities. Thus, farmers in several countries are organizing themselves in local seed producer groups to produce high-quality seed, with varying external support.

Long-term investment in farmer-participatory breeding and local seed systems
In West Africa, the McKnight Foundation's Collaborative Crop Research Program[191] has been working on the conservation of genetic diversity in smallholder production systems to enhance the resilience, productivity and sustainability of smallholder farmers. This work combines farmer participatory breeding of sorghum, pearl millet and legume crops with the strengthening of local seed systems. The inclusion of PGRFA from different *ex situ* collections in the participatory breeding process is offering new beneficial traits to the farmers. To foster smallholder farmers' access to and cultivation of the newly developed varietal diversity, the Programme funded parallel seed systems initiatives led by a Farmer Research Network consisting of several farmer organizations in Niger, Burkina Faso and Mali, as well as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Funded continuously since 2006, this work builds on local traditions, knowledge and networks related to seed. The long-term strengthening and training of farmer-led seed cooperatives contributes to the improved availability of quality seeds and diverse farmer-preferred varieties. Positive impacts on productivity, income, and nutrition have already been demonstrated (Ambrose, 2014; Christinck *et al.*, 2016; CCRP, 2019).

There is some evidence that ministries, extension services, research and breeding institutions, along farmer organizations, NGOs and national seed companies do increasingly support community-based farmer initiatives for seed production and diffusion, by providing trainings, seed of novel crops and varieties and other agricultural inputs, and by buying high-quality locally produced seed (Dey *et al.*, 2022). Some national programmes have begun to reflect the major role of farmer seed production and

[189] https://www.fao.org/plant-treaty/areas-of-work/benefit-sharing-fund/projects-funded/bsf-details/en/c/359497/
[190] https://www.opensourceseeds.org/en/gossi
[191] https://www.ccrp.org/

to address the need to better link farmer and formal sector seed systems. In this way, new regulation in the European Union supports farmer-breeders. Since January 2022, regulation 2021/1189 allows for organic heterogeneous seed populations to be traded on the European seed market.[192] Until recently, only varieties that that met the high standards of DUS (distinctiveness, uniqueness and stability), approved through a relatively long and expensive process, could be commercialized. Seed populations do not meet these standards, they are more heterogeneous and less stable but have great potential for adaptable agriculture. Heterogeneity can reduce the risk of crop failure due to extreme weather conditions and is becoming increasingly important in facing climate change. Variability of populations helps crops to adapt to site-specific conditions. The approval of organic seed populations is, therefore, a ground-breaking innovation in the region.

Further actions to link farmer seed systems to the formal market would contribute to meeting the overall objectives of the GPA.

Supporting farmers as breeders

The Sowing Diversity = Harvesting Security (SD=HS) programme, a joint effort of Oxfam Novib and civil society partners, is working for a global food system that supports Farmers' Rights and guarantees food and nutrition security through the sustainable management of crops. To this end, the programme has developed alliances with NGOs, government institutions, academic bodies and national breeding and research institutes to bring together expertise in quality seed development, policies and regulation, local seed enterprise development and public-private partnerships. Specifically, SD=HS supports Indigenous Peoples and smallholder farmers in accessing, developing and using PGRFA. Active in eight countries (Guatemala, Lao PDR, Nepal, Peru, Uganda, Zambia, Zimbabwe and China), it focusses on four goals, (1) facilitating farmers' crop improvement and adaptation to support sustainable use of PGRFA, (2) supporting Farmer Seed Enterprises to enhance livelihoods and seed security, (3) addressing nutrition through the use and management of neglected and underutilised species, and (4) promoting an enabling policy and institutional environment for farmers' seed systems and the implementation of Farmers' Rights. Under SD=HS, partners have established 1 050 Farmer Field Schools, trained 35 000 smallholder farmers and Indigenous People, with equal gender representation, selected and improved 392 crop varieties for climate resilience. A total of 200 000 farmers and Indigenous People were reached directly.

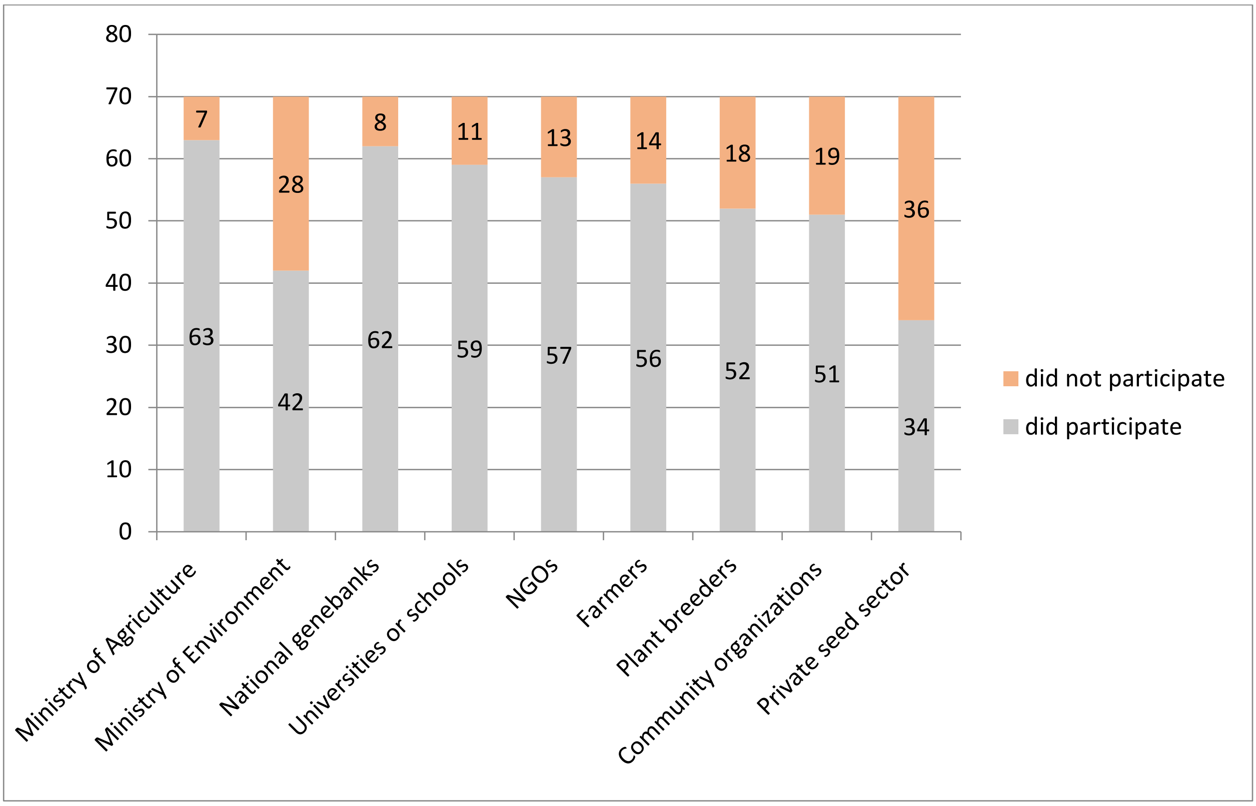
5.6.2 Public awareness

Seventy one countries out of 89 reported having established or strengthened a public-awareness programmes that actively promoted PGRFA conservation and utilization during the reporting period. No formal programme existed in Northern America, while in the other regions, the percentage of countries with a programme varied between 63 percent in Latin America and the Caribbean, to 90 percent in Sub-Saharan Africa. Through these programmes, an increased number of awareness activities have been carried out by a variety of stakeholders at all levels (see Figure 6.2.1 below), ranging from seed fairs and open field days to policy dialogues, television talk shows, and the compilation of recipe books based on native edible species, among others. These various activities and outputs have resulted in greater knowledge and understanding of the importance and multiple benefits of PGRFA. In some countries, increased public awareness is reflected in the better documentation of crops and native varieties including through the development of national catalogues of local species and varieties, such as in Canada, Madagascar, Nepal and the Kingdom of the Netherlands, or in newly adopted national strategies or legislation. For instance, in Guatemala, corn was recognized as a "Natural and Cultural Heritage" by legislative decree adopted in 2014, thereby promoting the identification, classification, documentation, protection and dissemination of the different uses, traditions and knowledge related to corn. Higher public awareness of the importance of PGRFA is also reflected in the growing involvement of new actors who have strong links with farmers and rural communities such as NGOs, social movements, civil society organizations and seed networks, among

[192] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32021R1189

others. For instance, at the international level, the Slow Food grassroots organization and La Vía Campesina have played an important role in promoting local food cultures and traditions and supporting local food and seed networks within many countries.

Figure 6.2.1. Participation of different stakeholder groups in public awareness programmes, by country response (n=70)



Country reports indicate that greater attention has been paid to local crops since publication of the SoW2. Local, regional and national seed and diversity fairs provide important platforms for raising awareness of the importance of PGRFA, especially local crop diversity, by showcasing the diversity of native varieties, local seeds and food products, and by engaging the public, including through workshops, field days, food tastings and artistic performance. Seed and diversity fairs also provide a platform to exchange seeds, knowledge and experience among farmers.

Genebanks also play an important role in displaying gene bank material, holding open days, giving talks and providing training to farmers, students and researchers. The existence of the Svalbard Global Seed Vault has also provided numerous opportunities for raising public awareness internationally. Other important activities include the organization of on-farm demonstration plots, awareness campaigns, exhibitions, research conferences, training and awareness workshops that support the dissemination of research findings to specific audiences.

In many countries, dissemination of PGRFA-related information is extended to a wider population through radio, television, and digital media through websites of public institutions, research centres and genebanks, among others. An important development of the past decade has been the greater diversity in the media used for communications, with increased importance of digital and social media platforms like Twitter, Facebook and YouTube which often reach and engage a much larger audience than traditional media, especially young people.

However, despite the increased number of awareness-raising activities in most regions, knowledge and understanding of the importance of PGRFA is still low, especially among policymakers and the wider population, but also among the research community, and professionals in the agri-food sector. Many countries have not adopted national public awareness plans or programmes yet, and awareness-raising activities are often carried out in an unstructured way on an ad-hoc basis within existing research projects.

Regional differences

Northern Africa
In the only two reporting countries, Egypt and Tunisia, staff from the genebank were actively involved in awareness activities including through the organization of open days and information days, participation in fairs, commemorative days and events such as the World Biodiversity Day, or through their involvement in videos and documentary films available online. Moreover, associations and civil society networks have become more active in the promotion of conservation and sustainable use of traditional local varieties. For instance, in Tunisia, the 'Seed Caravan' launched in 2018 by the Tunisian Association of Permaculture aims to identify the farmers' varieties existing across the country, whereas the 'Peasant Seeds' network, which has more than 16 800 members, uses social networks to provide a platform for the exchange of local seeds and knowledge.

> **In Tunisia**, the National Strategy for the Development and Sustainable Management of Forests and Rangelands (2015-2024) includes an information component to raise public awareness on protected areas, with a specific focus on women, whereas the implementation of the Sustainable Management of Oasis Ecosystems project led to the organization of a number of national and international fairs and festivals during the reporting period, including the first fair on biodiversity and processing industries; the first international forum on oasis dwellers; the first festival of Kebili dates; and the first international forum on dates and palms.

Sub-Saharan Africa
In Sub-Saharan Africa, seed fairs and agricultural shows are very popular activities for raising awareness on seed varieties. Nearly 70 percent of the reporting countries (15 of 22) declared that such events had been organized during the reporting period, including the first fair on farm-saved seed in Cameroon. These fairs contributed to raising the profile of traditional food and increasing awareness on their nutritional value and their importance in promoting healthy diets and eating habits. In Togo and Zimbabwe, they also act as platforms for seed and knowledge exchange and thereby contribute to increasing seed diversity especially in the rural and difficult-to-reach areas. The growing interest of civil society and the farming community in traditional local crops and varieties has given rise to new initiatives led by a range of associations and networks actively involved in the field of conservation and sustainable use of PGRFA.

> **In Niger**, the NGO Raya Karkara in collaboration with the Coalition for the Protection of Africa's Genetic Heritage organized caravans and awareness activities on the importance of local varieties and farmers' rights in several regions of the country in 2018. In Togo, the annual National Farmers' Forum brings together stakeholders to promote endangered species and underutilized local species such as fonio and sesame.

According to about 60 percent of the reporting countries (13 of 22), the use of local and national mass media to promote awareness on the importance of PGRFA, including broadcast, print and digital media, has greatly increased in the past decade. For example, in Namibia, Green Horizon is a weekly agricultural magazine TV programme created in 2013 that has established itself as a popular educative show and in Zambia, farmer seed systems are frequently addressed in radio and TV programmes. In Botswana, Ethiopia, Ghana, Kenya, Namibia, Senegal, South Africa and Togo, a large number of publications targeting different stakeholders and including scientific publications as well as fliers, newsletters, leaflets, fact sheets, policy briefs, posters, brochures and booklets, including on indigenous food recipes, practical handbooks for developing and supporting community seed banks, have been developed and disseminated, including online.

> **In Zimbabwe**, the Kurima Mari mobile app, pioneered by Welthungerhilfe (WHH) and partners under the Livelihoods and Food Security Programme funded by United Kingdom's DFID, has been used extensively in the Midlands province to raise awareness on different agronomic practices for target value chains such as local small grains (sorghum, pearl millet), Bambara nuts, as well as bio-fortified crops like bean variety Nua45 and vitamin-enriched orange maize. The Zimbabwe Agricultural Knowledge and Innovation Services (ZAKIS) also uses digital platforms to raise awareness on crops grown by smallholder farmers.

Northern America

In Canada, a number of initiatives and activities aimed to raise awareness of the importance of PGRFA have taken place in the past decade. For instance, community-based seed library initiatives have been created. A virtual symposium to mark the 50th anniversary of the national genebank took place in 2020 and brought together 400 participants from 27 countries. Besides, information on hundreds of community-organized events hosting seed exchanges, workshops and vendors is gathered on a dedicated website.

Latin America and the Caribbean

Most countries from Latin America and the Caribbean reported increased awareness activities since the SoW2, resulting in better understanding of the importance of PGRFA among decision-makers and civil society. Like in other regions, more attention was paid to promoting local genetic resources and varieties. This is shown in the increased number of local, regional and national agricultural fairs, seed fairs and gastronomic festivals organized in many countries including Argentina, Brazil, Cuba, Ecuador, Guatemala and Mexico, often with the support of NGOs and seed networks.

> **In Guatemala**, community organizations have been actively involved in the development of various documents including manuals, posters, and training modules on the importance of native varieties of maize and beans and their in situ conservation. They have also promoted the establishment of family, community and school gardens with native species. A model for sustainable healthy schools involving the creation of school gardens, food and nutrition education, and food purchases from local family farms, was implemented in 421 schools in San Marcos, Huehuetenango and Chiquimula. This has contributed to encouraging family farming while providing farmers with the opportunity to promote their products for school meals.

Other initiatives reflect the greater attention paid to the promotion of local seeds and varieties including for the consumption of local foods and products derived from native plants. NGOs, social movements and civil society organizations play an important role in this regard.

> **In Brazil**, the Society of Genetic Resources, created in 2008, has encouraged the development of regional and national genetic resources networks, associations and NGOs that carry out awareness activities and promote family farming such as, for instance, AS-PTA Family Agriculture and the Ecovida network that brings together 4 500 families. **In Argentina**, the ProHuerta Programme implemented by the National Institute of Agricultural Technology (INTA) has promoted the development of family, school and community gardens, resulting in the establishment of more than 600 000 gardens that provide seeds for food self-sufficiency, in addition to creating spaces for the exchange of plants, seeds, knowledge and practices in various fairs. **In Peru**, consumers' attention to local food has led to a 'gastronomic turn' with the involvement of chefs, local communities and the academic sector promoting the consumption of food derived from local varieties.

Scientific conferences and symposia open to the public also contributed to disseminating knowledge and raising awareness among the public and the scientific community.

Scientific Congresses on PGRFA in Mexico
In Mexico, the Second Fair of Agrodiversity and Agroproducts was held in 2013, in commemoration of the 11th anniversary of the creation of National System for PGRFA. It brought together over 300 producers from all over the country as well as other stakeholders representing more than 60 organizations, to disseminate knowledge and good practices in relation to PGRFA conservation and use. In addition to a variety of food tastings and workshops, it organized a Symposium on “Diversity and uses of PGR in Mexico and Latin America: Economic importance and environmental sustainability” that gathered experts, researchers, academics, seed inspectors and staff from international organizations including FAO and CIAT.
In 2015, the Autonomous University of Chapingo, in coordination with the National Seed Inspection and Certification Service organized the Second Congress on Phytogenetic Resources and the First International Congress on the Conservation and Sustainable Use of Agrobiodiversity. This provided the opportunity to disseminate recent research on PGRFA *in situ* conservation (genetic erosion, PPB, sustainable conservation models and traditional systems); *ex situ* conservation (core collections and the application of eco-geography for collections); and sustainable use (denominations of origin, climate change and genetic improvement).

In 2017, Mexico hosted the Symposium on Genetic Resources for the Americas and the Caribbean, where regional priorities for the conservation and sustainable use of PGRFA were elaborated.

Asia
In a few countries like Armenia, Jordan, Kyrgyzstan, Tajikistan and Yemen, the past decade has seen an increase in the number of awareness activities and projects implemented with the support of and in collaboration with international organizations and bilateral donors. Public foundations are also increasingly engaged in awareness raising activities.

In Armenia, the UNDP/GEF project “Creating Global Environmental Benefits through Environmental Education and Raising Awareness of Stakeholders” (2015-2019) greatly contributed to raising public awareness of the importance of biodiversity through the organization of round tables, the launch of education campaigns and the elaboration of strategies and methodologies for PGR conservation and sustainable use.
In Kyrgyzstan, the public foundation “Agency Development Initiatives” (ADI) within the framework of the project “Dyikan Muras” (Farmer's Legacy) provides training and consultations to farmers, organizes seminars to disseminate knowledge on the production of local vegetables to obtain seeds, and holds open field days to facilitate exchange of experiences among farmers. Additionally, the annual Apricot Festival in the Issyk-Kul region aims to promote Issyk-Kul apricots as well as agro-tourism in the region. Seminars, master classes, exhibitions and contests for the best apricot products are organized.

Greater attention paid to local crops and varieties has been reflected in the increased number of activities and initiatives promoting awareness of the importance of supporting their conservation and sustainable use. As such, seed fairs, diversity fairs, food fairs and festivals, often involving crop contests and farmers award ceremonies, have taken place in several countries, for example in India, Indonesia, Kyrgyzstan, Lebanon, Nepal, Türkiye and Yemen.

In Türkiye, the project “Our heritage: Local Seeds (Mirasımız Yerel Tohum)”, initiated by the Ministry of Agriculture and Forestry in 2017, aims to raise awareness of the local seeds from Anatolia, and festivals promoting wild edible plants and local crops and varieties are held every year.

Increased public awareness of the importance of PGRFA, including local crops and varieties, has been supported using traditional media products such as TV and radio programmes, as well as new digital media and social networks in Armenia, Bangladesh, India, Jordan, Lebanon and the Philippines.

India's National Plant Genome Saviour Awards
The Indian Protection of Plant Varieties and Farmers' Rights Authority annually confers the "Plant Genome Saviour Community Award". The award, doted with 1 million Rs from the Gene Fund, a national instrument for benefit-sharing, recognizes the efforts of Indian groups or communities of farmers in conservation or improvement of PGRFA and CWR. Since 2012, the Authority also confers the "Plant Genome Saviour Farmer Reward", doted with 100 000 Rs, and the "Farmer Recognition" to individual farmers who have engaged in exceptional efforts in the context of conservation of landraces and CWR. The genetic resources to which the awards relate to are then explored for further use. The awards not only recognize and compensate farmers for their contribution to the development and conservation of PGRFA; they are also an important means of raising awareness amongst the wider public.
Similar awards and recognitions also exist in other countries.

A larger number of publications, including newsletters, brochures, booklets, leaflets, production guides and articles in newspapers, magazines and scientific journals, have been widely distributed to increase awareness, for instance, on native crop diversity in Nepal; on indigenous vegetables in the Philippines; and on CWR in Armenia.

Europe
Many countries including, for instance, Belarus, Czechia, Germany, Ireland, Norway, Portugal, Sweden and Switzerland reported increased public awareness of the importance of PGRFA, with specific mentions of organic agriculture, on-farm conservation and heirloom crops and cultivars.

Collaborative learning for seed savers
In Northern Europe, the Seed Savers organizations from the Baltic states and Denmark have launched an international project "Growing Seed Savers: Baltic-Nordic Seed Savers' Education Innovation" (https://growingseedsavers.org/), funded by the Nordic Council of Ministers programme NORDPLUS. This project aims to create a local seed network as a support system - for heritage varieties and their growers - through the training of trainers in the Baltic countries to disseminate knowledge about agrobiodiversity, seed-saving practices, and seed legislation, as well as through the involvement of farmers, gardeners, chefs, and consumers in the collection, management, and sustainable use of heritage seed varieties. In Norway, the organization KVANN - Norwegian Seed Savers (https://kvann.no/), created in 2016, provides a forum where its over 800 members can access material and share information, experiences and expertise regarding the conservation of plant diversity.

Generally speaking, a range of private and public actors and institutions as well as civil society organizations involved in PGRFA conservation and use activities carried out targeted dissemination and information activities aimed at raising awareness about the importance of PGRFA among farmers and various groups of the population, including children and young people. These included, for instance, the organization of workshops, conferences, demonstration gardens, exhibitions and fairs in Czechia, Estonia, France, Germany, Hungary, the Kingdom of the Netherlands, Portugal, the Republic of Moldova, Switzerland, and the United Kingdom.

In the Republic of Moldova, the main objective of the 2017-2019 GEF/SGP-funded project "Environmental education for public awareness on biodiversity protection in the Republic of Moldova" was to raise the educational level and public awareness on the main issues surrounding the conservation of plant diversity in the Environmental Education Centre.

Raising public awareness also involved information dissemination via different media including the press, radio and television, for instance in Switzerland with the “Mission B” campaign launched on the national radio and television in 2019 to address the decline in biodiversity. In many countries, including Czechia, Estonia, France, Germany and Switzerland, social media and the Internet and digital information material, including web pages and online information, have played an increasingly important role. Several brochures, publications, pamphlets, magazines, articles and books were compiled and published during the reporting period. Market-based mechanisms can also play an important role in promoting local varieties in the region. For instance, in Switzerland, the ProSpecieRara quality label is a private, controlled and certified quality label aimed at promoting endangered and rare varieties and breeds on the market and recognizing the contribution and commitment of livestock keepers and variety managers.

Oceania
In Papua New Guinea, the organization of annual provincial agricultural shows, seminars and workshops, as well as the dissemination of information through local and national print and digital media, contribute to building public awareness of the importance of PGRFA. The National Agriculture Research Institute hosts events, demonstrations and hands-on training for farmers.

5.7 Conclusion

5.7.1 Changes since the Second State of the World

As this chapter has shown, human and institutional capacities have advanced in all dimensions. A number of specific changes since the publication of the SoW2 are worth highlighting.

National programmes

- The last decade has shown progress in development of national programmes for the management of PGRFA. Increasingly, programmes have been established or strategies to this end created. The development of NBSAPs has played a catalyzing role in this context.
- While great efforts have been made in some countries to build and strengthen national programmes and coordination of stakeholders, a significant amount of PGRFA work has been conducted through time-bounded projects and *ad hoc*, rather than integrated into coherent programmes.
- NISMs have fallen into disuse. Some countries have developed appropriate alternatives for information sharing amongst national stakeholders that also function as reporting mechanisms to international institutions, including the GPA.

Training and education

- The number of students and human resources has increased, as have higher levels of qualification. In some countries, the past decade has seen the creation of new universities and other educational institutions and the introduction of new courses and programmes related to genetic resources.
- Alongside universities and vocational agricultural schools, new actors have become increasingly involved in training and capacity development, such as botanical gardens, genebanks, seed networks, research institutes, regional and international organizations, NGOs, foundations, associations and museums.
- Cooperation among and between educational institutions, seed networks, research institutes, and regional and international genebanks has increased and led to joint educational and research activities.
- The increased use of online tools and platforms has enabled the development of a range of innovative teaching materials, including educational videos and learning resources, while contributing to wider distribution of training opportunities through remote participation.

PGRFA networks

- PGRFA networks have remained important hubs of activity and promotion for PGRFA conservation and sustainable use. While some important regional networks have had to pause or cease their activities, others have sprung up or renewed their efforts.
- The important benefits of international collaboration are now widely recognised amongst stakeholders.
- A greater number of publications have been produced through participation in networks.

Other forms of international collaboration

- Alongside the Treaty, the conservation and sustainable use of PGRFA, as well as Access and Benefit-sharing have been prioritized by several other international agreements and initiatives, including most recently the Kunming-Montreal Global Biodiversity Framework, which strengthens linkages between all biodiversity-related Conventions.
- Overall, there are more international initiatives that focus on or are relevant to PGRFA, including initiatives led by civil society.
- As public finance for PGRFA dwindles, innovative resource mobilisation is a focus of key PGRFA institutions, such as the Global Crop Diversity Trust and the Treaty.

Information systems for PGRFA

- Information systems have expanded, proliferated, and cross-platform interoperability and data-sharing initiatives herald further advances, with the development of GLIS (including Genesys) and GRIN-Global Community Edition being notable examples. The increasing number of countries reporting MCPD-standardized accession-level data on SDG indicator 2.5.1a reflects progress at country level in documenting and making publicly accessible *ex situ* germplasm holdings.

Monitoring systems for genetic erosion

- Awareness of the importance of monitoring mechanisms for genetic erosion, especially in the context of *in situ* conservation, has increased.
- Recognition of the benefits of combining *ex situ* and *in situ* conservation efforts has grown.

Access and Benefit-sharing

- Significant progress has been made in the development of access to PGRFA at the international level, notably through the increase in accessions having been made available under the Treaty's Multilateral System. Many national and regional genebanks now make all their PGRFA available under the Multilateral System, and there has been an increase in number of SMTAs reported per year. Moderate progress can be noted in the development of national policy and legislative measures for ABS.
- Awareness of the importance and challenges of benefit-sharing is now wide-spread, and existing mechanisms are in the process of being enhanced. Since 2013, a process to enhance the functioning of the Multilateral System has been conducted under the Treaty.
- DSI has increased exponentially in significance in the plant sciences and associated engineering and technologies, and the sharing of benefits arising from its use is being mandated under the Kunming-Montreal Global Biodiversity Framework.

Farmers' Rights

- Farmers' Rights have seen substantial development over the last decade, not least through the role of the Treaty and other international instruments.

Participation

- Participation of farmers, Indigenous Peoples, local communities and the wider public in decision-making and the development of solutions to PGRFA challenges has been advanced. International institutions, countries, and national stakeholders are increasingly building mechanisms for participatory governance of genetic resource management.

- The Global Biodiversity Framework enshrines full and equitable participation in decision-making related to biodiversity by Indigenous Peoples and local communities in its Target 22.

Public awareness

- An increased number of awareness-raising activities has taken place, and public awareness has grown significantly. The importance of and challenges to PGRFA are now more widely understood among decision-makers, civil society and farming communities than ever before. In particular, greater attention has been paid to the importance of local crop diversity by promoting the diversity of native varieties, local seeds and traditional food products and their nutritional value.
- There has been growing involvement in information dissemination of new actors who have strong links with farmers and rural communities such as NGOs, social movements, civil society organizations and seed networks.
- The increased use of digital and social media platforms has contributed to disseminating information on PGRFA to a much broader audience, including young people.

5.7.2 Gaps and Needs

Despite progress made in the context of human and institutional capacities for PGRFA since the publication of the SoW2, significant gaps across all regions remain.

National programmes

- Even where they exist or are in the process of being developed, national programmes for the management of PGRFA continue to lack adequate implementation in the majority of countries. Much PGRFA work continues to be realised through time-bounded projects and ad hoc, with individual initiatives in need of better connection and coordination. In many cases, weak collaborations among national stakeholders and institutions prevail. Initiatives driven by civil society organizations are not sufficiently supported and integrated into national programmes.
- Often, PGRFA strategies are folded into countries' NBSAPs, and there remain gaps in developing PGRFA-specific strategies and action plans that account for the unique needs of crop diversity.
- The lack of stable, continuous funding, and predominant short-term, project-based financing, is a key constraint in the development of coherent and effective national programmes, undermining knowledge transfer, capacity building and institutional evolution.

Training and education

- Despite significant progress in this area, strengthening of academic institutions and development of educational programmes was identified as a persistent need across all regions. Comprehensive programmes for plant breeding, genetic improvement and biotechnology are lacking in some countries. Needs remain to provide more targeted training courses, in all technical and legal aspects of PGRFA, to a greater number of professionals, farmers and civil society.
- A younger generation of professionals is needed to replace retiring experts in many country contexts. Building sufficient capacity and transferring knowledge is still a significant challenge.
- The lack of research funding, including for scholarships, post-doctoral fellowships, and long-term breeding programmes, is a noteworthy bottleneck for strengthened capacity building opportunities.
- Weaknesses in collaboration and partnerships within and between national higher education institutions, research centres, networks, and international institutions also remain unaddressed in many countries.

PGRFA networks

- The benefits provided by international collaboration are still unevenly distributed and not equally accessible to all, especially in contexts where financial resources are inconstant.

- Gaps and needs remain with respect to collaboration between different stakeholders within networks, as well as the coordination and management amongst networks at regional and international levels.
- Many networks are managed on a voluntary basis which implies fragility and dependency on project funds with a short time horizon.

Other forms of international collaboration

- While collaboration and shared initiatives at the international level are increasing, there is still room for strengthening coordination to improve synergies and leverage. This is particularly important as many global goals and targets to safeguard biodiversity have not been met in their timeframes.
- Dwindling funds is a key constraint across all regions for all PGRFA activities. In many cases this means that gaps are being plugged with project funding rather than dedicated budget streams. Key PGRFA institutions, notably the Treaty and the Crop Trust, are exploring innovative resource mobilisation opportunities, but actual solutions are yet to be found.

Information systems for PGRFA

- Important geographical and thematic gaps in terms of coverage of information systems endure, especially with regard to CWR and farmers' varieties/landraces. Asymmetries in technological capacities constitute significant hurdles in equal access to and adequate management of PGRFA-related information.
- Despite progress, a significant portion of *ex situ* conserved accessions has not been characterized and evaluated for traits, or this has not been documented. Where this information exists, it is often not publicly accessible. This situation is worse with regard to the geographical distribution of CWR and farmers' varieties/landraces, for which the realisation of systematic *in situ* monitoring and inventory is particularly needed.
- While increasingly addressed, the need still exists to improve the interoperability of existing information systems through shared, open standards.
- Key constraints for the strengthening of information systems are: gaps in technical capacity in the areas of taxonomy, information management and bioinformatics; gaps in the necessary digital infrastructure, particularly of genebanks; gaps in funding and financial support.

Monitoring systems for genetic erosion

- Monitoring mechanisms for genetic erosion, especially in the context of *in situ* conservation, remain in urgent need of development and implementation in most national and regional contexts. At the time of writing, only very few countries had put in place a national system for monitoring and safeguarding genetic diversity and minimising genetic erosion, with national policies mostly absent.
- Surveys and baseline studies are urgently needed in many countries, with the concomitant need to develop indicators for genetic vulnerability and erosion feeding into early warning systems.
- Lacking resources or long-term funding, as well as weak coordination amongst stakeholders remain significant hurdles to the minimisation of genetic erosion.

Access and Benefit-sharing

- While significant progress has been made in the development of access to PGRFA at the international level, concomitant benefit-sharing by comparison is relatively under-developed, and existing mechanisms, including the Treaty's Multilateral System, need enhancement.
- ABS regulation at the national level needs further development in many countries.

Farmers' Rights

- While Farmers' Rights have seen substantial development over the last decade, national implementation needs realisation. Moreover, crucial contradictions still remain between Farmers' Rights and the implementation of Seed Laws in many countries.

Participation

- Participation of farmers, Indigenous Peoples, local communities and the wider public in decision-making and in the development of solutions to PGRFA challenges needs further development in most institutional and national contexts.
- Capacities for effective facilitation of participatory processes need to be built at all scales.

Public awareness

- Despite significant growth of awareness on the importance of and challenges to PGRFA, understanding needs to be strengthened especially among professionals and policy makers in other sectors – such as environment, trade, health – in order to maximise synergies and catalyse needed changes in integrated fashion. National communication strategies and targeted public awareness programmes on the value of PGRFA exist only in very few countries.
- Inter-institutional coordination, collaboration and partnerships with respect to communication activities, including collaborations with media organizations, are still weak across all regions, resulting in shortcomings in information dissemination. Gaps also remain with respect to providing information that is adapted to a diversity of audiences, and in local languages.
- The lack of funding and permanent budgets for communication constitutes a key constraint for public awareness-raising.

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List of Acronyms

Acronyms	Names
ABNE	African Biosafety Network of Expertise
ABS	Access and Benefit Sharing
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
ADI	Agency Development Initiatives, Kyrgyzstan
AEGIS	European Genebank Integrated System for PGRFA
AfPBA	African Plant Breeding Academy
AfricaRice	Africa Rice Center
AGG (AUS165)	Australian Grains Genebank, Agriculture Victoria (Australia)
AGRA	Alliance for a Green Revolution in Africa
AGRESEARCH (NZL001)	Margot Forde Forage Germplasm Centre, AgResearch Ltd (New Zealand)
AGROSAVIA (COL017)	Corporación Colombiana de Investigación Agropecuaria, AGROSAVIA (Colombia)
AGROSAVIA (COL096)	Centro de Investigación El Mira, Corporación Colombiana de Investigación Agropecuaria (Colombia)
AGUAPAN	Asociación de los Guardianes de la Papa Nativa del Centro del Perú
AIRCA	Association of International Research and Development Centres for Agriculture
AOCC	African Orphan Crops Consortium
APAARI	Asia-Pacific Association of Agricultural Research Institutions
APG (AUS167)	Australian Pastures Genebank (Australia)
APSA	Asia and Pacific Seed Association
ARC (SDN002)	Agricultural Plant Genetic Resources Conservation and Research Centre (Sudan)
ARS	Agricultural Research Service
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AVRDC	World Vegetable Center
BFA	Biodiversity for Food and Agriculture
BGCI	Botanic Gardens Conservation International
BGUPV (ESP026)	Generalidad Valenciana. Universidad Politécnica de Valencia. Escuela Técnica Superior de Ingenieros Agrónomos. Banco de Germoplasma (Spain)
BNG (TUN029)	Banque Nationale de Gènes de Tunisie (Tunisia)
BOLD project	Biodiversity for Opportunities, Livelihoods and Development project
BPGV-INIAV (PRT001)	Banco Português de Germoplasma Vegetal (Portugal)
BPI-DNCRDC (PHL024)	Bureau of Plant Industry-Davao National Crop Research and Development Center (Philippines)
BSRI (BGD015)	Bangladesh Sugarcrop Research Institute (BSRI) (Bangladesh)
CABI	Centre for Agriculture and Bioscience International
CAPGERNET	Caribbean Plant Genetic Resources Network
CATIE	Center for Tropical Agricultural Research and Higher Education
CATIE (CRI085)	CATIE - Banco de Germoplasma (Colecciones Semillas Ortodoxas)
CATIE (CRI134)	CATIE - Jardín Botánico y Colecciones

CBD	Convention on Biological Diversity
CBM	Community Biodiversity Management
CCARDESA	Centre for Coordination of Agricultural Research and Development for Southern Afr
CCNY	Carnegie Cooperation of New York
CENARGEN	Embrapa Recursos Genéticos e Biotecnologia (Brazil)
CENARGEN (BRA003)	Embrapa Recursos Genéticos e Biotecnologia genebank (Brazil)
CENICAÑA (COL115)	Centro de investigación de la caña de azúcar (Colombia)
CePaCT	Centre for Pacific Crops and Trees
CePaCT (FJI049)	Centre for Pacific Crops and Trees genebank
CGIAR	Consultative Group for International Agricultural Research
CGN	Centre for Genetic Resources, Netherlands (Kingdom of the)
CIAT	International Center for Tropical Agriculture
CIFOR-ICRAF	World Agroforestry Centre
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CNPAF (BRA008)	Embrapa Arroz e Feijão (Brazil)
CNPH (BRA012)	Embrapa Hortaliças (Brazil)
CNPMF (BRA004)	Embrapa Mandioca e Fruticultura Tropical (Brazil)
CNPSO (BRA014)	Embrapa Soja (Brazil)
Commission	Commission on Genetic Resources for Food and Agriculture
COR (USA026)	National Clonal Germplasm Repository USDA, ARS (United States of America)
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
COT (USA049)	Crop Germplasm Research Unit USDA, ARS (United States of America)
CPAMN (BRA142)	Embrapa Meio Norte (Brazil)
CREA-OFA-REN (ITA401)	CREA-Centro di Ricerca Olivicoltura, Frutticoltura e Agrumicoltura, Sede di Rende (Italy)
CREA-OFA-RM (ITA378)	CREA-Centro di Ricerca Olivicoltura, Frutticoltura Agrumicoltura - Sede di Roma (Italy)
Crop Trust	Global Crop Diversity Trust
CSB	Community seed bank
CWR	Crop Wild Relatives
DAV (USA028)	National Germplasm Repository USDA, ARS, University of California (United States of America)
DB NRRC (USA970)	Dale Bumpers National Rice Research Center, United States Department of Agriculture, Agricultural Research Services (United States of America)
DENAREF (ECU023)	Departamento Nacional de Recursos Fitogenéticos (Ecuador)
DNA	Deoxyribonucleic Acid
DOI	Digital Object Identifiers
DSI	Digital Sequence Information
DUS	Distinctiveness, Uniqueness and Stability
E.E.A. Illpa-Puno (PER014)	Estación Experimental Agraria Illpa (Peru)
EAPGREN	East African Genetic Resources Network
EasySMTA	SMTA generation and reporting mechanism of the Treaty
EBI	Ethiopian Biodiversity Institute (Ethiopia)
EBI (ETH085)	Ethiopian Biodiversity Institute genebank (Ethiopia)

ECABREN	East and Central Africa Bean Research Network
ECPGR	European Cooperative Programme for Plant Genetic Resources
EE-Toralapa INIAF (BOL317)	Estación Experimental de Toralapa (Bolivia)
EETP (ECU330)	Estación Experimental Tropical Pichilingue (Ecuador)
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
EM-DAT	International Disaster Database
EU	European Union
EURISCO	European Search Catalogue for Plant Genetic Resources
FAO	Food and Agriculture Organization of the United Nations
FAQ	Frequently Asked Questions
FARA	Forum for Agricultural Research in Africa
FTGRİ (AZE009)	Fruit and Tea Growing Research Institute (Azerbaijan)
FV/LR	Farmers' Varieties/Landraces
GB-DOA (THA300)	Genebank (Thailand)
GBIF	Global Biodiversity Information Facility
GBIS	German Genebank Information System
GBO	The Global Biodiversity Outlook
GBO-5	Fifth Global Biodiversity Outlook
GCARD	Global Conference on Agricultural Research for Development
GEF	Global Environment Facility
GEN (USA167)	Plant Genetic Resources Unit, Cornell University, New York State Agricultural Experiment Station, USDA, ARS (United States of America)
GeNBIS	Nordic Baltic Genebanks Information System
GEO BON	Group on Earth Observations Biodiversity Observation Network
GeRRI (KEN212)	Genetic Resources Research Institute (Kenya)
GFAR	Global Forum on Agricultural Research and Innovation
GG-CE	GRIN-Global Community Edition
GHUs	Germplasm Health Units
GIAHS	Globally Important Agricultural Heritage Systems
GIZ	German Agency for International Cooperation
GLIS	The International Treaty's Global Information System on PGRFA
Global System	Global System on Plant Genetic Resources for Food and Agriculture
GOAL Master Class	The Genebank Operation Advanced Learning Master Class
GODAN	Global Open Data for Agriculture and Nutrition
GOSSI	Global Coalition of Open Source Seed Initiatives
GPA	Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture
GRIN	Germplasm Resources Information Network
GRIN-Global	Genetic Resource Information Global
GRULAC	Latin American and Caribbean Regional Group
GSLY (USA176)	C.M. Rick Tomato Genetic Resources Center, Department of Vegetable Crops, University of California (United States of America)
HBROD (CZE027)	Potato Research Institute Havlickuv Brod Ltd. (Czechia)
IARCs	International Agricultural Research Institutes
IBERS-GRU (GBR016)	Genetic Resources Unit, Institute of Biological, Environmental & Rural Sciences, Aberystwyth University (United Kingdom)
IBP	International Biological Programme
IBPGR	International Board on Plant Genetic Resources

ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture
ICCI-TELAVUN (ISR003)	Lieberman Germplasm Bank, Institute for Cereal Crops Improvement, Tel-Aviv University (Israel)
ICIA (ESP048)	Gobierno de Canarias. Consejería de Agricultura, Ganadería, Pesca y Medio Ambiente. Instituto Canario de Investigaciones Agrarias (Spain)
ICRAF	World Agroforestry Center
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFAPACOR (ESP046)	Junta de Andalucía. Consejería de Agricultura y Pesca. Instituto Andaluz de Investigación y Formación Agraria, Pesquera, Alimentaria y de la Producción Ecológica. Centro Alameda del Obispo (Spain)
IFG (BLR017)	Republican Unitary Enterprise 'Institute for Fruit Growing' (Belarus)
IGB (ISR002)	Israel Gene Bank for Agricultural Crops, Agricultural Research Organisation, Volcani Center (Israel)
IGPEB (UZB001)	Institute of Genetics and Plant Experimental Biology (Uzbekistan)
IHAR (POL003)	Plant Breeding and Acclimatization Institute (Poland)
IITA	International Institute of Tropical Agriculture
ILK/TK	Indigenous Local Knowledge and Traditional Knowledge
ILRI	International Livestock Research Institute
IMIDRA (ESP080)	Comunidad de Madrid. Consejería de Medio Ambiente, Vivienda y Ordenación del Territorio. Instituto Madrileño de Investigación y Desarrollo Rural (Spain)
INGER	International Network for the Genetic Evaluation of Rice
INIA Carillanca	Instituto de Investigaciones Agropecuarias
INIA-CRF (ESP004)	Centro Nacional de Recursos Fitogenéticos (Spain)
INIA-EEA.DONOSO (PER034)	Estación Experimental Agraria Donoso (Peru)
INIA-EEA.SR. (PER016)	Estación Experimental Agraria San Roque (Peru)
INIAV-Elvas (PRT196)	Departamento de Olivicultura, Estação nacional de Melhoramento de Plantas (Portugal)
INICA (CUB041)	Instituto Nacional de Investigación de la Caña de Azúcar (Cuba)
INIVIT (CUB006)	Instituto Nacional de Investigaciones en Viandas Tropicales (Cuba)
INRA CRRAS (MAR088)	Centre Régional de la Recherche Agronomique de Settat (Morocco)
INRAe (FRA015)	Institut National de Recherche pour l'Agriculture, l'alimentation et l'environnement, Departement de biologie et amelioration des plantes (France)
INRAe-ANTILLE (FRA109)	Génétique et Amélioration des Plantes, Plant Biology and Breeding, INRAe Antilles-Guyane (France)
INRAe-VASSAL (FRA139)	Centre de Ressources Biologiques de la Vigne de Vassal-Montpellier, Plant Biology and Breeding, INRAe Montpellier (France)
INTA	National Institute of Agricultural Technology
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPGR (BGR001)	Institute for Plant Genetic Resources 'K.Malkov' (Bulgaria)
IPGRI	International Plant Genetic Resources Institute
IPK	Leibniz Institute of Plant Genetics and Crop Plant Research

IPK (DEU146)	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research (Germany)
IPK (DEU159)	External Branch North of the Department Genebank, IPK, Potato Collection in Gross-Luesewitz (Germany)
IPK (DEU271)	External Branch North of the Department Genebank, IPK, Oil Plants and Fodder Crops in Malchow (Germany)
IPs	Indigenous Peoples
IPAs	Important Plant Areas
IR (UKR001)	Institute of Plant Production n.a. V.Y. Yurjev of UAAS (Ukraine)
IRD	Institut de Recherche pour le Développement (France)
IRD (FRA254)	Institut de Recherche pour le Développement genebank (France)
IRRI	International Rice Research Institute
IRTAMB (ESP014)	Generalitat de Catalunya. Institut de Recerca i Tecnologia Agroalimentàries. Centre Mas de Bover (Spain)
ISA (PRT018)	DRAT, DCEB - Instituto Superior de Agronomia (Portugal)
ISOPlexis (PRT102)	Banco de Germoplasma - Universidade da Madeira (Portugal)
ITC	Bioversity International Musa Germplasm Transit Centre, Belgium
ITC (BEL084)	Bioversity International Musa Germplasm Transit Centre
IUCN	International Union for Conservation of Nature
IVM (UKR050)	Institute of Grape and Wine 'Maharach' (Ukraine)
KBAs	Key Biodiversity Areas
KPS (UKR046)	Crimean Pomological Station (Ukraine)
KVANN	Norwegian Seed Savers Organization
LCs	Local Communities
M ha	Million hectares
MAT	Mutually Agreed Terms
MCPD	Multi-Crop Passport Descriptors
MDI-CTU	Mekong Delta Development Research Institute, Can Tho University
MIA (USA047)	Subtropical Horticultural Research Unit, National Germplasm Repository - Miami, USDA (United States of America)
MLS	Multilateral System under the International Treaty on Plant Genetic Resources for Food and Agriculture
MRC Bubia (PNG041)	Momase Regional Centre, Bubia (Papua New Guinea)
MSB	Millennium Seed Bank
NARCs	National Agricultural Research Centres
NARO	National Agriculture and Food Research Organizationk (Japan)
NARO (JPN183)	NARO Genebank (Japan)
NARS	National Agricultural Research System
NBPGR	National Bureau of Plant Genetic Resources (India)
NBPGR (IND001)	National Bureau of Plant Genetic Resources Genebank (India)
NBS (UKR036)	Nikitskyi Botanical Gardens (Ukraine)
NBSAPs	National Biodiversity Strategies and Action Plans
NC7 (USA020)	North Central Regional Plant Introduction Station, USDA-ARS, NCRPIS (United States of America)
NE9 (USA003)	Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit, USDA-ARS, New York State Agricultural Experiment Station, Cornell University (United States of America)
NENAPGRN	Near East & North Africa PGR Network

NFC (GBR030)	National Fruit Collections, University of Reading (United Kingdom)
NFP	National Focal Point
NGOs	Non-Governmental Organizations
NIFA	USDA National Institute of Food and Agriculture
NISMs	National Information Sharing Mechanisms
NODiK (HUN003)	Centre for Plant Diversity (Hungary)
NordGen	Nordic Genetic Resource Center
NORDPLUS	Nordic Council of Ministers program
NPAES	National Protected Areas Expansion Strategies
NPGRC	National Plant Genetic Resources Center
NPGS	National Plant Germplasm System, United States of America
NR6 (USA004)	Potato Germplasm Introduction Station, USDA-ARS (United States of America)
NSGC (USA029)	National Small Grains Germplasm Research Facility genebank, USDA-ARS (United States of America)
NSGC USA	National Small Grains Germplasm Research Facility, United States of America
OECD	Organization for Economic Cooperation and Development
OECM	Other Effective area-based Conservation Measures
OSSI	US-based Open Source Seed Initiative
PAPGREN	The Pacific Agricultural Plant Genetic Resources Network
PGRC (CAN004)	Plant Gene Resources of Canada, Saskatoon Research and Development Centre (Canada)
PGRFA	Plant Genetic Resources for Food and Agriculture
PIC	Prior Informed Consent
PPB	Participatory Plant Breeding
PRC (VNM049)	Plant Resources Center (Viet Nam)
PROCICARIBE	The Caribbean Agricultural Science and Technology Networking System
PROCINORTE	Cooperative Program in Research and Technology for the Northern Region
PROCISUR	El Programa Cooperativo para el Desarrollo Tecnológico Agroalimentario y Agroindustrial del Cono Sur
PROCITROPICOS	Cooperative Program on Research and Technology Transfer for the South American Tropics
PSR (CHE063)	ProSpecieRara (Switzerland)
PVS	Participatory Varietal Selection
QDS	Quality Declared Seed
RBG	Royal Botanic Gardens, Kew
RBG (GBR004)	Millennium Seed Bank Project, Seed Conservation Department, Royal Botanic Gardens, Kew, Wakehurst Place (United Kingdom)
REDBIO	Biotechnology Network in Latin America and the Caribbean
REGNES	Tuniusian National Register of Wild Species
REMERFI	Mesoamerican Network on Plant Genetic Resources
RIAC	Red Interamericana de Citricos
ROCAREG	Réseau Ouest et Centre Africain des Ressources Génétiques
RUFORUM	The Regional Universities Forum for Capacity Building in Agriculture

S9 (USA016)	Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, University of Georgia, USDA-ARS (United States of America)
SADC	Southern African Development Community
SD=HS	The Sowing Diversity = Harvesting Security Programme
SDG(s)	Sustainable Development Goal(s)
SDIS	SADC Plant Genetic Resources Documentation System
SEARICE	Southeast Asia Regional Initiatives for Community Empowerment
Second GPA	Second Global Plan of Action for Plant Genetic Resources
SGSV	Svalbard Global Seed Vault
SMTA	Standard Material Transfer Agreement
SoW	State of the World
SoW1	State of the World’s Plant Genetic Resources for Food and Agriculture
SoW2	The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture
SOY (USA033)	Soybean Germplasm Collection, USDA-ARS (United States of America)
SPGRC	SADC Plant Genetic Resources Centre
Third Report	Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture
TK	Traditional Knowledge
Treaty	International Treaty on Plant Genetic Resources for Food and Agriculture
UC Davis	University of California Davis
UDS (UKR008)	Ustymivka Experimental Station of Plant Production (Ukraine)
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNDROP	UN Declaration on the Rights of Peasants and other People Working in Rural Areas
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPOV	International Union for the Protection of New Varieties of Plants
USAID	United States Agency for International Development
UzRICBSP (UZB036)	Uzbek Research Institute of Cotton Breeding and Seed Production (Uzbekistan)
UzRIPI (UZB006)	Uzbek Research Institute of Plant Industry (Uzbekistan)
VIR	Federal Research Center N. I. Vavilov All-Russian Institute of Plant Genetic Resources
VIR (RUS001)	N.I. Vavilov Research Institute of Plant Industry (Russian Federation)
W6 (USA022)	Western Regional Plant Introduction Station, USDA-ARS, Washington State University (United States of America)
WFP	Wild Food Plants
WIEWS	World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture
WorldVeg	World Vegetable Center
ZAKIS	Zimbabwe Agricultural Knowledge and Innovation Services