The Second Report on
THE STATE OF THE WORLD's

PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

COMMISSION ON
GENETIC RESOURCES
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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Foreword

Plant genetic resources for food and agriculture are playing an ever growing role on world food security and economic development. As an integral component of agricultural biodiversity, these resources are crucial for sustainable agricultural production intensification and ensure the livelihood of a large proportion of women and men who depend on agriculture.

In a world where around one billion people go hungry every day, with an expectation of a world population of nine billion by 2050, countries must make greater efforts to promote the conservation and sustainable use of the plant genetic resources for food and agriculture.

Agriculture has a key role to play in reducing poverty and food insecurity in the world. The effects of longstanding underinvestment in agriculture, food security and rural development, spikes in food prices and the global financial and economic crisis have led to increased hunger and poverty in many developing countries.

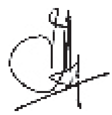
In the 21st century agriculture faces a number of challenges. It has to produce more food and fibre to meet the demand of a growing world population, mainly living in urban areas, while relying on a decreasing rural labour force. It has to produce more feedstock for a potentially huge bio-energy market and to contribute to overall development in the many agriculture-dependent developing countries, while adopting more efficient and sustainable production methods. Natural resources are also facing increasing pressure at the global, regional and local levels.

In addition, climate change is threatening to increase the number of hungry people even further in the future, and creating new and difficult challenges for agriculture. While the effects of climate change are only beginning to be felt, there is general agreement that unless appropriate measures are taken, their future impact will be enormous. Plant genetic resources that are also threatened by it, are the raw materials to improve the capacity of crops to respond to climate change and must be protected. An enhanced use of plant genetic diversity is essential to address these and other future challenges.

The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture provides a comprehensive picture of the global situation and trends regarding the conservation and use of plant genetic resources. The report was endorsed by the intergovernmental Commission on Genetic Resources for Food and Agriculture in 2009 as the authoritative assessment of the sector and a basis for updating the *Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture*.

The report was prepared with the active participation of member countries as well as the public and private sectors. It describes the most significant changes that have occurred since the publication of the first report in 1998 and focuses on the major gaps and needs which will serve countries and the world community to set future priorities for the conservation and sustainable utilization of plant genetic resources for food and agriculture. The report emphasizes the importance of an integrated approach to the management of plant genetic resources for food and agriculture. It points out the need to secure broad diversity of crop plants, including their wild relatives and underutilized species, in accessible conservation systems, and to increase capacities for plant breeding and seed delivery worldwide in order to tackle the challenges of climate change and food insecurity.

I hope and trust that the information in this report will be used as the basis for policy and technical decisions to strengthen national efforts to conserve and utilize the treasures incorporated in the world's plant genetic resources to address the urgent problems faced by agriculture today and tomorrow.



Jacques Diouf
FAO Director-General

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Preface

The first report on *The State of the World's Plant Genetic Resources for Food and Agriculture* (first SoW report) was presented to the Fourth International Technical Conference on Plant Genetic Resources held in Leipzig, Germany, in 1996. The Conference welcomed the report as the first comprehensive worldwide assessment of the state of plant genetic resource conservation and use. The full version of the first SoW report was published by the Food and Agriculture Organization of the United Nations (FAO) in 1998.

The Commission on Genetic Resources for Food and Agriculture (CGRFA), at its Eighth Regular Session, reaffirmed that FAO should periodically assess the state of the world's plant genetic resources for food and agriculture (PGRFA) to facilitate analyses of changing gaps and needs and contribute to the updating process of the rolling *Global Plan of Action on the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture* (GPA).

The CGRFA, at its Eleventh Regular Session, reviewed progress on the preparation of *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoWPGR-2) and noted that it should be a high quality document to identify the most significant gaps and needs, in order to provide a sound basis for the updating of the rolling GPA. It agreed that the SOWPGR-2 needed to be updated with the best data and information available, including country reports, information gathering processes and thematic studies, with the largest possible participation of countries, and should focus on changes that have occurred since 1996.

The preparatory process of the SoWPGR-2 used country reports as the main source of information on the status and trends of plant genetic resource conservation and use at the national level. As additional sources of information, FAO used scientific literature, thematic background studies and other relevant technical publications. Throughout the preparation, FAO strived to ensure high quality of the data and made considerable efforts to ensure that the process was country-driven, participatory and involved relevant international organizations.

The country reports were prepared based on the Guidelines for the Preparation of the Country Reports agreed by the CGRFA and made available in 2005. These Guidelines streamlined the process that had been established for the preparation of the SoWPGR-2 and introduced a new approach to monitor the implementation of the GPA.

The SoWPGR-2 was produced based on information provided by 113 countries (see Annex 1). FAO received the first of the 111 country reports in 2006, however, the majority were received in 2008. Two additional countries supplied data using a simplified reporting format. Reports from countries are available on the CD attached to this publication.

The progressive application of the new approach for the monitoring of the GPA implementation, that started in 2003, led to the establishment of National Information Sharing Mechanisms (NISM) in more than 60 countries worldwide (see Annex 1). Providing comprehensive information on the implementation of all the 20 priority activity areas of the GPA, the NISMs were widely used in the preparation of a large number of country reports.

A wide range of partners, including Bioversity International on behalf of the Consultative Group on International Agricultural Research (CGIAR), the Global Crop Diversity Trust (GCDT) and the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), as well as other relevant international organizations, provided inputs throughout the preparation process. 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.

The CGRFA requested that the SoWPGR-2 address the same seven chapter topics that were selected for the first SoW report, with one additional chapter discussing the contribution of PGRFA management to food security and sustainable development.

The CGRFA requested the preparation of in-depth studies on specific topics, including climate change, nutrition and health, as well as indicators on genetic erosion and seed systems, to complement the information provided through country reports. These studies were prepared in collaboration with several partners, including the CGIAR centres, and are available on the CD attached to this publication.

The SoWPGR-2 identifies the most significant gaps and needs on the conservation and use of PGRFA that have arisen since the first SoW report, provides the basis for the updating of the rolling GPA and for designing strategic national, regional and international policies for the implementation of its priority activities. At its Twelfth Session the CGRFA endorsed the report as the authoritative assessment of this sector. On the request of the CGRFA, a synthetic account of the report was also prepared containing the main findings and highlighting the gaps and needs that need urgent attention.

Acknowledgements

The SoWPGR-2 has been possible thanks to the contribution of time, energy and expertise by many individuals. FAO would like to take this opportunity to acknowledge their generosity. The report was prepared by FAO's Plant Production and Protection Division under the overall supervision of Elcio P. Guimarães. The core FAO team was composed of Stefano Diulgheroff, Kakoli Ghosh, Robert Gouantoueu Guei and Barbara Pick. Linda Collette, Juan Fajardo, Brad Fraleigh and Nuria Urquia also contributed to the work of the team. During the preparation process of the SoWPGR-2, there was very close collaboration with the Bioversity International team composed of Kwesi Atta-Krah, Ehsan Dulloo, Jan Engels, Toby Hodgkin and David Williams; the Global Crop Diversity Trust team was composed of Luigi Guarino and Godfrey Mwila.

The core information used to prepare the SoWPGR-2 was provided by 113 countries through country reports and data supplied through other mechanisms. The SoWPGR-2 team wishes to thank those governments and individuals for their contributions on the national status of PGRFA in their countries.

The preparation of this report would not have been possible without the generous financial support provided by the Governments of Canada, Italy, Japan, the Netherlands, Norway and Spain, and by FAO. Each chapter, annex and appendix of this report was prepared and reviewed by the individual experts or expert teams that are acknowledged below.

Chapter 1 – The state of diversity, was written by a team led by Bert Visser in association with Jan M.M. Engels, V.R. Rao, J. Dempewolf and M. van D. Wouw. The chapter was revised by Luigi Guarino and Danny Hunter.

Chapter 2 - The state of *in situ* management, was written by a team led by Ehsan Dulloo in association with Devra Jarvis, Imke Thormann, Xavier Scheldeman, Jesus Salcedo, Danny Hunter and Toby Hodgkin. The chapter was revised by Luigi Guarino.

Chapter 3 - The state of *ex situ* conservation, was written by Stefano Diulgheroff and Jonathan Robinson with the assistance of Morten Hulden, except for Section 3.10 Botanical Gardens, which was prepared by Suzanne Sharrock. The whole chapter was revised by Toby Hodgkin and Luigi Guarino.

Chapter 4 – The state of use, was written by Jonathan Robinson and Elcio P. Guimarães and was revised by Clair Hershey and Eric Kueneman.

Chapter 5 - The state of national programmes, training needs and legislation, was written by a team led by Patrick McGuire in association with Barbara Pick and Raj Paroda and was revised by Geoffrey Hawtin and Elcio P. Guimarães.

Chapter 6 - The state of regional and international collaboration, was written by Geoffrey Hawtin and Raj Paroda and was revised by Kakoli Ghosh.

Chapter 7 - Access to plant genetic resources, the sharing of benefits arising out of their utilization and the realization of Farmers' Rights, was written by Gerald Moore and was revised by Maria José Amstalden Sampaio and Geoffrey Hawtin.

Chapter 8 - The contribution of PGRFA to food security and sustainable agricultural development, was written by a team led by Leslie Lipper in association with Romina Cavatassi and Alder Keleman and was revised by Kakoli Ghosh and Robert Gouantoueu Guei.

Annex 1 - List of countries that provided information for the preparation of *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*, was prepared by Barbara Pick, Patrick McGuire and Elcio P. Guimarães.

Annex 2 - Regional distribution of countries, was prepared by Barbara Pick and Marike Brezillon-Millet.

Appendix 1 - Status by country of national legislation related to Plant Genetic Resources for Food and Agriculture, was prepared by Barbara Pick.

Appendix 2 - Major germplasm collections by crop and institute, was prepared by Morten Hulden and Stefano Diulgheroff.

Appendix 3 – The state-of-the-art: methodologies and technologies for the identification, conservation and use of plant genetic resources for food and agriculture, was prepared by Patrick McGuire and revised by Theresa M. Fulton and Chike Mba.

Appendix 4 – State of diversity of major and minor crops, was prepared by Patrick McGuire, revised by Stefano Diulgheroff and received inputs from Steve Beebe, Merideth Bonierbale, Hernan Ceballos, Bing Engle, José Esquinas, Luigi Guarino, Lorenzo Maggioni, Cesar P. Martínez, Elisa Mihovilovich, Matilde Orrillo, Rodomiro Ortiz and Hari D. Upadhyaya on specific crops.

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Executive summary

This report describes the current status of the conservation and use of PGRFA throughout the world. It is based on country reports, information gathering processes, regional syntheses, thematic background studies and published scientific literature. It describes the most significant changes that have taken place since the first SoW report was published in 1998 and describes major continuing gaps and needs. The structure follows that of the first SoW report with an additional chapter on the contribution of PGRFA to food security and sustainable agricultural development.

1 The state of diversity

The total number of accessions conserved *ex situ* worldwide has increased by approximately 20 percent since 1996, reaching 7.4 million. While new collecting accounted for at least 240 000 accessions, and possibly considerably more, much of the overall increase is the result of exchange and unplanned duplication. It is estimated that less than 30 percent of the total number of accessions are distinct. While the number of accessions of minor crops and crop wild relatives (CWR) has increased, these categories are still generally under-represented. There is still a need for greater rationalization among collections globally.

Scientific understanding of the on-farm management of genetic diversity has increased. While this approach to the conservation and use of PGRFA is becoming increasingly mainstreamed within national programmes, further efforts are needed in this regard.

With the development of new molecular techniques, the amount of data available on genetic diversity has increased dramatically, leading to an improved understanding of issues such as domestication, genetic erosion and genetic vulnerability. The introduction of modern varieties of staple crops appears to have resulted in an overall decrease in genetic diversity, although within the released varieties themselves the data are inconsistent and no overall narrowing of the genetic base can be discerned. The situation regarding genetic erosion in landraces and CWR is equally complex. While many recent studies have confirmed that diversity in farmers' fields and protected areas has eroded, this is not universally the case.

Many country reports expressed continuing concern over the extent of genetic vulnerability and the need for a greater deployment of diversity. However, better techniques and indicators are needed to monitor genetic diversity, to establish baselines and monitor trends.

There is evidence of growing public awareness with regard to the importance of genetic diversity, both to meet increasing demands for greater dietary diversity, as well as to meet future production challenges. The increased environmental variability that is expected to result from climate change implies that in the future, farmers and plant breeders will need to be able to access an even wider range of PGRFA than today.

2 The state of *in situ* management

Since the first SoW report was published, a large number of surveys and inventories have been carried out in many different countries, both in natural and agricultural ecosystems. Awareness of the importance and value of CWR and of the need to conserve them *in situ* has increased. A global strategy for CWR conservation and use has been drafted, protocols for the *in situ* conservation of CWR are now available, and a new Specialist Group on CWR has been established within the International Union for Conservation of Nature/ Species Survival Commission (SSC-IUCN). The number and coverage of protected areas has expanded by approximately 30 percent over the past decade and this has indirectly led to a greater protection of CWR. However, relatively little progress has been achieved in conserving wild PGRFA outside protected areas or in developing sustainable management techniques for plants harvested from the wild.

Significant progress has been made in the development of tools and techniques to assess and monitor PGRFA within agricultural production systems. Countries now report a greater understanding of the amount and distribution of genetic diversity in the field, as well as the value of local seed systems in maintaining such diversity. More attention is now being paid in several countries to increasing genetic diversity within production systems as a way to reduce risk, particularly in light of changes in climate, pests and diseases. The number of on-farm management projects carried out with the participation of local stakeholders has increased somewhat and new legal mechanisms have been put in place in several countries to enable farmers to market genetically diverse varieties.

There is still a need for more effective policies, legislation and regulations governing the *in situ* and on-farm management of PGRFA, both inside and outside protected areas, and closer collaboration and coordination are needed between the agriculture and environment sectors. Many aspects of *in situ* management still require further research and strengthened research capacity is required in such areas as the taxonomy of CWR and the use of molecular tools to conduct inventories and surveys.

3 The state of *ex situ* conservation

Since the publication of the first SoW report, more than 1.4 million accessions have been added to *ex situ* collections, the large majority of which are in the form of seeds. Fewer countries now account for a larger percentage of the total world *ex situ* germplasm holdings than was the case in 1996.

While many major crops are well-, or even overduplicated, many important collections are inadequately so and hence potentially at risk. For several staple crops, such as wheat and rice, a large part of the genetic diversity is currently represented in collections. However, for many others, considerable gaps remain. Interest in collecting CWR, landraces and neglected and underutilized species, is growing as land-use systems change and environmental concerns increase the likelihood of their erosion.

Many countries still lack adequate human capacity, facilities, funds or management systems to meet their *ex situ* conservation needs and obligations, and as a result, a number of collections are at risk. While significant advances have been made in regeneration in both national and international collections, further work remains to be done. The documentation and characterization of many collections is still inadequate and in cases where information does exist, it is often difficult to access.

Greater efforts are needed to build a truly rational global system of *ex situ* collections. This requires, in particular, strengthened regional and international trust and cooperation.

The number of botanical gardens around the world now exceeds 2 500, maintaining samples of some 80 000 plant species. Many of these are CWR. Botanical gardens took the lead in developing the Global Strategy for Plant Conservation adopted by the Convention on Biological Diversity (CBD) in 2002.

The creation of the GCDT and the Svalbard Global Seed Vault (SGSV) both represent major achievements since the first SoW report was published and the world's PGRFA is undoubtedly more secure as a result. However, while seed collections are larger and more secure overall, the situation has progressed less in the case of vegetatively propagated species and species whose seeds cannot be dried and stored at low temperatures.

4 The state of use

The sustainable use of PGRFA primarily through plant breeding and associated seed systems remains essential for food security, viable agricultural enterprise and for adaptation to climate change. By aggregating data globally, it appears that plant breeding capacity has not changed significantly during the last 15 years. A modest increase in the number of plant breeders has been reported in some countries and a decline in others. In many countries public sector plant breeding has continued to contract, with the private sector increasingly taking over.

Agriculture in many developing countries that reduced their support to public sector crop development, leaving instead, the sustainable use of PGRFA to the private sector, is more vulnerable than in the past as private sector breeding and seed enterprise is restricted largely to a few crops for which farmers buy fresh seed each season. Considerably more attention and capacity building is urgently needed to strengthen plant breeding capacity and the associated seed systems in most developing countries, where most of the important crops are not, and will not be, the focus of private enterprise.

The number of accessions characterized and evaluated has increased in all regions but not in all individual countries. More countries now use molecular markers to characterize their germplasm and undertake genetic enhancement and base-broadening to introduce new traits from non-adapted populations and wild relatives.

Several new important international initiatives have been established to promote the increased use of PGRFA. The Global Partnership Initiative for Plant Breeding Capacity Building (GIPB), for instance, aims to enhance the sustainable use of PGRFA in developing countries through helping to build capacity in plant breeding and seed systems. The GCDT, and the new Generation and Harvest Plus Challenge Programs of the CCGIAR, all support the increased characterization, evaluation and improvement of germplasm.

Genomics, proteomics, bioinformatics and climate change were all absent from the first SoW report but are important now, and greater prominence is also given to sustainable agriculture, biofuel crops and human health. Although progress in research and development of neglected and underutilized species, as recommended in the first SoW report, is difficult to gauge, it is clear that further efforts are needed.

In many countries there is a need for more effective strategies, policies and legislation, including seed and intellectual property (IP) legislation, to promote a greater use of PGRFA. Good opportunities exist to strengthen cooperation among those involved in conservation and use, at all stages of the seed and food chain. Stronger links are needed, especially between plant breeders and those involved in seed systems, as well as between the public and private sectors.

5 The state of national programmes, training needs and legislation

Although the first SoW report classified national programmes into three categories, it has since become clear that such a typology is too simplistic. There is huge heterogeneity among national programmes in terms of their goals, functions, organization and structure. Of the 113 countries that provided information for both the first and second SoW reports, 46 percent had no national programme in 1996 whereas 71 percent have one now. In most countries, national government institutions are the principal entities involved, however, the number of other stakeholders, especially universities, has expanded. Many of the country reports noted that funding remains inadequate and unreliable.

Even in countries with well-coordinated national programmes, certain elements are often missing. National, publicly accessible databases, for example are still comparatively rare, as are coordinated systems for safety duplication and public awareness.

Since the first SoW report was published, most countries have enacted new national phytosanitary legislation, or revised old legislation, in large part in response to the adoption of the revised International Plant Protection Convention (IPPC) in 1997. With respect to intellectual property rights (IPR), of the 85 developing and Eastern European countries that now recognize Plant Breeders Rights (PBR), 60 have done so in the last decade. Seven others are currently drafting legislation.

The importance of farmers as custodians and developers of genetic diversity was recognized in the ITPGRFA through the provisions of Article 9 on Farmers' Rights. Eight countries have now adopted regulations covering one or more aspects of Farmers' Rights.

Since the first SoW report, biosafety has emerged as an important issue and many countries have now either adopted national biosafety regulations or frameworks, or are currently developing them. As of February 2010, 157 countries and the European Union had ratified the Cartagena Protocol on Biosafety.

6 The state of regional and international collaboration

The entry into force of the ITPGRFA in 2004 marks what is probably the most significant development since the publication of the first SoW report. The ITPGRFA is a legally binding international agreement that promotes the conservation and sustainable use of PGRFA and the fair and equitable sharing of the benefits arising out of their use, in harmony with the CBD. International collaboration is strongly promoted by the ITPGRFA, for which FAO provides the Secretariat.

Given the high level of interdependence among countries with respect to the conservation and use of PGRFA, it is imperative that there be strong and extensive international cooperation. Good progress has been made in this area since the first SoW report was published. A number of new regional networks on PGRFA have been established and a few others have become stronger. However, not all have fared well. Several are largely inactive and one has ceased to function. Three new regional networks specifically addressing the issue of seed production, have been established in Africa.

FAO has further strengthened its activities in PGRFA since the first Sow report, for example, through establishing GIPB in 2006. The international centres of the CGIAR concluded agreements in 2006 with FAO, acting on behalf of the Governing Body of the ITPGRFA, in this way bringing their collections within the ITPGRFA's multilateral system of access and benefit sharing. The CGIAR itself is undergoing significant reform.

There have also been many other new international initiatives including the establishment of the International Center for Biosaline Agriculture (ICBA) in 1999, the Central Asia and the Caucasus Association of Agriculture Research Institution (CACAARI) and the Global Forum on Agricultural Research (GFAR) in 2000, the Forum for Agricultural Research in Africa (FARA) in 2002, the Global Cacao Genetic Resources Network (CacaoNet) in 2006, and the Crops for the Future and the SGSV in 2008. All have significant activities in PGRFA. In the area of funding, several new foundations now support international activities with regard to PGRFA. A special fund was set up in 1998 to support agricultural research in Latin America (FONTAGRO) and in 2004, the GCDT was established as an essential element of the funding strategy of the ITPGRFA.

7 Access to plant genetic resources, the sharing of benefits arising out of their utilization and the realization of Farmers' Rights

The international and national legal and policy framework for access and benefit sharing (ABS) has changed substantially since the publication of the first SoW report. Perhaps the most far-reaching development has been the entry into force of the ITPGRFA in 2004. The ITPGRFA established a Multilateral System of ABS that facilitates access to plant genetic resources of the most important crops for food security, on the basis of a Standard Material Transfer Agreement (SMTA). As of February 2010, there were 123 parties to the ITPGRFA. The FAO Commission on Genetic Resources for Food and Agriculture adopted a Multi-Year Programme of Work in 2007 that recommended that "FAO continue to focus on ABS for genetic resources for food and agriculture in an integrated and interdisciplinary manner…"

Negotiations under the CBD to develop an international regime on ABS are scheduled to be finalized in 2010. However, many issues remain to be settled, including the legal status of the regime. Discussions on matters related to ABS are also taking place in other fora such as the Trade-Related Aspects of Intellectual Property Rights Council (TRIPS), the World International Property Organization (WIPO) and the World Trade Organization (WTO). There is a need for greater coordination among the different bodies involved in these discussions at the national and international levels.

In February 2010, the CBD Database on ABS Measures listed 33 countries with legislation regulating ABS. Of these, 22 have adopted new laws or regulations since 2000. Most have been developed in response to the CBD rather than the ITPGRFA. Many countries have expressed a desire for assistance in confronting the complex legal and technical issues involved in drawing up new legislation. So far, there are few models that can be emulated and several countries are experimenting with new ways of protecting and rewarding traditional knowledge and the realization of Farmers' Rights.

8 The contribution of PGRFA to food security and sustainable agricultural development

Sustainable development has grown from being a movement focusing mainly on environmental concerns, to a widely recognized framework that aims to balance economic, social, environmental and intergenerational concerns in decision-making and action at all levels.

There have been growing efforts to strengthen the relationship between agriculture and the provision of ecosystem services. Schemes that promote Payment for Environmenal Services (PES), such as the *in situ* or on-farm conservation of PGRFA, are being set up in an attempt to encourage and reward farmers and rural communities for their stewardship of the environment. However, the fair and effective implementation of such schemes remains a major challenge.

Concerns about the potential impact of climate change have grown substantially over the past decade. Agriculture is both a source and a sink for atmospheric carbon. PGRFA are recognized as being critically important for the development of farming systems that capture more carbon and emit fewer greenhouse gasses, and for underpinning the breeding of new varieties that will be needed for agriculture to adapt to the anticipated future environmental conditions. Given the time needed to breed a new crop variety, it is essential that additional plant breeding capacity be built now.

There is a need for more accurate and reliable measures, standards, indicators and baseline data for sustainability and food security that will enable better monitoring and assessment of the progress made in these areas. Standards and indicators that will enable the monitoring of the specific role played by PGRFA are needed particularly.

In spite of the enormous contribution by PGRFA to global food security and sustainable agriculture, its role is not widely recognized or understood. Greater efforts are needed to estimate the full value of PGRFA, to assess the impact of its use and to bring this information to the attention of policy-makers and the general public so as to help generate the resources needed to strengthen programmes for its conservation and use.

Chapter 1

The state of diversity

1.1 Introduction

Chapter 1 of the first SoW report described the nature, extent and origin of genetic diversity between and within plant species, the interdependence among countries with respect to their need for access to resources from others and the value of this diversity, especially to small-scale farmers. This chapter updates the information provided in the first SoW report and introduces a number of new elements. It seeks to place PGRFA in the wider context of changing food production and consumption patterns and it summarizes what is known with regards to changes in the state of diversity in farmers' fields, *ex situ* collections and protected and unprotected natural areas across the globe. It provides an updated review of the status of genetic vulnerability and of the interdependence among countries and regions in the conservation and use of PGRFA. Furthermore, new information is provided on indicators of genetic diversity and on assessment techniques. The chapter ends with a summary of major changes that have taken place since 1996, and a list of gaps and needs for the future.

Since the first SoW report was published, certain trends have become more visible and new trends have emerged. Globalization has had a growing impact, food and energy prices have risen, organic foods have become increasingly popular as well as economically attractive and the cultivation of genetically modified (GM) crops has spread widely, although not without opposition. Investment in agricultural research, both in developed and developing countries has continued to show high economic rates of return, not least through the development and deployment of new crop varieties. Food security continues to be a worldwide concern and is likely to remain so for the foreseeable future as the world population continues to expand, resources become scarcer and pressure mounts to develop productive land for alternative uses. Climate change is now widely considered to be unavoidable. All these factors can be expected to have had an effect on the state of diversity in farmers' fields.

The development of new varieties and cropping systems adapted to the new environmental and socio-economic conditions will be crucial in order to limit yield losses in some regions and to take advantage of new opportunities in others (see Section 4.9.5).[1,2,3] In many areas of the world, crop yields have started to plateau or even decline as a result of environmental degradation, increasing water and energy shortages and a lack of targeted investment in research and infrastructure (see Chapter 8).[4] Facing these challenges will require an increased use of genetic diversity, resulting in an increasing demand for novel material from the world's genebanks.

1.2 Diversity within and between plant species

Only a few of the country reports contain data that allow a direct and quantitative comparison of changes in the status of diversity within and between crops in the period since 1996. Furthermore, where quantitative comparisons have been included, these mainly concern the number of released varieties or changes in crop acreages, both of which are only very indirect indicators of change in genetic diversity in farmers' fields. However, it seems clear that on-farm management initiatives have expanded in the past decade as the scientific basis of such work has become better understood and appropriate methodologies developed and implemented. The linkages between those primarily concerned with on-farm management of PGRFA and those involved in *ex situ* conservation and use have also become stronger, although in many ways the two sectors remain compartmentalized. The continued growth of *ex situ* collections and the increased inclusion of threatened genetic diversity within them is a positive trend, although backlog in regeneration and over-duplication continue to be areas of concern. No quantitative data were provided in the country reports on the changing status of CWR, but several countries reported on specific measures that had been undertaken to promote their conservation. Finally, there is evidence that public awareness of the importance of crop diversity, especially of formerly neglected and underutilized species such as traditional vegetables and fruits, is growing both in developing and developed countries.

1.2.1 Changes in the status of on-farm managed diversity

Throughout most of the developed world, industrialized production now supplies the majority of food. Modern breeding has resulted in crop varieties that meet the requirements of high-input systems and strict market standards (although there is also limited breeding work aimed at low-input and organic agriculture). Strong consumer demand for cheap food of uniform and predictable quality has resulted in a focus on cost-efficient production methods. As a result, over the last decade multinational food companies have gained further influence and much of the food consumed in industrialized countries is now produced beyond their national borders.[5] This pattern of food production and consumption is also spreading to many developing countries, especially in South America and parts of Asia,[6] as incomes rise in those regions.

However, in spite of this trend, a substantial portion of the food consumed in the developing world is still produced with few, if any, external chemical inputs and is sold locally. Such farming systems generally rely heavily on diverse crops and varieties and in many cases on a high level of genetic diversity within local varieties. This represents a traditional and widespread strategy to increase food security and reduce the risks that result from the vagaries of markets, weather, pests or diseases. Through the continuing shift from subsistence to commercial agriculture, much of the diversity that still exists within these traditional systems remains under threat. The maintenance of genetic diversity within local production systems also helps to conserve local knowledge and vice versa. With the disappearance of traditional lifestyles and languages across the globe, a large amount of knowledge about traditional crops and varieties is probably being lost and with it much of the value of the genetic resources themselves, justifying the need for greater attention to be paid to the on-farm management of PGRFA. The concept of agrobiodiversity reserves has gained currency in this context. These are protected areas whose objective is the conservation of cultivated diversity and its associated agricultural practices and knowledge systems.

Over the last decade, promoting and supporting the on-farm management of genetic resources, whether in farmers' fields, home gardens, orchards or other cultivated areas of high diversity, has become firmly established as a key component of crop conservation strategies, (as methodologies and approaches have been scientifically documented and their effects monitored) see Chapter 2. Having said this, it is not possible from the information provided in the country reports to make definitive statements about overall trends in on-farm diversity since 1996. It seems clear that diversity in farmers' fields has decreased for some crops in certain areas and countries and the threats are certainly getting stronger; but, on the other hand, other attempts to rigorously measure changes in crop genetic diversity in published literature have not yielded the expected evidence of erosion. This issue will be dealt with in more detail in Section 1.3.

Participatory plant breeding (PPB) has become more widely adopted as an approach to the management of diversity on farm, with the objective of both developing improved cultivars and conserving adaptive and other traits of local importance. It provides a particularly effective linkage to both *ex situ* conservation and use. More information on the status of PPB is given in Section 4.6.2.

1.2.2 Changes in the status of diversity in *ex situ* collections

As reported in Chapter 3, the total number of accessions conserved *ex situ* worldwide has increased by approximately 20 percent (1.4 million) since 1996, reaching 7.4 million. It is estimated, however, that less than 30 percent of this total are distinct accessions (1.9-2.2 million). During the same period, new collecting accounted for at least 240 000 accessions and possibly considerably more (see Chapter 3). Major trends can be inferred by comparing the current state of diversity of a set of well-documented *ex situ* collections with that pertaining to the time when the first SoW report was produced. To that end, data on 12 collections held by the centres of the CGIAR and the World Vegetable Centre (former Asian Vegetable Research and Development Centre, AVRDC) as well as 16 selected collections held

TABLE 1.1
Comparison between the collections maintained by AVRDC and the CGIAR centres in 1995 and 2008

Centre [a]	1995 (no.)			2008 (no.)			Change (%)		
	Genera	Species	Accessions	Genera	Species	Accessions	Genera	Species	Accessions
AVRDC	63	209	43 205	160	403	56 522	154	93	31
CIAT	161	906	58 667	129	872	64 446	-20	-4	10
CIMMYT	12	47	136 259	12	48	173 571	0	2	27
CIP	9	175	13 418	11	250	15 046	22	43	12
ICARDA	34	444	109 223	86	570	132 793	153	28	22
ICRAF	3	4	1 005	3	6	1 785	0	50	78
ICRISAT	16	164	113 143	16	180	118 882	0	10	5
IITA	72	155	36 947	72	158	27 596	0	2	-25
ILRI	358	1 359	13 470	388	6	18 763	0	28	39
INIBAP/Bioversity	2	21	1 050	2	1 746	1 207	0	10	15
IRRI	11	37	83 485	11	23	109 161	0	5	31
WARDA	1	5	17 440	1	39	21 527	0	20	23
Total	**494**	**2 813**	**627 312**	**612**	**3 446**	**741 319**	**24**	**23**	**18**

Sources: Individual genebanks; System-wide Information Network for Genetic Resources (SINGER) Web site 2008; WIEWS 1996, 1995 data for IITA and ICRAF are from SINGER CD 1997. Undetermined genera were not counted.

[a] World Vegetable Centre (former Asian Vegetable Research and Development Centre, AVRDC); Centro Internacional de Agricultura Tropical (CIAT); Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT); Centro Internacional de la Papa (CIP); International Centre for Agricultural Research in the Dry Areas (ICARDA); International Centre for Research in Agroforestry [now the World Agroforestry Centre] (ICRAF); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); International Institute of Tropical Agriculture (IITA); International Livestock Research Institute (ILRI); International Network for the Improvement of Banana and Plantain, (INIBAP); International Rice Research Institute (IRRI); West African Rice Development Association [now the Africa Rice Centre - AfricaRice] (WARDA).

TABLE 1.2
Comparison between the collections maintained by selected national genebanks in 1995 and 2008[a]

Country	Genebank	1995 (no.)			2008 (no.)			Change (%)		
		Genera[b]	Species	Accessions	Genera	Species	Accessions	Genera	Species	Accessions
Brazil	CENARGEN	136	312	40 514	212	670	107 246	56	115	165
Canada	PGRC	237	1 028	100 522	257	1 166	106 280	8	13	6
China	ICGR-CAAS	-	-	358 963	-	-	391 919	-	-	9
Czech Republic	RICP	34	96	14 495	30	175	15 421	-12	82	6
Ecuador	INIAP/DENAREF	207	499	10 835	272	662	17 830	31	33	65
Ethiopia	IBC	71	74	46 322	151	324	67 554	113	338	46
Germany	IPK Gatersleben[c]	633	2 513	147 436	801	3 049	148 128	27	21	0
Hungary	ABI	238	742	37 969	294	915	45 321	24	23	19
India	NBPGR	73	177	154 533	723	1 495	366 333	890	745	137
Japan	NIAS	-	-	202 581	341	1 409	243 463	-	-	20
Kenya	KARI-NGBK	140	291	35 017	855	2 350	48 777	511	708	39
Nordic Countries	NGB[d]	88	188	24 241	129	319	28 007	47	70	16
Russian Federation	VIR	262	1 840	328 727	256	2 025	322 238	-2	10	-2
Netherlands	CGN	30	147	17 349	36	311	24 076	20	112	39
Turkey	AARI	317	1 941	32 122	545	2 692	54 523	72	39	70
United States of America	NPGS[e]	1 582	8 474	411 246	2 128	11 815	508 994	35	39	24
Average		**289**	**1 309**	**140 205**	**502**	**2 098**	**178 294**	**74**	**60**	**27**

TABLE 1.2 (continued)
Comparison between the collections maintained by selected national genebanks in 1995 and 2008[a]

[a] Genebanks selected according to the size of the collections and availability of data. Figures represent accession numbers. Data sources are as follows: Brazil genebank manager; Canada genebank manager; Country reports China, 1995 and 2008; Czech Republic, WIEWS 1996 and EURISCO 2008; Ethiopia, WIEWS 1996 and NISM (2007); Ecuador, genebank dataset, WIEWS 1996 and NISM (2008); Germany, WIEWS 1996, EURISCO 2008, Country reports 1995 and 2007; Hungary, genebank manager; India, genebank manager; Kenya WIEWS 1996 and NISM (2008); Nordic Countries, genebank dataset; the Russian Federation, genebank manager; the Netherlands, genebank manager; Turkey, genebank manager; United States of America, USDA Germplasm Resources Information Network (GRIN) dataset.

[b] Taxonomic systems vary among genebanks, and may have changed over time. Hybrids and unidentified species are included.

[c] 1995 data refer to germplasm holdings from IPK and its two external branches in Gross-luesewitz and Malchow, plus those from PGRC in Braunschweig, as this was shut down and the biggest part of its collections was transferred to IPK by 2004.

[d] Excluding accessions held in field genebanks, but including special seed collections and genetic stocks. Additional data from Sweden's Country report, 1995.

[e] The National Plant Germplasm System (NPGS) includes the following repository centres: C.M. Rick Tomato Genetic Resources Centre (GSlY), Davis, California; Clover Collection, Department of Agronomy, University of Kentucky (ClO), Lexington, Kentucky; Crop Germplasm Research Unit (COT), College Station, Texas; Dale Bumpers National Rice Research Centre (DB NRRC), Stuttgart, Arkansas; Desert Legume Programme (DlEG), Tucson, Arizona; Fruit laboratory, ARS Plant Germplasm Quarantine Office (PGQO), Beltsville, Maryland; G.A. Marx Pea Genetic Stock Centre, Western Regional Plant Introduction Station (GSPI), Pullman, Washington; Maize Genetics Cooperation, Stock Centre (MGCSC; GSZE), Urbana, Illinois; National Arctic Plant Genetic Resources Unit, Alaska Plant Materials Centre (PAlM), Palmer, Alaska; National Arid Land Plant Genetic Resources Unit (PARl), Parlier, California; National Centre for Genetic Resources Preservation (NCGRP), Fort Collins, Colorado; National Clonal Germplasm Repository (COR), Corvallis, Oregon; National Clonal Germplasm Repository for Citrus and Dates (NCGRCD), Riverside, California; National Germplasm Repository (DAV), Davis, California; National Germplasm Repository (HILO), Hilo, Hawaii; National Germplasm Resources laboratory (NGRl), Beltsville, Maryland; National Small Grains Germplasm Research Facility (NSGC), Aberdeen, Idaho; National Tree Seed Laboratory, Dry Branch, Georgia; North Central Regional Plant Introduction Station (NC7), Ames, Iowa; Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit (NE9), Geneva, New York; Ornamental Plant Germplasm Centre (OPGC), Columbus, Ohio; Oxford Tobacco Research Station (TOB), Oxford, North Carolina; Pecan Breeding and Genetics, National Germplasm Repository (BRW), Somerville, Texas; Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station (S9), Griffin, Georgia; Plant Genetic Resources Unit, New York State Agricultural Experiment Station (GEN), Geneva, New York; Potato Germplasm Introduction Station (NR6), Sturgeon Bay, Wisconsin.

in national agricultural research systems (NARS) have been analysed (see Tables 1.1 and 1.2, respectively). These collections account for a substantial proportion of total global *ex situ* resources. They are not meant to provide a comprehensive or regionally-balanced view of the global situation: they are simply the genebanks for which sufficiently high-quality data is available for both 1996 and today, allowing a reasonable estimate to be made of trends.

Overall, these *ex situ* collections have grown considerably in size. Between 1995 and 2008, the combined international collections maintained by the CGIAR and AVRDC increased by 18 percent and national collections by 27 percent. However, how much of this is completely new and distinct material and how much represents the acquisition of materials already present in other genebanks is unknown.

Although the prevailing opinion in 1995 was that the coverage of the diversity of the major staple crops[7] within the CGIAR collections was fairly comprehensive,[8] many collections have grown since then as gaps in the geographic coverage of the collections have been identified and filled and additional samples of CWR added. Adjustments to the numbers have also been made as a result of improved documentation and management. In addition, several of the CGIAR genebanks have taken on responsibility for collections of materials with special genetic characteristics and orphan collections provided by others.

Although the major growth in the CGIAR collections regards species that were already present before 1995, a considerable number of new species has also been added.

In the case of the national collections analysed, there has been a particularly large increase in the number of species and accessions of non-staple crops and CWR conserved – although these are still generally under-represented in collections.[9] The increase in species coverage has been dramatic: an average of 60 percent since 1995. However, there are large differences among countries: some collections are still being put together and have shown large increases (e.g. Brazil, Ecuador and India), others are stable or in a consolidation phase (e.g. Germany and the Russian Federation). Even greater variability is to be expected across the full range of genebanks in all regions.

The standard of conservation of the CGIAR collections has advanced over the past decade, largely as a result of additional financial support from the World Bank. Regeneration backlogs have decreased substantially and no significant genetic erosion is reported. However, in the case of national genebanks, a more complex picture emerges. A recent series of studies supported by the GCDT covering 20 major crops[10] reports large regeneration backlogs in a considerable number of national collections. Other concerns include:

- neglected and underutilized species remain generally under-represented in collections;
- the situation may become even more serious if there is a greater shift in the focus of attention to crops that are included within the multilateral system (MLS) of access and benefit-sharing (ABS) under the ITPGRFA;
- the number of individuals (seeds, tissues, tubers, plants, etc.) conserved per accession is frequently below the optimum for maintaining heterogeneous populations;
- CWR are generally expensive to maintain and remain under-represented in *ex situ* collections, a situation that is unlikely to change unless considerably more resources are provided for the task.

While it appears that substantially more diversity is now conserved *ex situ* than a decade ago, a word of caution is warranted, as suggested above. Some, and perhaps most of the increases, result from the exchange of existing accessions among collections, leading to an overall increase in the amount of duplication.[11] This may at least in part, reflect a tendency for increased "repatriation" of collections. In addition, at least part of the change may be attributed to better management of the collections and more complete knowledge about the numbers involved. However, it should also be noted that numbers of accessions are not necessarily synonymous with diversity. Sometimes a smaller collection can be more diverse than a larger one.

Efforts to rationalize collections have been reported by several genebanks and networks. One example is an initiative of the European Cooperative Programme for Plant Genetic Resources (ECPGR) to rationalize European plant genetic resources collections that are dispersed over approximately 500 holders and 45 countries. The identification of undesirable duplicates is an important component of the initiative, named AEGIS (A European Genebank Integrated System for PGRFA). The so-called 'most appropriate accessions' are being identified among duplicate accessions, based on criteria such as genetic uniqueness, economic importance and ease of access, conservation status and information status. The adoption of common data standards greatly facilitates the comparison of data and hence the identification of duplicates and unique accessions.[12]

1.2.3 Changes in the status of crop wild relatives

The *in situ* management of CWR is discussed in Chapter 2 and figures on the *ex situ* conservation of CWR are provided in Chapter 3. While *ex situ* conservation and on-farm management methods are most appropriate for the conservation of domesticated crop germplasm, CWR and species harvested from the wild, *in situ* conservation is generally the strategy of choice, backed up by *ex situ*, which can greatly facilitate their use. In spite of a growing appreciation of the importance of CWR, as evidenced by many country reports, the diversity within many species, and in some cases even their continued existence, remains under threat as a result of changes in land-use practices, climate change and the loss or degradation of natural habitats.

Many new priority sites for conserving CWR *in situ* have been identified around the world over the last decade, generally following some form of ecogeographic survey.[13] In some cases, new protected areas have been proposed for conserving a particular genus or even species. The diversity of CWR in some existing protected areas has decreased over this period, while others still harbour significant diversity.

Across regions, the distribution of reserves that include CWR populations within their boundaries, remains uneven and several major regions, such as Sub-Saharan Africa, are still under-represented. However, *in situ* conservation of CWR has gained increasing attention in many countries, for example, in those countries that are participating in a project managed by Bioversity International entitled '*In situ* conservation of CWR through enhanced information management and field application' (see Box 2.1). Preparatory activities, such as research and site selection, were mentioned in several country reports, however, there is still a need for formal recognition and/or the adoption of appropriate management regimes. The CGRFA recently commissioned a report on the "Establishment of a global network for the *in situ* conservation of CWR: status and needs".[14] This report identifies global conservation priorities and suggests locations for CWR reserves of 12 selected crops (see Figure 1.1 and Table 2.1). These, together with additional priority locations to be identified in the future when further crop genepools are studied, will form a global CWR *in situ* conservation network.

The threat of climate change to CWR has been highlighted by a recent study[15] that focused on three important crop genera: *Arachis*, *Solanum* and *Vigna*. The study predicts that 16–22 percent of species in these genera will become extinct before 2055 and calls for immediate action in order to preserve CWR *ex situ* as well as *in situ*. Back-up samples conserved *ex situ* will become increasingly important, especially when environmental change is too rapid for evolutionary change and adaptation, or migration (even assisted migration), to be effective. Samples stored *ex situ* also have the advantage of being more readily accessible. However, significant gaps exist in the taxonomic and geographic coverage of CWR in *ex situ* collections. A recent study by CIAT and Bioversity International has highlighted these gaps for a number of genepools.

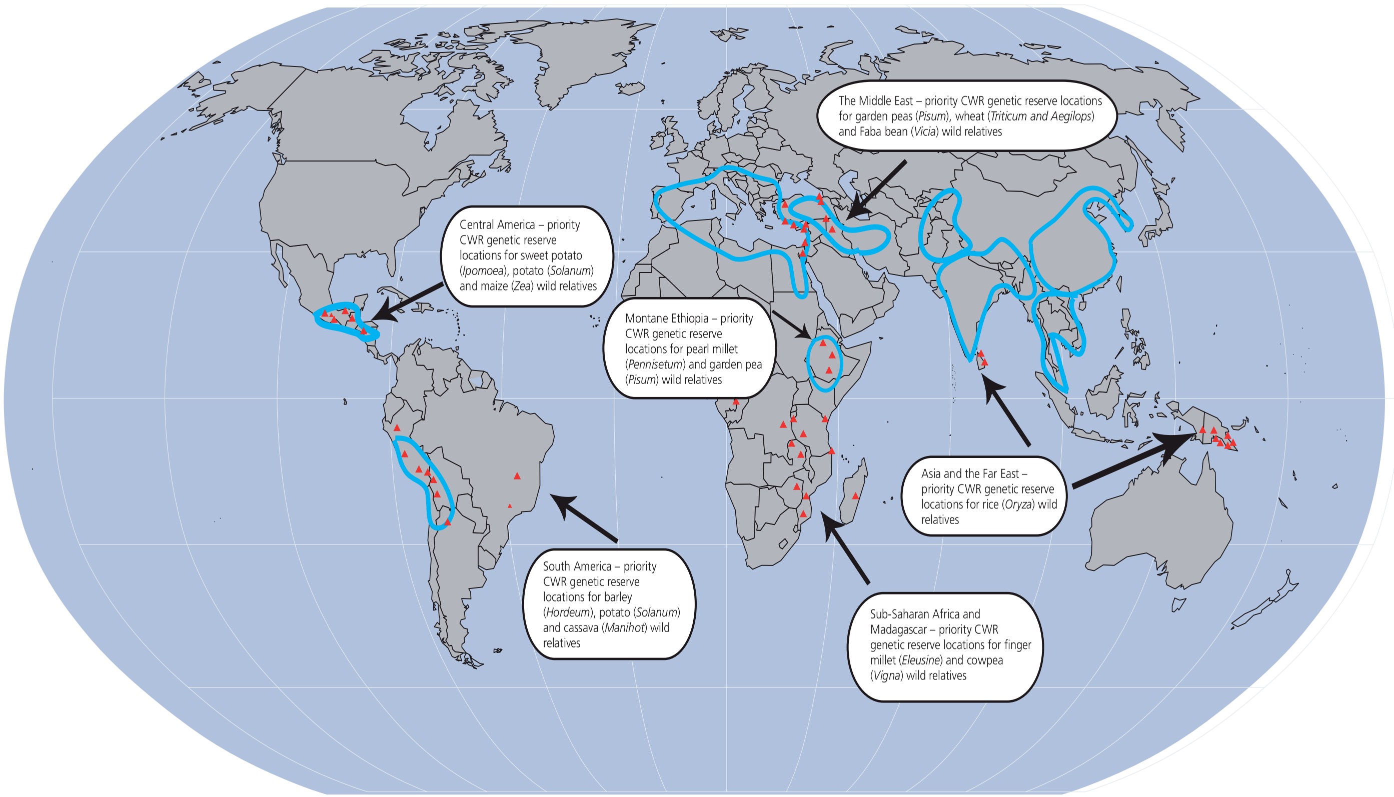
Figure 1.2 summarizes the findings for the 12 crops in question.[16] It highlights areas of the world where CWR species are expected to exist for these crops, based on herbarium specimens, but are missing from *ex situ* collections.

Advances in research techniques and their greater availability during the past decade have resulted in some significant new insights into the extent and distribution of genetic diversity, both in space and time, as outlined in the following sections.

1.2.3.1 Molecular technologies

Since the first SoW report was published, there has been a proliferation of new molecular techniques,

FIGURE 1.1
Global priority genetic reserve locations for wild relatives of 12 food crops



Source: Maxted, N. & Kell, S.P. 2009. The eight Vavilov centres of origin/diversity of cultivated plants, indicated by the enclosed lines, are likely to contain further priority sites for other crop genepools.

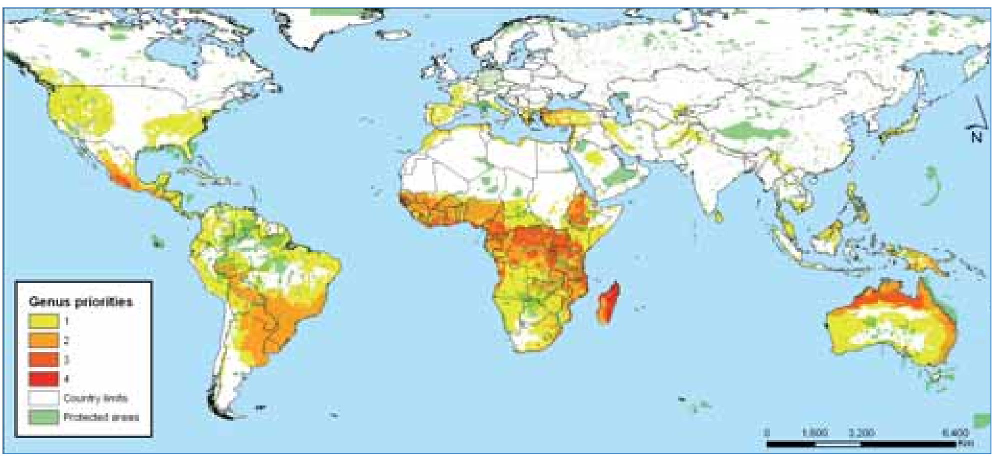
many of which, are simpler to use and less expensive than earlier techniques. This has led to the generation of a vast and rapidly increasing amount of data on genetic diversity, much of which is publicly available. The huge increase in Deoxyribonucleic acid (DNA) sequence capacity has, for example, enabled the rice genome to be sequenced, as well as comparisons to be made between the *japonica* and *indica* rice genomes and between rice and wheat genomes.[17] The application of molecular techniques is increasing rapidly both in crop improvement (see Section 4.4) and in the conservation of plant genetic resources. However, the process has generally been slower than was foreseen a decade ago and few country reports, especially from the less developed countries, mention these techniques. Box 1.1 lists a few selected examples to illustrate some of the uses being made of these new techniques.

While many molecular techniques, from allele identification and marker assisted selection (MAS) to gene transformation, have been developed specifically to enhance crop improvement, many are also proving invaluable in conservation. These include, for example: techniques for estimating the spatial and temporal distribution of genetic diversity and relationships between and within populations;[18] gaining insights into crop domestication and evolution;[19] monitoring gene flows between domesticated and wild populations;[20] and increasing the efficiency and effectiveness of genebank operations[21] (e.g. deciding what material to include within a collection;[22] identifying duplicates;[23] increasing the efficiency of regeneration;[24] and establishing core collections). As a result, much more is known about the history and structure of genetic diversity in key crop genepools than was the case a decade ago.

1.2.3.2 Geographic Information Systems

New geographic methods are also proving to be of significant value in the management of plant genetic resources. Global Positioning Systems (GPS) are highly

FIGURE 1.2
Gaps in *ex situ* collections of selected crop genepools[a]



[a] The coloured areas are those that have the greatest number of CWR genepool gaps. The darker the shading (orange and red) the larger the number of CWR genepool gaps present.

Source: Ramirez, J., Jarvis, A., Castaneda, N. & Guarino, L. 2009, Gap Analysis for crop wild relatives, International Centre for Tropical Agriculture (CIAT), available at http://gisweb.ciat.cgiar.org/gapanalysis/

Box 1.1
Examples of the use of molecular tools in conservation and characterization, as reported in selected country reports

AFRICA	
• **Benin**	Molecular characterization of yam germplasm has been initiated.
• **Burkina Faso**	Molecular characterization of millet, sorghum, taro, bean, *Abelmoschus esculentus*, *Macrotyloma geocarpum*, *Pennisetum glaucum*, *Solenostemon rotundifolius*, *Sorghum bicolour*, *Colocasia esculenta, Vigna unguiculata* and *Ximenia americana*.
• **Ethiopia**	Molecular techniques used in characterization and genetic diversity studies for several field crop species.
• **Kenya**	Application of Restriction Fragment Length Polymorphisms (RFLPs), DNA finger printing and Polymerase Chain Reaction (PCR) techniques.
• **Malawi**	Molecular characterization of sorghum accessions has been initiated.
• **Namibia**	Genetic diversity studies in sorghum and *Citrullus*.
• **Niger**	Molecular characterization of millet has been initiated.
• **United Republic of Tanzania**	Molecular markers have been used for 50 percent of coconut collection, 46 percent of cotton *Gossypium* spp. collection and 30 percent of cashew nut *Anacardium occidentale* collection.
• **Zimbabwe**	Molecular characterization has been done on landraces collected in the Nyanga and Tsholotsho areas and for accessions held in the Genetic Resources and Biotechnology Institute.
AMERICAS	
• **Bolivia (Plurinational State of)**	Molecular characterization has been applied to a limited number of collections, primarily Andean root and tuber crops.
• **Brazil**	Geographic Information System (GIS) studies on the distribution of wild relatives of groundnut.
• **Costa Rica**	Molecular characterization has been carried out for clones of chayote, banana germplasm, cocoa and in the establishment of the world's first cryoseed bank for coffee.
• **Ecuador**	Molecular characterization and evaluation has been completed for several crop species.
• **Jamaica**	MAS breeding was adopted in the improvement of scotch bonnet peppers and a state-of-the-art molecular biology laboratory is in use for coconut variety improvement.
• **Mexico**	Sequencing and transcript analysis has been carried out with accessions of *Agave tequilana* at the Campeche Campus of the Colegio de Postgraduados.
• **Peru**	Molecular characterization has been carried out with accessions of yuca, yacon, mani, aji (Chile) and 75 varieties of native potato.
• **Venezuela (Bolivarian Republic of)**	Molecular characterization of sugar cane, cacao, potato and cotton genebank accessions, among other taxa, has been carried out.

Box 1.1 (continued)
Examples of the use of molecular tools in conservation and characterization, as reported in selected country reports

ASIA AND THE PACIFIC	
• **Bangladesh**	Molecular characterization of lentil and barley has been carried out through collaboration between the Bangladesh Agricultural Research Institute and ICARDA.
• **China**	On the basis of modern molecular marker technology, core collections and mini-core collections have been assembled for many crops and used to associate molecular markers with targeted genes.
• **Fiji**	With collaboration from regional and international institutions, molecular approaches have been used in germplasm characterization.
• **India**	Molecular markers for disease and insect-pest resistance have been deployed for wheat and triticale improvement.
• **Indonesia**	Analysis of molecular genetic diversity was used to confirm Papua as a secondary centre of diversity for sweet potato. Molecular markers have been in use for several years for characterization of accessions of several food crops (rice, soybean and sweet potato) and for crop improvement programmes.
• **Japan**	Molecular markers have been integrated into the characterization activity of the national genebank and MAS is routine for improvement of crops such as rice, wheat and soybeans
• **Lao People's Democratic Republic**	Molecular markers for quantitative trait loci (QTL) traits have been incorporated into rice breeding programmes.
• **Thailand**	Genetic diversity of *Curcuma*, mangrove tree species (*Rhizophora mucronata*) and *Tectona grandis*. The country has also used agroclimatic data together with molecular marker data in GIS studies to predict the location of diverse populations in order to identify areas for *in situ* conservation and for future collecting missions.
EUROPE	
• **Belgium**	The majority of the 1 600 apple accessions in the Centre for Fruit Culture have been described by use of molecular markers.
• **Estonia**	Molecular markers were used to map some wheat accessions.
• **Finland**	Molecular marker analysis has been used in estimations of genetic diversity in CWR.
• **Greece**	Molecular characterization and evaluation of cereal and vegetable crops have been initiated.
• **Ireland**	Analysis of the diversity of collected samples of wild oats (*Avena fatua*), wild rape (*Brassica rapa* subsp. *campestris*) and Irish populations of wild asparagus (*Asparagus officinalis* ssp. *prostratus*) was carried out.
• **Italy**	Molecular analysis has played a key role in evaluating the genetic variation expressed in clones of the same variety for some fruit species.
• **Portugal**	Molecular characterization of plum, apricot, cherry and almond accessions in Portuguese collections has been partially carried out.
• **Netherlands**	The Centre of Genetic Resources' collections of lettuce (2 700 acc.) and (partly) *Brassica* (300 acc.) and potato (300 acc.) and a selection of eight Dutch apple collections (800 acc.) have been screened in order to improve insight into the collection structure, whereas part of the potato collection (800 acc.) has been analysed by molecular means for the presence of certain potential resistance genes.

Box 1.1 (continued)
Examples of the use of molecular tools in conservation and characterization, as reported in selected country reports

NEAR EAST	
• **Cyprus**	Molecular tools for the assessment of genetic material have been introduced and molecular assessment for tomato accessions is in process.
• **Egypt**	Molecular genetic data employed in PGR evaluation of accessions in national genebank.
• **Iran (Islamic Republic of)**	Molecular markers have been integrated into characterization programmes of national plant genebank and MAS and genetic transformation technologies are being used for breeding new cultivars.
• **Jordan**	Molecular biology laboratories are in place at the national research centre as well as at several universities and GIS and remote sensing are being used in three institutions.
• **Kazakhstan**	The assessment of genetic diversity and study of pedigree using molecular markers was made for wheat and barley.
• **Lebanon**	Molecular genetic characterization has been conducted for olive and almond varieties.
• **Morocco**	Molecular markers and GIS have been used in evaluation of germplasm of cereals to target regions for collection.
• **Oman**	Molecular markers used for characterizing alfalfa accessions (Random Amplification of Polymorphic DNA - RAPDs) and evaluating progeny in date palm breeding populations.
• **Yemen**	The national genetic resources centre has the capacity to undertake molecular characterization of germplasm.

effective at pinpointing the exact location where a plant was collected in the field. Such data is invaluable, especially when combined with other georeferenced data, e.g. on topography, climate or soils, and analysed using GIS software. This information can greatly facilitate decisions on what to collect and where, and can help elucidate relationships between crop production, genetic diversity and various agro-ecological parameters. Such techniques can also be used to draw up agro-ecological models that can predict, for example, the impact of climate change on different crops and in different locations. These methods have demonstrated through the Focused Identification of Germplasm Strategy (FIGS) that they have a significant impact on the effectiveness and efficiency in 'mining' germplasm for specific adaptive traits for crop improvement.[25]

No country report indicates the extent to which geographic information tools are available and used within the country concerned and most of the reports that do mention studies involving GIS do not describe the outcomes of the work. Rather, such studies appear to have been largely subsumed within crop distribution, ecogeographic and other similar studies. Their relevance to PGRFA management is not generally as well recognized as it perhaps should be.

1.2.3.3 Information and communication technologies

The ability to measure and monitor the state of diversity has benefited from huge advances in information and communication technologies during the past decade, in the form of faster and cheaper computer processors with larger memory and storage capacities, incorporated into a wide range of instruments and devices equipped with more advanced software and better user interfaces. The speed and effectiveness of communication and of gathering, managing and sharing data have improved dramatically since 1996 as a result of the incorporation of computers into data capture devices, improvements in data and database management software and the expansion of local computer networks and the Internet. These improvements have also resulted in rapid advances in the ability to undertake sophisticated processing and analysis of large complex datasets as, for example, in the emergence and application of the science of bioinformatics for molecular data.

1.3 Genetic vulnerability and erosion

As defined in the first SoW report, genetic vulnerability is the "condition that results when a widely planted crop is uniformly susceptible to a pest, pathogen or environmental hazard as a result of its genetic constitution, thereby creating a potential for widespread crop losses". Genetic erosion, on the other hand, was defined 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. The term 'genetic erosion' is sometimes used in a narrow sense, i.e. the loss of genes or alleles, as well as more broadly, referring to the loss of varieties". Thus, while genetic erosion does not necessarily entail the extinction of a species or subpopulation, it does signify a loss of variability and thus a loss of flexibility.[26] These definitions take into account both sides of the diversity coin, that is richness and evenness, the first relating to the total number of alleles present and the second to the relative frequency of different alleles. While there has been much discussion of these concepts since the first SoW report, these definitions have not changed.

1.3.1 Trends in genetic vulnerability and erosion

While few country reports give concrete examples, about 60 report that genetic vulnerability is significant and many mention the need for a greater deployment of genetic diversity in order to counter the potential threat to agricultural production. In Benin, for example, there was concern that the current agricultural system is dominated by monocultures, in particular of yam and commercial crops. China reported cases in which rice and maize varieties have become more uniform and thus more genetically vulnerable. Ecuador reports that endemic plants are particularly vulnerable due to their restricted distribution. In the Galapagos Islands, at least 144 species of native vascular plants are considered rare; 69 of these are endemic to the Archipelago, including 38 species which are restricted to a single island. In Lebanon, the decrease in national production of almonds has been attributed to the genetic vulnerability of the few varieties grown. The largest global example of the impact of genetic vulnerability that has occurred since the first SoW report was published is the outbreak and continued spread of the Ug99 race of stem rust, to which the large majority of existing wheat varieties is susceptible. On the other hand, some countries reported on successful measures that had been put in place to counter genetic vulnerability. Cuba, for example, reported that the introduction of a wide range of varieties and the increased use of diversified production systems has reduced genetic vulnerability. Thailand promotes the use of greater diversity in breeding programmes and released varieties.

In the case of genetic erosion, while the country reports mention a substantial number of causes, in general these were the same as those identified in 1996. Major causes included: replacement of local varieties, land clearing, overexploitation, population pressures, environmental degradation, changing agricultural systems, overgrazing, inappropriate legislation and policy, as well as pests, diseases and weeds. From an analysis of country reports, it also appears that genetic erosion may be greatest in the case of cereals, followed by vegetables, fruits and nuts and food legumes (see Table 1.3). This may, however, be an artifact of the greater attention that is generally paid to field crops.

The following examples of genetic erosion cited in five of the country reports give a flavour of the diversity of situations and may serve to illustrate the overall situation. It should be noted, however, that the list is not intended to be complete and as the information contained in the country reports was not standardized, it is not possible to make cross-country or cross-crop comparisons, or use the information as a baseline for future monitoring. Madagascar reported that the rice variety Rojomena, appreciated for its taste, is now rare whereas the Botojingo and Java varieties of the northeastern coastal area have disappeared. The cassava variety Pelamainty de Taolagnaro and certain varieties of bean have disappeared from most producing areas and in the case of coffee, 100 clones out of 256, as well as five species (*Coffea campaniensis, C. arnoldiana, C. rostandii, C. tricalysioides* and *C. humbertii*) have disappeared from collections in the last 20 years. Wild yam species are also considered likely to disappear soon. Costa Rica reports that *Phaseolus* spp., including *P. vulgaris*, are threatened by serious genetic erosion; the same occurs to the indigenous crop *Sechium tacaco* and four related species: *S. pittieri, S. talamancense, S. venosum* and *S. vellosum*. In India, a large number of rice varieties in Orissa, some rice varieties with medicinal properties in Kerala and a range of millet species in Tamil Nadu, are no longer cultivated in their native habitats.[27] Yemen reports that varieties of finger millet (*Eleusine coracana)* and *Eragrostis tef* as well as oil rape *(Brassica napus)*, which used to be among the most important traditional crop varieties grown in the country, are no longer grown or only grown in very specific areas and that the cultivation of wheat, including *Triticum dicoccum*, has drastically decreased. In Albania, all primitive wheat cultivars and many maize cultivars, have reportedly been lost.

Notwithstanding such reports on the loss of local varieties, landraces and CWR, the situation regarding the true extent of genetic erosion is clearly very complex. While some recent studies have confirmed that diversity in farmers' fields and in protected areas has indeed decreased, it is not possible to generalize and in some cases there is no evidence that it has occurred at all. For example, a large on-farm conservation project that studied genetic diversity in farmers' fields in nine developing countries found that, overall, crop genetic diversity continued to be maintained.[28] Other studies, however, have reported genetic shifts in farmers' varieties, for example in pearl millet in the Niger[29] and sorghum in Cameroon,[30] and in studies on the adoption by farmers of improved varieties of rice in India[31] and Nepal,[32] it was found that adoption can result in the substantial disappearance of farmers' varieties. On the other hand, it has also been noted that many farmers who plant modern varieties (especially large and medium landholders) also tend to maintain their landraces and that in such circumstances adoption of modern varieties might increase diversity in farmers' fields rather than reduce it.[33] In summary, it seems that general statements purporting to quantify the overall amount of genetic erosion that has occurred over the past decade are not warranted.

TABLE 1.3
Crop groups and number of countries that provide examples of genetic erosion in a crop group

Crop group	Number of countries reporting genetic erosion
Cereals and grasses	30
Forestry species	7
Fruits and nuts	17
Food legumes	17
Medicinal and aromatic plants	7
Roots and tuber	10
Stimulants and spices	5
Vegetables	18
Miscellaneous	6

As with the situation of traditional farmer varieties and CWR, studies on diversity trends within released varieties also do not give a consistent picture over time. Some report no reduction nor even an increase in genetic diversity and allelic richness in released varieties, for example in the CIMMYT spring bread wheat varieties,[34] maize and pea varieties in France,[35] fruit varieties in Yemen[36] and barley in Austria and India[37]. In cases such as these, the new varieties may be less vulnerable than was originally thought. Other studies report either an initial decrease followed by an increase of genetic diversity, e.g. in *indica* and *japonica* rice varieties in China,[38] or a continuous decline such as for wheat in China,[39] oats in Canada,[40] and maize in Central Europe.[41] A meta analysis based on these and other published reports on diversity trends has shown that, overall, there appears to have been no substantial reduction in genetic diversity as a result of crop breeding in the twentieth century and no overall gradual narrowing of the genetic base of the varieties released.[42] However, the context of the meta analysis needs to be carefully considered to understand whether the results might be extrapolated, in particular to developing country conditions and a wide range of different crops.

Whereas convincing evidence may be lacking for genetic erosion in farmer varieties on the one hand and released varieties on the other hand, much more consensus exists on the occurrence of genetic erosion as a result of the total shift from traditional production systems depending on farmer varieties to modern production systems depending on released varieties.

1.3.2 Indicators of genetic erosion and vulnerability

Over the last decade, interest in direct and indirect indicators of genetic vulnerability and erosion has increased, at least in part, due to the paucity of concrete evidence for either process. The CGRFA called for the development of 'higher level indicators' for genetic erosion and genetic vulnerability in relation to monitoring the implementation of the GPA.

The 2010 Biodiversity Indicators Programme under the auspices of the CBD brings together a large number of international organizations to develop indicators relevant to the CBD, including those for the monitoring of trends in genetic diversity. However, to date, no really practical, informative and generally accepted indicators of genetic erosion are available and therefore their development should be a priority. Several qualities are important for such indicators to be effective:

- they should be sensitive to changes in the frequency of important alleles and give these more weight than less important alleles: the loss of an allele at a highly polymorphic microsatellite locus, for example, is likely to be of only minor importance compared with the loss of a disease resistance allele;
- they should provide a measure of the extent of the potential loss, e.g. by estimating the fraction of genetic information at risk compared with the total diversity;
- they should enable an assessment to be made of the likelihood of loss over a specific time period, in the absence of human intervention.

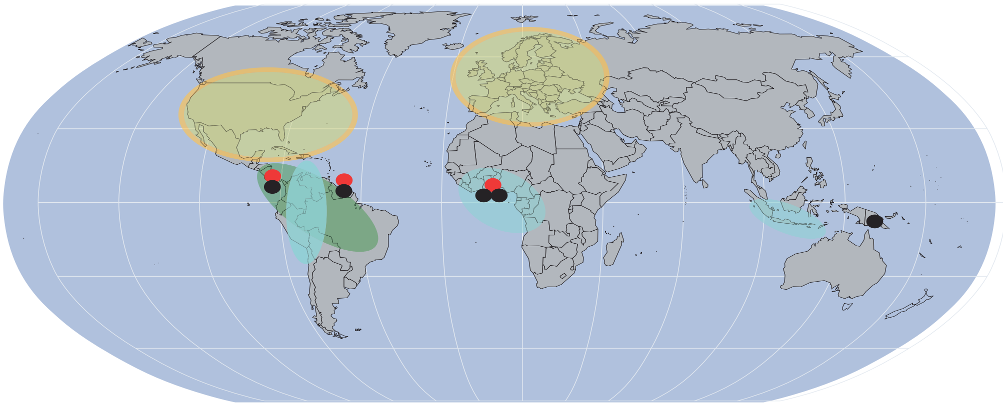
Indicators for estimating genetic vulnerability should consider not only the extent of genetic uniformity *per se*, but also take into consideration possible genotype x environment interactions. A given genotype (population or variety) might succumb to a particular biotic or abiotic stress differently in diverse environments. Useful indicators of genetic vulnerability might include:

- the extent of genetic diversity of genes conferring resistance to, or tolerance of, actual and potential major pests and diseases or abiotic stresses;
- the extent of diversity in host-pathogen interactions and the occurrence of differential responses to different biotypes of pests and diseases. This indicator would provide information on the variety of coping mechanisms available and hence the likelihood of a shift in pathogen population resulting in widespread virulence;
- the occurrence of severe bottlenecks during domestication, migration or breeding: indicators of a genetic bottleneck could be derived from molecular data, historic information or pedigree analyses;
- the extent to which single varieties dominate over large areas could be a useful first indicator for estimating genetic vulnerability, based on the assumption that genetic vulnerability is higher when large areas are cropped with one variety;
- the genetic distances between the parental lines of a variety could be a proxy indicator, in certain circumstances, for the degree of heterogeneity and hence genetic vulnerability of the variety.

1.4 Interdependence

Interdependence regarding PGRFA can take many forms and may involve a wide range of stakeholders over space and/or time. Most crops, CWR and other useful wild plant species, are not confined within national boundaries. Their distribution reflects the

FIGURE 1.3
Interdependency illustrated by the example of cocoa genetic resources



geography of ecosystems and global dispersal by humans or nature. As a result, people interested in using PGRFA often have to access material and the knowledge that goes with it, from beyond the borders of the country where they happen to be working. Whereas all countries are both providers and recipients of PGRFA, not all countries have been equally endowed with them, or with the capacity to use them. This has led to a mutual but unequal interdependence and can be seen as either a potential threat to national sovereignty or as an opportunity for constructive collaboration[43] (see Figure 1.3 and Table 1.4).

The concept of interdependence applies not only to the international level, but also in the respective roles of farmers, breeders and genetic resource managers. Farmers are the managers of the genetic resources they grow, genebank managers have been entrusted with safeguarding collections of this diversity, and breeders, to a large extent, depend on both for the raw materials they need to produce new varieties for farmers' use. All are interdependent.

Considerable interdependence also occurs at the local level among farmers who frequently trade or barter seed and other planting materials with each other. Local systems of germplasm exchange are often deeply ingrained in rural societies and may be an important element in relationships among families and local communities. Such systems are generally 'robust' and able to cope well under stress[44] as their high level of interdependence contributes to their resilience.

At the regional and global levels, a major consequence of interdependence among nations is the need for international exchange of germplasm. Studies have suggested that in many cases, such exchange has become more complex and difficult over recent years. There is a danger that reduced international flows of PGRFA may pose a threat not only to its use, but also to its conservation and ultimately to food security. These were among the key factors that led to the adoption of the ITPGRFA.

With the growing impact of climate change, there will undoubtedly be an increase in demand for varieties that are adapted to the new environmental conditions and pest and disease spectra. The ability to access a wide range of genetic diversity is central to meeting this demand, implying that in future there will be even greater interdependence between countries and regions than today.

Uncertainty about legal issues is widely considered to be a significant factor hindering international and

TABLE 1.4
Indicators of global interdependency of selected crops

Crop	Region(s) of significant genetic diversity [1]	Major *ex situ* collections [2]	Major producing countries [3]	Major breeding and research activities	Countries for which major consumption has been recorded [4]	Products/ importing countries [5]
Cacao (*Theobroma cacao*)	Amazon Basin, Central America	Brazil, Costa Rica, Trinidad and Tobago, Venezuela (Bolivarian Republic of)	Brazil, Côte d'Ivoire, Ghana, Indonesia, Nigeria	Brazil, Costa Rica, Côte d'Ivoire, Ghana, Papua New Guinea, Trinidad and Tobago	France, Germany, Japan, Russian Federation, United States of America	Cocoa beans Belgium, Germany, Malaysia, Netherlands, United States of America
Eggplant (*Solanum melongena*)	Indo-Myanmar region	AVRDC, India	China, India, Egypt, Turkey, Indonesia	AVRDC, India	African countries, China, India, Indonesia, Malaysia, Nepal, Pakistan, Sri lanka	France, Germany, Iraq, United Kingdom, United States of America
Groundnut (*Arachis hypogea*)	South America	CGIAR, USDA, India, China, Senegal,Brazil	China, India, Indonesia, Nigeria, United States of America	Australia, Brazil, China, India, United States of America	Confectionary China, India, Indonesia, Nigeria, United States of America	Groundnut shelled Canada, Mexico, Netherlands, Russian Federation, United Kingdom
Maize (*Zea mays*)	Asia, Central America and Mexico, North America, South America	CGIAR, India, Mexico, Russian Federation, United States of America	Argentina, Brazil, China, Mexico, United States of America	CGIAR, Africa, Brazil, China, Europe, India, United States of America	China, India, Indonesia, Mexico, South Africa	China, Japan, Mexico, Republic of Korea, Spain
Noug (*Guizotia abyssinica*)	Horn of Africa	Ethiopia, India	Ethiopia, India, Nepal	Ethiopia, India	Ethiopia, India, Nepal, United Kingdom, United States of America	United Kingdom, United States of America
Oil Palm (*Elais* spp.)	Amazon Basin, West Africa	Brazil, Ghana, Malaysia	Colombia, Indonesia, Malaysia, Nigeria, Thailand	Malaysia, MPOB	China, India, Indonesia, Nigeria, Pakistan	China, Germany, India, Netherlands, Pakistan

TABLE 1.4 (continued)
Indicators of global interdependency of selected crops

Crop	Region(s) of significant genetic diversity [1]	Major *ex situ* collections [2]	Major producing countries [3]	Major breeding and research activities	Countries for which major consumption has been recorded [4]		Products/ importing countries
Potato (*Solanum tuberosum*)	South America	CGIAR, Colombia, Czech Republic, Japan, Netherlands	China, India, Russian Federation, Ukraine, United States of America	CGIAR, Argentina, Australia, Canada, Chile, China, Colombia, Ecuador, France, Germany, India, Netherlands, Poland, Republic of Korea, South Africa, United Kingdom, United States of America	China, India, Russian Federation, United Kingdom, United States of America		Belgium, Germany, Italy, Netherlands, Spain
Quinoa (*Chenopodium quinoa*)	Andean Cordillera	CGIAR, United States of America	Bolivia (Plurinational State of), Ecuador, Peru	Bolivia (Plurinational State of), Peru	Bolivia (Plurinational State of), Canada, Europe, Peru, United States of America		N/A
Rice (*Oryza* spp.)	South, East, and Southeast Asia, Africa	CGIAR, Benin, China, India, Philippines, Thailand, United States of America	China, Bangladesh, India, Indonesia, Viet Nam	CGIAR, China, India, Philippines United States of America	Bangladesh, China, India, Indonesia, Viet Nam		Rice, milled Iran (Islamic Republic of), Iraq, Nigeria, Philippines, Saudi Arabia
Safflower (*Carthamus tinctorius*)	Egypt, Ethiopia, Far East, India, Middle East, Pakistan, Southern Europe, Sudan	China, Ethiopia India, Mexico, United States of America	Australia, China, India, Kazakhstan, United States of America	Australia, Canada, China, India, Mexico, Spain, United States of America	Seed Belgium, China, Netherlands, Philippines, United Kingdom	Oil Germany, Japan, Netherlands, United States of America, Yemen	Safflower seed Belgium, China, Netherlands, Philippines, United Kingdom
Sesame (*Sesamum indicum*)	Central Asia, China, Horn of Africa, India, Near East	China, India, Israel, Mexico, Venezuela (Bolivarian Republic of)	China, India, Myanmar, Sudan, Uganda	India, Turkey, United States of America	Seed China, Egypt, India, Japan, Uganda	Oil China, India, Myanmar, Republic of Korea, Sudan	Sesame seed China, Japan, Republic of Korea, Syrian Arab Republic, Turkey

TABLE 1.4 (continued)
Indicators of global interdependency of selected crops

Crop	Region(s) of significant genetic diversity [1]	Major *ex situ* collections [2]	Major producing countries [3]	Major breeding and research activities	Countries for which major consumption has been recorded [4]		Products/ importing countries
Soybean (*Glycine max*)	East Asia	AVRDC (Regional), China, Russian Federation, Ukraine, United States of America	Argentina, Brazil, China, India, United States of America		Seed Brazil, China, Indonesia, Japan, Republic of Korea	Oil Brazil, China, India, Japan, United States of America	China, Germany Japan, Mexico, Netherlands
Sunflower (*Helianthus annuus*)	North America	France, Romania, Russian Federation, Serbia, United States of America	Argentina, China, France, Hungary, India, Russian Federation, Turkey, Ukraine, United States of America	Russian Federation, United States of America	Seed Brazil, Bulgaria, Myanmar, Spain, United States of America	Oil China, India, Russian Federation, Spain, Ukraine	Sunflower seed France, Italy, Netherlands, Spain, Turkey
Wheat (*Triticum aestivum*)	Central Asia, East Africa, East Asia, Europe, South and East Mediterranean, South Asia, West Asia	CGIAR, Australia, Italy, Russian Federation, United States of America	China, France, India, Russian Federation, United States of America	CGIAR, Australia, Brazil, Canada, China, France, India, United Kingdom, United States of America	China, India, Pakistan, Russian Federation, United States of America		Brazil, Egypt, India, Italy, Japan

[1] Source: first SoW report.

[2] Source: first SoW report and Country reports for the SoWPGR-2.

[3] Source: FAOSTAT, 2007.

[4] Source: FAOSTAT, 2003; for safflower import data for 2006; for quinoa and eggplant anecdotal evidence.

[5] Source: FAOSTAT, 2006.

even national, germplasm exchange. While the CBD has been in force for many years, a lack of clear and efficient procedures for accessing PGRFA still hampers the collection and/or cross-boundary movement of genetic resources in many countries (see Chapter 7). Likewise, a number of national governments have yet to join the ITPGRFA even though it is essential for ensuring the facilitated flow of PGRFA, that as many countries as possible ratify the ITPGRFA and put in place the necessary procedures to ensure its effective implementation.

Just as the world's plant genetic resources are unevenly distributed, so is the capacity to use them. Many countries lack adequate institutions, facilities or breeders to effectively undertake modern, or even conventional, crop improvement work, especially on minor crops. Thus, there is still a heavy reliance by many countries on outside support for plant breeding, whether directly for improved varieties or indirectly through training and research collaboration. There have been a number of positive developments in this area recently, including the GIPB[45] and the development of regional centres of excellence for biotechnology, such as Biosciences Eastern and Central Africa (BECA).[46] Such centres enable scientists from developing countries to apply their knowledge and skills to specific national crop improvement challenges. These and other similar initiatives are an important aspect of interdependence and are an integral part of systems for benefit-sharing. More detail on the status of crop improvement and other uses of PGRFA is provided in Chapter 4.

1.5 Changes since the first State of the World report was published

Key changes that have occurred in relation to the state of diversity since the publication of the first SoW report include:

- *ex situ* collections have grown substantially, both through new collecting and through exchange among genebanks. The latter has contributed to the continuing problem of unplanned duplication;
- scientific understanding of the on-farm management of genetic diversity has increased, and this approach to the conservation and use of PGRFA has become increasingly mainstreamed within national programmes;
- interest in and awareness of the importance of conserving CWR, both *ex situ* and *in situ* and their use in crop improvement have increased substantially;
- there is growing interest in hitherto 'neglected' and underutilized species such as traditional vegetables and fruits;
- with modern molecular genetic techniques, it has been possible to generate a large amount of data on the extent and nature of genetic erosion and vulnerability in specific crops in particular areas. The picture that is emerging is complex and it is not possible to draw clear conclusions about the magnitude and extent of these effects;
- the extent of interdependence among countries with respect to their need to have access to materials held by others is arguably more important than ever. This is especially true in the face of the need to develop varieties that are adapted to the new environmental conditions and pest and disease spectra that will result from climate change. The ITPGRFA has provided a sound basis for improving and facilitating such access.

1.6 Gaps and needs

Based on the information provided in this chapter, the following points describe some of the major gaps and needs that have been identified with regards to genetic diversity:

- there is still an ongoing need to improve the coverage of diversity in *ex situ* collections, including CWR and farmers' varieties, coupled with better characterization, evaluation and documentation of the collections;
- a better understanding of, and support for, farmers' management of diversity is still needed, in spite of significant advances in this area. Opportunities exist to improve the livelihoods of rural communities through an improved management of diversity;
- there is still a need for greater rationalization of the global system of *ex situ* collections, as called

for in the GPA and the ITPGRFA and as reflected in initiatives such as those of the GCDT and AEGIS;

- greater attention is needed regarding the conservation and use of PGRFA of neglected and underutilized crops and non-food crops. Many such species can make a valuable contribution to improving diets and incomes;
- there is a need to promote standard definitions and means of assessing genetic vulnerability and genetic erosion, as well as to agree on more and better indicators, in order to be able to establish national, regional and global baselines for monitoring diversity and changes in it and for establishing effective early warning systems;
- many countries still lack national strategies and/or action plans for the management of diversity, or if they have them, they do not fully implement them. Areas that require particular attention include setting priorities, enhancing national and international cooperation, the further development of information systems and identifying gaps in the conservation of PGRFA, including CWR;
- in spite of the growing awareness of the importance of CWR, there is still a need in many countries for appropriate policies, legislation and procedures for collecting CWR, for establishing protected areas for CWR and for better national coordination of these efforts.

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Chapter 2

The state of *in situ* management

2.1 Introduction

The CBD defines *in situ* conservation as "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties." While the concept has evolved since the CBD was adopted, this definition is used in several major international treaties and initiatives including the ITPGRFA and the Global Strategy for Plant Conservation (GSPC). *In situ* conservation is often envisaged as taking place in protected areas or habitats (as opposed to *ex situ* conservation) and can either be targeted at species or the ecosystem in which they occur. It is a particularly important method of conservation for species that are difficult to conserve *ex situ,* such as many CWR.

The on-farm conservation and management of PGRFA is often regarded as a form of *in situ* conservation. However, in many cases the reasons why farmers continue to grow traditional varieties may have little to do with the desire to conserve and much more to do with reasons of tradition and preferences, risk avoidance, local adaptation, niche market opportunities or simply the lack of a better alternative. Nevertheless, much important diversity continues to be maintained in farmers' fields and efforts to improve management and use have gained much ground during the past decade. There is now a clearer understanding of the factors involved.[1]

This chapter describes progress that has been made since the first SoW report was published in the conservation and management of PGRFA in wild ecosystems, agricultural production systems and the interface between the two. It reviews new knowledge regarding the amount and distribution of diversity of landraces, CWR and other useful plants and assesses current capacity for conserving and managing diversity *in situ*. The chapter describes a few major global challenges that exist today, summarizes the main changes that have occurred since the first SoW report was published and concludes by identifying further gaps and needs.

2.2 Conservation and management of PGRFA in wild ecosystems

Many plant species growing in wild ecosystems are valuable for food and agriculture and may play an important cultural role in local societies. They can provide a safety net when food is scarce and are increasingly marketed locally and internationally, providing an important contribution to household incomes. Approximately a third of the country reports received mentioned the use of wild-harvested plants. Nigeria, for example, cited the use of African mango (*Irvingia gabonensis*) and locust bean (*Parkia biglobosa*) in times of food shortage.

Grassland and forage species are another important component of agrobiodiversity, especially in countries where livestock production is a major contributor to the national economy.[2] However, natural grasslands are becoming seriously degraded in many parts of the world, resulting in a need for greater attention to be devoted to *in situ* conservation in such ecosystems. In many cases the conservation and use of natural grasslands is important in strategies to conserve and use animal genetic resources.

With the development of new biotechnological methods, CWR are becoming increasingly important in crop genetic improvement. Taking a broad definition of CWR as any taxon belonging to the same genus as a crop, it has been estimated that there are 50-60 000 CWR species worldwide.[3] Of these, approximately 700 are considered of highest priority, being the species that comprise the primary and secondary genepools of the world's most important food crops, of which many are included in Annex 1 of the ITPGRFA.

2.2.1 Inventory and state of knowledge

Since the publication of the first SoW report, most countries have carried out specific surveys and inventories, either as part of their National Biodiversity Action Plans[4] or, more commonly, within the framework of individual projects. Switzerland, for example, completed an inventory of its CWR in 2009 in which 142 species were identified as being of priority for conservation and use.[5] Most surveys, however, have been limited to single crops, small groups of species or to limited areas within the national territory.[6] For example, in Senegal inventories were made of selected species of fonio, millet, maize, cowpea and some leafy vegetables. Mali reported carrying out 16 inventories and surveys of 12 crops, and Albania and Malaysia have both conducted inventories of wild fruit species.

Very little survey or inventory work has been carried out on PGRFA in protected areas compared with other components of biodiversity in these areas.[7] The observation made in the first SoW report remains valid, i.e. that *in situ* conservation of wild species of agricultural importance occurs mainly as an unplanned result of efforts to protect particular habitats or charismatic species. While many countries assume that PGRFA, including CWR, are conserved by setting aside protected areas,[8] the reality is that in many countries this tends to fall between the cracks of two different conservation approaches, ecological and agricultural; the former focusing mainly on rare or threatened wild species and ecosystems and the latter mainly on the *ex situ* conservation of domesticated crops. As a result, the conservation of CWR has been relatively neglected.[9] Efforts to redress this situation have included a global project led by Bioversity International, to promote collaboration between the environment and agriculture sectors in order to prioritize and conserve CWR in protected areas (see Box 2.1).

Compared with the first SoW report in which only four countries[10] reported that they had surveyed the status of CWR, the past decade has seen significant progress in this area, with CWR inventories compiled in at least 28 countries. Some also reported that specific sites for *in situ* conservation of CWR had been identified.[11] In Venezuela (Bolivarian Republic of), between 1997 and 2007, 32 inventories and surveys were carried out prioritizing areas of the country where PGRFA were at risk. Jordan, Lebanon, the West Bank and Gaza Strip and the Syrian Arab Republic in collaboration with ICARDA, conducted surveys over the period 1999-2004 to assess the density, frequency and threats to wild relatives of cereals, food legumes, forage legumes and of seven genera of fruit trees and neglected species.

Box 2.1
A Crop Wild Relatives Project: increasing knowledge, promoting awareness and enhancing action

The global project, '*In situ* conservation of CWR through enhanced information management and field application', supported by United Nations Environment Programme (UNEP)/Global Environment Facility (GEF) and coordinated by Bioversity International, has made significant advances in promoting the *in situ* conservation of CWR in protected areas. The project works in Armenia, the Plurinational State of Bolivia, Madagascar, Sri Lanka and Uzbekistan and has sought to establish effective partnerships among stakeholders from both the agriculture and environment sectors. The project has comprehensively assessed threats to CWR and identified activities for their mitigation. Outputs have included the development of CWR national action plans; management plans for specific species and protected areas; guidelines for conserving CWR outside protected areas; and improved legislative frameworks for CWR conservation. Selected species of CWR have been evaluated to identify traits of value in crop improvement. Information from the project has been integrated within national information systems and is available through a Global Portal. This, combined with training and innovative public awareness efforts, means that the project is helping to enhance the conservation of CWR not only in the participating countries but also throughout the world.

At the regional and global level, efforts have been made by several international organizations to carry out inventories and to determine the conservation status of wild plants. An analysis of the IUCN's Red List of Threatened Species[12] shows that of the14 important crops for food security, identified in the thematic study, (banana/plantain, barley, cassava, cowpea, faba bean, finger millet, garden pea, maize, pearl millet, potato, rice, sorghum, sweet potatoes and wheat), only 45 related wild species have been assessed globally, the majority of which are relatives of the potato.[13] The SSC-IUCN has established a new CWR Specialist Group to support and promote the conservation and use of CWR. Botanic Gardens Conservation International (BGCI) has made an inventory of all CWR occurring in botanical gardens and has added a CWR flag in its plant database.[14] The most comprehensive inventory of CWR is the catalogue for Europe and the Mediterranean,[15] which lists over 25 000 species of CWR that occur in the Euro-Mediterranean region. As a first step towards the creation of a European inventory of *in situ* CWR populations, the ECPGR has called for focal points to be appointed with the responsibility of developing national *in situ* inventories.[16]

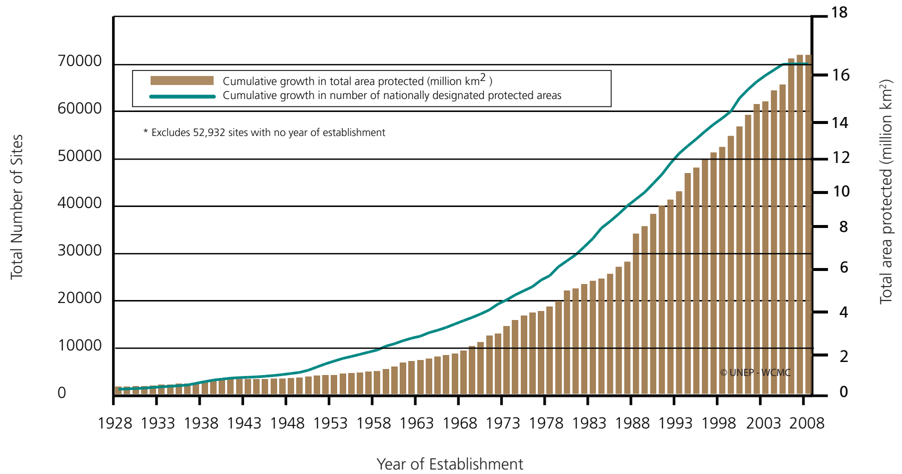
Many of the country reports listed major obstacles to systematic national inventorying and surveying of PGRFA. These include: lack of funding, lack of human resources, skills and knowledge,[17] lack of coordination and unclear responsibilities,[18] low national priority,[19] inaccessibility of *in situ* areas,[20] and difficulties in obtaining necessary permissions.

2.2.2 *In situ* conservation of crop wild relatives in protected areas

The number of protected areas in the world has grown from approximately 56 000 in 1996 to about 70 000 in 2007 and the total area covered has expanded in the same period from 13 to 17.5 million km^2 (see Figure 2.1).[21] This expansion is reflected at the national level with most countries reporting an increase in the total area protected. Paraguay, for example, has increased its protected area from 3.9 to 14.9 percent of the country's territory and Madagascar pledged that one-third of its territory would be protected by 2008.[22]

Figure 2.1 shows the cumulative growth in nationally designated protected areas (marine and terrestrial) in both total number of sites and total area protected (km^2) from 1928 to 2008. Only sites that are designated and have a known year of establishment have been included.

FIGURE 2.1
Growth in nationally designated protected areas (1928-2008)



Source: World Database on Protected Areas (WDPA).[24]

In an assessment of the extent to which wild PGRFA is actually conserved in protected areas[23] it was observed that, in general, areas with the greatest diversity (e.g. within centres of origin and/or diversity) received significantly less protection than the global average. Most countries have less than five percent of their areas under some form of protection.

Since the last report, there has been a substantial increase in the number of articles published describing the status of CWR[25] and drawing attention to specific action needed.[26] However, few of the recommendations have been implemented, largely due to a lack of funds and appropriately skilled personnel (see Section 2.5).

A recent study of the current status and trends in the conservation of CWR in 40 countries[27] has shown that conservation activities can take many forms including field or database inventories and mapping;[28] ecogeographic surveys;[29] investigation of policy structures and decision-making;[30] studies of traditional and indigenous ethnobiology;[31] and monitoring of CWR once management plans have been adopted.[32]

While a global survey of *in situ* conservation of wild PGRFA,[33] as well as an analysis of the country reports, reveal that relatively few countries have been active in conserving PGRFA in protected areas, some progress has been made as the following examples show:

- CWR are actively conserved in at least one protected area in each of the five countries of the CWR project coordinated by Bioversity International (see Box 2.1);
- in Ethiopia, wild populations of *Coffea arabica* are being conserved in the montane rainforest and studies are being carried out to assess the extent of Ethiopian coffee genetic diversity and its economic value. The aim is to develop models for conserving *C. arabica* genetic resources both within and outside protected areas;[34]
- Mali reported that wild fruit trees, that are important for food security, are managed in protected forests and in southern United Republic of Tanzania, special conservation methods are used to manage the indigenous fruit tree *Uapaca kirkiana*;
- in Guatemala, priority conservation areas have been recommended for 14 'at risk' species including *Capsicum lanceolatum, Carica cauliflora, Phaseolus macrolepis, Solanum demissum* and *Zea mays* subsp. *huehuetenangensis*;[35]
- the Sierra de Manantlán Reserve in Southwest Mexico has been established specifically for the conservation of the endemic perennial wild relative of maize, *Zea mays*;
- in the Asia and Pacific region, a comprehensive conservation project on native tropical fruit species, including mango, citrus, rambutan, mangosteen, jackfruit and litchi, was implemented by ten Asian countries with technical support from Bioversity International.[36] In China, 86 *in situ* conservation sites for wild relatives of crops had been established by the end of 2007 and a further 30 sites planned. In Viet Nam, *Citrus* spp. are included in six Gene Management Zones (GMZs) and, in India, sanctuaries have been established in the Garo Hills of Meghalaya to conserve the rich native diversity of wild *Citrus* and *Musa* species;[37]
- in Europe, surveys have been carried out on wild *Prunus* species[38] and on wild apples and pears.[39] The European Crop Wild Relative Diversity Assessment and Conservation Forum[40] has established *in situ* conservation methodologies for CWR[41] with the aim of promoting genetic reserves for crop complexes such as those of the *Avena*, *Beta*, *Brassica* and *Prunus* species;
- the Erebuni Reserve has been established in Armenia to conserve populations of cereal wild relatives (for example *Triticum araraticum*, *T. boeoticum*, *T. urartu*, *Secale vavilovii S. montanum*, *Hordeum spontaneum, H. bulbosum and H. glaucum*)[42] and in Germany, the Flusslandschaft Elbe Biosphere Reserve is important for the *in situ* conservation of wild fruit crop genetic resources and perennial ryegrass (*Lolium perenne*);
- in the Near East, in addition to the protected area established in Turkey for conserving wild relatives of cereals and legumes, in 2007 the Syrian Arab Republic established a protected area at Alujat and has banned the grazing of small ruminants in the Sweida region to contribute to conserving wild relatives of cereals, legumes and fruit trees.

In spite of the aforementioned examples and the overall increase in the number of protected areas, the range of genetic diversity of target species within them remains inadequately represented and many of the ecological niches that are important for wild PGRFA remain unprotected. In a study of wild peanut (*Arachis* spp.) in South America, it was found that the current conservation areas poorly cover the distribution of the species, with only 48 of the 2 175 georeferenced observations included in the study originating from national parks.[43]

2.2.3 *In situ* conservation of PGRFA outside protected areas

A World Bank study[44] reported that while existing parks and protected areas are the cornerstones of biodiversity conservation, they are insufficient to ensure the continued existence of a vast proportion of tropical biodiversity. A significant number of important PGRFA species, including CWR and useful plants collected from the wild, occur outside conventional protected areas and consequently do not receive any form of legal protection.[45] Cultivated fields, field margins, grasslands, orchards, recreation areas and roadsides may all harbour important CWR and other useful wild plants. Plant diversity in such areas faces a variety of threats including the widening of roads, removal of hedgerows or orchards, overgrazing, expansion in the use of herbicides or even just different regimes for the physical control of weeds.[46]

The effective conservation of PGRFA outside protected areas requires that social and economic issues be addressed. This may require, for example, specific management agreements to be concluded between conservation agencies and those who own or have rights over prospective sites. Such agreements are becoming more common, especially in North America and Europe. Microreserves, for example, have been established in the Valencia region of Spain.[47] In Peru, farming communities have signed an agreement with the CIP to establish a 15 000 ha 'Potato Park' near Cusco where the genetic diversity of the region's numerous potato varieties is protected by local indigenous people who own the land and who are also allowed to control access to these local genetic resources.

Many CWR and other useful species grow as weeds in agricultural, horticultural and silvicultural systems, particularly those associated with traditional cultural practices or marginal environments. In many areas such species may be particularly threatened as a result of the move away from traditional cultivation systems. Several national governments, especially in developed countries[48] now provide incentives, including financial subsidies, to maintain these systems and the wild species they harbour. While such options are largely unaffordable and unenforceable throughout most of the developing world, opportunities do exist for integrating the on-farm management of landraces and farmer varieties with the conservation of CWR diversity.[49] Several countries in West Africa, for example, have commented on the important role of local communities and traditional methods in the sustainable management of grassland ecosystems.

While several country reports mention that measures have been taken to support *in situ* conservation outside protected areas, few details have been provided. In Viet Nam, a research project on the *in situ* conservation of landraces and CWR outside protected areas was developed to conserve globally significant agrobiodiversity of rice, taro, litchi, longan, citrus and tea, at 11 sites in 7 provinces. The strategy was to promote community-based Plant Genetic Resources Important Zones (PGR-IZs). In Germany, the '100 fields for biodiversity'[50] project focuses on the conservation of wild plant species (including CWR) outside protected areas through the establishment of a nationwide conservation network for wild arable plant species. Research in West Asia has found significant CWR diversity in cultivated areas, especially at the margins of fields and along roadsides.[51] It has also been reported that in Jabal Sweida in the Syrian Arab Republic, rare wheat, barley, lentil, pea and faba bean CWR are common in modern apple orchards.[52]

2.2.4 Global system for *in situ* conservation areas

The first SoW report recommended the establishment of a system of *in situ* conservation areas and the development of guidelines for site selection and management. In response, the CGRFA commissioned a study[53] on the establishment of a global network for the *in situ* conservation of CWR. The study report proposed conservation priorities and specific locations in which to conserve the most important wild relatives of 14 of the world's major food crops (see Table 2.1). The report points out that about 9 percent of the CWR of the 14 crops require urgent conservation attention. A brief summary of the regional priorities presented in the report is given below:

Africa

High priority locations have been identified in Africa for the conservation of wild relatives of finger millet (*Eleusine* spp.), pearl millet (*Pennisetum* spp.), garden pea (*Pisum* spp.) and cowpea (*Vigna* spp.).

Americas

In the Americas, priority locations for genetic reserves have been identified for barley (*Hordeum* spp.), sweet potato (*Ipomoea* spp.), cassava (*Manihot* spp.), potato (*Solanum* spp.) and maize (*Zea* spp.).

Asia and the Pacific

Potential genetic reserve locations have been identified for the four highest priority taxa of wild rice (*Oryza* spp.) and ten priority taxa related to cultivated banana/plantain (*Musa* spp.).

Near East

The highest priority locations for conserving the wild relatives of garden pea (*Pisum* spp.), wheat (*Triticum* spp. and *Aegilops* spp.), barley (*Hordeum spontaneum* and *H. bulbosum*), faba bean (*Vicia* spp.), chickpea (*Cicer* spp.), alfalfa (*Medicago* spp.), clover (*Trifolium* spp.) and wild relatives of fruit trees, particularly, Pistachio (*Pistacia* spp.) and stone fruits (*Prunus* spp.) occur in this region.

These highest priority sites provide a good basis for establishing a global network of CWR genetic reserves, in line with the draft Global Strategy for Crop Wild Relative Conservation and Use[54] developed in 2006.

2.3 On-farm management of PGRFA in agricultural production systems

The on-farm management and conservation of PGRFA, in particular the maintenance of traditional crop varieties in production systems, has gained much ground since the publication of the first SoW report. Many new national and international programmes have been set up around the world to promote on-farm management and the published literature over the last ten years has resulted in a clearer understanding of the factors that influence it.[55] New tools have been developed that enable this diversity and the processes by which it is maintained, to be more accurately assessed and understood[56] and there is a better understanding of the complementarities between *in situ*/on-farm and *ex situ* conservation. However, relatively little is still known about how to achieve the best balance in the use of these two approaches, or about the dynamic nature of that relationship. The country reports provided information, summarized in Table 2.1, on the extent and distribution of crop genetic diversity within agricultural production systems, the management processes that have maintained this diversity, the national capacity to support the maintenance of diversity and progress in on-the-ground conservation interventions.

2.3.1 Amount and distribution of crop genetic diversity in production systems

Efforts to measure genetic diversity within production systems have ranged from the evaluation of plant phenotypes using morphological characters, to the use of new tools of molecular biology. Considerable variation exists among production systems and many country reports pointed out that the highest levels of crop genetic diversity occurred most commonly in areas where production is particularly difficult, such as in desert margins or at high altitudes, where the environment is extremely variable and access to resources and markets is restricted.

Little information was available from country reports regarding actual numbers of traditional varieties

TABLE 2.1
Summary of 14 priority CWR species as reported by Maxted & Kell, 2009

Crop	High priority CWR	Centers of diversity	Likely occurrence inside protected area	Known occurrence inside protected area	Known occurrence outside protected area	Countries in which suggested priority site/ areas should be located	Suggested sites are specific protected areas or in their vicinity? (Y/N)
Finger millet (*Eleusine coracana*)	*E. intermedia*	East Africa	X			Burundi, Democratic Republic of the Congo, Ethiopia, Kenya, Rwanda, Uganda	Y
	E. kigeziensis		X		X		Y
Barley (*Hordeium vulgare*)	*H. chilense*	Main: Southwestern Asia; Others: Central Asia, Southern South America, Western North America	X		X	Chile	Y
Sweet potato (*Ipomoea batatas*)	*I. batatas* var. *apiculata*	Main: Northwestern South America Others: Indonesia, Papua New Guinea, Sub-Saharan Africa	X			Mexico	Y
	I. tabascana				X		N
Cassava (*Manihot esculenta*)	*M. alutacea* *M. foetida* *M. leptopoda* *M. neusana* *M. oligantha* *M. peltata* *M. pilosa* *M. pringlei* *M. tristis*	Brazil, Bolivia (Plurinational State of), Latin America				Brazil	N

TABLE 2.1 (continued)
Summary of 14 priority CWR species as reported by Maxted & Kell, 2009

Crop	High priority CWR	Centres of diversity	Likely occurrence inside protected area	Known occurrence inside protected area	Known occurrence outside protected area	Countries in which suggested priority site/ areas should be located	Suggested sites are specific protected areas or in their vicinity? (Y/N)
Banana/plantain *(Musa acuminate)*	*M. basjoo* *M. cheesmani* *M. flaviflora* *M. halabanensis* *M. itinerans* *M. nagensium* *M. ochracea* *M. schizocarpa* *M. sikkimensis* *M. textilis*	India, Malaysia				Bhutan, India, Papua New Guinea, Sumatra, Philippines	N
Rice (*Oryza sativa*)	*O. longiglumis* *O. minuta*			X			Y
	O. rhizomatis	Asia, Pacific, Africa		X	X	India, Papua New Guinea, Sri Lanka	Y
	O. schlechteri		X		X		Y
Pearl millet *(Pennisetum glaucum)*	*P. schweinfurthii*	Western Africa	X		X	Sudan	Y
Garden pea *(Pisum sativum)*	*P. abyssinicum* *P. sativum* subsp. *elatius* var. *brevipedunculatum*	Ethiopia, Mediterranean, Central Asia			X	Cyprus, Ethiopia, Syrian Arab Republic, Turkey, Yemen	N
Potato *(Solanum tuberosum)*	110 species with 5 or fewer observation records	Southcentral Mexico, South America				Argentina, Bolivia (Plurinational State of), Ecuador, Mexico, Peru	N
Sorghum *(Sorghum bicolor)*	none	Southeast Asia, India, South America, Africa					

TABLE 2.1 (continued)
Summary of 14 priority CWR species as reported by Maxted & Kell, 2009

Crop	High priority CWR	Centres of diversity	Likely occurrence inside protected area	Known occurrence inside protected area	Known occurrence outside protected area	Countries in which suggested priority site/areas should be located	Suggested sites are specific protected areas or in their vicinity? (Y/N)
Wheat (*Triticum aestivum*)	*T. monococcum* subsp. *aegilopoides* *T. timopheevii* subsp. *armeniacum* *T. turgidum* subsp. *aleocolchicum* *T. turgidum* subsp. *dicoccoides* *T. turgidum* subsp. *polonicum* *T. turgidum* subsp. *turanicum* *T. urartu* *T. zhukovskyi*	Transcaucasia, Fertile Crescent, Eastern Mediterranean		X	X	Georgia, Iran (Islamic Republic of), Iraq, Lebanon, Turkey	N (except one)
Faba bean (Vicia faba)	*V. eristalioides* *V. faba* subsp. *paucijuga V. galilaea* *V. hyaeniscyamus* *V. kalakhensis*				X	Syrian Arab Republic, Turkey	N
Cowpea (*Vigna unguiculata*)	*V. unguiculata* - subsp. *aduensis* - subsp. *alba* - subsp. *baoulensis* - subsp. *burundiensis* - subsp. *letouzeyi* - subsp. *unguiculata* var. *spontanea*	India/Southeast Asia; Tropical Africa			X	Numerous African countries	Y
	V. unguiculata - subsp. *pawekiae* - subsp. *pubescens*			X			
Maize (*Zea mays*)	*Z. luxurians* *Z. mays* subsp. *huehuetenangensis* *Z. diploperennis*	Mexico	X 	 X	X X 	Guatemala, Nicaragua Guatemala Mexico	Y/N

Source: Maxted, N. & Kell, S.P. 2009. Establishment of a Global Network for the *In Situ* Conservation of CWR: Status and Needs. FAO CGRFA. Rome, Italy. 266 pp.

maintained in farmers' fields. The Georgia country report mentioned that 525 indigenous grape varieties are still being grown in the mountainous countryside and isolated villages, while in the Western Carpathians of Romania, more than 200 local landraces of crops have been identified.

In contrast to the country reports, published scientific literature since the first SoW report contains a considerable amount of information on numbers of traditional varieties grown on farm. A major conclusion from these publications is that a significant amount of crop genetic diversity in the form of traditional varieties continues to be maintained on farm even through years of extreme stress.[57] In a study in Nepal and Viet Nam of whether traditional rice varieties are grown by many households or only a few, and over large or small areas,[58] it was found that more than 50 percent of traditional varieties are grown by only a few households in relatively small areas.

Farmers' variety names can provide a basis for estimating the actual numbers of traditional varieties occurring in a given area and, more generally, as a guide to the total amount of genetic diversity. However, different communities and cultures approach the naming, management and distinguishing of local cultivars in different ways and no simple, direct relationship exists between cultivar identity and genetic diversity.[59]

2.3.2 Management practices for diversity maintenance

Practices that support the maintenance of diversity within agricultural production systems include agronomic practices, seed production and distribution systems and the management of the interface between wild and cultivated species.

A widespread system that conserves a wealth of traditional varieties is production in home gardens. Cuba, Ghana, Guatemala, Indonesia, Venezuela (Bolivarian Republic of) and Viet Nam all reported that significant crop genetic diversity exists in home gardens, which can act as refuges for crops and crop varieties that were once more widespread. Farmers often use home gardens as a site for experimentation, for introducing new cultivars, or for the domestication of wild species. Useful wild species may be moved into home gardens when their natural habitat is threatened, e.g. through deforestation, as in the case of loroco (*Fernaldia pandurata*) in Guatemala.[60]

A recent review[61] revealed that traditional varieties and landraces of horticultural crops, legumes and grains are still extensively planted by farmers and gardeners throughout Europe and they are often found in the home gardens of rural households. Invaluable diversity of traditional varieties of many crops, especially of fruits and vegetables but also of maize and wheat, is still available, even in countries where modern commercial varieties dominate the seed systems, crop fields and commercial orchards.

Many country reports indicated that 'informal' seed systems remain a key element in the maintenance of crop diversity on farm (see Section 4.8) and can account for up to 90 percent of seed movement.[62] While seed exchange can take place over large distances, in many cases it appears to be more important locally, especially within traditional farming systems. In Peru, for example, between 75 and 100 percent of the seeds used by farmers in the Aguaytia Valley was exchanged within the community with little going outside.[63]

Access to seeds of traditional varieties of field crops can be an issue in some developed countries. In the European Union, for example, only certified seeds of officially registered varieties can be marketed commercially, although local, small-scale, non-commercial exchange of planting material remains quite common. However, the European Union Directive 2008/62/EC provides for a certain flexibility in the registration and marketing of traditional, locally adapted but threatened agricultural landraces and varieties; so-called 'conservation varieties'. For more information on seed legislation and its impacts see Section 5.4.2.

Several countries report on how the genetic make-up of local varieties depends on the effects of both natural selection and selection by farmers. In Mali, studies have shown that local varieties of sorghum collected in 1998 and 1999 matured seven to ten days earlier than those collected 20 years earlier, as the result of natural selection, farmer selection, or both. This underlines the dynamic nature of *in situ* management, it can result in the conservation of many components of the genetic makeup of the varieties concerned, but also allows genetic change to occur.

Farmer seed selection practices vary widely. They may select seeds from plants growing in a certain part of a field, from particularly 'healthy' plants, from a special part of the plant, from plants at different stages of maturity, or they may simply take a sample of seeds from the overall harvest. In some local communities in Ouahigouya, Burkina Faso, for example, pearl millet farmers harvest seeds from the centre of the field to maintain 'purity', selecting a range of types and taking into account uniformity of grain colour and spikelet dehiscence. This practice appears to favour seed quality and seed vigour.[64]

The Cyprus and Greece country reports indicated that many farmers in these countries prefer to save their own seeds and when replaced, the same variety is generally obtained from a relative, neighbour, or the local market (usually in that order of preference). In this way, over a period of years much mixing occurs. Community genebanks have also been established in a number of countries[65] and can be important sources of seeds for local farmers.

A sharp decrease in the number of farmers growing a particular variety and a switch to a single, or restricted number of new varieties, can create a genetic bottleneck and may result in the loss of genetic diversity. This can occur, for example, as a result of natural disasters, war or civil strife when local seed availability may be severely reduced; seeds and other propagating materials may be lost or eaten, supply systems disrupted and seed production systems destroyed (see Chapter 1). At the same time, relief organizations may distribute seeds of new cultivars that can result in further changes in the number and type of varieties grown.

The interface between wild and agricultural plants and ecosystems is highly complex and can result in both positive and negative effects regarding the maintenance of genetic diversity. The natural introgression of new genes into crops can expand the diversity available to farmers. Geneflows between crop cultivars and their wild relatives have been a significant feature of the evolution of most crop species[66] and continue to be important today.[67] In Benin and other West African countries, for example, it has been reported that introgression between wild and domesticated yams is important in the continuing improvement of yam cultivars by farmers.[68] At the same time, many wild relatives and crop cultivars avoid losing their identities even when they grow in close proximity, often using reproductive mechanisms such as pollen competition. This can happen for example when a wild relative is surrounded by cultivated fields, as in the teosinte-maize relationship in Mexico,[69] and in the opposite case when wild relatives surround crop fields, such as pearl millet in the Sahel.[70]

Several country reports provide examples of the management of the crop-wild interface. In southern Cameroon, for example, wild yams (*Dioscorea* spp.) are important as a food and in the culture of the Baka Pygmies. Through a variety of technical, social and cultural practices, referred to as 'paracultivation', they are able to make use of the wild resources while keeping them in their natural environment. In Tajikistan, superior genotypes of walnut (*Juglans regia*) and pistachio (*Pistacia vera*) have been selected from the wild and are now in cultivation, and wild apples have been planted in orchards in some parts of the Pamir mountain range.

In Jordan and in the Syrian Arab Republic, natural gene flows between cultivated and wild *Triticum* species were confirmed using morphological and molecular techniques.[71]

2.3.3 Farmers as custodians of diversity

During the last decade extensive work has been carried out to improve understanding on why and how farmers continue to maintain diversity in their fields. This has resulted in a greater appreciation of the range of custodians, the role of traditional knowledge and the needs and choices farmers have within their livelihood systems. The diversity of stakeholders who maintain and use PGRFA has been looked at in many countries. Work in China and Nepal, for example, has found that only one or two expert farmers in a given community account for the maintenance of most of the diversity.[72] Age, gender, ethnic group and wealth status all have a bearing on who maintains diversity, what diversity is maintained and where (see Chapter 8). Especially in developed countries, individuals may be involved for hobby or other non-commercial reasons. Japan has implemented a system to recognize and register people as leaders in the cultivation of local crops, based on their experience and technical capabilities.

Many country reports recognize the importance of traditional knowledge in the conservation and use of PGRFA on farm. Bangladesh, Ethiopia, India, Kazakhstan, the Lao People's Democratic Republic and the United Republic of Tanzania, for example, all describe efforts to document and protect indigenous knowledge, while many others state the need to do so or point to a need for appropriate policies to this end.

Many factors influence the choice of how many and which varieties to grow and in which areas, including the need to minimize risk, maximize yields, ensure nutritional balance, spread workloads and capture market opportunities. A series of empirical studies in Burkina Faso, Hungary, Mexico, Nepal, Uganda and Viet Nam have suggested that major factors affecting varietal choice also include market access, seed supply, farmer age and gender and whether the variety is common or rare.[73]

2.3.4 Options to support the conservation of diversity in agricultural production systems

While there are many ways in which farmers can benefit from a greater use of local crops and varieties, in many cases action is needed to make them more competitive with modern varieties and major crops. Potential interventions to increase competitiveness include: better characterization of local materials, improvement through breeding and processing, greater access to materials and information, promoting increased consumer demand and more supportive policies and incentives. Often, efforts to implement such interventions are led by Non-governmental Organizations (NGOs) that may or may not be linked to national research and education institutes.

2.3.4.1 Adding value through characterizing local materials

While work has been carried out in a number of countries on characterization of local materials, land-races are often inadequately characterized, especially under on-farm conditions. There is some indication from the country reports that greater efforts have been made to characterize traditional and local varieties over the past decade and the Czech Republic reported that state financial support is available for the evaluation of neglected crops.

2.3.4.2 Improving local materials through breeding and seed processing

Improvement of local materials can be achieved through plant breeding and/or through the production of better quality seed or planting material. Since the first SoW report was published, particular attention has been given to participatory approaches to crop evaluation, improvement and breeding, especially involving local farmer varieties (see Chapter 4). Several case studies have been conducted by the ECPGR Working Group on on-farm conservation and management. These relate to cowpea and beans in Italy, Shetland cabbage in Scotland, fodder beets in Germany, Timothy grass in Norway and tomatoes in Spain.[74]

2.3.4.3 Increasing consumer demand through market incentives and public awareness

Raising public awareness of local crops and varieties can help build a broader base of support. This can be achieved in many ways, for example, through personal contacts, group exchanges, diversity fairs, poetry, music and drama festivals and the use of local and international media.[75] Albania, Azerbaijan, Jordan, Malaysia, Namibia, Nepal, Pakistan, Portugal, the Philippines and Thailand, for example, all reported on the establishment of markets and fairs for the promotion of local products. Other ways of income generation include promoting ecotourism and branding products with internationally accepted certificates of origin or the like for niche markets.[76] In Jamaica, on-farm management is supported by the development of local and export markets for a wide range of traditional and new products originating from local underutilized crops. Malaysia, likewise, reported on efforts to develop commercial value-added, 'diversity-rich' products.

2.3.4.4 *Improved access to information and materials*

The importance of maintaining and managing information and knowledge about diversity at the community or farmer level is recognized in many country reports. A number of initiatives have been developed through the NGO community, aiming to strengthen indigenous knowledge systems, for example 'Community Biodiversity Registers' in Nepal, that record information on cultivars grown by local farmers.[77] Cuba, Ethiopia, Nepal, Peru and Viet Nam all report that 'diversity fairs' allow their farmers to see the extent of diversity available in a region and to exchange materials. In Azerbaijan, for example, action was taken by the Government to improve farmer's PGRFA knowledge. These fairs have proven to be a popular and successful way of strengthening local knowledge and seed supply systems.[78] In Finland, the project 'ONFARMSUOMI: Social and cultural value, diversity and use of Finnish landraces' aims to find new ways to encourage the on-farm management of traditional crop diversity. It has developed a web based 'landrace information bank' to encourage and support the cultivation of landraces among farmers as well as to enhance awareness among the general public.

2.3.4.5 *Supportive policies, legislation and incentives*

Traditional varieties are generally dynamic and evolving entities, characteristics that need to be recognized in policies designed to support their maintenance. Recent years have seen several countries enact new legislation to support the use of traditional varieties. In Cyprus, for example, the Rural Development Plan 2007-2013 is the main policy instrument covering the on-farm management of PGRFA. It contains a range of different measures to promote the conservation and use of diversity in agricultural and forest land within protected areas. In Hungary, the National Agri-Environment Programme (NAEP) has adopted a system of Environmentally Sensitive Areas (ESA) through which areas of low agricultural productivity that have, however, high environmental value are designated for special conservation attention. (For a more extensive discussion of policy issues in relation to the conservation and use of PGRFA see Chapters 5 and 7).

2.4 Global challenges to *in situ* conservation and management of PGRFA

The Millennium Ecosystem Assessment (MEA)[79] identified five major drivers of biodiversity loss: climate change, habitat change, invasive alien species, overexploitation and pollution. Of these, the first three arguably pose the greatest threat to PGRFA and are discussed in the following sections. In addition, in many countries, the introduction of new varieties is also seen as a significant factor in the loss of traditional crop diversity and is also discussed briefly below.

2.4.1 Climate change

Many country reports[80] refer to the threat of climate change to genetic resources. All the predicted scenarios of the Intergovernmental Panel on Climate Change (IPCC)[81] will have major consequences for the geographic distribution of crops, individual varieties and CWR. Even the existing protected area system will require a serious rethink in terms of size, scale and management.[82] Wildlife corridors, for example, will become increasingly important to enable species to migrate and adjust their ranges. Small island states, which often have numerous endemic species, are also highly vulnerable to climate change, particularly to rises in sea level.

A recent study[83] used current and projected climate data for 2055 to predict the impact of climate change on areas suitable for a number of staple and cash crops. A picture emerged of a loss of suitable areas in some regions, including many parts of Sub-Saharan Africa and gains in other regions. Of the crops studied, 23 were predicted to gain in terms of overall area suitable for production at the global level while 20 were predicted to lose. Another study predicted similar trends[84] including the overall loss of suitable land and potential production of staple cereal crops in Sub-Sahara Africa. Many developed nations, on the other hand, are likely to see an expansion of suitable arable land into latitudes further away from the equator.

Ex situ conservation will become increasingly important as a safety net for conserving PGRFA that is threatened with extinction due to climate change. At the same time, the genetic diversity conserved in genebanks will become increasingly important in underpinning the efforts of plant breeders as they develop varieties adapted to the new conditions. Likewise *in situ* conservation, because of its dynamic nature, will also become more important in the future as a result of climate change. In cases where *in situ* populations of CWR and landraces are able to survive climate change, their evolution under climatic selection pressure will result in populations that may not only be important in their own right but also have the potential to contribute valuable new traits for crop genetic improvement.

2.4.2 Habitat change

The expansion of agriculture itself, in large part due to the direct and indirect effects of a growing and increasingly urbanized human population, is one of the biggest threats to the conservation of wild genetic diversity of agricultural importance. MEA has reported that cultivated land covers one-quarter of the Earth's terrestrial surface and that while the cropped areas in North America, Europe and China have all stabilized since 1950, this is not true in many other parts of the world. A further 10–20 percent of land currently under grass or forest will be converted to agriculture by 2050. Some countries, e.g. Argentina and the Plurinational State of Bolivia, specifically refer to the expansion of land devoted to agriculture as a major threat to CWR.

2.4.3 Invasive alien species

The MEA cited invasive alien species, including pest and disease organisms, as one of the biggest threats to biodiversity. While the problem may be particularly severe on small islands, several continental countries, including Bosnia and Herzegovina, Nepal, Slovakia and Uganda, also specifically reported this as a threat to wild PGRFA. The problem has been exacerbated in recent years due to increased international trade and travel. Many small island developing states now have to confront huge problems of biological invasion. French Polynesia, Jamaica, Mauritius, Pitcairn, Reunion, Saint Helena and the Seychelles, are all among the top ten most affected countries based on the percentage of their total flora, under threat.[85] Cyprus reported that a variety of crop species are known as invasive alien species and are having negative effects on local biodiversity.

2.4.4 Replacement of traditional with modern varieties

The replacement by farmers of traditional varieties with new, improved modern varieties, has been recognized as an issue in more than 40 of the country reports (see Chapter 1). Ecuador reported this effect in the Sierra region. Georgia, for example, cited the fact that local varieties of apples and other fruits were being replaced by introduced modern varieties from abroad and Pakistan reported that the release of high yielding varieties of chickpea, lentil, mung bean and blackgram have resulted in the loss of local varieties from farmers' fields. Jordan reported that crops such as wild almond and historical olive trees are under threat due to the replacement by the new varieties.

2.5 Changes since the first State of the World report was published

The first SoW report emphasized the need to develop specific conservation measures for CWR and wild food plants, particularly in protected areas; sustainable management systems for rangelands, forests and other humanized ecosystems; and systems for the conservation and sustainable use of landraces or traditional crop varieties in farmers' fields and in home gardens. While there is good evidence of progress over the past decade in developing tools to support the assessment, conservation and management of PGRFA on farm, it is less evident that the *in situ* conservation of wild relatives has advanced significantly, especially outside protected areas. Major trends and developments since the first SoW report was published are summarized below:

- a large number of surveys and inventories of PGRFA have been conducted;
- the *in situ* conservation of PGRFA (in particular CWR) in wild ecosystems still occurs mainly in protected areas. Less attention has been given to conservation elsewhere. There has been a significant increase in the number and coverage of protected areas;
- CWR have received much more attention. A global strategy for CWR conservation and use has been drafted, protocols for the *in situ* conservation of CWR are now available and a new Specialist Group on CWR has been established within SSC-IUCN;
- while many countries have reported an increase in the number of *in situ* and on-farm conservation activities, they have not always been well coordinated;
- there has been little progress on the development of sustainable management techniques for plants harvested from the wild, which are still largely managed following traditional practices;
- the last decade has seen an increase in the use of participatory approaches and multistakeholder teams implementing on-farm conservation projects;
- a number of new tools, especially in the area of molecular genetics, have become available and training materials have been developed for assessing genetic diversity on farm;
- new legal mechanisms enabling farmers to market genetically diverse varieties, coupled with legislation supporting the marketing of geographically identified products have provided additional incentives for farmers to conserve and use local crop genetic diversity in a number of countries;
- significant progress has been made in understanding the value of local seed systems and in strengthening their role in maintaining genetic diversity on farm;
- there is evidence that more attention is now being paid to increasing the levels of genetic diversity within production systems as a means of reducing risk, particularly in the light of the predicted effects of climate change.

2.6 Gaps and needs

An analysis of the country reports, regional consultations and thematic studies identified a number of gaps and needs for the improvement of *in situ* conservation and on-farm management of PGRFA. While the major issues identified in the first SoW report remain (lack of skilled personnel, financial resources and appropriate policies) a few new needs have also been identified:

- the draft global strategy on the conservation of CWR needs to be finalized and adopted by governments as a basis for action;[86]
- there is a need to strengthen the ability of farmers, indigenous and local communities and their organizations, as well as extension workers and other stakeholders, to sustainably manage agricultural biodiversity;
- there is a need for more effective policies, legislation and regulations governing the *in situ* and on-farm management of PGRFA, both inside and outside of protected areas;
- there is a need for closer collaboration and coordination, nationally and internationally, especially between the agriculture and environment sectors;
- there is a need for specific strategies to be developed for conserving PGRFA *in situ* and for managing crop diversity on farm. Special attention needs to be given to the conservation of CWR in their centres of origin, major centres of diversity and biodiversity hotspot areas;
- the involvement of local communities is essential in any *in situ* conservation or on-farm management effort and traditional knowledge systems and practices need to be fully taken into account. Collaboration between all stakeholders needs to be strengthened in many countries;
- there is a need in all countries to develop and put in place early warning systems for genetic erosion;
- greater measures are needed in many countries to counter the threat of alien invasive species;
- strengthened research capacity is required in many areas and, in particular, in taxonomy of CWR and conducting inventories and surveys using new molecular tools;

- specific research needs relating to on-farm management or *in situ* conservation of PGRFA include:
  - studies on the extent and nature of possible threats to existing diversity on farm and *in situ;*
  - the need for better inventories and characterization data on land races, CWR and other useful wild species, including forages, in order to better target *in situ* conservation action;
  - studies on the reproductive biology and ecological requirements of CWR and other useful wild species;
  - ethnobotanical and socio-economic studies, including the study of indigenous and local knowledge, to better understand the role and limits of farming communities in the management of PGRFA;
  - studies of the effectiveness of different mechanisms for managing genetic diversity and how to improve them;
  - studies of the dynamic balance between *in situ* and *ex situ* conservation. What combination works best, where, under what circumstances and how should the balance be determined and monitored;
  - studies on the mechanisms, extent, nature and consequences of geneflow between wild and cultivated populations;
  - further research to provide information to underpin the development of appropriate policies for the conservation and use of genetic diversity, including the economic valuation of PGRFA.

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Chapter 3

The state of *ex situ* conservation

3.1 Introduction

Ex situ conservation continues to represent the most significant and widespread means of conserving PGRFA. Most conserved accessions are kept in specialized facilities known as genebanks maintained by public or private institutions acting either alone or networked with other institutions. PGRFA can be conserved as seed in specially designed cold stores or, in the case of vegetatively propagated crops and crops with recalcitrant seeds, as living plants grown in the open in field genebanks. In some cases, tissue samples are stored *in vitro* or cryogenically and a few species are also maintained as pollen or embryos. Increasingly, scientists are also looking at the conservation implications of storing DNA samples or electronic DNA sequence information (see Section 3.4.6).

Following a general overview of the status of genebanks around the world, this chapter addresses a number of facets of *ex situ* conservation: collecting, types of collection, security of conserved germplasm, regeneration, characterization and documentation, germplasm movement and botanical gardens. It ends with a brief overview of the changes that have taken place since the first SoW report was published and an assessment of gaps and needs for the future.

3.2 Overview of genebanks

There are now more than 1 750 individual genebanks worldwide, about 130 of which hold more than 10 000 accessions each. There are also substantial *ex situ* collections in botanical gardens of which there are over 2 500 around the world. Genebanks are located on all continents, but there are relatively fewer in Africa compared with the rest of the world. Among the largest collections are those that have been built up over more than 35 years by the CGIAR and are held in trust for the world community. In 1994, the CGIAR centres signed agreements with FAO, bringing their collections within the International Network of *Ex Situ* Collections. These were brought under the ITPGRFA (see Chapter 7).

Based on figures from the World Information and Early Warning System (WIEWS)[1] and country reports, it is estimated that about 7.4 million accessions are currently maintained globally, 1.4 million more than were reported in the first SoW report. Various analyses suggest that between 25 and 30 percent of the total holdings (or 1.9-2.2 million accessions) are distinct, with the remainder being duplicates held either in the same or, more frequently, a different collection.

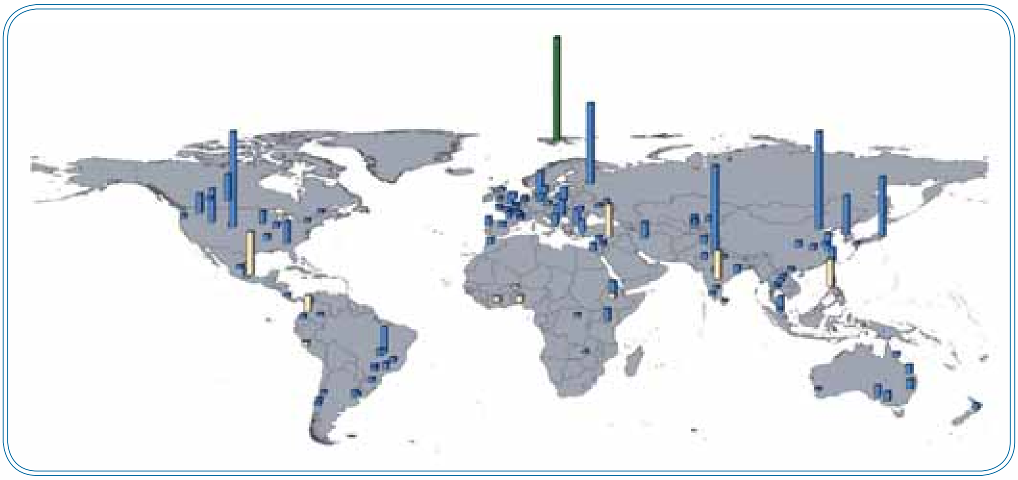
Germplasm of crops listed under Annex I of the ITPGRFA is conserved in more than 1 240 genebanks worldwide and adds up to a total of about 4.6 million samples. Of these, about 51 percent is conserved in more than 800 genebanks of the Contracting Parties of the ITPGRFA and 13 percent is stored in the collections of the CGIAR centres. Of the total 7.4 million accessions, national government genebanks conserve about 6.6 million, 45 percent of which held in only seven countries[2] down from 12 countries in 1996. This increasing concentration of *ex situ* germplasm in fewer countries and research centres highlights the importance of mechanisms to ensure facilitated access, such as that of the MLS under the ITPGRFA.

The geographic distribution of accessions stored in genebanks and as safety backup samples in the SGSV is summarized in Figure 3.1 and Table 3.1.

3.3 Collecting

According to the country reports, the trends reported in the first SoW report appear to have continued with respect to the decline in international germplasm collecting, an increase in national collecting and the greater importance now given to CWR. According to the country reports and on-line databases, more than 240 000 new accessions have been collected and added to *ex situ* genebanks over the period 1996-2007.[3] The large majority of missions collected germplasm of direct national interest, particularly obsolete cultivars, landraces and related wild species. Cereals, food legumes and forages were the main crop groups targeted. The number of accessions collected every year since 1920 and stored in selected genebanks,[4] including those of the CGIAR centres, is illustrated in Figure 3.2. There was a gradual increase in the annual collecting rate between 1920 and the

FIGURE 3.1
Geographic distribution of genebanks with holdings of >10 000 accessions (national and regional genebanks in blue; CGIAR centres genebanks in beige; SGSV in green)[5]



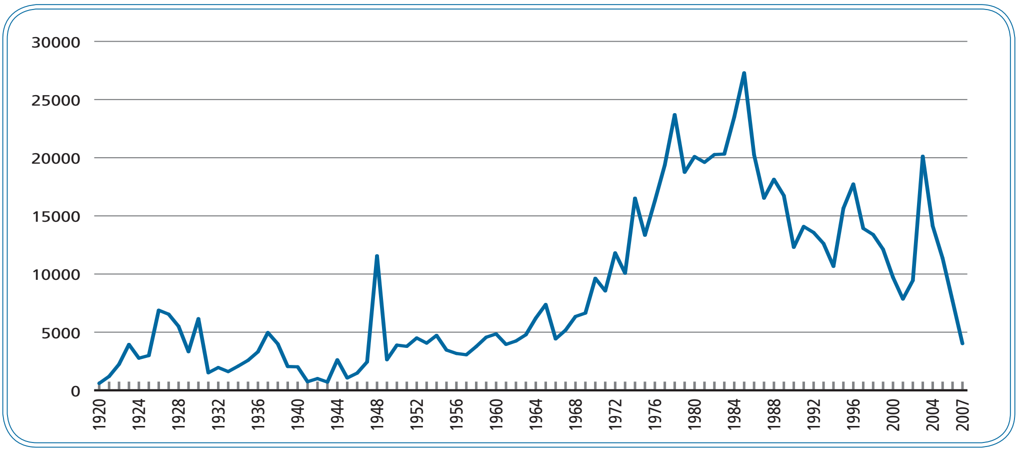
Source: WIEWS 2009; Country reports; USDA-GRIN 2009

TABLE 3.1
Regional and subregional distribution of accessions stored in national genebanks (international and regional genebanks are excluded)

Region [6]	Sub-region	Number of accessions
Africa	East Africa	145 644
Africa	Central Africa	20 277
Africa	West Africa	113 021
Africa	Southern Africa	70 650
Africa	Indian Ocean Islands	4 604
Americas	South America	687 012
Americas	Central America and Mexico	303 021
Americas	Caribbean	33 115
Americas	North America	708 107
Asia and the Pacific	East Asia	1 036 946
Asia and the Pacific	Pacific	252 455
Asia and the Pacific	South Asia	714 562
Asia and the Pacific	Southeast Asia	290 097
Europe	Europe	1 725 315
Near East	South/East Mediterranean	141 015
Near East	Central Asia	153 849
Near East	West Asia	165 930

Source: WIEWS 2009 and Country reports

FIGURE 3.2
Number of accessions collected each year since 1920 and stored in selected genebanks, including those of the CGIAR centres



Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/Departamento Nacional de Recursos Fitogenéticos y Biotecnología (DENAREF) (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008).

late 1960s and a rapid increase from then until the mid-1980s. Since then, collecting rates have gradually eased off with collecting by the CGIAR centres having levelled off since the early 2000s.[7]

An indication of the type of accessions collected by selected genebanks over two time periods, 1984-95 and 1996-2007 is shown in Figure 3.3 whereas Figure 3.4 shows the types of crop collected over the latter period, 1996-2007.

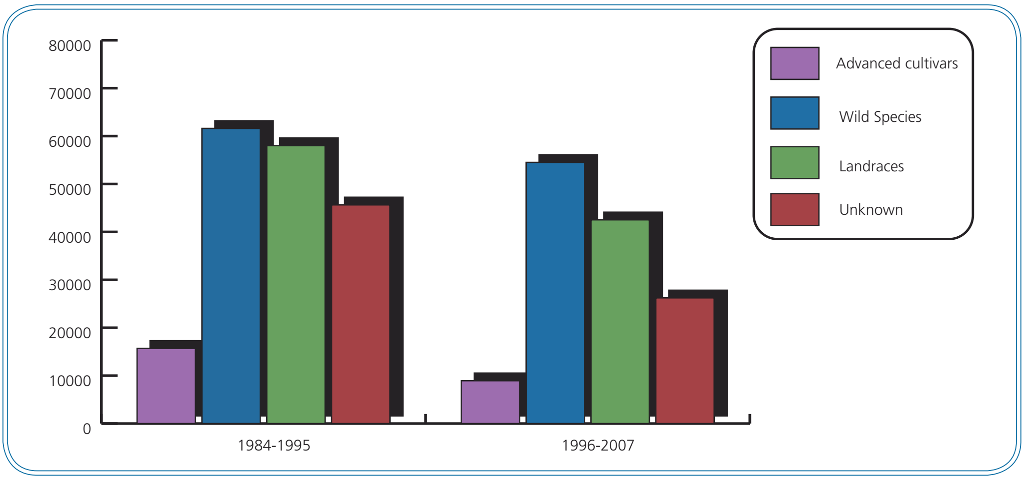
3.3.1 Situation in the regions

Most collecting missions during the last ten years have taken place in-country and have mostly aimed either to fill gaps in collections or to recollect germplasm lost during *ex situ* conservation. With changing patterns of land use and increasing environmental degradation in many parts of the world, there has been a perceived need to collect material for *ex situ* conservation that might otherwise have been conserved *in situ*. Concern about the effects of impending climate change has also steered some germplasm collecting in the direction of specific traits, such as drought and heat tolerance.[8]

Africa

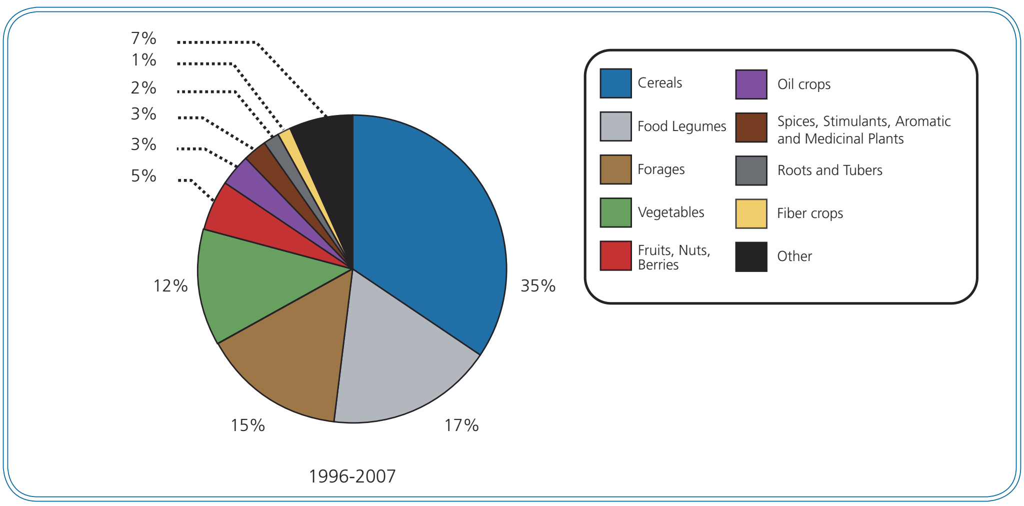
Many African nations have reported carrying out collecting missions over recent years, resulting in more than 35 000 new accessions. Since 1995, more than 4 000 accessions from some 650 genera have been collected and added to the collection in the National Genebank of Kenya. A wide range of species including cereals, oil plants, fruits and roots and tubers have been collected in Benin and the country reports of Angola, Cameroon, Madagascar, Togo, the United Republic of Tanzania and Zambia all reported the collecting of germplasm over recent years. Five missions were organized in Ghana yielding nearly 9 000 new accessions of legumes, maize, roots and tubers and fruits and nuts. The largest number of missions was carried out in Namibia; 73 between 1995 and 2008, to collect rice wild relatives and local vegetables and legumes.

FIGURE 3.3
Type of accessions collected by selected genebanks over two time periods, 1984-95 and 1996-2007



Source: genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/DENAREF (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info, 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008)

FIGURE 3.4
Accessions collected by selected genebanks over the period 1996-2007 according to crop group



Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/DENAREF (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, ILRI and WARDA (source: SINGER, 2008)

Americas

Germplasm collection missions carried out in South America over the last decade included 13 by Argentina, yielding over 7 000 accessions of various crops including forages, ornamentals and forest species; 18 by the Plurinational State of Bolivia for crops of national interest including oxalis, quinoa, beans and maize; and 4 by Paraguay to collect maize, peppers and cotton. Chile carried out an unspecified number of missions that resulted in over 1 000 new accessions and Uruguay also reported collecting, mainly forages. In total about 10 000 accessions were reported to have been collected in South America. In North America, the United States Department of Agriculture (USDA) has collected samples of more than 4 240 species since 1996, from many different countries. In total, more than 22 150 accessions have been collected of which some 78 percent were wild materials. The genera yielding the largest number of accessions were: *Malus* (2 795), *Pisum* (1 405), *Poa* (832), *Cicer* (578), *Medicago* (527), *Glycine* (434), *Vicia* (426) and *Phaseolus* (413). Canada has collected accessions of wild relatives and native crop-related biodiversity. In Central America and the Caribbean, over the past decade, Cuba has carried out 37 national collecting missions, Dominica 3 and Saint Vincent and the Grenadines 2, mainly to collect fruits, vegetables and forages. The Dominican Republic, El Salvador and Trinidad and Tobago also reported having collected germplasm. In Guatemala, between 1998 and 2008, more than 2 300 accessions of a wide range of crops were collected including maize, beans, peppers and vegetables. Based on the country reports, about 2 600 accessions have been collected in Central America since 1996.

Asia and the Pacific

Many Asian country reports listed germplasm collecting missions undertaken since the publication of the first SoW report. Collectively, they resulted in more than 129 000 new accessions. India undertook 78 national missions, collecting about 86 500 new accessions of 671 species. Bangladesh added about 13 000 accessions to its national genebank through national collecting missions. Between 1999 and 2007 Japan organized 40 foreign collecting missions (rice and legumes) and 64 national ones (fruits, legumes, forages, spices and industrials). Several other Asian countries reported that they had undertaken collecting but did not provide details. In the Pacific, the Cook Islands, Fiji, Palau, Papua New Guinea and Samoa all indicated that regular germplasm collecting missions had been carried out for traditional crops including bananas, breadfruit, yams, taro and coconuts.

Europe

Many European countries reported collecting germplasm over the past ten years, the majority of which was collected nationally or from nearby countries. In total, more than 51 000 accessions were collected. Hungary reported having undertaken 50-100 national missions that gathered several thousand new accessions of cereals, pulses and vegetables; Finland reported four missions in the Nordic region resulting in 136 new accessions of bird cherry and reed canary grass; Romania reported undertaking 36 national missions to collect cereals and legumes; and Slovakia carried out 33 missions nationally and in neighbouring countries that resulted in over 6 500 landraces and CWR. Poland mounted 13 missions at home, in Eastern Europe and Central Asia that collected about 7 000 new accessions and more than 2 500 accessions were collected by Portugal in 42 separate missions.

Near East

In-country collecting was reported by Egypt, Jordan and Morocco, the latter targeting mainly fruit trees and cereals. Missions were undertaken in Oman, in collaboration with ICARDA and ICBA, to collect barley, forage and pasture species and by national institutions in the Islamic Republic of Iran, Pakistan, the Syrian Arab Republic, Tajikistan and Tunisia focusing mainly on cereals and legumes. Holdings of PGR in the national genebank of the Islamic Republic of Iran have doubled since 1996 due to extensive collecting missions conducted in the country. Both Afghanistan and Iraq, having lost considerable amounts of conserved germplasm during recent conflicts, carried out national collecting missions; Iraq mainly for cereal wild relatives and Afghanistan primarily for food staples as well as almond, pistachio and pomegranate. Collecting missions took place in Kazakhstan in 2000, 2003 and 2004, targeting cereals, fodder crops and medicinal plants and since 2000 the collecting of CWR has been conducted annually. Azerbaijan carried out 55 national missions between 1999 and 2006 that yielded more than 1 300 new accessions of a very large range of crops. According to the country reports, more than 14 000 accessions have been collected in the region over the past decade or so. However, this figure probably fails to fully reflect the total number of accessions collected in the almost 200 collecting missions carried out by countries of the region but for which, no figures were provided.

3.4 Types and status of collections

Both seed genebanks and field genebanks differ in their species coverage, the extent of the crop genepool that is covered, the types of accessions conserved (CWR, landraces, breeding lines, advanced cultivars, etc.) and the origin of the material. The large majority of genebanks, however, conserve germplasm of the major crop species, on which humans and livestock rely most for food and feed.

3.4.1 International and national genebanks

Eleven of the CGIAR centres manage germplasm collections on behalf of the world community: Bioversity International, CIAT, CIMMYT, CIP, ICARDA, the World Agroforestry Center (formerly ICRAF), ICRISAT, IITA, ILRI, INIBAP, IRRI and AfricaRice (formerly WARDA). The CIMMYT, ICARDA, ICRISAT and IRRI collections all comprise more than 100 000 accessions each. Collectively, the centres maintain a total of about 741 319 accessions of 3 446 species of 612 different genera (see Table 1.1 in Chapter 1).

In addition, many other international and regional institutions conserve important collections, for example:

- the AVRDC maintains about 56 500 accessions of vegetable germplasm;
- the Nordic Genetic Resource Center (NordGen) conserves about 28 000 accessions of a range of crops from 129 genera;
- the Center for Tropical Agricultural Research and Education (CATIE) has a total of more than 11 000 accessions of vegetables, fruits, coffee and cocoa;
- the Southern African Development Community (SADC) Plant Genetic Resources Centre (SPGRC) maintains more than 10 500 accessions of a range of crops important for African agriculture;
- the West Indies Central Sugarcane Breeding Station (WICSBS) in Barbados conserves about 3 500 accessions;
- the International Cocoa Genebank, Trinidad and Tobago (ICGT) at the University of the West Indies conserves about 2 300 accessions;
- the Centre for Pacific Crops and Trees (CePaCT) of the Secretariat of the Pacific Community holds collections of about 1 500 accessions from several crops, including taro, yam and sweet potato.

A highly significant development since the publication of the first SoW report has been the creation of the SGSV. While not a genebank in the strictest sense, the SGSV provides secure facilities for the storage of back-up samples of accessions from genebanks around the world (see Section 3.5).

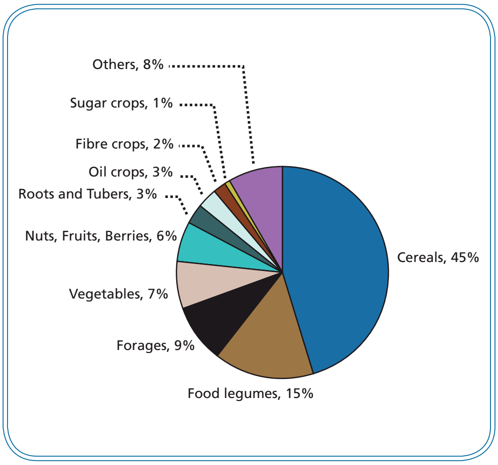
Around the globe, genetic resources are maintained in genebanks at the local and national level by governments, universities, botanical gardens, NGOs, companies, farmers and others in the private and public sectors. They house a wide range of different types of collection: national collections maintained for the long term, working collections maintained for the medium or short term, collections of genetic stocks or others. The four largest national genebanks are those housed at the Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences (ICGR-CAAS) in China, the National Center for Genetic Resources Preservation in the United States of America,[9] the National Bureau of Plant Genetic Resources (NBPGR) in India and the N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry (VIR) (see Table 1.2, Chapter 1). National genebanks housing more than 100 000 accessions are also found in Brazil, Canada, Germany, Japan and the Republic of Korea. The NPGS of USDA operates a system of germplasm conservation that networks 31 genebanks within the country and conserves more than 7 percent of the germplasm holdings representing more than 50 percent of the genera, conserved in genebanks worldwide. The Millennium Seed Bank is the world's largest seed genebank devoted to the conservation of wild species. It is run by the Royal Botanic Gardens at Kew, which also has sizeable living collections as well as herbarium and carpological collections.

3.4.2 Crop species coverage

Information in the WIEWS database indicates that about 45 percent of all the accessions in the world's genebanks are cereals. The country reports confirm this. Food legumes are the next largest group, accounting for about 15 percent of all accessions while vegetables, fruits and forage crops each account for 6-9 percent of the total number of accessions maintained *ex situ*. Roots and tubers, as well as oil and fibre crops each account for 2-3 percent of the total (see Figure 3.5). These percentages are very similar to those presented in the first SoW report.

Many countries have reported increases in the number of accessions held in their genebanks since 1996 and additional information on this is available in the WIEWS database. Angola, for example, added more than 1 800 local landraces of more than 33 species to its national genebank. Most countries in South America reported increases in their germplasm holdings, many of which, now house more than 50 percent more accessions than they did in 1996.[10] The only significant increase in holdings reported in Central America was in Mexico, where total holdings have increased by more than 160 percent since the first SoW report was published. In Asia, since 1996, the number of accessions stored at NBPGR in India grew by 137 percent and Bangladesh added more than 13 000 accessions to its national collection. During the same period, holdings in China's national genebank increased by nearly 33 000 accessions. Within the Pacific, only Australia's holdings appear to have increased, from 123 000 at the time the first SoW report was published, to 212 545 today. In Europe, Hungary added over 4 500 accessions in 1998 and

FIGURE 3.5
Contribution of major crop groups in total *ex situ* collections



Source: 31 genebanks of the NPGS of USDA (source: GRIN, 2008); 234 genebanks from Europe (source: EURISCO, 2008); 12 genebanks from SADC (source: SDIS, 2007); NGBK (Kenya) (source: dir. info., 2008); INIAP/DENAREF (Ecuador) (source: dir. info., 2008); NBPGR (India) (source: dir. info., 2008); IRRI, ICARDA, ICRISAT and AVRDC (source: dir. info., 2008); CIP, CIMMYT, ICRAF, IITA, IlRI, WARDA (source: SINGER, 2008).

between 130 and over 700 new accessions annually thereafter. Spain reported adding more than 24 000 new accessions to its national collection over the last ten years. Yemen doubled the number of accessions conserved in its field genebanks and added over 4 000 accessions, mainly of cereals and legumes, to its national collection.

Although the overall growth in the number of accessions conserved over the past decade is impressive, it should be noted, however, that some or even much of this is probably due to an increase in the level of duplication, both planned safety duplication as well as the unplanned, redundant duplication of samples within and among collections. It may also reflect improved data management and reporting.

3.4.2.1 Major crops

Holders of the six largest *ex situ* collections of selected major crops are listed in Table 3.2. The largest total

TABLE 3.2
Holders of the six largest *ex situ* collections of selected crops

Genus (crop)	Total world accessions	Major holders rank			
		1	%	2	%
Triticum (wheat)	856 168	CIMMYT	13	NSGC (USA029)	7
Oryza (rice)	773 948	IRRI	14	NBPGR (IND001)	11
Hordeum (barley)	466 531	PGRC (CAN004)	9	NSGC (USA029)	6
Zea (mays)	327 932	CIMMYT	8	BPGV-DRAEDM (PRT001)	7
Phaseolus (bean)	261 963	CIAT	14	W6 (USA022)	6
Sorghum (sorghum)	235 688	ICRISAT	16	S9 (USA016)	15
Glycine (soybean)	229 944	ICGR-CAAS (CHN001)	14	SOY (USA033)	9
Avena (oat)	130 653	PGRC (CAN004)	21	NSGC (USA029)	16
Arachis (groundnut)	128 435	ICRISAT	12	NBPGR (IND001)	10
Gossypium (cotton)	104 780	UzRICBSP (UZB036)	11	COT (USA049)	9
Cicer (chickpea)	98 313	ICRISAT	20	NBPGR (IND001)	15
Solanum (potato)	98 285	INRA-RENNES (FRA179)	11	VIR (RUS001)	9
Pisum (pea)	94 001	ATFCC (AUS039)	8	VIR (RUS001)	7
Medicago (medicago)	91 922	AMGRC (AUS006)	30	UzRICBSP (UZB036)	11
Lycopersicon (tomato)	83 720	AVRDC	9	NE9 (USA003)	8
Trifolium (clover)	74 158	WARDA (AUS137)	15	AGRESEARCH (NZL001)	9
Hevea (rubber)	73 656	MRB (MYS111)	81	RRII (IND031)	6
Capsicum (capsicum)	73 518	AVRDC	11	S9 (USA016)	6
Prunus (prunus)	69 497	VIR (RUS001)	9	UNMIHT (USA276)	9
Pennisetum (pearl millet)	65 447	ICRISAT	33	CNPMS (BRA001)	11
Vigna (cowpea)	65 323	IITA	24	S9 (USA016)	12
Malus (apple)	59 922	GEN (USA167)	12	VIR (RUS001)	6
Vitis (grape)	59 607	INRA/ENSA-M (FRA139)	9	JKI (DEU098)	6
Lens (lentil)	58 405	ICARDA	19	NBPGR (IND001)	17
Vicia (faba bean)	43 695	ICARDA	21	ICGR-CAAS (CHN001)	10
Saccharum (sugar cane)	41 128	CTC (BRA189)	12	INICA (CUB041)	9
Aegilops (wheat)	40 926	ICCI-TELAVUN (ISR003)	22	ICARDA	9
Cucurbita (cucurbita)	39 583	VIR (RUS001)	15	CATIE	7
Helianthus (sunflower)	39 380	IFVCNS (SRB002)	14	NC7 (USA020)	9
x Triticosecale (wheat)	37 440	CIMMYT	46	VIR (RUS001)	5
Ipomoea (sweet potato)	35 478	CIP	18	NIAS (JPN003)	16
Festuca (fescue)	33 008	IHAR (POL003)	14	NIAS (JPN003)	13

TABLE 3.2 (continued)
Holders of the six largest *ex situ* collections of selected crops

Major holders rank							
3	%	4	%	5	%	6	%
ICGR-CAAS (CHN001)	5	NBPGR (IND001)	4	ICARDA	4	(several)	4
CNRRI (CHN121)	9	NIAS (JPN003)	6	RDAGB-GRD (KOR011)	3	DB NRRC (USA970)	3
CENARGEN (BRA003)	6	ICARDA	6	NIAS (JPN003)	5	IPK (DEU146)	5
NC7 (USA020)	6	ICGR-CAAS (CHN001)	6	INIFAP (MEX008)	4	VIR (RUS001)	3
CNPAF (BRA008)	6	INIFAP (MEX008)	5	IPK (DEU146)	3	ICGR-CAAS (CHN001)	3
ICGR-CAAS (CHN001)	8	NBPGR (IND001)	7	IBC (ETH085)	4	CNPMS (BRA001)	3
RDAGB-GRD (KOR011)	8	AVRDC	7	CNPSO (BRA014)	5	NIAS (JPN003)	5
VIR (RUS001)	9	IPK (DEU146)	4	KARI-NGBK (KEN015)	3	TAMAWC (AUS003)	3
S9 (USA016)	8	UNSE-INSIMA (ARG1342)	6	ICRISAT (NER047)	6	ICGR-CAAS (CHN001)	5
CICR (IND512)	9	ICGR-CAAS (CHN001)	7	VIR (RUS001)	6	IRCT-Cirad (FRA002)	4
ICARDA	13	ATFCC (AUS039)	9	W6 (USA022)	6	NPGBI-SPII (IRN029)	6
CIP	8	IPK (DEU159)	5	NR6 (USA004)	5	NIAS (JPN003)	3
ICARDA	7	IPK (DEU146)	6	W6 (USA022)	6	IGV (ITA004)	4
ICARDA	10	W6 (USA022)	9	INRA CRRAS (MAR088)	4	VIR (RUS001)	3
IPB-UPLB (PHL130)	6	IPK (DEU146)	5	VIR (RUS001)	3	NIAS (JPN003)	3
ICARDA	6	WPBS-GRU-IGER (GBR016)	6	SIAEX (ESP010)	5	W6 (USA022)	5
IDEFOR-DPL (CIV061)	3	FPC (LBR004)	2	IAC (BRA006)	1	RRI (VNM009)	1
INIFAP (MEX008)	6	NBPGR (IND001)	5	IAC (BRA006)	3	NIAS (JPN003)	3
CRA-FRU (ITA378)	3	EFOPP (HUN021)	3	AARI (TUR001)	3	(several)	2
NBPGR (IND064)	9	ORSTOM-MONTP (FRA202)	7	PGRC (CAN004)	6	ICRISAT (NER047)	4
CENARGEN (BRA003)	8	LBN (IDN002)	6	NBPGR (IND001)	5	ICGR-CAAS (CHN001)	4
NIAS (JPN003)	4	NFC (GBR030)	4	PSR (CHE063)	3	(several)	3
RAC (CHE019)	5	DAV (USA028)	5	IVM (UKR050)	4	CRA-VIT (ITA388)	4
ATFCC (AUS039)	9	NPGBI-SPII (IRN029)	5	W6 (USA022)	5	VIR (RUS001)	4
ATFCC (AUS039)	6	IPK (DEU146)	4	INRA-RENNES (FRA010)	4	UC-ICN (ECU003)	4
WICSBS	8	NIAS (JPN003)	7	MIA (USA047)	6	GSC (GUY016)	5
NPGBI-SPII (IRN029)	6	NIAS (JPN003)	6	VIR (RUS001)	5	NSGC (USA029)	5
CENARGEN (BRA003)	5	ICGR-CAAS (CHN001)	4	INIFAP (MEX008)	4	NIAS (JPN003)	3
ICGR-CAAS (CHN001)	7	INRA-CLERMON (FRA040)	6	CNPSO (BRA014)	6	VIR (RUS001)	4
NSGC (USA029)	5	SCRDC-AAFC (CAN091)	5	LUBLIN (POL025)	5	IR (UKR001)	5
S9 (USA016)	3	MHRP (PNG039)	3	CNPH (BRA012)	3	BAAFS (CHN146)	2
W6 (USA022)	7	IPK (DEU271)	7	WPBS-GRU-IGER (GBR016)	5	AGRESEARCH (NZL001)	3

TABLE 3.2 (continued)
Holders of the six largest *ex situ* collections of selected crops

Genus (crop)	Total world accessions	Major holders rank			
		1	%	2	%
Manihot (cassava)	32 442	CIAT	17	CNPMF (BRA004)	9
Dactylis (grasses)	31 394	BYDG (POL022)	19	NIAS (JPN019)	9
Coffea (coffee)	30 307	IRCC/Cirad (CIV011)	22	IAC (BRA006)	14
Mangifera (mango)	25 659	Ayr DPI (AUS088)	73	CISH (IND045)	3
Beta (sugarbeet)	22 346	W6 (USA022)	11	IPK (DEU146)	10
Elaeis (oil-palm)	21 103	INERA (COD003)	84	MPOB (MYS104)	7
Panicum (millet)	17 633	NIAS (JPN003)	33	KARI-NGBK (KEN015)	13
Chenopodium (chenopodium)	16 263	BNGGA-PROINPA (BOL138)	27	INIA-EEA.ILL (PER014)	9
Dioscorea (yam)	15 903	IITA	21	UNCI (CIV006)	10
Musa (banana)	13 486	INIBAP	9	Cirad (FRA014)	4
Theobroma (cocoa)	12 373	ICGT	19	CRIG (GHA005)	8
Eragrostis (millet)	8 820	IBC (ETH085)	54	W6 (USA022)	15
Colocasia (taro)	7 302	WLMP (PNG006)	12	RGC (FJI049)	12
Psophocarpus (bean)	4 217	DOA (PNG005)	11	DGCB-UM (MYS009)	10
Corylus (nut)	2 998	COR (USA026)	28	AARI (TUR001)	14
Olea (olive)	2 629	CRA-OLI (ITA401)	17	CIFACOR (ESP046)	12
Bactris (peach palm)	2 593	UCR-BIO (CRI016)	31	CATIE	24
Pistacia (pistachio)	1 168	NPGBI-SPII (IRN029)	29	DAV (USA028)	26

TABLE 3.2 (continued)
Holders of the six largest *ex situ* collections of selected crops

Major holders rank							
3	%	4	%	5	%	6	%
IITA	8	ICAR (IND007)	4	NRCRI (NGA002)	4	SAARI (UGA001)	4
IPK (DEU271)	6	W6 (USA022)	5	WPBS-GRU-IGER (GBR016)	3	AGRESEARCH (NZL001)	2
Cirad (FRA014)	13	CATIE	6	ECICC (CUB035)	5	JARC (ETH075)	4
HRI-DA/THA (THA056)	1	MIA (USA047)	1	ILETRI (IDN177)	1	NUC (SLE015)	1
IFVCNS (SRB002)	10	INRA-DIJON (FRA043)	7	ICGR-CAAS (CHN001)	6	VIR (RUS001)	6
CPAA (BRA027)	3	ICA/REGION 5 (COL096)	1	IOPRI (IDN193)	1	NUC (SLE015)	1
S9 (USA016)	4	CN (CIV010)	3	CIAT	3	ORSTOM-MONTP (FRA202)	3
IPK (DEU146)	6	DENAREF (ECU023)	4	UBA-FA (ARG1191)	3	U.NACIONAL (COL006)	2
UAC (BEN030)	7	PGRRI (GHA091)	5	DCRS (SLB001)	3	PU (LKA002)	3
DTRUFC (HND003)	4	QDPI (AUS035)	3	CNPMF (BRA004)	3	CARBAP (CMR052)	3
CEPEC (BRA074)	6	CORPOICA (COL029)	6	CATIE	6	(several)	6
KARI-NGBK (KEN015)	12	NIAS (JPN003)	4	NBPGR (IND001)	3	CIFAP-CAL (MEX035)	3
MARDI (MYS003)	9	NBPGR (IND024)	6	HRI-DA/THA (THA056)	6	PRC (VNM049)	5
TROPIC (CZE075)	10	IDI (LKA005)	9	LBN (IDN002)	9	(several)	6
KPS (UKR046)	6	HSCRI (AZE009)	6	IRTAMB (ESP014)	4	UzRIHVWM (UZB031)	4
NPGBI-SPII (IRN029)	9	DAV (USA028)	5	HSCRI (AZE009)	5	AARI (TUR001)	5
IAC (BRA006)	13	CORPOICA (COL029)	10	EENP (ECU022)	6	INRENARE (PAN002)	3
IRTAMB (ESP014)	9	GRI (AZE015)	5	ACSAD (SYR008)	4	CSIRO (AUS034)	4

number of *ex situ* accessions are of wheat, rice, barley and maize accounting for 77 percent of the total cereal and pseudo-cereal holdings. Other large cereal holdings include sorghum (about 235 000 accessions) and pearl millet (more than 65 000 accessions). In some tropical countries, roots and tubers, including cassava, potato, yam, sweet potato and aroids, are more important as staple foods than cereals, but being more difficult to conserve, collection sizes tend to be smaller. CIP holds the world's largest sweet potato collection (more than 6 400 accessions) as well as the third largest potato collection (representing about 8 percent of total world holdings of about 98 000 accessions) after those of the Institut national de la recherche agronomique (INRA)-Rennes (France) and VIR (the Russian Federation). Other important collections of *Solanum* are found at the External Branch North of the Department Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research, Oil Plants and Fodder Crops in Malchow, Germany (IPK) and USDA (Sturgeon Bay, United States of America). The largest cassava collection (more than 5 400 accessions) is held by CIAT in Colombia, followed by the collections of the Brazilian Agricultural Research Corporation (Embrapa), in Brazil and IITA in Nigeria.

The genebanks of the CGIAR centres generally represent the major repositories for germplasm of their mandate crops. For example: the world's major wheat (13 percent of the total) and maize (8 percent of the total) collections are held at CIMMYT, that of rice (14 percent of total) is at IRRI. ICRISAT maintains the world's largest collections of sorghum (16 percent), pearl millet (33 percent), chickpea (20 percent) and groundnut (12 percent). ICARDA houses the world's largest collections of lentil (19 percent), faba bean (21 percent) and vetches (16 percent). CIAT is responsible for the world's largest collections of beans (14 percent) and cassava (17 percent).

China holds the largest collection of soybean germplasm (14 percent of the world's accessions). Among fruits, *Prunus* species are represented by more than 69 000 accessions, including breeding and research materials, with the VIR in the Russian Federation holding 9 percent and the Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Centro di Ricerca per la Frutticoltura (CRA-FRU) in Italy 3 percent of the total. *Malus* and *Vitis* species are represented by the second and third largest number of accessions, the largest collections of *Malus* being held by USDA in Geneva, Cornell University (12 percent), while for *Vitis* these are held at INRA/Centre régional de la recherche agronimique, Station de recherches viticoles (ENSA-M) in France (9 percent) and the Julius Kühn-Institut - Federal Research Centre for Cultivated Plants (JKI) in Germany (6 percent). After Bioversity International's *Musa* collection maintained at the International Transit Centre in Leuven, the most important banana germplasm holdings are at the Centre de coopération internationale en recherche agronomique pour le développement (Cirad) in Guadeloupe, Laloki Dry-lowlands Research Programme (DLP) Laloki in Papua New Guinea and the Honduran Agricultural Research Foundation (FHIA) in Honduras. Among vegetables, most accessions are of tomatoes followed by peppers (*Capsicum* spp.). The largest collections are at AVRDC, which accounts for about 10 percent of the total for both crops. Other important collections of tomato are held at USDA in Geneva and IPK in Germany and of *Capsicum* at USDA in Griffin and the Istituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) in Mexico.

Australia is the predominant holder of forage legume germplasm, with 30 percent of the world holdings of *Medicago* at the Australian Medicago Genetic Resource Centre (AMGRC) and 15 percent of the world's clover holdings at the Western Australian Department of Agriculture (WADA). The most important temperate forage grasses include *Festuca*, *Dactylis* and *Lolium* (approximately 92 000 accessions among them). Some of the largest collections of these are held in Germany, Japan and Poland. Among the tropical forage grasses, Kenya Agricultural Research Institute's National Genebank of Kenya (KARI-NGBK) holds the largest collection of *Cenchrus*, while CIAT and ILRI together hold the largest collection of *Brachiaria*. Among oilseed crops, sesame accounts for more than 50 000 accessions globally and sunflower almost 40 000. The largest single collections of these are held by India (17 percent) and Serbia (14 percent), respectively.

Cotton is the most important fibre crop in terms of the total number of accessions held, with almost 105 000 accessions being maintained worldwide. Of these, 11 percent are held in Uzbekistan at the

Uzbek Research Institute of Cotton Breeding and Seed Production (UzRICBSP). About 80 percent of the over 70 000 accessions of rubber are conserved in Malaysia at the Malaysia Rubber Board (MRB). Among the major beverages, the largest collection of coffee is held in Côte d'Ivoire (22 percent) and that of cacao is held by ICGT at the University of the West Indies in Trinidad and Tobago (19 percent).

3.4.2.2 Minor crops and wild relatives

According to the country reports, since 1995, there has been a growing interest in collecting and conserving minor, neglected and underutilized crops. In the case of yam, for example, the number of conserved accessions has increased from 11 500 in 1995 to 15 900 in 2008, and in the case of bambara groundnut from 3 500 in 1995 to 6 100 in 2008. This increased interest in minor crops reflects, in part, the growing realization that many of them are under threat due to replacement by major crops or the disappearance of the agricultural environments in which they are grown. Similarly, concerns exist for CWR whose natural habitats are under threat, compounded by concerns over climate change and the realization that many CWR could possess traits such as biotic and abiotic stress resistance or tolerance that could be useful in adapting crops to changing conditions.

3.4.3 Types of material stored

The nature of the accessions (for example whether they comprise advanced cultivars, breeding lines, landraces, wild relatives, etc.) is known for about half of the material conserved *ex situ*. Of these, about 17 percent are advanced cultivars, 22 percent breeding lines, 44 percent landraces and 17 percent wild or weedy species.[11] As Figure 3.6 shows, the number of accessions of landraces, breeding material and wild species conserved worldwide has increased since the first SoW report was published, possibly reflecting a growing interest in securing such material before it is lost, as well as for use in genetic improvement programmes.

Table 3.3 provides a breakdown of type of accession by crop group. Forages and industrial crops show a relatively high percentage of accessions that are wild relatives. The reverse is true for sugar crops, the majority of which are represented by advanced cultivars.

3.4.4 Source of material in genebanks

About 55 percent of all accessions held in genebanks globally for which the country of origin is known, are indigenous, i.e. they originated in the country where the collection is maintained. Table 3.4 shows the total number of accessions and the proportion of indigenous germplasm on a subregional basis.

The percentage of indigenous accessions is greatest for Southern Africa, West Asia and South Asia and is lowest for Central Africa, North America and the Pacific. In general, the distribution of accessions held in genebanks between native and exotic germplasm appears little changed from that reported in the first SoW report and overall, large national genebanks tend to maintain a greater proportion of non-indigenous materials than smaller ones.

For Africa, indigenous germplasm predominates in the collections of the SADC countries, Ethiopia and Kenya. Country reports from the Asia and the Pacific region indicate that accessions are predominantly indigenous in Papua New Guinea, Samoa, Sri Lanka and Viet Nam while in the Cook Islands, Fiji and Palau they are exclusively so. In China, 82 percent of materials in seed collections are reportedly indigenous, while at NIAS in Japan, native accessions are about 39 percent of the total conserved.

In the Americas, the majority of accessions in the Caribbean and in Central and South American national genebanks were of native origin, with the exception of Brazil and Uruguay that reported more than five times and more than once respectively, the number of foreign accessions compared with native ones. According to the USDA's GRIN database, native accessions comprise about 16 percent of the total germplasm conserved in the NPGS of USDA.

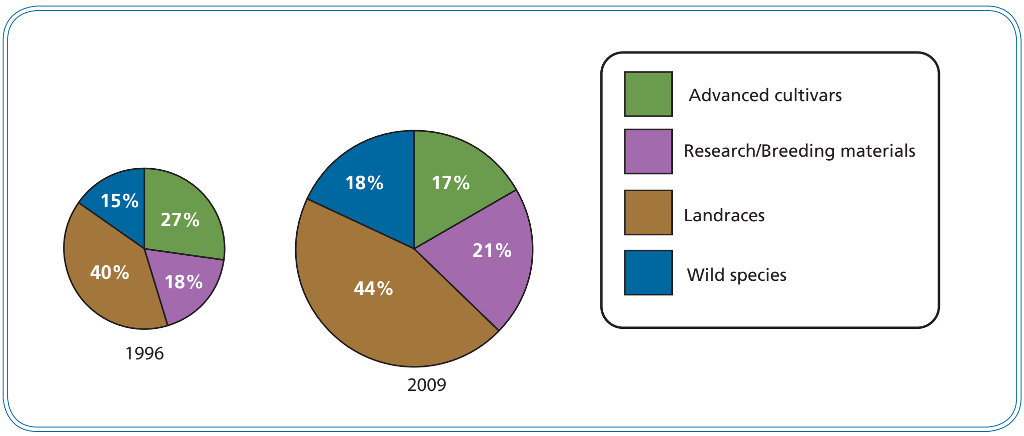
A wide range in origins of germplasm is reported in European genebanks. More than 75 percent of germplasm holdings stored in Greece, Romania, Portugal and Spain, are indigenous, as are those conserved at NordGen, originating in the five

TABLE 3.3
Global germplasm holdings in terms of type of accession (mean percentage) for groups of crops included in Appendix 2

Commodity group	No. of accessions	% Wild species	% Landraces	% Breeding materials	% Advanced cultivars	% Others
Cereals	3 157 578	5	29	15	8	43
Food legumes	1 069 897	4	32	7	9	49
Roots and tubers	204 408	10	30	13	10	37
Vegetables	502 889	5	22	8	14	51
Nuts, fruits and berries	423 401	7	13	14	21	45
Oil crops	181 752	7	22	14	11	47
Forages	651 024	35	13	3	4	45
Sugar crops	63 474	7	7	11	25	50
Fibre crops	169 969	4	18	10	10	57
Medicinal, aromatic, spice and stimulant crops	160 050	13	24	7	9	47
Industrial and ornamental plants	152 325	46	1	2	4	47
Other	262 993	29	4	2	2	64
Total/overall mean	**6 998 760**	**10**	**24**	**11**	**9**	**46**

Source: WIEWS 2009

FIGURE 3.6
Types of accessions in *ex situ* germplasm collections in 1996 and 2009 (the size difference in the charts represents the growth in total numbers of accessions held *ex situ* between 1996 and 2009)



Source: WIEWS 1996 and 2009

TABLE 3.4
Number and percentage of accessions of local origin in *ex situ* genebanks, excluding collections held in international and regional genebanks

Region	Subregion	Number of indigenous accesions	Total number of accessions ([a])	% of indigenous accessions
Africa	West Africa	32 733	40 677	80
Africa	Central Africa	934	18 829	5
Africa	Eastern Africa	100 125	119 676	84
Africa	Sourthern Africa	40 853	41 171	99
Africa	Indian Ocean Islands	131	273	48
America	South America	145 242	180 604	80
America	Central America and Mexico	41 370	51 513	80
America	Caribbean	13 746	23 671	58
America	North America	114 334	521 698	22
Asia and the Pacific	East Asia	179 055	255 673	70
Asia and the Pacific	South Asia	420 019	443 573	95
Asia and the Pacific	Southeast Asia	74 466	137 763	54
Asia and the Pacific	Pacific	42 649	188 988	23
Europe	Europe	354 015	939 620	38
Near East	South/East Mediterranean	66 363	73 428	90
Near East	West Asia	54 735	55 255	99
Near East	Central Asia	20 375	25 283	81
World		**1 701 145**	**3 117 695**	**55**

[a] Total number of accessions whose country of origin is reported.
Source: WIEWS 2009

countries served by the genebank. However, the percentage of indigenous accessions in the national genebanks of Bulgaria, the Czech Republic, Germany, the Netherlands and the Russian Federation varies between 14 and 20 percent. Austria, France, Hungary, Italy, Poland and Ukraine conserve more foreign germplasm than native.

In the Near East region, either all or the majority of accessions in the national genebanks are of native origin; exclusively so for Jordan, Kyrgyzstan and Lebanon and predominantly so for Pakistan, Tajikistan and Yemen.

3.4.5 Gaps in collection coverage

The extent of coverage of the total diversity of different crops in *ex situ* collections is difficult if not impossible to estimate with any real precision as it varies considerably according to crop and according to the perceptions of different stakeholder groups. Over recent years, the GCDT has supported the development of a number of crop and regional conservation strategies.[12] These have brought together information from different countries and organizations and, *inter alia*, have attempted to identify major gaps in *ex situ* collections as estimated by different stakeholders. Thus, for wheat, according to the opinion of collection managers, the major gaps in collections are of landraces and cultivars. Key users of wheat genetic resources, however, indicated the need for more mapping populations, mutants, genetic stocks and a wider range of wild relatives. For maize, the situation is slightly different as there are relatively few areas where no comprehensive collection has been made. Major gaps identified in existing *ex situ* maize collections thus include hybrids and tropical inbred lines, in addition to gaps resulting from the loss of accessions from collections; for example, the entire collection of Dominica was lost as was much of the maize collected by the International Board for Plant Genetic Resources (IBPGR) in the 1970s. For barley there are gaps in collections of wild relatives and many species and populations are endangered as a result of the loss of their natural habitats.

For potatoes, the most useful genetic material has already been collected and there are currently few significant gaps. However, several Latin American collections are threatened by lack of funding and, if lost, would result in critical gaps in the overall coverage of the genepool. The situation for sweet potato is somewhat different, as important geographic as well as trait gaps have been identified. Among the best estimates of genepool coverage are those for banana and plantain. About 300-400 key cultivars are known to be missing from the International Transit Collection including 20 plantains from Africa, 50 *Callimusa* from Borneo, 20-30 *Musa balbisiana* and 20 other types from China and India, 10 accessions from Myanmar, 40 wild types from Indonesia and Thailand and up to 100 wild types from the Pacific.

The situation for legumes differs from those described above. For lentils, landraces from China and Morocco and wild species, particularly from southeast Turkey, are not well represented in collections. There are gaps in chickpea collections from Central Asia and Ethiopia and there are relatively few accessions of wild relatives collected, particularly from the secondary genepool. For faba beans, various geographic gaps have been identified including local varieties and landraces from North Africa, the Egyptian oases, South America and China. The small-seeded subspecies, *paucijuga*, is also under-represented in collections and there are trait gaps, especially for heat tolerance. An important consideration for many legume collections is also the need to collect and maintain samples of *Rhizobium*. This is especially the case for wild legume species, for which *Rhizobium* collections are rare.

While there are still sizeable gaps in the *ex situ* collections of many major crops, these tend to be small in comparison with those in the collections of the numerous minor crops. Indeed, many useful plant species only occur in the wild or as landraces in farmers' fields. In many cases these species are threatened by the vagaries of climate and changes in land use.

A problem common to many crops is the difficulty in conserving their wild relatives, especially perennials. As a result, they are often missing from collections and are generally best conserved *in situ* as they can be difficult to collect and maintain *ex situ*, or can become serious weeds.

While today there is a better understanding of the extent and nature of gaps in *ex situ* collections than at the time of the first SoW report, the picture is still far from complete. The use of molecular data to improve understanding on the nature, extent and distribution of genetic diversity, more detailed field surveys and better georeferencing of accessions would all be helpful in efforts to more accurately identify gaps and redundancy within and among individual collections and in genepools as a whole.

3.4.6 Conservation of deoxyribonucleic acid samples and nucleotide sequence information

In addition to storage of seeds, whole plants and tissues, isolated DNA can be maintained at low temperatures or electronically as sequence data on computers, *in silico*. The latter is becoming increasingly possible as data storage costs fall and the power of analytical tools increases. While current technology does not permit the regeneration of the original plant from isolated DNA or electronic information sources, these can be used in many ways, e.g. in genetic diversity and taxonomic studies. In 2004, Bioversity International surveyed international and national conservation programmes, botanic gardens, universities and private companies involved in PGRFA conservation in 134 countries.

The results provide useful baseline information on the use of plant DNA storage. Only 21 percent of the 243 respondents stored plant DNA, with about as many in developing as in developed countries. Lack of funds, equipment, personnel and training were cited as the main reasons by the remainder for not employing DNA storage. Nearly half of the institutions that conserve DNA, supply it to others for research, despite that many considered it to be a somewhat unclear legal situation. Bioversity International published the results of the survey in 2006[13] in a publication that also discusses options and strategies for integrating DNA and sequence information with other conservation approaches. There is still considerable debate within the PGRFA community about the current and potential future role of DNA and sequence information storage for conservation purposes.

3.5 Storage facilities

Since the publication of the first SoW report there has been an increase in storage capacity as new genebanks have been established and existing ones expanded. However, this says little about storage conditions and whether there has been a general improvement. There remains an enormous range in types and conditions of storage facilities worldwide. The problems associated with storage facilities in the developed world are magnified in the developing world, where utilities are less reliable and funding more constrained.

Technical requirements for conserving seeds have been widely published[14,15] and broad recommendations can generally be made. The same is not true for conserving plants in field genebanks, *in vitro* storage or cryopreservation, where requirements can be highly crop specific and techniques demanding of management and facilities. While some countries in the developed and developing world are able to meet such demands, many are not, and consequently some collections are degenerating.

One of the major developments that has occurred since the publication of the first SoW report is the establishment of the SGSV, as a safety net for *ex situ* seed collections of the world's crops. This is the first and only truly global germplasm conservation facility in the world. Located in the permafrost, 130 metres into a mountainside on an island just 800 km from the North Pole, SGSV provides unprecedented levels of physical security. The Government of Norway built the facility as a service to humanity and maintains and operates it with support from the GCDT and the NordGen. The seed vault opened in early 2008 and as of June 2009 has housed more than 412 000 accessions, all of which are safety duplicate copies of material already held in *ex situ* collections elsewhere. All materials in SGSV remain under the ownership and control of the depositor, who is responsible for the periodic monitoring of viability and regeneration of accessions deposited at SGSV. Details of the collections deposited in SGSV are provided in Table 3.5.

The following sections describe the status of facilities for conserving PGRFA in various regions and in International Agricultural Research Centres (IARCs).

Africa

Based on the country reports, data on storage facilities in Africa are less complete than for other regions. Most countries reported having seed and field genebanks, but only Benin, Cameroon, the Congo, Ghana, Kenya, Mali, Nigeria and Uganda reported having *in vitro* storage facilities. No country specified having the ability to conserve germplasm cryogenically. Seed genebanks are generally much more important and widespread than field genebanks in the continent. Ethiopia, for example, reported having 60 000 accessions in its national seed genebank and 9 000 in its field genebank. Burkina Faso, the Niger and Zambia all reported having many more accessions in their seed genebanks than in their field genebanks. Although most countries reported having long-, medium- and/or short-term storage facilities, they also mentioned numerous problems in their use, including reliability of electricity supplies, pests and disease related problems as well as lack of staff, equipment, or funds. Guinea reported the loss of its entire *ex situ* collection as a result of a failure in the electricity supply.

TABLE 3.5
Germplasm holdings at SGSV as of 18 June 2009

Depositor	Number of			
	Genera	Species	Accessions	Countries of origin
Centre for Genetic Resources (Netherlands)	31	224	18 212	143
Department of Agriculture, Food and Rural Development (Ireland)	3	4	100	4
Institute of Plant Production n.a. V.Y. Yurjev of UaaS (Ukraine)	5	7	885	31
Leibniz Institute of Plant Genetics and Crop Plant Research (Germany)	408	1 272	17 671	110
N.I. Vavilov all-Russian Scientific Research Institute of Plant Industry (Russian Federation)	12	40	945	68
National Agrobiodiversity Center (Republic of Korea)	26	32	13 185	1
National Genebank of Kenya (Kenya)	3	4	558	1
National Plant Genetic Resources Laboratory (Philippines)	3	4	500	16
National Plant Germplasm System (United States of America)	223	827	30 868	150
Nordic Genetic Resource Center	84	226	12 698	73
Oak Park Research Centre (Ireland)	6	7	577	1
Plant Gene Resources of Canada, Saskatoon Research Centre (Canada)	50	154	9 233	83
Plant Genetic Resources Institute, National Agricultural Research Centre (Pakistan)	5	8	480	1
Seed Savers Exchange (United States of America)	19	39	1 421	66
Station fédérale de recherches en production végétale de Changins (Switzerland)	3	3	3 845	21
Taiwan Agricultural Research Institute	1	1	4 018	1
AVRDC	12	55	7 350	89
CIAT	88	502	34 111	125
CIMMYT	4	6	80 492	57
CIP	2	173	5 847	23
ICARDA	29	249	62 834	117
ICRAF	63	120	508	27
ICRISAT	7	7	20 003	84
IITA	3	30	6 513	85
ILRI	112	506	4 008	91
IRRI	6	45	70 180	121
WARDA	1	4	5 404	64
Total [a]	**664**	**3 286**	**412 446**	**204**

[a] Distinct for genera, species and countries of origin (former country denominations e.g. Soviet Union are also counted); undetermined genera and species are not counted. (Elaborated from http://www.nordgen.org/sgsv)

Asia and the Pacific

Virtually all Asian countries that submitted country reports indicated that they maintained both seed genebanks and field genebanks, but less than half stored germplasm *in vitro*, and only India, Indonesia, Japan, Nepal, Pakistan and the Philippines used cryopreservation. China reported having 53 separate storage facilities, India 74 and the Philippines 45. Several other Asian countries reported having up to ten storage facilities. Long-, medium- and short-term facilities are available in most countries, although the numbers of each differed markedly among countries. While Japan and Pakistan reported meeting international standards for germplasm storage, according to the country reports, many other countries were unable to meet such standards indicating that there was room for improvement. The reasons stated for failure to meet international standards included lack of funds, insufficient and inadequately trained staff, lack of space, poor equipment and unreliable electricity supplies. Field genebanks predominate in the Pacific Islands countries, reflecting the regional importance of crops such as taro, coconut and banana that cannot be stored as seed. Fiji and Papua New Guinea were the only countries in the subregion to report having *in vitro* storage. No information was supplied on the existence of long-, medium- or short-term seed storage facilities, although numerous problems were reported with regards to the vulnerability of germplasm stored under field conditions.

Americas

All nine South American countries that submitted country reports, reported that they maintained both seed and field genebanks and stored germplasm *in vitro*. Only Ecuador reported using cryopreservation, although the Bolivarian Republic of Venezuela was preparing for it. Long-, medium- and short-term storage facilities were available in all countries. Brazil reported having 383 separate conservation facilities, Argentina 33 and the Bolivarian Republic of Venezuela 26. Most other countries reported fewer than ten. Uruguay and the Bolivarian Republic of Venezuela reported that they had built new long-term facilities in the last ten years. Several countries met internationally agreed standards for genebank operations, but widespread problems of funding and staffing were reported.

The majority of countries in Central America and the Caribbean maintain long-, medium- and short-term seed stores, field genebanks and *in vitro* genebanks. In the subregion, only Cuba reported activities on germplasm cryopreservation. As elsewhere, fewer accessions tend to be stored in field than seed genebanks: Cuba, for example reported having 4 000 accessions in the field compared with more than 12 000 seed accessions, and Mexico has approximately 61 000 field accessions and 107 000 seed accessions, although only half of these are in cold storage. However, roughly equal proportions of field and seed accessions are maintained in Costa Rica and El Salvador, while the Dominican Republic conserves about four times more material in the field than in its seed genebank. Most countries reported having ten or fewer genebanks, while Mexico reported having about 150 genebanks, 22 of these having cold storage facilities but only three meeting international standards for long-term conservation. As elsewhere in the developing world, many countries reported difficulties in maintaining international genebank standards for the same reasons, indicated by others. However, Cuba and Dominica also reported problems created by extreme weather events. In North America, both Canada and the United States of America operate long- and medium-term conservation genebanks, including cryopreservation facilities.

Europe

According to country reports, most European states have long-, medium- and short-term seed storage facilities as well as field genebanks. Belgium, Germany, Poland and the Russian Federation maintain cryopreservation facilities and virtually all countries conserve some germplasm *in vitro*. Hungary and Italy both reported having more than 60 separate storage facilities, but most countries have fewer than 20. However, the relative importance of the different types of storage varies considerably. Italy, for example, conserves more germplasm in the field than in seed genebanks and Germany reported having more than 155 000 accessions in genebanks (seed and field collections), of which 3 200 *in vitro*. Belgium too, reported substantial numbers of *in vitro* accessions (more than 1 500), largely as a result of the international collection of banana germplasm maintained in Leuven. In all cases, international standards were met and few problems were encountered, e.g. Albania reported a limitation of financial resources and skilled staff and The former Yugoslav Republic of Macedonia was hampered by the lack of a national strategy.

Near East

In 2004, the National Genebank of Egypt became operational with a storage capacity for 200 000 accessions (15 percent of capacity was being used by the end of 2006) as well as facilities for *in vitro* conservation and cryopreservation. New long-term storage facilities have also been established in Morocco (2002) and Tunisia (2007). Tajikistan stated its reliance on donor funds to maintain storage facilities in good order and Uzbekistan indicated that it is modernizing its facilities. Most of the remaining countries conserve their genetic resources under ambient or medium-term conservation conditions (5-10°C with no relative humidity control). While several countries in this region have no genebank some, including Kuwait, Saudi Arabia and the United Arab Emirates have made plans for the establishment of long-term storage facilities to serve national and regional needs. A number of countries reported problems relating to funding, staffing and reliability of utilities.

International Agricultural Research Centre Genebanks

Since the publication of the first SoW report there has been considerable upgrading of storage facilities among the IARCs. In 1996, the Government of Japan funded a new genebank at CIMMYT. More recently, the World Bank supported two projects to upgrade the standards of all the CGIAR genebanks. Through these projects, CIAT received a grant to convert cold rooms into a low temperature seed vault; ILRI has recently installed new humidifiers and a new irrigation system for its field genebank and in 2007, IRRI built a new long-term seed store and enlarged its screenhouse complex. The projects also funded the renovation of IITA's facilities, where there are now improved cold storage chambers, drying rooms, *in vitro* laboratories and a store for yams. WARDA built a new cold room, screenhouses, a drying room and laboratories in Cotonou, Benin.

3.6 Security of stored material

Many of the world's collections of PGR are maintained under suboptimal conditions that have a negative impact on the viability of the collections. Two main areas of concern are the extent of safety duplication and backlogs with respect to regeneration. Both were also identified as significant constraints in the first SoW report.

Although a substantial number of the world's collections are partly or entirely duplicated in more than one genebank, current data and information often do not allow identification of the same accession in different genebanks and the clear distinction between safety and redundant duplicates. In this respect, there has been little change since the publication of the first SoW report. Analyses based on country of origin suggest that only about 25-30 percent of the total number of accessions worldwide are distinct, in line with the first SoW report, but there are large differences according to species. A preliminary estimate of the duplication for selected crops based on WIEWS data indicates that for barley about 120 000 distinct accessions are stored worldwide compared with a total of 467 000 accessions. This figure is in line with a separate study undertaken by the GCDT on the process of developing the Barley Crop Strategy.[16] Considerable safety duplication exists among the four largest barley collections; those of PGRC, USDA, Embrapa and ICARDA. There is a large overlap between the Canadian and USDA collections following safety duplication of the USDA collection of oats and barley in Canada in 1989 and the Brazilian collection is mostly integrated into that of USDA. The ICARDA collection is to be duplicated in the SGSV as a second level of safety, as are many other CGIAR collections; 33 percent of this collection is already duplicated at CIMMYT and 65 percent is duplicated elsewhere. Many other barley collections are partly or wholly safety duplicated, but those of Bulgaria, Ecuador, France, Hungary and Italy, for example, are not. The duplication of accessions among collections, whether planned or unplanned, may result in large numbers of common accessions among different genebanks which, in turn, may be duplicated again as part of the planned safety duplication of entire collections. Whether duplication tends to occur primarily through a small number of samples being duplicated many times, or through a larger number of samples being duplicated only a few times, has yet to be determined for any crop.

Many wheat and maize germplasm collections are partially or wholly safety duplicated. According to a preliminary analysis, the lowest level of duplication is associated with vegetatively propagated and recalcitrant seeded plants, including cassava, yam and taro, cashew and rubber. Inadequate duplication also occurs for *Chenopodium*, *Eragrostis*, *Psophocarpus* and bambara groundnut, all of which are of high importance in local areas. CWR, neglected and underused crops and newly domesticated crops also appear more vulnerable in terms of lack of safety duplication. Banana germplasm is largely safety duplicated *in vitro*, but the situation for potato remains uncertain. For other crops, including lentil and chickpea, the degree of safety duplication is not well documented.

The CGRFA invited countries to report on risks and threats to *ex situ* genetic resources in their national collections, as part of an international Early Warning System. In the late 1990s, the Russian Federation alerted the CGRFA about the difficulties the Vavilov Institute was facing at that time.

Since the publication of the first SoW report, a major step forward in ensuring the safety of collections has been the establishment of the GCDT,[17] described elsewhere in this report (see Section 6.5). The GCDT funds operations at the SGSV and supports long-term storage in a small but growing number of genebanks.

The following sections summarize the germplasm security status of collections in the different regions.

Africa

Burkina Faso, Cameroon, Ethiopia, Mali and the Niger reported the safety duplication of some of their germplasm in genebanks of the CGIAR countries. Ghana and Namibia both indicated that the majority of their germplasm was duplicated within the country. The regional SADC genebank provides safety duplication for all member country collections under long-term storage conditions. Uganda had not yet embarked on a programme of safety duplication, but Kenya reported having deposited safety duplicates of some of its germplasm in the Millennium Seed Bank, Kew.

Americas

In South America, Argentina reported safety duplicating its germplasm at CIP, CIMMYT, CIAT, IITA and the NCGRP of USDA. Chile reported similarly, but other countries provided no information. Very little information was provided in most of the country reports from Central America and the Caribbean, but Cuba and Mexico have undertaken a small amount of safety duplication.

Asia and the Pacific

As with Africa and the Americas, most of the Asia and the Pacific country reports provided little information on duplication, but major germplasm holding nations, including China and India, reported safety duplicating all accessions in-country. Rice growing nations such as Indonesia, the Lao People's Democratic Republic and Malaysia, all reported that IRRI maintains safety duplicates of their rice collections. Other IARCs hold safety duplicates of crops from other countries. For example, Indonesia has deposited safety duplicates of banana germplasm at the International Transit Centre in Leuven, Belgium. The CePaCT maintains safety duplicates of the national vegetatively propagated crop collections from the Pacific islands.

Europe

Most European countries indicated that their germplasm collections were safety duplicated to some extent, usually within their own national systems. The Nordic countries, Denmark, Finland, Iceland, Norway and Sweden, all reported having secured their accessions through depositing duplicate samples in Denmark as well as SGSV. Other countries, including Romania, reported not having safety duplicated their collections and the Russian Federation offered to make available facilities for safety duplication to other countries.

Near East

Kazakhstan reported storing safety duplicates at VIR and IRRI and other countries in the region, including the Islamic Republic of Iran, Turkey and Uzbekistan, reported having safety duplicated at least some germplasm in-country. Most of the cereal, legume and range species collected from the region are duplicated at ICARDA. Pakistan reported having safety duplicates of crop germplasm collections at ICARDA, IRRI and AVRDC.

3.7 Regeneration

As aging of conserved accessions occurs even under optimal *ex situ* storage conditions, periodical monitoring of the viability and timely regeneration of materials are an essential, though often neglected, part of *ex situ* conservation. Limited financial resources, infrastructure and human capacity still represent the main constraints to regeneration, as was reported in the first SoW report. The need for skilled staff is especially great in the case of difficult and poorly researched species, such as many of the CWR. The crop and regional conservation strategies supported by the GCDT have highlighted the fact that regeneration backlogs occur in all types of conserved germplasm and in all regions.[18] According to information from NISM databases,[19] since 1996, capacity has worsened in 20 percent of the surveyed genebanks, regeneration backlogs have persisted in 37 percent of them and in 18 percent they have increased. Recently, regeneration and documentation updating efforts have been supported by the GCDT in over 70 countries for about 90 000 accessions in collections identified by crop experts as being of highest priority.

Africa

Regular viability testing was carried out in Madagascar, Nigeria, Uganda and Zambia, but generally not elsewhere. The systematic regeneration of stored material appears sporadic, although Ethiopia reported regular regeneration of germplasm when viability fell below 85 percent. Funding, staffing and facilities were frequently reported to be inadequate to allow the necessary germplasm regeneration to be undertaken. Ongoing regeneration backlogs have been reported for the fonio and sorghum national collections in Mali, as well as for cereal and vegetable collections held at the Institut sénégalais de recherche agricole – Unité de recherche comune en culture *in vitro* (ISRA-URCI) in Senegal and at the Institute of Biodiversity Conservation (IBC) in Ethiopia. The national genebank of the United Republic of Tanzania also warned about a decreasing capacity to manage regeneration that has resulted in growing backlogs for both cross- and self-pollinated crop collections.

Americas

Viability testing in Argentina has not been carried out as regularly as desired, but a considerable amount of regeneration has been done since the first SoW report was published. The Plurinational State of Bolivia, Cuba, Ecuador, Peru, Uruguay and the Bolivarian Republic of Venezuela also reported having carried out viability testing and regeneration, but many problems were reported including lack of finance, staff and equipment. Ongoing backlogs were reported for vegetatively propagated species *inter alia* by INIA Carillanca (Chile), INIAP/Departamento Nacional de Recursos Fitogenéticos y Biotecnología Instituto Nacional Autonomo de Investigaciones Agropecuarias (DENAREF, Ecuador), INIA-Maracay the Bolivarian Republic of Venezuela, Instituto de Investigaciones Fundamentales en Agricultura Tropical "Alejandro de Humboldt" (INIFAT) and the Centro de Bioplantas (Cuba). Important field collections such as the coffee collection held at CATIE are also in need of regeneration and in Brazil, regular seed regeneration is still recognized as a bottleneck for many active collections especially of cross-pollinated species.

Asia and the Pacific

Many of the Asian country reports provided little information on regeneration. While many countries practiced regeneration, they frequently faced difficulties due to lack of funds and facilities. Viet Nam reported the loss of entire collections. Some countries, including Sri Lanka and the Philippines, were able to carry out regular viability testing of stored germplasm, but this was not always possible in other countries. Regeneration backlogs for vegetatively propagated crops were reported *inter alia* by PGRC (Sri Lanka), Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, SKUAST (India) and the Central Institute of Temperate Horticulture (CITH, India), the Field Crops Research Institute - Department of Agriculture (FCRI-DA, Thailand) and the Lam Dong Agricultural Research and Experiment Centre (LAREC, Viet Nam). Regarding cross-pollinated species regeneration backlogs were reported by the Directorate of Oilseeds Research (DOR, India) and the Philippine Coconut Authority-Zamboanga Research Center (PCA-ZRC) (the Philippines). China reported regeneration activities that addressed more than 286 000 accessions and New Zealand reported the systematic regeneration of all crop germplasm, including fruits.

Europe

While viability testing was carried out regularly in most countries, the country reports contained few details on this. There were differences among countries regarding the level to which viability was allowed to fall before regeneration was considered necessary. Iceland, Norway and Sweden specified 60 percent, while the Russian Federation used a value of 50 percent and Poland a value between 80 and 85 percent. In general, there were no major problems reported by European countries regarding regeneration, although Finland indicated that in some cases small amounts of seeds made regeneration difficult. Notwithstanding an overall increase in capacity to perform regeneration, Armenia reported urgent regeneration needs and growing backlogs for its cereal and vegetatively propagated collections.

Near East

Uzbekistan reported some loss of accessions arising from reduced viability. Many countries have faced difficulties in ensuring that the genetic integrity of cross-pollinated species is maintained during regeneration. Cyprus, Egypt, the Islamic Republic of Iran and Pakistan reported having regenerated more than 50 percent of the accessions stored in their national genebanks. The main genebanks in Kazakhstan, Morocco and Uzbekistan have undertaken substantial regeneration while the other genebanks in these countries have only carried out regeneration to a more limited extent. There is a need to regenerate the entire wheat collections held in the national genebanks of Azerbaijan, Tajikistan and Turkmenistan.[20]

3.8 Documentation and characterization

3.8.1 Documentation

The first SoW report highlighted the poor documentation available on much of the world's *ex situ* PGR. This problem continues to be a substantial obstacle to the increased use of PGRFA in crop improvement and research. Where documentation and characterization data do exist, there are frequent problems in standardization and accessibility, even for basic passport information.

Nonetheless, there has been an overall improvement in the accessibility of information. A number of national genebanks have published collection data on the web or are in the process of doing so, often with the facility of being able to order materials on-line. However, a significant imbalance exists among regions and countries within regions. The large majority of countries still do not maintain an integrated national information system on germplasm holdings. According to the country reports and NISM data, important *ex situ* holdings in at least 38 countries are still, at least partly, documented only on paper (16 countries) and/or in spreadsheets (32 countries).[21] Dedicated information management systems are used to manage passport and characterization data on *ex situ* collections in only 60 percent of the countries that provided information on this topic, while generic database software is used in about 34 percent of countries.

The lack of a freely available, flexible, up-to-date, user-friendly, multilanguage system has constrained documentation improvement in many countries, although in some cases, regional and/or bilateral collaboration has helped to meet information management needs through the sharing of experiences and tools.

Almost all the CGIAR centres have developed their own documentation systems that, in most cases, include characterization data as well as an on-line ordering system. They contribute data to the SINGER, which holds passport, collecting mission and distribution data on CGIAR and AVRDC collections.[22]

The crop strategies sponsored by the GCDT contain information which is relevant to the state of documentation and characterization on a crop basis. For wheat, most developed and developing countries have computerized management systems and many provide web-based access to passport information as well as characterization data. However, the major problem is the lack of standardization among systems. A similar problem exists for maize, in that there are passport data for most accessions in most collections, but there is little uniformity in its management. Tracing materials through donor collection identifiers is generally quite difficult in web-accessible information systems. For barley, some characterization information is available on the web, but there is a lack of electronically available evaluation data.

Electronic documentation of potato accessions world-wide is only partially complete and few genebanks are able to provide characterization and evaluation data through their own web sites. For sweet potato a similar situation exists and inadequate documentation and characterization information is available, particularly in Africa. For banana, however, the research community is well served regarding information and there is an effective information network managed through INIBAP. The *Musa* Information System contains information on more than 5 000 accessions managed in 18 of the approximately 60 collections. A similar information system has been put in place for rice by IRRI. For pulses, a considerable amount of evaluation and documentation still remains to be recorded and standardized; electronic global information systems are needed for most collections.

The following sections describe the status of documentation in the various regions, based mainly on information contained in the country reports.

Africa

Most African nations reported having characterization and evaluation data on their collections, but with some exceptions (e.g. most SADC countries, Ethiopia, Kenya and Mali), it was generally incomplete and not standardized. Togo indicated that its documentation was in a rudimentary state and several other countries reported serious weaknesses. Kenya reported its intention to develop national documentation systems that are in line with the SADC Documentation and Information System (SDIS) system in use in all SADC countries. While three countries reported that they still maintained some records on paper and eight use spreadsheets, at least eight others have dedicated electronic systems.[23] Ghana, Kenya and Togo reported using generic databases to manage information on *ex situ* collections.

Americas

A significant amount of information is publicly available on the *ex situ* holdings in North America. Passport information is freely accessible through the web-based GRIN[24] on more than half a million accessions of about 13 000 species stored in 31 NPGS genebanks belonging to the USDA. In addition, more than 6.5 million observations are available on various morphological and agronomic traits for 380 000 accessions. The Canadian GRIN-CA has also adopted this information system.[25]

Country reports from South America indicate that documentation and characterization systems are working relatively well and that electronic databases containing comprehensive data on germplasm accessions are commonly used. Chile, Paraguay and Peru, however, reported that paper systems are still in use for some collections and no data from national programmes in the region are accessible via the web. Passport data were generally reported to be available for large numbers of accessions. The Sistema para la Documentación de Recursos Genéticos Vegetales (DBGERMO), developed by INTA, Argentina, is a dedicated germplasm data management system that is popular in the region and is being used in Argentina, Chile, Ecuador, Paraguay, Uruguay and by CATIE in Costa Rica. Paraguay expressed the need for DBGERMO to be adopted at a regional level in order to harmonize data collection and retrieval. The Sistema brasileiro de informação de recursos genéticos (SIBRAGEN) is the documentation and dissemination system in use by Embrapa in Brazil. GIS are reportedly used in Argentina and Ecuador for the geographical analysis of collected materials.

In their country reports, most countries in Central America and the Caribbean indicated that while documentation of germplasm holdings existed, it was often not standardized. Little information on the availability of passport data was provided in the country reports. The use of dedicated genebank documentation systems and databases are relatively rare in this region. They are reportedly in use only in Cuba, Mexico and Trinidad and Tobago and by the genebank at CATIE in Costa Rica. Some genebanks in Mexico still use paper records in addition to electronic filing and in more than 40 percent of the reporting countries spreadsheets are the most common tool for data management.

Asia and the Pacific

In their country reports, all Asian countries indicated that at least some documentation existed on their germplasm holdings. Passport data were generally available across the region, for the large majority of accessions. About 75 percent of the reporting countries make use of a dedicated information system for the management of *ex situ* germplasm, although in four countries some data have not been put in electronic format yet. China reported having a web-based database, but only in Chinese. Sri Lanka reported the use of GIS and together with Bangladesh, Thailand and Viet Nam recognized the need for a nationwide *ex situ* germplasm information system. Significant advances in making information on *ex situ* holdings publicly available were reported by Japan and the Republic of Korea, including passport and characterization data on more than 87 000 accessions held at the National Institute of Aerobiological Sciences in Japan[26] and passport data on about 20 000 accessions at the National Agrobiodiversity Centre in the Republic of Korea.[27]

Country reports from the Pacific suggested that relatively little comprehensive documentation work has been done in this region. Fiji, New Zealand, Palau, Papua New Guinea and Samoa all reported that documentation existed, but did not generally follow standard formats. Some information was available in electronic databases, and the Cook Islands, for example, stated that the development of a database was a national priority. Efforts to increase the availability of data on *ex situ* collections have been undertaken by Australia and New Zealand through web-based systems. The Australian Plant Genetic Resource Information Service (AusPGRIS)[28] at present includes passport data on about 40 000 accessions from 229 genera stored at Biloela of the Queensland Department of Primary Industries (QUPI), the web sites of the Margot Forde Forage Germplasm Centre[29] and the Arable crop genebank and online database.[30]

Europe

The state of documentation is generally good across Europe, according to the country reports. A variety of tools are used for data storage and management, among which spreadsheets and generic databases are the most common. Standardized passport data from 38 countries have been published by the European Internet Search Catalogue (EURISCO),[31] a centralized web-based catalogue that has been managed by Bioversity International since 2003 under the ECPGR. The network has also supported the establishment and maintenance of European Central Crop Databases that compile and disseminate characterization and evaluation data on several crops. The Nordic countries have standardized their approach to documentation and characterization and provide information through NordGen using the Sesto system.[32] The former Yugoslav Republic of Macedonia reported that it was ready to adopt the same information system. Croatia reported that it still had not compiled characterization data, although passport data were recorded for most accessions.

Near East

Good progress has been made since 1996 on documenting accessions held in the main genebanks. Egypt, Jordan, Morocco, Pakistan, the Syrian Arab Republic and Turkey all reported that their germplasm information is now fully maintained in a dedicated system supported technically by ICARDA and Bioversity International. Significant progress has also been made in Azerbaijan with the inclusion of passport data from the national genebank in EURISCO and the recording of characterization and evaluation data electronically for more than 60 percent of the *ex situ* cereal accessions and 50 percent of the fruit and fibre accessions.[33] Passport data for some accessions from Cyprus are also recorded in EURISCO. Other countries, including Kazakhstan and Lebanon, reported that documentation was not systematic or standardized, although Lebanon reported that evaluation data for vegetables are available via the Horticulture Cultivars Performance Database (HORTIVAR).[34] Iraq and Kazakhstan reported using crop registers in paper format and Tajikistan reported that a joint computerized system was being developed with Kyrgyzstan. Egypt maintains documentation on all germplasm accessions and has substantial amounts of data on morphological and molecular characteristics as well as on agronomically important traits.

3.8.2 Characterization

In 1996 the GPA highlighted the importance of characterization both as a way to help link the conservation of PGRFA with its use, and to facilitate the identification of gaps in collections and the development of core collections. Since then, in spite of the considerable work on characterization reported by many genebanks and associated programmes, often involving regional and international collaboration (see Chapter 6), overall, the information produced has been underused due largely to a lack of standardization and to accessibility constraints. Many country reports indicated that the lack of readily available characterization and evaluation data is a major limitation to the greater use of PGRFA in breeding programmes.

An indication of the level of characterization of the collections held by international centres is reported in Table 3.6

TABLE 3.6
Extent of characterization for some of the collections held by CGIAR centres and AVRDC

Crop groups	% of accessions characterized	Total number of accessions	Reporting centres
Cereals[35]	88	292 990	6
Food legumes	78	142 730	4
Vegetables	17	54 277	1
Fruits (banana)	44	883	2
Forages	45	69 788	3
Roots and tubers	68	25 515	3
Total	**73**	**586 193**	**11**

Source: CGIAR System-wide genetic resources programme (SGRP) 2008

TABLE 3.7
Average extent of characterization and evaluation of national collections in 40 countries[36]

Crop groups	Percentage of germplasm holdings						
	Characterized	Evaluated				Total number of	
	Morphologically	*Agronomically*	*Biochemically*	*For abiotic factors*	*For biotic factors*	*Accessions*	*Reporting countries*
Cereals	63	44	10	13	23	410 261	34
Food legumes	67	56	14	13	20	139 711	33
Vegetables	65	44	12	7	14	48 235	27
Oil crops	63	42	52	11	17	40 700	18
Fiber crops	89	84	9	19	18	37 879	15
Fruits, nuts and berries	66	54	12	24	30	31 838	26
Forages	43	50	15	13	15	27 120	20
Roots and tubers	66	54	13	17	24	22 834	27
Spices	82	81	39	7	22	17 755	10
Stimulants	53	64	20	22	35	10 413	15
Sugar crops	46	80	22	36	57	6 413	14
Medicinal plants	65	64	24	11	43	3 744	7
Ornamental plants	74	23	0	48	47	2 622	8
Others	34	85	3	8	22	20 189	11
Total	**64**	**51**	**14**	**14**	**22**	**319 528**	**40**

Sources: NISM on PGRFA, 2004, 2006, 2007, 2008

The extent to which selected national germplasm collections have been characterized and evaluated is provided in Table 3.7, based on data from 40 countries and 262 stakeholders. It is evident that while most crop commodity groups have been substantially characterized morphologically, relatively little biochemical evaluation has been done. Among the crop commodity groups, fibre crops and spices have been the most extensively characterized and evaluated, while biochemical evaluation has been chiefly carried out in oil crops and spices.

Africa

In most African nations there has been an increase in the morphological characterization of materials in *ex situ* collections since the publication of the first SoW report. The work has mostly been carried out by national PGRFA centres and programmes, sometimes in collaboration with research institutes and universities. The level of morphological characterization is high for Ethiopia's collections of cereals, pulse and oil crops (97 percent), Mali's collections of cereals and vegetables (99 percent)[37] and Senegal's collection of groundnut (100 percent). Ninety percent of Ghana's important cocoa collection is characterized for morphological traits, 10 percent using molecular makers and 80 percent has been evaluated agronomically and for biotic stresses.[38] Several countries including Kenya, Malawi and Namibia reported having generated morphological characterization data, but agronomic and particularly, molecular characterization data were scarce across Africa. Generally, it was apparent from the country reports that a considerable amount of work is still needed in most countries and capacity, particularly for new molecular techniques, is still far from adequate.

Americas

In South America many countries reported having recorded characterization data on a range of morphological, agronomic, molecular and biochemical traits. In Argentina, the Plurinational State of Bolivia, Ecuador and Peru, a large proportion of total *ex situ* holdings has been morphologically characterized and almost half evaluated for agronomically important traits including tolerance to environmental and other stresses. Cuba reported that it had characterized its germplasm holdings using morphological, agronomic, molecular and biochemical traits for 51, 80, 7 and 6 percent of accessions, respectively.[39] Mexico reported morphological and agronomic characterization for 46 percent of accessions and Nicaragua for 100 percent. Within the Caribbean, Saint Vincent and the Grenadines stated that characterization and evaluation were rarely carried out, but Trinidad and Tobago reported considerable progress in this area.

Asia and the Pacific

In their country reports, all Asian countries indicated that morphological characterization and agronomic evaluation data were widely available; for example Japan has compiled a full complement of characterization data and in India, characterization and evaluation data are available on 74 and 73 percent respectively of the national germplasm collections. The equivalent figures for the Philippines are 40 and 60 percent, respectively. While India reported that it has molecular characterization data on 21 percent of its accessions, only 3 percent of the total holdings of Malaysia, the Philippines, Sri Lanka, Thailand and Viet Nam have any molecular characterization data on them and these are mainly of food legume and cereal crops. A number of countries including Malaysia, the Philippines and Thailand also reported using biochemical markers. In the Pacific, characterization based on morphological, agronomic and molecular traits was reported for taro by Fiji, Palau and Samoa.

Europe

According to the country reports, the state of characterization has generally improved across Europe since the first SoW report was published. For example, at the Institute for Agrobotany (ABI) in Hungary, approximately 90 percent of the accessions of cereals and legumes, 50 percent of the root and tubers, 75 percent of the vegetables, 80 percent of the forages and 30 percent of the underused crops have now been characterized and evaluated. The

Czech Republic reported relatively comprehensive data on morphological and agronomically important traits including abiotic and biotic stresses, on its collections of fruit trees, wheat, barley, peas and soybean. In Romania, about 20 percent of the total holdings in the national genebank have been phenotypically characterized and biochemically evaluated. Albania reported on its extensive use of morphological and agronomic descriptors but indicated that, with few exceptions, the characterization data are not readily accessible.

Near East

The characterization and evaluation of genetic resources using standard descriptors have advanced in almost all countries of the region since the publication of the first SoW report. Characterization has been carried out on a wide range of species for morphological traits of agronomic importance, quality attributes and for tolerance and resistance to biotic and abiotic stresses. Several countries, for example, Egypt, the Islamic Republic of Iran, Jordan, Morocco, Pakistan, the Syrian Arab Republic, Tunisia and Turkey also reported that they had undertaken molecular characterization, largely through academic studies. Molecular characterization of date palm has been carried out in Kuwait, Qatar, Saudi Arabia and the United Arab Emirates.

3.9 Germplasm movement

Information on germplasm movement provides a valuable indicator of the use of PGR (see Chapter 4). However, such information is often not recorded and only limited data were provided in the country reports. However, there is now more information available on this issue than was the case at the time when the first SoW report was published.

Genebanks play a central role in the movement of germplasm within and among countries. Germplasm movement includes exchange among genebanks, sometimes as part of repatriation agreements, material collected in field collecting missions, acquisitions by genebanks from research and breeding programmes and distribution to plant breeders, researchers and directly to farmers.

While some information on total numbers of samples moved is available, this is often not broken down into the different crops or types of germplasm concerned, or the nature of the recipient or providing institution. More detailed information on these factors would enable better understanding of patterns of use. Figure 4.1 in Chapter 4 provides an indirect estimate of one aspect of germplasm exchange; sources of germplasm for use in plant breeding programmes.

The ability of a potential recipient to access a particular accession is often limited by the size of a stored sample and its phytosanitary status (see Chapter 7). Furthermore, inadequate information systems often make it difficult to access the same accession from an alternative source.

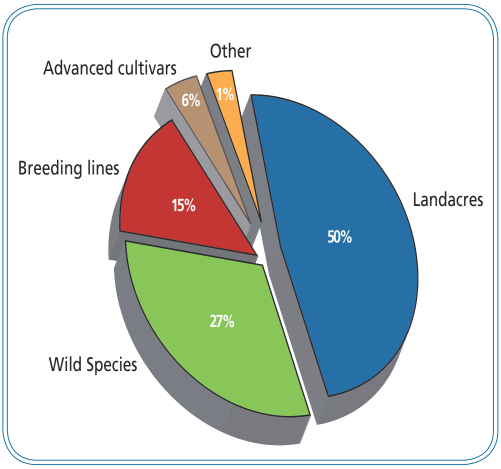
Comprehensive data on germplasm acquisition and distribution are readily available only for the genebanks of the IARCs. Over the past 12 years, the CGIAR centres and AVRDC have distributed more than 1.1 million samples, 615 000 of which, (about 50 000 per year), went to external recipients. In general, total distribution has remained steady over the period from 1996 to 2007 at about 100 000 accessions each year, although it peaked in 2004. These figures are similar to those reported in the first SOW report for the period 1993 to 1995.

In terms of the types of germplasm distributed by the IARCs, Figure 3.7 shows that the largest proportion are landraces, followed by wild species and breeding lines.

Figure 3.8 shows the distribution of germplasm by the IARCs to different types of recipient organizations. Nearly half the germplasm was distributed within or between the centres themselves and 30 percent went to developing country NARS. Developed country NARS received 15 percent and the private sector 3 percent. Breeding materials and advanced cultivars went mainly to NARS in developing countries, whereas developed country NARS requested mainly landraces. Wild species were requested equally by most types of organizations.

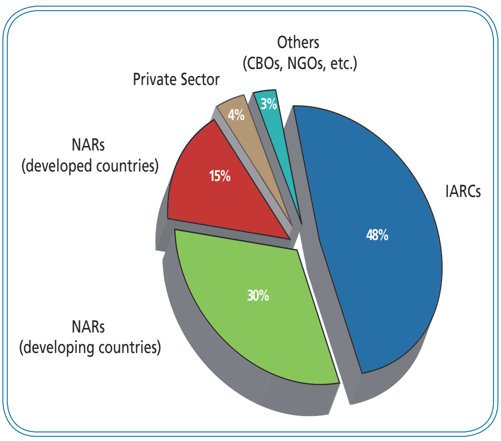
The following sections describe the status of germplasm movement on a regional basis, based on information contained in the country reports.

FIGURE 3.7
Distribution of germplasm held by the IARCs by type of germplasm (1996-2007)



Source: CGIAR, SGRP 2008

FIGURE 3.8
Distribution of germplasm from the IARCs to different types of recipient organization between 1996 and 2007



Source: CGIAR, SGRP 2008

Africa

Little data on germplasm movement was provided in the country reports from Africa. Uganda indicated that there was no national monitoring system for germplasm movement in place and Mali reported that germplasm movement was poorly documented. Both Ghana and Guinea stated that there was considerable movement, but no figures were available. A significant increase in germplasm movement since 1996 was reported by Malawi, which distributed more than 1 000 accessions and Kenya which distributed 3 189 accessions over a five year period. In its country report, Ethiopia estimated that an average of 5 000 samples were distributed annually to national programmes.

Asia and the Pacific

Little detailed information on germplasm movement was also reported from Asia, however, China has distributed 212 000 accessions since 1998, 95 percent of which, were within the country. India has distributed more than 164 000 accessions over the past ten years, while Pakistan has supplied some 13 000 samples to national institutions and more than 5 000 to international organizations since 1996. Japan distributed more than 36 000 samples in-country and about 1 300 abroad over the period 2003-2007.

Europe

The extent of germplasm movement in Europe and the availability of associated data varied considerably among countries. While Romania reported little movement of germplasm, Germany reported that since 1952, IPK had distributed about 710 000 samples to various users with, for example, more than 13 000 samples being distributed in 2006 alone. Between 1985 and 2003, 140 000 samples were requested from the Federal Centre of Breeding Research on Cultivated Plants (Braunschweig, Germany) (BAZ) genebank in Braunschweig. Poland distributed between 5 000 and 10 000 samples annually between 1996 and 2007 and Switzerland distributed an annual average of 270 samples nationally and internationally.

Near East

Jordan reported that most germplasm movement occurred among farmers, a situation that is also likely to occur in many other countries of this region and elsewhere. However, it is difficult to assess the importance of farmer-farmer exchanges in relation to the overall distribution of genetic diversity nationally, regionally and internationally. Cyprus indicated that there was little public awareness of the existence of its genebank and hence few requests for germplasm – a problem that likely has occured in other countries too. There was otherwise little information from this region.

3.10 Botanical gardens

There are over 2 500 botanical gardens worldwide that together grow over 80 000 plant species (approximately one-third of all known plant species).[40] As well as their living collections, botanical gardens often have herbaria and carpological collections and an increasing number have seed banks and *in vitro* collections. In general, botanical gardens focus on conserving the interspecific diversity of flora and thus, tend to maintain a large number of species with relatively few accessions for each species.

Over the last ten years, the number of botanical gardens recorded in Botanic Gardens Conservation International's global database increased from 1 500 to more than 2 500,[41] at least partly reflecting the current interest in establishing new botanical gardens in many parts of the world. In its country report, China indicated that it had 170 botanical gardens and India reported 150. The Russian Federation reported that it had about 75 botanical gardens, Germany 95, Italy 102, Mexico 30 and Indonesia 12. Most other countries, however, reported having less than ten. Botanical gardens often maintain very substantial germplasm holdings although only a percentage of these are important for food and agriculture. The German botanical gardens together conserve about 300 000 accessions of 50 000 taxa.

Botanical gardens are diverse institutions; many are associated with universities and focus on research and teaching (as mentioned in 19 country reports), while others may be governmental, municipal or private. Throughout their history, botanical gardens have been concerned with cultivating plants of importance to humankind for medicinal, economic and ornamental purposes. In recent years, the focus of many gardens is turning to the conservation of species found in the native wild flora (as mentioned in 19 country reports), especially those under threat of extinction. Many of these species are either of direct socio-economic or cultural importance to local communities or in some cases are CWR; both are groups that tend to be less well represented in traditional collections of PGRFA.

The GSPC,[42] adopted by the CBD in 2002, includes some measurable targets for conserving plants. Botanical gardens played a key role in developing the strategy and are expected to be important contributors to its implementation. Other international organizations, including Bioversity International, FAO and IUCN, have also been identified as lead international partners for specific targets, with a role in supporting country implementation of the Strategy. In some countries, stakeholder consultations held to develop national responses to GSPC have been successful in bringing the botanical garden and environmental sectors together with the agricultural sector, forging closer linkages on the conservation of PGRFA. However, in many countries cross-sectoral linkages remain poorly developed and botanical gardens are not generally included in national PGR programmes or networks. Despite this, botanical gardens are mentioned as being involved in plant conservation by 98 countries and the country reports of Kenya, Uganda and Zambia specifically note that botanical gardens are included in their national PGR networks.

3.10.1 Conservation facilities, statistics and examples

The majority of botanical gardens are located in Europe (36 percent) and the Americas (34 percent) with 23.5 percent in Asia and the Pacific and only 5.5 percent in Africa. Worldwide, over 800 botanical gardens specifically focus on conservation and their *ex situ* collections include a wide range of socio-economically important species. CWR are well

TABLE 3.8
Botanical garden collections of selected crops listed in Annex 1 of the ITPGRFA[44]

Crop	Genus	Number of species recorded in plant search
Breadfruit	*Artocarpus*	107
Asparagus	*Asparagus*	86
Brassica	13 genera	122
Chickpea	*Cicer*	16
Citrus	*Citrus*	18
Yams	*Dioscorea*	60
Strawberry	*Fragaria*	16
Sunflower	*Helianthus*	36
Sweet potato	*Ipomoea*	85
Grass pea	*Lathyrus*	82
Apple	*Malus*	62
Pearl millet	*Pennisetum*	23
Potato	*Solanum tuberosum*	190
Sorghum	*Sorghum*	15
Wheat	*Triticum aestivum* *Agropyron* *Elymus*	36
Faba bean/vetch	*Vicia*	77
Cowpea *et al.*	*Vigna*	12

represented in botanical garden collections with, for example, over 2 000 CWR taxa in botanical gardens in Europe. Further details on CWR in botanical garden collections are provided in Table 3.8. Similarly, some 1 800 medicinal plant taxa are represented in botanical garden collections globally.[43]

Ex situ conservation in botanical gardens tends to focus on living collections and in this regard they can play a useful role in the conservation of vegetatively propagated species, those with recalcitrant seeds and tree species. In Poland's country report, for example, specific mention is made of the conservation of apple germplasm by a botanical garden. However, seed conservation is important for some botanical gardens and at least 160 gardens around the world have seed banks. The Millennium Seed Bank Project (MBSP) of the Royal Botanical Gardens, Kew, is the largest and together with its partners around the world, aims to conserve seed of 24 200 species by 2010, with particular focus on dryland species. China's largest seed bank, the Germplasm Bank of Wild Species (GBWS), is located at the Botanical Garden of the Kunming Institute of Botany. In Europe, the European Native Seed Conservation Network (ENSCONET) brings together the seed conservation activities of over twenty European botanical gardens and other institutes. Through this network, seeds of nearly 40 000 accessions of more than 9 000 native European plant taxa are conserved.[45]

3.10.2 Documentation and germplasm exchange

The global PlantSearch database maintained by BGCI includes some 575 000 records on around 180 000 taxa[46] which are in cultivation in about 700 botanical gardens worldwide. However, this information consists of species names only and does not include descriptive information or the country of origin of accessions. At the national level, some countries have developed national databases of plants in cultivation in botanical gardens that provide more detailed accession-level information. These include PlantCol in Belgium,[47] SysTax in Germany,[48] and the Dutch National Plants Collection.[49] In the United States of America, the Plant Collections Consortium aims to bring together information on collections in 16 United States of America institutions and 4 international institutions.[50] In the the United Kingdom and Northern Ireland, the Electronic Plant Information Centre (ePIC) developed by the Royal Botanical Gardens, Kew, provides a single point of search across all Kew's major specimen, bibliographic and taxonomic databases. Kew's Seed Information Database is included in ePIC, which is an ongoing compilation of species' seed characteristics and traits, both from the MSBP's own collections and from the published and unpublished data of many seed biologists worldwide.[51]

One of the main international mechanisms for the exchange of germplasm between botanical gardens is the germplasm catalogue, the *Index seminum*. While still popular in Europe, concerns over the potential spread of invasive species have limited the use of the *Index seminum* in the United States of America. In Europe, the International Plant Exchange Network (IPEN) was developed as a response to the ABS provisions of the CBD, to facilitate the exchange of germplasm for non-commercial use.[52]

3.11 Changes since the first State of the World report was published

While significant advances have been made over the period since the first SoW report was published, in almost all areas further work is needed. Major changes include:

- more than 1.4 million germplasm accessions have been added to *ex situ* collections, bringing the total number now conserved worldwide to about 7.4 million. The majority of these are maintained in seed genebanks;
- more than 240 000 new accessions have been collected and are now being conserved *ex situ*. This number, however, is believed to be a considerable underestimate in that many countries did not provide figures on the number of accessions collected;
- fewer countries account for 45 percent of the total world *ex situ* germplasm holdings than was the case in 1996;
- interest in collecting and maintaining collections of CWR is growing as land-use systems change, concerns about the effects of climate change grow and techniques for using the material become more powerful and more readily available;
- interest is also growing in neglected and underutilized crops in recognition of their potential to produce high-value niche products and as novel crops for the new environmental conditions that are expected to result from climate change;
- significant advances have been made in regeneration: at the international level, largely as a result of funding provided to the CGIAR centres for the 'Global Public Goods' project, and at the national level, in part as a result of funding by the GCDT. However, much more remains to be done;
- documentation and characterization data on collections have progressed somewhat, although there are still large data gaps and much of the existing data is not accessible electronically;
- the number of botanical gardens around the world now exceeds 2 500, maintaining samples of some 80 000 plant species, including CWR. Botanical gardens took the lead in developing the GSPC adopted by the CBD in 2002;
- the GCDT, founded in 2004, represents a major step forward in underpinning the world's ability to secure PGRFA in the long term;
- with the establishment of the highly innovative SGSV, a last resort safety back-up repository is now freely available to the world community for the long-term storage of duplicate seed samples.

3.12 Gaps and needs

The overall needs of *ex situ* conservation remain largely the same as those listed in the first SoW report. This does not suggest that good progress has not been made, but that progress has not been complete and that many of the most important constraints can only be addressed through long-term commitments and action. Continuing gaps and needs include:

- many countries, although aware of the importance of collecting, conserving, regenerating, characterizing, documenting and distributing PGR, do not have adequate human capacity, funds or facilities to carry out the necessary work to the required standards. Many valuable collections are in jeopardy as their storage and management are suboptimal;
- greater efforts are needed to build a truly rational global system of *ex situ* collections. This requires, in particular, strengthened regional and international trust and cooperation;
- while there are still high levels of duplication globally for a number of crops, especially major crops, much of this is unintended and many crops and important collections remain inadequately safety duplicated. The situation is most serious for

vegetatively propagated species and species with recalcitrant seeds;

- in spite of significant advances in the regeneration of collections, many countries still lack the resources needed to maintain adequate levels of viability;
- for several major crops, such as wheat and rice, a large part of the genetic diversity is now represented in collections. However, for many other crops, especially many neglected and underutilized species and CWR, comprehensive collections still do not exist and considerable gaps remain to be filled;
- in order to improve the management of collections and encourage an increased use of germplasm, documentation, characterization and evaluation, need to be strengthened and harmonized and the data need to be made more accessible. Greater standardization of data and information management systems is needed;
- *in situ* and *ex situ* conservation strategies need to be better linked to ensure that a maximum amount of genetic diversity is conserved in the most appropriate way and that biological and cultural information is not lost inadvertently;
- greater efforts are needed to promote the use of the genetic resources maintained in collections. Stronger links are needed between the managers of collections and those whose primary interest lies in using the resources, especially for plant breeding;
- in the effort to mobilize additional resources for *ex situ* conservation, greater efforts are needed to raise awareness among policy-makers and the general public, of the importance of PGRFA and the need to safeguard it.

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2 Country reports: Brazil, China, India, Japan, Mexico, Russian Federation and the United States of America.

3 More than 40 countries that reported having undertaken collecting missions since 1996 did not provide figures on the number of accessions collected.

4 Collecting of duplicate samples derived from joint missions are included.

5 Excluding specialized genebanks only holding genetic stocks of plants that are not for food and agriculture.

6 Country grouping by region and subregion as per Appendix 1 of the first State of the World's Plant Genetic Resources for Food and Agriculture.

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Chapter 4

The state of use

4.1 Introduction

In a world of changing climates, expanding populations, shifting pests and diseases, ever-increasing resource scarcity and financial and social turmoil, the sustainable use of PGRFA has never been more important or offered greater opportunities. The development of new varieties of crops critically depends on breeders and farmers having access to the genetic diversity in order to develop varieties with higher and more reliable yields, resistant to pests and diseases, tolerant to abiotic stresses, making more efficient use of resources, and producing new and better quality products and by-products.

Of course PGRFA also have many other uses including direct introduction for production on farm, as well as education and scientific research on topics ranging from crop origins to gene expression. They are also used for land restoration and traditional and local varieties are often very important socially and culturally. While there is an indication from the country reports that the value of PGRFA for such uses is increasing, this chapter will concentrate mainly on what remains their primary use: breeding new crop varieties and their dissemination to farmers. The chapter provides an overview of the current state of PGRFA use, with special attention paid to the situation in developing countries that, in many cases, still lack the human and financial resources needed to make full use of PGRFA. A summary of changes that have taken place since the first SoW report was published is provided and major gaps and needs for the future are identified.

4.2 Germplasm distribution and use

Data on the dissemination of germplasm by genebanks provide an indication of trends in the use of PGRFA by different groups. Table 4.1 shows PGRFA movement from the IARC genebanks to users from 1996 to 2006. The values within each column indicate the relative importance of each type of accession for the given class of user. The last column shows that the IARCs distribute more accessions of landraces than all other types of material put together, followed by wild species.

Comprehensive information on germplasm distribution by national genebanks for a given period is seldom available in the country reports. However, Japan reported that their genebank distributed 12 292 accessions in 2003 and only 6 150 in 2007. In this five-year period most of the accessions (24 251) were sent to independent corporations or public research institutions within the country, followed by universities (10 935), other countries (1 299) and the private sector (995). The report from Poland indicated that the number of accessions sent out in 1997 and 2007 was

TABLE 4.1
Percentage of accessions of different types of PGRFA distributed by the IARCs to different classes of user from 1996 to 2006

Type of accession	Within/ between IARCs	NARS developing countries	NARS developed countries	Private sector	Others	Total number of accessions	% of the total
Landraces	57.9	48.5	45.0	51.7	65.7	194 546	51
Wild species	29.2	19.0	40.5	7.1	19.1	104 982	27
Breeding lines	8.5	23.1	5.4	36.0	6.5	56 804	15
Advanced cultivars	3.5	8.0	9.1	5.1	8.6	24 172	6
Others	0.9	1.4	0.1	0.1	0.1	3 767	1

Source: Survey carried out by the SGRP of the IARCs. The information was provided by genebank managers and is not consistent among genebanks with respect to the inclusion or absence of data on material distributed by breeders through their networks.

very similar (approximately 5 700); nevertheless there was a significant increase in 2002 when about 10 000 accessions were distributed.

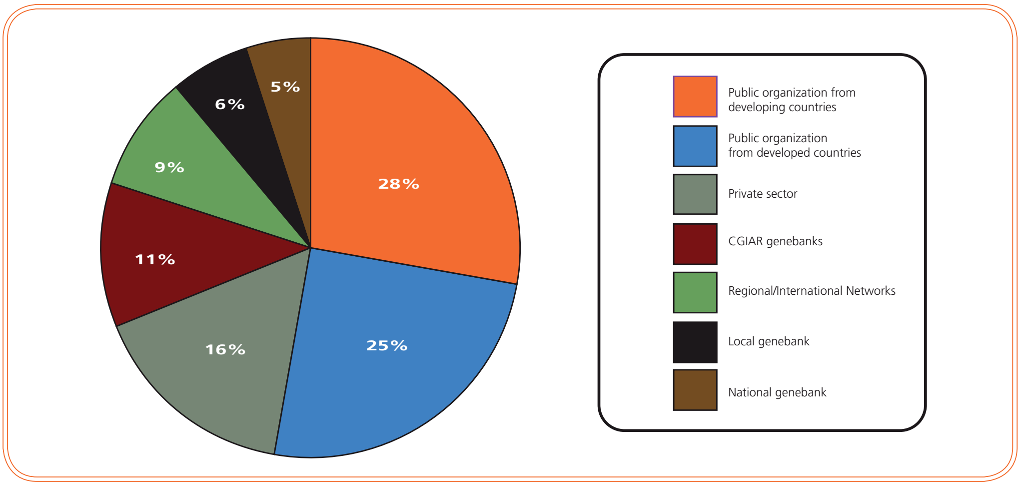
Although a wide range of genetic resources is available nationally and internationally, breeders often select the majority of their parental materials from their own working collections and from nurseries supplied by the CGIAR centres. This is largely because of the difficulty of transferring genes from non-adapted backgrounds and the fact that germplasm collections often lack useful characterization or evaluation data. In spite of this, as indicated in Figure 4.1, national plant breeding programmes make reasonable use of the genetic resources stored in genebanks.

4.3 Characterization and evaluation of PGRFA

Characterization of PGRFA is the process by which accessions are described with regard to a particular set of morphological traits. These traits are usually highly heritable, easily measured or assessed and expressed the same way in all environments. PGRFA accessions can also be characterized using modern biotechnological tools such as different kinds of molecular markers (genotypic markers). The evaluation of PGRFA, on the other hand, provides data about traits that are generally considered to have actual or potential agronomic utility. Often, the expression of these traits varies with the environment, so valid conclusions require evaluation in different environments, preferably corresponding to those experienced by the target client groups.

The country reports were virtually unanimous in suggesting that one of the most significant obstacles for greater use of PGRFA is the lack of adequate characterization and evaluation data and the capacity to generate and manage such data. Greater characterization and evaluation are a major priority in the GPA (Priority Activity Area 9). More comprehensive and more readily available data, on both traits and crops, would enable plant breeders and other researchers to select germplasm more efficiently and help obviate the need to repeat screenings. The problem of lack of data extends from a paucity of basic passport and characterization data for many accessions, to a relative lack of publicly

FIGURE 4.1
Sources of PGRFA used by breeders working in national breeding programmes



Source: NISM 2008 (available at: www.pgrfa.org/gpa). The figures are based on the response of 268 breeders from 39 developing countries to a question on the origin of the PGRFA used in their breeding programmes.

available evaluation data for most accessions, even on standard agronomic and physiological traits. While the problem is serious in many collections of major crops, it becomes acute for underutilized crops and CWR. Thailand was one of a few countries that reported carrying out economic evaluation of its accessions. China called for better evaluation standards, while the Netherlands reported that it had largely harmonized its evaluation data and that these are now available online. Spain also reported progress in this area.

An indication of the extent and nature of characterization of germplasm is given in Table 4.2. In general, it appears that the greatest effort has gone into characterizing morphological and agronomic traits and that molecular markers have been used relatively little outside the Near East. Abiotic and biotic stresses have received roughly equal attention.

Since the first SoW report was published, core collections and other collection subsets have become increasingly important as a means of improving the efficiency and efficacy of evaluation. A core collection is a subset of a larger collection that aims to capture the maximum genetic diversity within a small number of accessions.[1] While the topic was not covered in the first SoW report, many country reports pointed out the value of well-documented core and mini-core collections to plant breeders,[2] and several suggested that it would be useful to expand the number of core collections to cover more crops than at present. Other countries, however, did not consider them useful.[3] Bangladesh stated that there was only limited knowledge about core collections in the country and Sri Lanka reported that core collections "have not been prepared for any of the crop species … (which) will hinder utilization of the conserved germplasm". Argentina noted that core collections are useful for pre-breeding and could help increase the use of the country's national collections. However, it also noted that the "development of core collections … requires broad understanding and characterization of the germplasm".

Several instances were reported in which core collections were developed in an attempt to improve the use of PGRFA. In the Americas, the six Southern Cone countries have collaborated in creating a regional maize core collection, made up of independently managed national components. Collectively, this core collection represents a significant percentage of the region's genetic heritage and includes 817 of the 8 293 accessions maintained in the region.[4] In addition to maize, Brazil has assembled core collections on beans and rice and Uruguay on barley. Other examples include Kenya, which has established a core collection for sesame; Malaysia, which has established ten core collections, including cassava, sweet potato and taro; and China, which has established six core collections

TABLE 4.2
Traits and methods used for characterizing germplasm: percentage of accessions characterized and/or evaluated using particular methods, or evaluated for particular traits, averaged across countries in each region

Region	No. [a]	Morphology	Molecular markets	Agronomic traits	Biochemical traits	Abiotic stresses	Biotic stresses
Africa	62	50	8	38	9	14	24
Americas	253	42	7	86	23	18	25
Asia and the Pacific	337	67	12	66	20	27	41
Europe	31	56	7	43	8	22	23
Near East	229	76	64	77	57	63	69

Source: NISM 2008 (available at: www.pgrfa.org/gpa). The figures are based on the response of 323 stakeholders from 42 developing countries to a question on the percentage of accessions characterized and/or evaluated for the various traits.

[a] Total number of *ex situ* collections surveyed for which characterization data exist.

including rice, maize and soybean. In Europe, Portugal has maize and rice core collections and the Russian Federation has 20 core collections, including wheat, barley and oats. Neither the Near East country reports nor the regional consultation highlighted efforts on core collections.

Table 4.3 indicates the principal perceived constraints to the definition and establishment of core collections. A lack of adequate information on accessions is considered to be the major obstacle. Uganda, for example, stated that at present "… there are no core collections as the PGR accessions held have not been evaluated extensively …". Lack of funds and personnel are also regarded as a significant hindrance as is an apparent lack of suitable accessions.

While core collections remain the most common way to subdivide collections in order to facilitate their evaluation and use, other useful and powerful methods have recently been developed. The FIGS, for example, is a methodology that uses geographic origins to identify custom subsets of accessions with single and multiple trait(s) that may be of importance to breeding programmes. This methodology has been established for the combined VIR, ICARDA, Australian Winter Cereals Collection (AWCC) wheat landrace collection. Their database, which is publicly accessible, can be searched for using FIGS.[5]

Since the publication of the first SoW report, there have been several new international initiatives that support the increased characterization and evaluation of germplasm. Among them are several activities undertaken by the GCDT and the Generation Challenge Programme (GCP) of the CGIAR. Both provide additional tools to facilitate the establishment of subcollections and promote the use of PGRFA, the latter through the application of molecular techniques.

4.4 Plant breeding capacity

There are numerous ways to improve crops genetically, from traditional crossing and selection to the most recent gene transfer techniques. But all of these depend on the ability of plant breeders to assemble genes for the desired traits within new varieties. Recognizing the importance of plant genetic improvement, most countries support some form of public and/or private plant breeding system. The GIPB[6] has assessed plant breeding capacity worldwide and the information assembled can be found in the Plant Breeding and Related Biotechnology Capacity Assessment (PBBC)[7] database. While the allocation of resources to plant breeding over the past decade has been relatively constant at the global level, there is considerable variation among individual countries and among regions. Certain national programmes, for example in Central America and East and North Africa, have reported a modest increase in the number of

TABLE 4.3
Major obstacles to the establishment of core collections: percentage of respondents in each region who indicated that a particular restriction represented an important constraint in the region

Region	Funds	Lack of personnel	Limited number accessions	Need not recognized	Limited information on accessions	Poor access to germplasm	Method too complex	Lack of interest
Africa	100	67	50	17	67	0	8	8
Asia and the Pacific	44	67	44	67	78	33	44	11
Americas	92	75	42	33	75	17	0	8
Europe	100	33	67	33	100	0	0	0
Near East	67	89	67	44	33	22	22	22

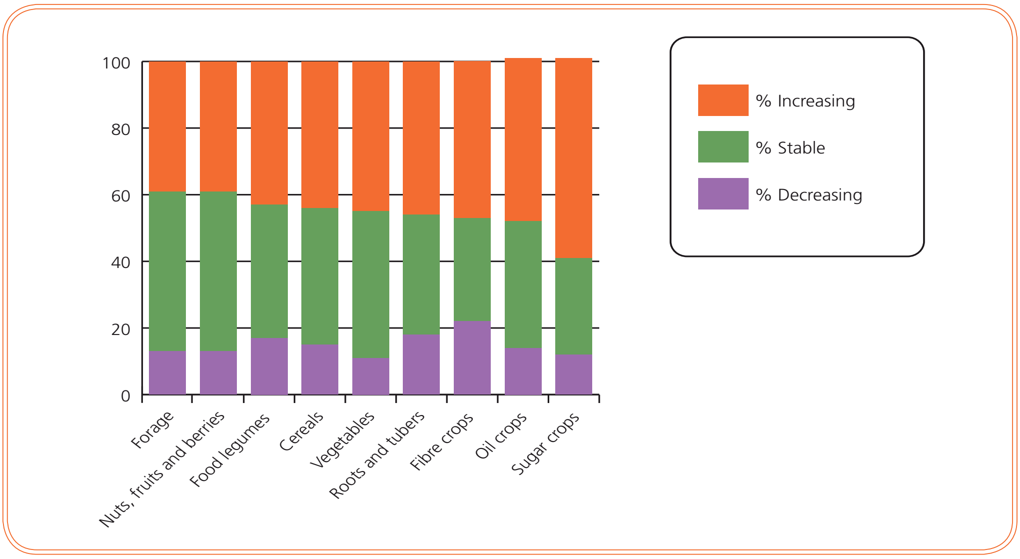
Source: NISM 2008 (available at: www.pgrfa.org/gpa). The figures are based on the response of 45 plant breeders from 45 developing countries to a question on the obstacles to establishing core collections in the country.

plant breeders[8] but there has been a decline in others, e.g. in Eastern Europe and Central Asia. Within the rest of Asia there have been decreases in Bangladesh and the Philippines while numbers have risen in Thailand.[9]

The results of a survey looking at trends in plant breeding capacity in developing countries are summarized in Figure 4.2. According to the perception of plant breeders, since 1996, for most crops or crop groups the overall capacity has remained stable or decreased. There appear to be relatively few areas where higher investment has allowed progress in capacity building necessary to solve problems that will arise in the future.

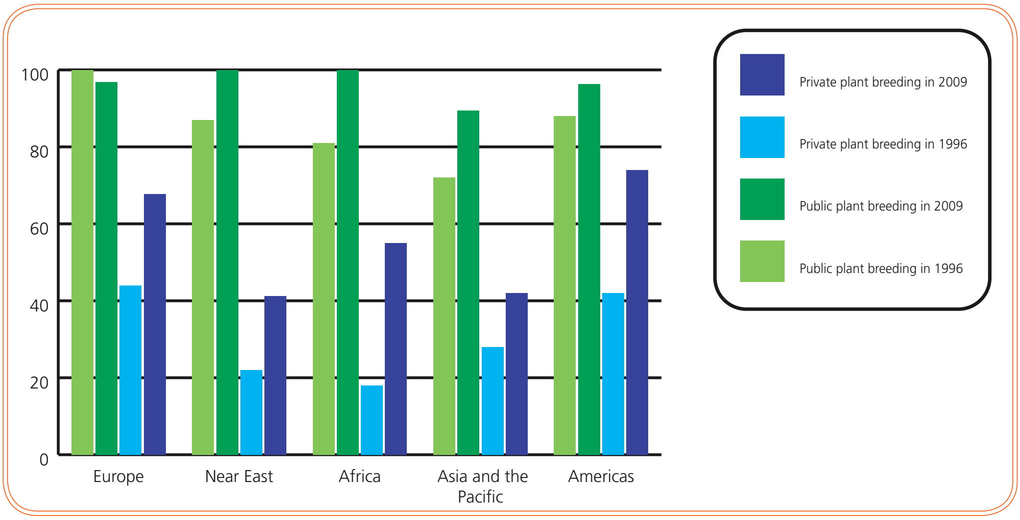
Based on information from the country reports and the GIPB-PBBC database, a comparison has been made between countries that reported in the first SoW report and a similar set of countries in 2009, regarding public versus private plant breeding programmes. Overall, there has been an increase in the number of countries reporting the existence of public breeding programmes; Europe is an exception. The increase is even more impressive for the private sector (see Figure 4.3). Both public and private sectors have shown the highest percentage increase in Africa, indicating that many new programmes have been created in this region since the first SoW report. However, while most countries have both public and private plant breeding programmes, many country reports indicate that there is a trend to move away from the public sector.[10] Even where there has been an increase in resources for public plant breeding in nominal terms, this often hides a reduction in real terms as a result of inflation and currency devaluation. Resources for field trials and other essential activities are often limiting.[11]

FIGURE 4.2
Trends in plant breeding capacity; percentage of respondents indicating that human, financial and infrastructure resources for plant breeding of specific crops in their country had increased, decreased or remained stable since the first SoW report



Source: NISM 2008 (available at: www.pgrfa.org/gpa). The figures are based on the response of 404 plant breeders from 49 developing countries to a question on the current trend within the stakeholders' organization in terms of capacity to breed specific crops or crop groups.

FIGURE 4.3
Percentage of countries that reported the existence of public and private breeding programmes in the first and second SoW reports



Source: Data from a set of similar countries that presented country reports for both the first and second SoW reports, complemented with information from the GIPB-PBBC database (available at: http://km.fao.org/gipb/pbbc/).

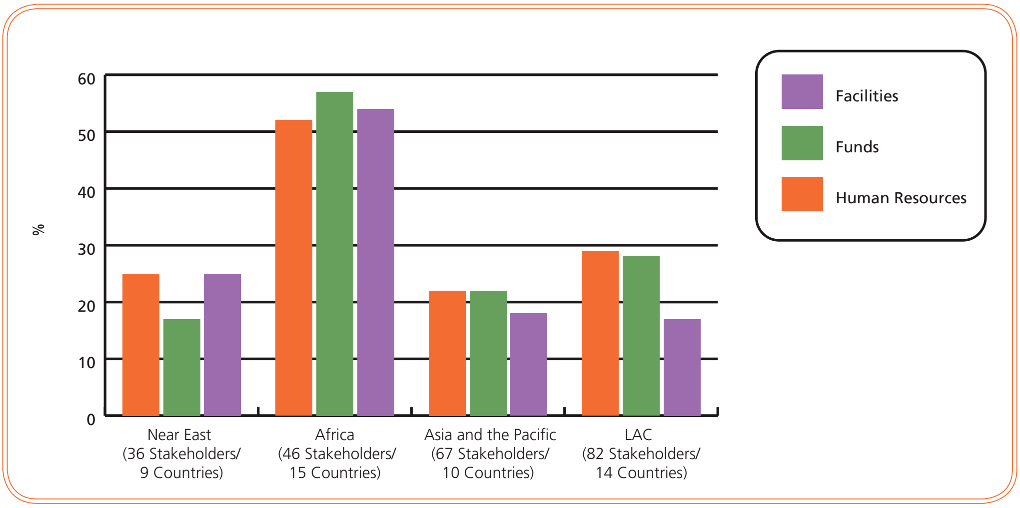
In the United States of America, it has been reported that "the decline in classical plant breeding [over recent years] is likely underestimated because marker development and other breeding related molecular genetics are included in plant breeding data".[12]

Major constraints to plant breeding, based on NISM databases, are summarized in Figure 4.4. While the data are indicative only and should be interpreted with care, stakeholders in all regions reported constraints in funding, human resources and, with the sole exception of Europe, facilities. The relative importance of these three areas of constraints is unchanged since the first SoW report, as is the fact that the greatest constraints are felt in Africa and the least, in Europe.

In spite of these constraints, many opportunities remain for exploiting the genetic variation in landraces and relatively unimproved populations, using simple breeding techniques or even through direct release. For example, Zambia's country report stated, "There has been renewed interest in recent years for the need to screen and evaluate local germplasm of major crops' and that there is a … lack of appreciation of locally available PGR …". The Lao People's Democratic Republic stated "Several local landraces of aromatic rice were identified and released for multiplication". In addition, since the publication of the first SoW report a number of initiatives and legal instruments have been developed to promote the use of PGRFA at national and international levels. Box 4.1 presents some examples.

There appears to have been an increase in the use of wild species in crop improvement, in part, due to the increased availability of methods for transferring useful traits from them to domesticated crops. The country report of the Russian Federation stated that CWR "… maintained and studied at VIR are also valuable as source materials and are often included in breeding programmes …". However, in spite of their potential importance they remain relatively poorly represented in *ex situ* collections[13] (see Sections 1.2.2 and 3.4.3).

FIGURE 4.4
Major constraints to plant breeding: percentage of respondents indicating that a particular constraint was of major importance in their region



Source: NISM 2008 (available at: www.pgrfa.org/gpa). The figures are based on the response of 195 plant breeders from 36 developing countries in 5 regions to a question on the constraints to plant breeding.

Biotechnological techniques have evolved considerably over the last ten years and there has been a concomitant increase in their use in plant breeding worldwide. A recent assessment of molecular markers in developing countries, for example, reported a significant increase in their use.[14] A similar trend has been reported in the number of plant biotechnologists in national plant breeding programmes.[15] Molecular characterization of germplasm has also become more widespread across regions and crops, although much remains to be done both to generate more data and make it more readily available. Tissue culture and micropropagation have become routine tools in many programmes, particularly for improving and producing disease-free planting materials of vegetatively propagated crops. In the Congo, micropropagation has been used to propagate threatened edible wild species. Tissue culture methods, important in their own right, are also essential for the application of modern biotechnology in crop improvement. They have become increasingly available in developing countries because of their relatively limited technical requirements and cost.

The use of MAS has also expanded considerably over the past decade and is now employed widely across the developed and developing world.[16] However, it has been used most often for research in academic institutions rather than in crop improvement *per se*. Currently, MAS is mainly used for a restricted number of traits in major crops notably in the private sector, although its application is expanding rapidly. Molecular marker based methods have also grown in popularity for use in research on genetic variation at the DNA level. However, molecular characterization of germplasm is still in its early stages and is seldom used routinely because of its high cost and the need for relatively sophisticated facilities and equipment.

According to the country reports, GM-crops are now grown in more countries and on a larger area than was the case a decade ago. However, the number of crops and traits concerned remains small, in large part due to poor public acceptance and a lack of effective

Box 4.1
Examples of initiatives and legal instruments developed to promote PGRFA use

- The African Centre for Crop Improvement (ACCI),[17] established in 2004 by the University of KwaZulu-Natal, trains plant breeders from eastern and southern Africa in conventional and biotechnological methods, with a focus on crops that are important for the food security of the poor. ACCI has a network of 47 plant breeders and co-supervisors in 13 countries. A parallel programme, the West African Centre for Crop Improvement (WACCI),[18] was set up by the University of Ghana to improve the crops that feed the people of West Africa.

- A scheme has been launched in the United States of America to halt the decline of public investment in plant breeding. It is coordinated through a task force of the Plant Breeding Coordinating Committee.[19]

- The GCP[20] is an initiative of the CGIAR that aims to create improved crops for small farmers through partnerships among research organizations. It focuses on using biotechnology to counter the effects of drought, pests, diseases and low fertility of soil through subprogrammes on genetic diversity, genomics, breeding, bio-informatics and capacity building.

- The GIPB[21] is a multistakeholder partnership of public and private sector parties from developing and developed countries. It aims to enhance a plant breeding capacity and seed delivery systems of developing countries and improve agricultural production through the sustainable use of PGRFA. It is an internet-based initiative facilitated by FAO and provides a major portal for information dissemination and sharing.

biosafety monitoring and other regulations. The most commonly involved traits are resistance to herbicides and insects. Argentina, Brazil, Canada, China, India, South Africa and the United States of America grow the most GM-crops; principally soybean, maize, cotton and oilseed rape.[22]

Many developing countries reported that their capacity to apply recombinant DNA techniques in plant breeding remains limited and even in Europe problems were reported with regard to integrating modern and classical techniques. Portugal, for example, stated that "… there is no organized structure that integrates classical (breeding) methodologies with modern ones", whereas Japan reported that modern biotechnologies have become routine in plant breeding.

Numerous new fields of biotechnology have developed over the past decade that can have important applications in plant breeding research and practice, for example in facilitating the understanding of gene function and expression as well as the structure and function of proteins and metabolic products. Some of these fields are:

- proteomics – the study of protein expression;
- transcriptomics – the study of messenger Ribonucleic acid (mRNA);
- genomics – the study of the structure and functions of DNA sequences;
- metabolomics – the study of chemical processes involving metabolites;
- phylogenomics – the study of gene function according to phylogenetics.

In spite of such scientific advances, many programmes, especially in developing countries, are still unable to apply them in practical crop improvement. Not only do they remain expensive and demanding but many are also proprietary. However, it is expected that costs will fall in the future, opening up possibilities for these techniques to be taken up by an increasing number of programmes throughout the world.

4.5 Crops and traits

The crop focus of breeding programmes varies across countries and regions, but there has been little change since the first SoW report was published. In general, based on data from the country reports and information from the FAO Statistical Database (FAOSTAT) programme,[23] investment in crop improvement seems to mirror a crop's economic importance. Thus, major crops are still receiving more breeding investments than all other crops. Nevertheless, several country reports highlighted the increased importance of giving attention to underutilized crops (see Section 4.9.2). In the Americas region, for example, Latin America invests major resources in improving rice, maize, grain legumes and sugar cane, with some countries, including Ecuador and Uruguay, also devoting considerable efforts to roots and tubers. Coffee, cocoa and fruits also feature strongly. North America concentrates on major food staples, such as maize, wheat, rice and potato, but also invests heavily in improving pasture species, fruits and vegetables. Brazil and North America now invest heavily in biofuel, as do an increasing number of other countries, including several in Asia. However, in most cases attention is focused on the genetic improvement of existing major crops for biofuel use rather than on new biofuel crops such as switch grass or jatropha.

In Africa, countries in the East and Central regions and the coastal areas of West Africa tend to concentrate on breeding maize and roots and tubers, especially cassava, while the Sahelian countries mainly seek improvement for rice, cotton, millet and sorghum. The Near East and North Africa countries allocate substantial resources to improving wheat, barley, lentils, chickpeas, fruits and vegetables while South Asia concentrates on rice but also invests heavily in some industrial and high value crops. Sri Lanka's country report, for example, details the substantial contribution of fruits and vegetables to the national economy. Central Asian countries mainly invest in improving cotton and cereals, particularly wheat, but they are also responding to the expanding market for fruits in Asia. Eastern Europe directs most effort to fruits and vegetables while Central Europe gives greatest attention to cereals such as barley and wheat.

According to the country reports, the principal traits sought by plant breeders continue to be those related to yield per unit area of the primary product. In addition to increasing actual yield potential, attention is paid to tolerance, avoidance or resistance to pests, diseases and abiotic stresses. Among the latter, drought, salinity, acid soil and heat are all important in the light of continuing land degradation, the expansion of production onto more marginal land and climate change. The priority given to breeding against biotic threats has changed little over the past ten years: disease resistance remains the most important trait, especially for major staple crops. While the potential value of exploiting polygenic resistance has long been recognized, the complexity of breeding and the generally lower levels of resistance as a result, have meant that many breeders still tend to rely largely on major genes.

Breeding for climate change *per se* did not feature markedly in the country reports, although it was mentioned by a few, including Germany, the Netherlands, the Lao People's Democratic Republic and Uruguay. However, a growing interest in the topic is apparent in scientific literature and some plant breeding programmes are beginning to take the issue into account more overtly. Of course many address this indirectly, particularly through breeding for abiotic and biotic stress resistance, tolerance or avoidance. Breeding for low-input and organic agriculture was also rarely mentioned in-country reports, but it too is becoming a focus in some programmes, as is breeding for specific nutritional traits.

Special attention may be paid to plant breeding in the event of high profile catastrophes such as severe and widespread pests and diseases. This was the case, for example, with the epidemic of brown-streak virus in cassava in Eastern and Southern Africa and wheat stem rust race Ug99 that led to the creation of the Borlaug Global Rust Initiative (BGRI).[24]

4.6 Breeding approaches for use of PGRFA

Plant breeders have at their disposal a wide range of breeding approaches, tools and methods for crop improvement. While the first SoW report makes reference to many of them, this report will only discuss pre-breeding; base-broadening and PPB (highlighted in Article 6 of the ITPGRFA), in which significant developments have occurred over the last decade.

4.6.1 Pre-breeding and base-broadening

Priority Activity Area 10 of the GPA lists genetic enhancement and base-broadening as priority activities. Pre-breeding was recognized in many country reports as an important adjunct to plant breeding, as a way to introduce new traits from non-adapted populations and wild relatives. Broadening the genetic base of crops to reduce genetic vulnerability was also regarded as important, but in spite of certain progress that has been made over the past ten years and the increasing availability of molecular tools, there is still a long way to go.

Country reports indicated the use of different methods to assess genetic diversity and to implement pre-breeding and base-broadening strategies. Disease resistance is the main trait sought, but a few country reports also indicated that new variability was necessary to increase the opportunities to breed for complex traits such as abiotic stresses and even yield potential. For example, Cuba reported using both conventional and molecular marker techniques to exploit the genetic variability of beans, tomatoes and potatoes and to design strategies to broaden the genetic base of such crops. Tajikistan, in its country report, stated that "… participation in international and regional cooperation networks can be an efficient way of broadening the genetic base of the local breeding programmes". Brazil presented several examples of the use of wild species to expand the genetic base of different crop species. Box 4.2, for example, shows the case of passion fruit (*Passiflora* spp.).

Pre-breeding occupies a unique and often crucial step between genetic resources conserved in collections and their use by plant breeders. In some countries, plant breeders carry out pre-breeding activities as a matter of course; in others, such as Ethiopia and the Russian Federation, the national genetic resources programmes participate strongly. Many of the problems associated with increasing pre-breeding activities are similar to those relating to the wider issue of broadening genetic diversity within crops. NISM data on obstacles to increasing genetic diversity as well as diversifying crop production are summarized in Table 4.4. It is evident from the table that the most serious constraints relate to marketing and commerce.

4.6.2 Farmers' participation and farmer breeding

PPB is the process by which farmers participate with trained, professional plant breeders to make decisions on plant breeding. Farmer breeding refers to the process that has gone on for millennia whereby farmers themselves slowly improve crops through their own intentional or inadvertent selection and even hybridization.

According to the country reports, farmer's participation in plant breeding activities has increased in all regions over the past decade, in line with Priority Activity Area 11 of the GPA. Several countries reported using PPB approaches as part of their PGRFA management strategies; Table 4.5 provides examples. As farmers are in the best position to understand a crop's limitations and potential within their own farming system, their involvement in the breeding process has obvious advantages. These have been noted in many of the country reports.

Several developing countries, including the Plurinational State of Bolivia, Guatemala, Jordan, the Lao People's Democratic Republic, Mexico and Nepal, reported that for certain crops, participatory breeding approaches are the most suitable way to develop varieties adapted to farmers' needs. Several countries rely almost exclusively on participatory methods to develop improved varieties. Currently, there are national and international organizations that devote significant resources to promoting and supporting participatory breeding programmes, for example, Local Initiatives for Biodiversity, Research and Development (LI-BIRD) in Nepal and the Working Group on PPB established in 1996 under the framework of the CGIAR System-wide Programme on Participatory Research and Gender Analysis (PRGA).

TABLE 4.4
Major obstacles to base-broadening and crop diversification: percentage of respondents in each region reporting a particular obstacle as being important

Region	Policy and legal issues	Marketing and commerce	Obstacles to release heterogeneous materials as cultivars
Africa	53	86	43
Asia and the Pacific	51	89	30
Americas	53	86	19
Europe	58	83	58
Near East	30	89	20

Source: NISM 2008 (available at: www.pgrfa.org/gpa). The figures are based on the response of 323 stakeholders from 44 countries to a question on the major constraints in the country to broaden diversity in the main crops grown

TABLE 4.5
Examples of country reports that mention the use of participatory plant breeding

Country	Crop
Angola	Maize
Algeria	Barley and date palm
Azerbaijan	Wheat, barley, rice, melon and grape
Benin	Rice and maize
Burkina Faso	Cereals and pulses
Costa Rica	Bean, cocoa, maize, banana, potato and coffee
Cuba	Bean, maize, pumpkin and rice
Dominican Republic	Pigeon pea
Ecuador	Various
Guatemala	Maize
India	Maize, rice and chickpea
Jamaica	Pepper, coconut and pumpkin
Jordan	Barley, wheat and lentil
Lao People's Democratic Republic	Rice
Netherlands	Potato
Malawi	Bambara groundnut
Malaysia	Cocoa
Mali	Sorghum
Morocco	Barley, faba bean and wheat
Namibia	Millet, sorghum and legumes
Nepal	Rice and finger millet
Nicaragua	Beans and sorghum
Philippines	Maize, vegetables and root crops
Portugal	Maize
Senegal	Rice
Thailand	Rice and sesame
Uganda	Beans
Venezuela (Bolivarian Republic of)	Local underutilized crops

In the Near East, 10 of the 27 countries that participated in the regional consultation indicated that they used participatory breeding approaches to improve different crops. In the Americas, the Latin America and the Caribbean regional consultation report stated: "Participatory breeding activities at the farm level are often mentioned as a priority, in order to add value to local materials and preserve genetic diversity". Similar statements can be found in the reports of many countries in Asia,[25] Africa[26] and Europe.[27]

In spite of the overall increase in PPB, farmer involvement has largely remained limited to priority setting and selection of finished crop cultivars. This is a similar situation to that reported in the first SoW report. India, for example, stated in its country report that "farmers' participation is highest either at the stage of setting priorities or at the implementation stage".

In addition to the efforts of trained plant breeders, many farmers around the world, especially small-scale and subsistence farmers, are themselves intimately involved in the improvement of their crops. Indeed, most of the underutilized crops and a significant proportion of the major crops grown in developing countries are of varieties developed and in many cases continually improved, by farmers. While the majority of farmer breeding efforts are focused on the local

Box 4.2
Improvement of passion fruit (*Passiflora* spp.) using genetic resources from wild relatives[a]

It is estimated that the genus *Passiflora* includes some 465 species, approximately 200 of which, originated from Brazil. In addition to their medicinal and ornamental properties, some 70 species bear edible fruit. In order for this enormous range of genetic diversity to be used in breeding programmes, either interspecific crossing among species or the direct transfer of genes through recombinant DNA technology are needed. Research at the Embrapa Cerrados station has resulted in several fertile interspecific hybrids with a potential application in plant breeding. For example, some types have been obtained that combine commercial traits with disease resistance.

Wild species can contribute to the improvement of cultivated passion fruit in many different ways. Work currently underway in Brazil has shown that:

- a number of interspecific hybrids, e.g. with *P. nítida*, can be used as rootstocks due to their strong stems;
- wild relatives can be used to develop cultivated forms with resistance to bacteriosis, virosis and Cowpea Aphid-Borne Mosaic Virus (CABMV). Wild species with resistance to anthracnose have also been noted;
- a number of wild species of *Passiflora* are fully self-compatible, a trait that is potentially important where Africanized bees are a problem, or labour for manual pollination is expensive. Other wild species, e.g. *P. dontophylla*, have a flower structure that facilitates pollination by insects that otherwise fail to pollinate the flowers;
- wild species, such as *P. setacea* and *P. coccinea* could contribute daylength insensitivity which, under the conditions of the centre south region of Brazil, would enable production to occur all year round;
- *P. caerulea* and *P. incarnata* both have tolerance to cold, a potentially important trait for several growing regions in Brazil;
- several wild species also have the potential to improve the physical, chemical or taste characteristics of fruit for the fresh market or the pulp for sweets or ice-cream, e.g. larger fruit size from *P. nitida* and purple colouration from *P. edulis*;
- interspecific crossing has also resulted in several new ornamental types.

[a] Information taken from Brazil's country report

exchange of material and selection among and within heterogeneous populations and landraces, cases have also been described where farmers make deliberate crosses and select within the resulting segregating populations.[28]

Farmers and other rural dwellers are involved in improving not only crops, but also wild species. Cameroon, for example, pointed out in its country report that local selection of the wild species African pear (*Dacroydes edulis*) is carried out by farmers to eliminate poor individual plants from the local stands.

In addition to genetic improvement by farmers, some of the country reports mentioned efforts by producers to bring to the attention of consumers the nutritional, cultural and other benefits of locally developed and managed varieties.

However, there are examples of the need for further planning and coordination to make farmer contributions to plant breeding fully effective. Policies and legislation have a significant impact on how farmers can benefit from their involvement in PPB programmes. In a large number of countries, varieties can only be registered when they comply with specific distinctness, stability and uniformity standards. Seed laws for maintaining and multiplying registered seed also influence how farmers can participate in variety development. Nepal presents an example of how the national varietal release and registration committee of the national seed board supported the release and the custodianship of a landrace. The European Commission Directive accepts, under certain conditions, marketing seeds of landraces and varieties that are adapted to the local conditions and threatened by genetic erosion.[29]

While some progress has been achieved with regards to the integration of PPB in national breeding strategies, this area still requires attention. Although there are exceptions (in the Netherlands, and some international centres including CIAT and ICARDA) opportunities for building PPB capacity among farmers and plant breeders are often lacking.

4.7 Constraints to improved use of PGRFA

There was wide agreement among all stakeholders surveyed, on the major constraints for greater and more effective use of PGRFA. These constraints do not differ greatly from those identified at the time when the first SoW report was published. Similar constraints were mentioned across the country reports.

4.7.1 Human resources

One of the most commonly cited constraints is the lack of adequately trained personnel to carry out effective research and breeding. This is also supported by data in the GIPB-PBBC database. Not only is there an ongoing need for training in conventional plant breeding, but with the growing importance of molecular biology and information science, the need for capacity building in these areas has also grown.

Capacity building efforts cannot be effective unless incentives, such as structured career opportunities, are provided, to help ensure that experienced staff are retained and remain productive. As with other constraints, improved international collaboration could help cut training costs and reduce unnecessary duplication of investments. In this regard, the use of regional centres of excellence has been suggested as a means of reducing costs and duplication.

4.7.2 Funding

Plant breeding, seed systems and associated research are all expensive and require a long-term commitment of financial, physical and human resources. Success, for both the public and private sectors, is greatly dependent on government support through appropriate policies as well as funds. External development assistance is also essential to keep many programmes operating. Public investment is particularly needed to improve crops that do not promise substantial short-term economic returns such as minor and underutilized crops.[30] Many countries reported a decrease in public investment in crop improvement,[31] although a number of donor agencies and philanthropic bodies have increased their commitment to both breeding and germplasm conservation (see Chapter 5). However, the short-term nature of most grants and awards,[32] and the shifting priorities of donors have meant that funding is frequently not sustained and it has rarely been possible to develop and maintain strong programmes for the periods of time needed to breed and disseminate new varieties. Uganda was one of several countries that indicated that a lack of funds was responsible for suboptimal levels of germplasm characterization and evaluation.

4.7.3 Facilities

To a large extent, national programmes view the three major constraints, i.e. human resources, funds and facilities, to be at similar levels of importance, e.g. all are very high (Africa) or all are relatively low (Europe). The principal exception to this generalization is the case of facilities in the Americas, where they are seen as considerably less constraining than either human resources or funds. The details on which type of facilities are most constraining vary by region, but generally field and laboratory facilities are both inadequate and this is especially true in Africa.

4.7.4 Cooperation and linkages

Several country reports expressed concern at the lack of fully effective linkages between basic researchers, breeders, curators, seed producers and farmers. As suggested by Pakistan, "weak links between breeders and curators have limited the use of germplasm resources in crop breeding". However, some countries, such as the Philippines, reported instances of "close collaboration between breeders and genebank managers…" and cited coconut, sweet potato, yam and taro as examples.

Oman, Saint Vincent and the Grenadines and Trinidad and Tobago all commented specifically on weak researcher-breeder-farmer linkages, but many other countries also considered weak internal linkages among national bodies to be a problem. This was true in both developed and developing countries; Greece and Portugal, for example, reported similar problems to Ghana and Senegal. Uganda commented that participatory planning and collaboration paid dividends in strengthening internal links.

4.7.5 Information access and management

Problems related to information access and management lie behind many of the constraints to the improved and expanded use of PGRFA. Although, according to the country reports, the problem is widespread, it was considered most severe in countries such as Afghanistan and Iraq where much germplasm and information has been lost in recent years. Albania, Guinea, Peru and the Philippines all reported that lack of information and documentation limited the use of PGRFA. Namibia cited a specific problem, which could be widespread, of poor feedback from PGRFA users, who have the obligation to return information on accessions received through the MLS.

While many countries still do not have PGRFA information in national electronic databases, others, such as many of the European countries, have contributed passport information to regional electronic databases such as EURISCO. Other large databases that contain comprehensive information and are publicly accessible include some CGIAR centres' crop databases and the USDA's GRIN, which have accession level data, as well as the GIPB-PBBC and NISM databases that contains global information on plant breeding. Several countries, including Germany, China and New Zealand, reported using comprehensive web-based information systems for major crops while the Czech Republic, Hungary and Spain reported considerable progress in making information available online. In addition to evaluation data online, the Netherlands also published online a knowledge bank for educational purposes. The Caucasus and the Central Asia countries created a regional database in 2007 with the aim of strengthening documentation and thereby enhancing use.[33]

Bioinformatics, not discussed at all in the first SoW report, was briefly referred to in several country reports as a relatively new subject. For the many countries that experience difficulties with modern electronic information technology, the benefits of bioinformatics are only likely to become available through collaboration with partners who have greater Information technology (IT) capacity.

An effective example of a global information platform to promote the use of PGRFA is the GCP Molecular Breeding Platform, which distributes crop research information generated by GCP partners.

4.8 Production of seeds and planting material

In order for agriculture to be successful, sufficient good quality seed has to be available to farmers at the right time and at an affordable price. Seed is traded at the local, national and global levels and underpins, directly or indirectly, almost all agricultural production. Seed also has a cultural value in many societies and is part of a wealth of traditional knowledge.

There is a large diversity of means by which farmers obtain seeds. Some authors have classified seed systems into two broad categories; 'formal' and 'informal'. 'Formal' systems involve institutions in both the public and private domains that develop, multiply and market seed to farmers through well-defined methodologies, controlled stages of multiplication and within the framework of national regulations. Seed produced within 'formal' systems often pertains to modern varieties. The 'informal' system, on the other hand, is that often practiced by farmers themselves who produce, select, use and market their own seed through local, generally less regulated channels. Of course, a given farmer will generally resort to either or both of these approaches for different crops or in different seasons and they generally do not make a big distinction between the two. Several countries in Africa, including Benin, Madagascar and Mali reported that the farmer seed sector is dominant nationally, although there is crop specificity; 100 percent of Mali's cottonseed, for example, is supplied by the private sector. 'Formal' systems are developing in many emerging economies and the international seed trade is expanding with increasing globalization. Often 'formal' and 'informal' systems co-exist and sometimes 'informal' seed production becomes 'formalized' as it becomes more regulated. India, for example, indicated that the two systems operate through different, but complementary mechanisms. In its country report, Kenya acknowledged that the 'informal' seed trade, despite being illegal, was responsible for the maintenance of rare crop varieties. Uzbekistan commented similarly and Peru noted the importance of informal exchange of seed of underutilized crop species.

Several multinational companies have recently increased their market share through takeovers and mergers. The top five are now responsible for more than 30 percent of the global commercial seed market and much more for crops such as sugar beet, maize and vegetables.[34] The private sector tends to target large markets that offer high profit margins. Five of the top ten seed companies listed in the first SoW report have ceased to exist as independent companies and the current top company is the size of the former top six combined. Companies in several developing countries, including the Philippines and Thailand, are now able to supply many of the vegetable seeds formerly supplied by American, European and Japanese multinationals. Other countries, including Chile, Hungary and Kenya, have greatly increased their certified seed production. Egypt, Japan and Jordan all mentioned their reliance on the private sector for the supply of hybrid vegetable seed. The global seed market, worth USD 30 billion in 1996 is now valued in excess of USD 36 billion.

In developed countries, the tendency has been to encourage the private sector to produce seed, with public funding moving further upstream into research and germplasm development. In developing countries, substantial investments were made to develop public seed production in the 1980s and 1990s; however, this proved to be very costly, resulting in donors curtailing their support and encouraging states to disengage from the sector. Some countries, such as India, consider seed production to be of strategic importance for food security and have maintained a strong public seed production system. In other countries and for crops like hybrid maize, the state has withdrawn from seed production and the private sector has taken over. For crops with less market opportunities, such as self-pollinated crops, seed production systems have essentially collapsed in many countries. In spite of the overall decline in public sector involvement in the seed sector, there are indications that this situation may now be reversing in some parts of the world. The country reports of Afghanistan, Ethiopia, Jordan and Yemen, for example, all mentioned that community-based production and supply systems and village-based seed enterprises have been promoted in an effort to increase the production of quality seed.

Investment by the private seed sector has mainly been targeted at the most profitable crops (hybrid cereals and vegetables), and mostly in countries with market-oriented agriculture. Some governments in countries such as India, have therefore tried to find an optimal way forward, with the public sector investing in areas that are of relatively little commercial interest such as pre-breeding, developing varieties for resource poor farmers and focusing on crops of limited market potential.

With increasing professionalism in the ecological farming sector, there is a small but increasing demand for high quality organic seed. In spite of problems related to compliance with seed certification requirements, especially regarding seed-borne diseases, seed production for organic and low-input agriculture is expanding. Lebanon, for example, indicated that it has a small organic seed market. Likewise there is a growing organic seed market in the Netherlands, but there are difficulties in adapting current conventional seed legislation to meet the needs and concerns of this sector.

There is also an expanding market for old, 'heritage' varieties. While the United States of America allows the marketing of local varieties without restriction, the European Union has a strict seed regulatory framework, although it is currently developing mechanisms that would permit the legal marketing of the seed of 'conservation varieties' of vegetables that would not meet normal uniformity requirements (see Section 5.4.2). Norway reported that its government outlaws the marketing of seed of old varieties in harmony with European Union legislation. However, it has instituted a heritage system for historical gardens and museums. It is possible to market uncertified landrace seeds in Finland with the intention of conserving and promoting diversity and Greece permits the use of heritage seed in ecological farming systems. In France, it is possible to market seeds of old vegetable varieties for home gardening and in Hungary the production of seed of old varieties and landraces is considered a priority. Ghana and Jamaica both also reported interest in heritage seed programmes.

Transgenic seed production has increased over the past ten years and the seed market has grown in value from USD 280 million in 1996 to over USD 7 billion in 2007.[35] In the latter year, a total of 114.3 million hectares was planted with GM-crops, mainly soybean, maize, cotton and oilseed rape. While the rate of increase in the area under GM-crops is slowing in developed countries, it continues to rise steadily in the developing world. However, even though the number of countries where GM-crops are being tested is rising fast, the number of countries where significant acreages of GM-crops are commercially planted is still limited, mainly in Argentina, Brazil, Canada, China, India, South Africa and the United States of America. GM-varieties have met with strong opposition from the general public and civil society in many European and other countries in relation to concerns about their potential impact on human health and the environment. This has resulted in the prohibition or restricted adoption of this technology in many countries. However, there are signs that, in recent years, GM-varieties are starting to be adopted in Africa, for example, GM cotton in Burkina Faso. Philanthropic foundations are also funding the development of transgenic crops such as cassava for Africa.

The expansion of the seed trade over the last several decades has been accompanied by the development of increasingly sophisticated seed regulatory frameworks. These are generally aimed at supporting the seed sector and improving the quality of seed sold to farmers. However, more recently, questions have been raised about many of these regulatory systems. In some cases, regulations can lead to more restricted markets and reduced cross-border trade. This can limit farmers' access to genetic diversity, or lead to long delays in variety release. Seed regulations can be complex and costly and there are even cases in which seed regulations have outlawed 'informal' seed systems even though they are responsible for supplying most of the seed.

In recognition of these concerns, there has been an evolution in seed regulations in many countries over the last decade. Several regions, e.g. Europe, Southern Africa and West Africa have simplified procedures, facilitated cross-border trade and harmonized seed regulatory frameworks. Such harmonization started at the end of the 1960s in Europe and at the beginning of this century in some African countries. Furthermore, PBR legislation has played an important role in making new varieties more accessible to farmers in many member countries of the International Union for the Protection of New Varieties of Plants (UPOV).

Biosafety regulatory systems have been developed in order to manage any potentially negative effects that might arise from the exchange and use of GM-crops. The Cartagena Protocol on Biosafety which entered into force in 2001, represents a new dimension to seed production and trade and underpins the current development of national biosafety regulations in many countries. In spite of concerns over the capacity of some developing countries to fully implement such regulations, it is likely that they will lead, in the near future, to a wider adoption of GM-varieties. (see Section 5.4.5).

Emergency seed aid is an area that has received increased attention in recent years. Following natural disasters and civil conflicts, in order to quickly restart crop production, local and international agencies have often relied on direct distribution of seed to farmers. Such seed has often originated outside the local area or even outside the country concerned. However, recent studies have shown the potentially negative side-effects of such practices including undermining the national seed sector and reducing local crop diversity. New intervention approaches based on markets (seed fairs and vouchers, for example) and on in-depth assessments of the seed security situation, are increasingly being used by aid agencies in their efforts to restore agricultural production following a disaster.

Many of the country reports referred to the suboptimal state, or even the non-functionality, of seed production and distribution systems. Bangladesh and Senegal, for example, indicated that despite considerable private sector involvement, there were serious problems related to the cost, quality and timeliness of seed delivery. Albania indicated there was a paucity of formal markets, while others, including Cuba, cited the lack of incentives and appropriate legislation. It was widely reported that certified seed production was often unreliable and could not cope adequately with demand. However, various other countries, including Germany, Slovakia and Thailand, reported having highly organized seed production and marketing systems, based on effective national legislation and cooperation between the public and private sectors.

NISM data from 44 developing countries indicated that the major constraint to seed availability by farmers resulted more from the lack of sufficient quantities of basic, commercial and registered seed than the availability and cost of the seed itself or inadequate distribution systems.

4.9 Emerging challenges and opportunities

Since 1996, several of the issues discussed in the first SoW report have become more significant and new issues have emerged. Among these: globalization of economies has continued to move forward (albeit sometimes unevenly), food and energy prices have risen, organic foods have become more popular and economically attractive and the cultivation of GM-crops has spread widely, even though it has sometimes caused debate. Several of the emerging issues are intertwined with the wide fluctuations in food and energy prices that have impacted both producers and consumers of agricultural products over recent years. The following sections discuss five such issues. These are: sustainable agriculture and ecosystem services, new and underutilized crops, biofuel crops, health and dietary diversity and climate change.

4.9.1 Use of PGRFA for sustainable agriculture and ecosystem services

Sustainable agriculture has been defined as *agriculture that meets the needs of today without compromising the ability of future generations to meet their needs*. Whether high-input systems, reduced external inputs and/or higher input-use efficiency, sustainability takes into account due regard for the conservation of natural resources (biodiversity, soils, water, energy, etc.) and social equity (see Chapter 8). While promotion of sustainable agriculture is the Priority Activity Area 11 of the GPA, few country reports referred specifically to it or to the use of PGRFA to promote or protect ecosystem services, a more recently recognized feature of sustainable agriculture. However, countries did mention various aspects of crop production that have a direct bearing on biodiversity loss, soil erosion, soil salinity, water use and the mitigation of climate change.

Many of the key ecosystem services provided by biodiversity sustain agricultural productivity, e.g. nutrient cycling, carbon sequestration, pest regulation and pollination. Promoting the healthy functioning of ecosystems helps ensure the resilience of agriculture as it intensifies to meet growing demands. In the context of agricultural production, it is also crucial to understand and optimize the ecosystem goods and services provided by PGRFA and associated biodiversity (e.g. pest and disease organisms, soil biodiversity, pollinators, etc.). This is of particular importance in the face of increasing global challenges, such as feeding expanding populations and climate change. With appropriate incentives and support, farmers can enhance and/or manage ecosystem services e.g. providing wildlife habitats, better rain infiltration and ultimately help with clean water flows and waste absorption.

A number of countries[36] described action taken to encourage agricultural tourism through, for example, the development of low-input agriculture, museum plots, historical gardens, heritage and food festivals and cultural landscapes. These aim, *inter alia*, to take land out of intensive food crop production, secure the future for heritage crop varieties, maintain levels of agricultural biodiversity, reduce pollution and support education and public awareness. In addition, several country reports[37] indicated a growing interest in organic agriculture systems using crop varieties bred to perform well under low-input conditions. Dominica reported that "The entire island is a 'green zone' where organic farming is actively being promoted and conservation measures implemented".

Many country reports stressed the importance of breeding for resistance or tolerance to pests and diseases, salt, drought, cold and heat, both to improve yield security and reduce the need for pesticides, thereby limiting pollution and biodiversity loss. Crops that are genetically engineered for such resistances and which are already grown in many countries,[38] can also contribute to sustainable agriculture by helping reduce requirements for agrochemicals. However, their use is often limited by policies and legislation in producing and/or importing countries. The potential negative impact of the cultivation of genetically engineered crops on PGRFA, especially in their centres of origin and diversity has sometimes been an issue of heated debate.

Biodiversity loss has many causes including changes in habitat and climate, invasive species, overexploitation and pollution. Loss of agrobiodiversity can ultimately affect key ecosystem services, including soil erosion control, pest and disease regulation and maintenance of nutrient cycles. Ghana noted the effects of environmental degradation in its country report and Djibouti specifically mentioned the role of PGRFA in halting desert encroachment and helping stabilize the environment.

4.9.2 Underutilized species

There are numerous public and private breeding programmes for the world's major crops; however there is relatively little research on, or improvement of, less-utilized crops and species harvested from the wild, even though they can be very important locally. Such crops often have important nutritional, taste and other properties, or can grow in environments where other crops fail. Initiatives such as "Crops for the Future" and the Global Horticulture Initiative promote research on and the improvement of underutilized crops.[39]

The development of new markets for local varieties and diversity-rich products is the subject of Priority Activity Area 14 of the GPA; however it is difficult to gauge the extent to which the objectives outlined in the Area have been accomplished. Several country reports did indicate progress in developing new, diversity-rich products and markets for underutilized species. Uganda, for example, has started processing, packaging and selling Vitamin A enriched sweet potato juice and an antifungal soap made from sweet potato leaves. Uzbekistan reported that "many farmers continue to grow local varieties and that the distribution of (endangered) local varieties is supported." The Plurinational State of Bolivia reported 38 underutilized species for which various activities were taking place, but little full-scale breeding. Uruguay also cited a large number of underutilized species that were grown in the country for food, beverages, medicines and ornamentals. There were several additional reports from the Americas detailing the use of local fruits in making jams, juices and preserves.

There appears to be considerable variation among countries with regard to their perceptions of the availability and size of local and international markets for underutilized crops. Ghana suggested there was a lack of markets. Ecuador and Fiji both indicated that although there was an interest in commercializing local fruits, their future was predicted to be mainly in expanded local consumption. Thailand has researched markets for local and diversity-rich products but concentrated on medicinal and pharmaceutical species rather than food crops. Trinidad and Tobago has developed both local and foreign niche markets and the Netherlands reported on its niche markets for underutilized vegetables. Benin was one of only a few countries that envisaged greatly expanded market opportunities.

According to many of the country reports, there is a general lack of awareness of the importance and potential of diversity-rich and local varieties which, if addressed, would do much to encourage greater use.

Cuba, for example, stated that it "… is necessary to increase public awareness regarding production of diverse and local products and increase markets for them".

There were no reports of truly new food crops but some traditional crops were finding new uses. Cassava, for example, was being used to make biodegradable plastic in India, cocoa butter was used in making cosmetics in Ghana and New Zealand reported new uses for certain marine algae. Many 'new' tropical fruits, vegetables and ornamentals have made their way into European markets over the past decade, giving rise to speculation that there might be opportunities to market many more products internationally.

A NISM survey appraised the current situation and potential for underutilized crops in Africa, the Americas, Asia and the Pacific and the Near East (185 stakeholders in 37 countries). Of the more than 250 crops mentioned, fruits were considered to have a particularly high potential in three of the regions, followed by vegetables. Survey respondents reported on various initiatives underway for expanding market opportunities, including strengthening cooperation among producers, street fairs, organic farming, niche variety registration systems, initiatives in schools and product labelling schemes. Among the main constraints listed were the lack of priority given by local and national governments, inadequate financial support, lack of trained personnel, insufficient seed or planting material, lack of consumer demand and legal restrictions.

4.9.3 Biofuel crops

Crops for the production of biofuel were scarcely mentioned in the country reports although the Philippines reported an interest in biofuels and Zambia mentioned *Jatropha curcas*, the oil of which is a diesel substitute. This and several more traditional crops that can be used for biofuel, including maize, rapeseed, sunflower, soybean, oil palm, coconut and sugar cane, were included in the crop lists of several reports, but rarely with reference to their biofuel use. Since the publication of the first SoW report, the merits and demerits of biofuels have been hotly debated. Concerns have been expressed over possible competition with food production and the consequent impact on food prices, as well as over possible negative environmental impacts arising from intensive biofuel production.[40] On the other hand, biofuels offer new opportunities for agriculture[41] and could make an important contribution to reducing net global CO_2 emissions.

Biofuel crops for use in power stations were mentioned by Germany and several European countries[42] and the United States of America[43] reported on a number of plant species that are being bred for energy production. These include willows, poplars, *Miscanthus* spp. and switchgrass. A number of countries are researching high-density algal systems to produce biodiesel and fuel alcohol,[44] although New Zealand saw no immediate useful biofuel application for its collection of freshwater algae.

4.9.4 Health and dietary diversity[45]

Plants provide the majority of nutrients in most human diets around the world. While hunger, linked to an inadequate total food intake, remains a major problem in many parts of the developing world and in some areas in developed countries, there is also growing recognition of health problems associated with inadequate food quality and the lack of specific nutrients in diets. Such problems are particularly acute among poor women and children and can be addressed both through increasing dietary diversity as well as through breeding crops, especially the major staples, for improved nutritional quality. Nonetheless, there was scant mention in country reports of breeding crops for better nutritional quality, although several mentioned the relationship between PGRFA and human health. Malawi, for example, recognized the importance of dietary diversity in relation to the Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS) and Thailand saw market opportunities from linking PGRFA to the health sector. It was even reported from Africa that kola nuts were being processed to produce an appetite suppressant to help combat obesity. Kenya and several countries in West Africa confirmed a renewed interest in traditional foods, in part due to perceived nutritional advantages.

Different plants are rich in different dietary constituents, the combination of which underlies the health-promoting effects of a diverse diet. Such compounds include, for example, various antioxidants as found in many fruits, tea, soybean, etc.; fibre that can help reduce hypercholesterolemia; and sulphoraphane, an anticancer, antidiabetic and antimicrobial compound found in many *Brassica* species. Plant breeding could play a useful role in developing crops that are richer in such compounds but much more needs to be done to characterize and evaluate both cultivated and wild germplasm for nutritionally related traits. However, in many cases little is known about the relative importance of genetics, production conditions and food processing on the level and availability of specific nutrients in a given food product.

Important amino acid mutants have been identified in several crops, but have been exploited to the greatest extent in breeding maize for high lysine content (quality protein maize, QPM) and in interspecific crossing to produce high protein New Rice for Africa (NERICA) rice.[46] The application of biochemistry, genetics and molecular biology to manipulate the synthesis of specific plant compounds offers a promising avenue for increasing the nutritional value of crops. Examples include:

- golden rice, which contains high levels of beta-carotene, the precursor of Vitamin A, through an introduced biosynthetic pathway;
- iron-enhanced rice containing a ferritin gene introduced from beans, plus a heat-tolerant phytase system from *Aspergillus fumigatus* to degrade phytic acid that inhibits iron absorption;
- numerous ongoing research projects on iron, zinc, provitamin A, carotenoids, selenium and iodine; three major international programmes have been initiated on biofortification:[47]
- HarvestPlus, a programme of the CGIAR that targets the nutritional improvement of a wide variety of crop plants through breeding and focuses on the enhancement of beta-carotine, iron and zinc;[48]
- the Grand Challenges in Global Health Initiative, targeting banana, cassava, sorghum and rice, mostly through genetic modification;[49]
- the Biodiversity and Nutrition Initiative led by the CBD, FAO and Bioversity International.

Since the publication of the first SoW report, the belief that improved quality diets can help people survive certain medical conditions and can prevent the occurrence of others has gained recognition. Sufferers of HIV/AIDS, for example, can live healthier and more productive lives when they are better nourished. Uganda, in its country report, stated that "the increased emphasis on the value of nutrition in treatment of HIV/AIDS patients has drawn attention to local herbs and … diversity rich products." While some PGRFA can also have direct medical benefits through specific pharmaceutical properties, a fact that was mentioned in several country reports, none mentioned the breeding of crops for pharmaceutical production.

4.9.5 Climate change[50, 51]

All of the climate models of the IPCC predict that conditions for agriculture in the future will be dramatically different from those that prevail today.[52] Of all economic activities, agriculture will be among those in greatest need to adapt. Many of the poorer, food-insecure countries are particularly vulnerable to the effects of climate change on crop production and there will be significant risks to wild biodiversity, including CWR. These changes are expected to result in a growing demand for germplasm that is adapted to the new conditions, more effective seed systems and international policies and regulations that will facilitate even greater access to PGRFA.

The country reports made relatively few references to the predicted impact of climate change. However, together with a rapidly growing demand for greater production, such change is likely to result in increased pressure to cultivate more marginal land. Africa is the continent that is most vulnerable to climate change and it has been suggested that maize will probably be eliminated from southern Africa by 2050. It is also predicted that groundnut, millet and rapeseed productivity will also drop in South Asia.[53] Small islands, that often have high levels of threatened endemic species, are also under particular threat as a result of the expected rise in sea levels.

The range and migration patterns of pests and pathogens is likely to change, biocontrol agents will be affected and synchronization of pollinators and flowering may be disrupted. Although switching to new cultivars and crops has the potential to alleviate many of the expected disturbances, this will require a greatly increased access to genetic diversity and a substantial strengthening of plant breeding efforts. Breeding must take into account the environment predicted for the crop's target area at least 10 to 20 years hence, requiring that prediction methods be further developed in order to be as reliable as possible. Certain currently underutilized crops are likely to assume greater importance as some of today's staples become displaced. It will be very important to characterize and evaluate as wide a range of germplasm as possible for avoidance, resistance or tolerance to major stresses such as drought, heat, water-logging and soil salinity. Research is also needed to gain a better understanding of the physiological mechanisms, biochemical pathways and genetic systems involved in such traits.

In order to meet the challenges posed by climate change, it will be vital that effective plant breeding programmes are in place, with adequate human and financial resources, in all key agro-ecologies. It is predicted that climate change will have a significant impact within the relatively near future and given the long time required for a typical crop breeding cycle, it is essential that all necessary action be taken immediately to strengthen and accelerate breeding efforts.

4.10 Cultural aspects of PGRFA

The use of PGRFA represents a broad continuum of activities that runs across the cultural, ecological, agricultural and research landscapes. Among these, agricultural uses of PGRFA get by far the most attention, although other uses are also extremely important in certain situations and to certain communities. Local and traditional foods, for example, are of great importance to almost all cultures, an importance that goes well beyond their nutritional significance. They might have important ceremonial or religious associations and in many cases are important to a society's identity. However, traditional cultural uses tend to change slowly over time and are unlikely to have changed substantially since the first SoW report was published. However, having the basic programmes with adequate human and financial resources to screen germplasm and to run variety trials in key agro-ecologies is of paramount importance. A good example of this dimension was the well documented case of potato in developing countries that was highlighted as part of the celebration of the 'International Year of the Potato'.[54]

4.11 Changes since the first State of the World report was published

The country reports indicated that during the period between the first and the second SoW reports there have been increased efforts to improve the state of use of plant genetic resources. Some of the most important changes since the first SoW report are:

- overall global plant breeding capacity has not changed significantly;
- a modest increase in the number of plant breeders has been reported by certain national programmes and a decline by others;
- there has been little change in the crop focus of the breeding programmes as well as in the principal traits sought by plant breeders. Major crops still receive the most attention and yield per unit area continues to be the primary trait sought. However, recently more attention has been paid to underutilized crops and to the use of CWR;
- the number of accessions characterized and evaluated and the number of countries where characterization and evaluation are carried out have increased in all regions but not in all individual countries. An increasing number of countries use molecular markers to characterize their germplasm;
- progress has been made in genetic enhancement and base-broadening with several countries now reporting the use of these techniques as a way to introduce new traits from non-adapted populations and wild relatives;
- while country reports from all five regions indicated an increase in farmer participation in plant

breeding activities over the past decade, farmers' involvement is still largely limited to priority setting and selecting from among advanced lines or finished varieties;

- the constraints (human resources, funding and facilities) to greater use of PGRFA and their relative importance are similar to those reported in the first SoW report. However, issues such as the lack of fully effective linkages between researchers, breeders, curators, seed producers and farmers and lack of comprehensive information systems were also highlighted this time;
- since the publication of the first SoW report, several new challenges have been recognized and these are beginning to be addressed in national analyses and strategies. Those highlighted in this report include: sustainable agriculture and ecosystem services, new and underutilized crops, biofuel crops, health and dietary diversity and climate change;
- over the past decade, there has been a substantial increase in awareness of the extent and nature of the threats posed by climate change and of the importance and potential of PGRFA in helping agriculture to remain productive under the new conditions through the underpinning of efforts to breed new, adapted crop varieties;
- the area sown with transgenic crops has increased substantially since 1996 and the seed market has grown in value in step with this. In 2007, 114.3 million hectares were planted with GM-crops, mainly soybean, maize, cotton and oilseed rape;
- there has been a major increase in the international seed trade, which is dominated by fewer and larger multinational seed companies than in 1996. The focus of interest of these companies remains primarily on the development of improved varieties and the marketing of high quality seeds of major crops for which farmers replace seed yearly;
- investment by the public sector in seed production, already at a low level in most developed countries at the time of first SoW report, has since then also decreased significantly in many developing countries. In many countries access to improved varieties and quality seed remains limited, especially for non-commercial farmers and the producers of minor crops;
- there is a trend to harmonize seed regulations at the regional level (Europe, East Africa, Southern Africa and West Africa) in order to facilitate seed trading and foster the development of the seed sector;
- there has been an increasing move to integrate local seed systems within emergency responses aimed at supporting farmers in the aftermath of natural disasters and civil conflicts;
- there is a growing market for specialized 'niche' seeds, such as for 'heritage' varieties.

4.12 Gaps and needs

While good progress has been made in several areas relating to the use of PGR since the first SoW report was published, the country reports still recognize a number of gaps and needs. These include:

- the urgent need to increase plant breeding capacity worldwide in order to be able to adapt agriculture to meet the rapidly expanding demand for more and different food, as well as non-food products, under substantially different climatic conditions from those prevailing today. The training of more breeders, technicians and field workers and the provision of better facilities and adequate funds are all essential;
- the need for greater awareness of the value of PGRFA and the importance of crop improvement, in meeting future global challenges among policy-makers, donors and the general public;
- the need for countries to adopt appropriate and effective strategies, policies, legal frameworks and regulations that promote the use of PGRFA, including appropriate seed legislation;
- considerable opportunities exist for strengthening cooperation among those involved in the conservation and sustainable use of PGRFA, at all stages of the seed and food chain. Stronger links are needed, especially between plant breeders and those involved in the seed system, as well as between the public and private sectors;
- greater efforts are needed in order to mainstream new biotechnological and other tools within plant breeding programmes;

- more investment is needed in the improvement of underutilized crops as well as of traits in major crops that are likely to assume greater importance in the future as increased attention is paid to health and dietary concerns and as the effects of climate change intensify;
- in order to capture the potential market value of native crops, local varieties, underutilized crops and the like, there is a need for greater integration of the efforts of individuals and institutions having a stake in different parts of the production chain, from the development and testing of new varieties, through value added activities, to the opening up of new markets;
- a lack of adequate characterization and evaluation data and the capacity to generate and manage it, remain a serious constraint to the use of many germplasm collections, especially of underutilized crops and wild relatives;
- greater attention is needed in the development of core collections and other collection subsets, as well as in pre-breeding and base-broadening efforts, as effective ways to promote and enhance the use of PGRFA;
- in order to promote and strengthen the use of participatory breeding, many countries need to reconsider their policies and legislation, including developing appropriate intellectual property protection and seed certification procedures for varieties bred through PPB. Greater attention also needs to be paid to capacity building and to ensuring PPB is integrated in national breeding strategies;
- greater efforts are needed to encourage and support entrepreneurs and small-scale enterprises concerned with the sustainable use of PGRFA.

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Chapter 5

The state of national programmes, training needs and legislation

5.1 Introduction

National programmes for the conservation and sustainable use of PGRFA aim to support economic and social development and underpin efforts to develop more productive, efficient and sustainable agricultural systems. They lie at the heart of the global system for conserving and using PGRFA. While international cooperation between national programmes is essential and is dealt with in Chapter 6, this chapter attempts to define and categorize national programmes, describes developments that have taken place since 1996, identifies current needs and opportunities for training and capacity building and describes the status of national legislation. The chapter concludes with a summary of the main changes that have taken place since the publication of the first SoW report and presents key gaps and needs for the future.

5.2 State of national programmes

5.2.1 Purpose and functions of national programmes

Priority Activity Area 15 of the GPA advocates the formation or strengthening of national programmes for PGRFA as a strategy to involve and coordinate all relevant institutions and organizations in a country, in a holistic enterprise aimed at promoting and supporting the conservation, development and use of PGRFA. Countries vary in the extent to which national PGRFA programmes are incorporated in national developmental plans, or are included in more specific agricultural or environmental policies and strategies. Components of a national programme include both the institutions and organizations involved in PGRFA as well as the linkages and communications among them. In practice, the design and function of a national programme is country specific, shaped by many factors such as history, geography, the status of biodiversity, the nature of agricultural production and relationships with neighbouring countries with respect to shared biodiversity.

An efficient national PGRFA programme should have well-defined goals, clear priorities and a blueprint for implementation. It needs to be well structured and coordinated, involving all relevant stakeholders, no matter how diverse. Its success depends to a large extent on the commitment of national governments to provide the necessary funding, policies and institutional framework.

Given the aforementioned, it is not surprising that there is considerable heterogeneity among national programmes in terms of their goals, functions, organization and infrastructure. At the same time there are many commonalities, in part arising from obligations incurred under various international instruments such as the CBD, the ITPGRFA, the GPA and various other trade and IPR agreements (see Chapter 7).

5.2.2 Types of national programmes

In the first SoW report, an attempt was made to classify the diversity of national programmes into three categories: (i) a formal, centralized system; (ii) a formal, sectorial system in which different institutions take on a leadership role for specific components of the national programme, with national coordination; and (iii) a national mechanism for coordination only, involving all relevant institutions and organizations. In retrospect, this scheme may have been too simplistic.

The process of compiling information for the SoWPGR-2 revealed a wide diversity of national PGRFA systems, in terms of size, structure, organization, institutional composition, funding and objectives. It was difficult to distinguish the three categories of national PGRFA activities used for the first SoW report. For example, there are centralized systems that may not be 'formal' and there are sectorial systems that do not have coordination mechanisms.

Perhaps the most familiar model is a national centralized system based on a vertical integration of PGRFA units within a national institution, such as a Ministry of Agriculture, funded by the national government, with linkages to relevant sectors outside the central organization, such as academic institutions, NGOs and the private sector, coordinated by a national advisory coordinating committee. Another model is a national system based on decentralized but strongly coordinated sectorial leadership, with funding arising independently from each sector. Yet another model might be a regional structure involving other countries, balancing components that are missing in one country with components that are well developed in another. In this case, expertise and germplasm are shared, training opportunities are enhanced and greater efficiency is achieved as a result of no single country having to develop every component independently.

Countries were not asked to self-identify their type of national programme with respect to the three categories, for either the first or second SoW reports. In many instances, factors that would have helped in the categorization were not reported. Information on the current status and trends in national programmes since the first SoW report was published should thus be interpreted with caution. Interpretation is complicated further by the fact that a different and smaller set of countries provided information for the second report compared with those reporting in 1996 and that in most cases a different person or group of people was responsible for providing country report information in the two time periods. In spite of these difficulties, some revealing and relevant comparisons are possible.

5.2.3 Status of development of national programmes

There has been considerable progress over the last decade in the percentage of countries having a national programme of one type or another. Of the 113 countries[1] that contributed information for both the first and second SoW reports, 54 percent reported having a national programme in 1996, whereas 71 percent report having some form of national programme now.

At the time of the first SoW report, 10 percent of reporting countries had a national programme 'under development'. Of these, seven provided information for SoWPGR-2 and all but one had followed through, now being able to report a national programme in place.

Of the 120 countries that provided information for the SoWPGR-2 either through a country report, a NISM, or participation in a regional workshop,[2] the most common type of national programme reported is a sectorial type (67 percent of reporting countries), whether formal or informal, with national coordination or not.

Most of the current reports from countries that still lack a national programme recognize the value of establishing one and are discussing what form it might take and what is needed. A few of these indicated that committees are currently looking into the situation.

It is clear that there is still room for countries to improve national systems and coordination of PGRFA. Comprehensive PGRFA management requires the integration of efforts within and outside the country concerned, involving the participation of a diverse set of institutions. As described elsewhere in this report (see, for example, Section 4.7.3), the weak links between the PGRFA conservation and use sectors are still a major concern. There are some signs that the situation may be improving, for example, a number of countries now include their PGRFA programmes within the context of their national development plans and the like. However, strong and fully effective institutional links between national genebanks and plant breeders and/or farmers are still comparatively rare, especially in developing countries.

Even in countries with active and well-coordinated national programmes, certain key elements may be missing. National, publicly accessible databases, for example, are still comparatively rare as are coordinated systems for safety duplication and collaborative public awareness.

Another area that still requires greater attention in many national programmes is a more effective integration of the efforts of the public and private sectors (see Chapters 1 and 4). In a number of countries, private plant breeding and seed sector companies need to see the value of devoting time and resources to strengthening their collaboration with public sector technical institutions. In other cases, however, it was the private sector that insisted that governments should establish national programmes.

Country reports from many regions mentioned NISMs in relation to the implementation of the GPA, as a valuable tool for establishing and improving national programmes.[3] Participating countries recognized NISM helpful role in facilitating the management of information and the exchange of PGRFA, as well as for fostering within-country identification of stakeholders and promoting collaboration.

The process of contributing to a NISM integrates the efforts of different stakeholders, thus helping to build a broader institutional base for the conservation and use of PGRFA. NISMs provide a key platform for information sharing, policy setting, scientific exchange, technology transfer, research collaboration and for determining and sharing responsibilities. They are also important in the regional and international context in helping to raise awareness of the value of PGRFA and the actions being undertaken by other countries to conserve and use it.

5.2.4 National programme funding

The majority of the country reports indicated that the primary source of funding to sustain their national programme was from the national government. This is one indicator that can be used to help define a 'formal' programme. In some cases this is supplemented by funds from international donors. Individual components of the national system (e.g. units involved with conservation, crop improvement, seed systems, crop protection, protected areas, extension, education, or training) generally receive funds from a variety of different sources: different ministries, national or international funding agencies and foundations, or private philanthropy. To a large extent, the participation of private, for-profit companies within national systems is self-funded.

Although several countries, especially in Europe, reported that overall funding has increased substantially since 1996, many of the country reports noted that their national programme received inadequate and unreliable funding, making it difficult to plan over multiple years. While national genebanks *per se* generally have direct and identifiable funds provided by the national government, the financing of national coordinating mechanisms and other elements of a national system are often buried within other budget categories and hence, subject to greater uncertainty.

In some regions, for example, Africa, the country reports have highlighted the need for greater support for infrastructure. Where this has not been forthcoming from national governments, help has sometimes come from international and regional organizations, bilateral agencies and private foundations. In general, funding support from such agencies for the conservation and use of PGRFA in developing countries appears to have increased since the first SoW report was published.

Although there are no figures available to indicate overall trends in funding, the CBD, GPA and ITPGRFA have all clearly helped to give greater prominence to the subject and overall, this has almost certainly had a positive impact. Likewise, the international publicity surrounding events such as the launching of the GCDT and the opening of the SGSV have served to raise awareness of the importance of conserving and using PGRFA in the minds of the general public, policy-makers and donors.

While the level and reliability of funding are major factors that determine the strength and effectiveness of a national PGRFA programme, other factors are also important such as the extent of public awareness and support, political will and the quality of leadership and management. These factors clearly vary from country to country and from region to region, as does financial support.

5.2.5 Role of the private sector, non-governmental organizations and educational institutions

As described above, in most countries the national government is the principal entity involved in national programmes for the conservation and use of PGRFA, generally through multiple public sector institutions under one or several ministries. However, the involvement of other stakeholders appears to have expanded since the publication of the first SoW report. These include private, for-profit companies, NGOs, farmer organizations and other rural community groups and educational institutions, especially universities.

5.2.5.1 Private sector

Private sector companies are very diverse in size, scope and core business and their participation in national programmes reflects this diversity. Their interests and involvement vary from the collecting and maintenance of germplasm collections (generally breeders' working collections) and the evaluation of germplasm, to genetic improvement, multilocation testing, biosafety and seed release, multiplication and distribution. They are also sometimes actively involved in education, training and public awareness activities. Over recent years, public-private research and development partnerships appear to have grown in importance, especially in the area of biotechnology.[4] Within Western Europe, Australia and the United States of America and other industrialized countries, the private sector now accounts for a large proportion of the total breeding effort (see Section 4.4) and it is expanding rapidly elsewhere, especially in parts of Latin America and Asia. Stronger links between private companies and public institutions involved in basic research, conservation, genetic enhancement, information systems, and the like, offer considerable potential benefits for all parties concerned.

5.2.5.2 Non-governmental organizations

In many countries NGOs play a very important role at the farm and community level in promoting and supporting the conservation and management of PGRFA. Their activities range from direct involvement in *in situ* conservation in protected areas to promoting the on-farm management of PGRFA for the benefit of local households and communities. Many are also active in lobbying governments to devote more attention to these issues. In a number of countries, NGOs actively participate in nationally coordinated efforts. It is not possible to provide a comprehensive overview or analysis of NGO activities in PGRFA because they are so numerous and diverse, especially at the regional and national levels.

According to the country reports, NGOs are active in most regions and are particularly strong in Africa, Asia, Europe and parts of Latin America. Germany, the Netherlands and Switzerland reported the effective involvement of NGOs. In Asia, NGOs such as LI-BIRD in Nepal and the M.S. Swaminathan Research Foundation and Gene Campaign in India have been very active in promoting the on-farm management of PGRFA. Farmers' unions and cooperatives are recognized as important and crucial stakeholders in many countries of the Near East region. A number of national PGR workshops and training programmes have helped enhance the role of NGOs within national programmes, especially in technology transfer, public awareness and capacity building.

5.2.5.3 Universities

Universities are active participants and collaborators in national PGRFA programmes in many countries and in all regions. Many examples have been cited elsewhere in this report. Not only are universities vital for their role in the development of human resources but they also contribute substantially to research and the development of PGRFA. They have become increasingly involved in the application of biotechnology to conservation and crop improvement, for example, in cryopreservation, *in vitro* propagation, the development and application of molecular markers, the measurement and monitoring of genetic diversity, and the analyses of species relationships.

While they play a vital role, many universities and other learning institutions, especially in developing countries, lack adequate facilities and financial support, which limits their ability to contribute to their maximum capacity.

5.3 Training and education

Meeting national programme needs for training and capacity building is among the priorities listed in the GPA. Expanding and improving education and training is Priority Activity Area 19 in the GPA and capacity building is addressed by the entire fourth section. Strengthened staff competence is needed in all sectors: scientists and technicians, development workers, NGOs and farmers. Special efforts are needed to educate research managers and policy-makers. In many countries biological sciences curricula at all educational levels need to be developed or updated to include conservation biology, especially with respect to agrobiodiversity.

Since 1996, a number of developments have taken place in training and education, with significant new opportunities opening up in several countries.

Collaboration for training between national programmes and international and regional organizations, especially with FAO and the CGIAR centres, has expanded and capacity building opportunities have increased. Much of this has been the result of additional funding becoming available from bilateral and multilateral donors for research projects that have a human resources development component. More universities are now offering short-term informal courses as well as longer-term M.Sc. and Ph.D. courses in areas related to PGRFA. New training materials are becoming available and field and laboratory facilities for training have improved in a number of countries. However, in spite of these developments, there is still a need for greater capacity in education and training to meet the expanding demand for new, well-trained professionals and for upgrading the skills and expertise of those already engaged in the conservation or use of PGRFA.

Most national programmes concerned with on-farm management of PGRFA aim to build both their own professional capacity as well as that of the farmers with whom they work. However, many NGOs and development agencies lack sufficient qualified personnel to impart the necessary training to farming communities. While higher-degree training in *in situ* conservation and on-farm management of PGRFA was specifically mentioned by Indonesia, Malawi and Zambia, most capacity building in these areas has been less formal. Cuba, India and Nepal, for example, all indicated that there has been an increase in the number of groups trained in PPB (see Section 4.6.2) and the compilation of community biodiversity registers. Several country reports[5] mentioned activities on the on-farm management of PGRFA that include technical courses for farmers, farmer-to-farmer training, the setting up of farmer associations, courses for extension workers and short-term professional training. Participatory approaches have been central to much of the work undertaken in this area and have resulted in the enhancement of local capacity for informal research and the evaluation of diversity.

In Morocco and Nepal, work on diversity has been linked to literacy campaigns that *inter alia* help strengthen diversity management capabilities. Increased gender awareness has been another important facet within many projects, not only through the collection of gender-disaggregated data and the participation of women farmers, but also as a result of the increased involvement of women in research and project management.

Since the first SoW report was published, many new manuals and other tools have been developed to support training on how to manage on-farm genetic diversity. Examples include a training guide developed by Bioversity International,[6] a source book on the conservation and sustainable use of agricultural biodiversity by CIP,[7] and a 'tool kit' to help the development of strategies for the on-farm management of PGRFA.[8] The community biodiversity management approach, including community biodiversity registries, aims to build the capacity of local communities to make their own decisions on the conservation and use of biodiversity.[9] It does this through facilitating community access to knowledge, information and genetic materials.

The following sections summarize major developments in relation to training and education on a regional basis.

Africa

From an analysis of the country reports it appears that in spite of advances in several countries, overall capacity to carry out training and education on PGRFA in Africa remains limited. Universities in Benin, Ghana, Kenya and Madagascar all reported that courses on genetic resources have been included in university curricula at both the undergraduate and postgraduate levels. In Benin and Côte d'Ivoire, postgraduate courses have been initiated in collaboration with Bioversity International and a partnership has been established in Kenya to teach a diploma course on PGR conservation involving Maseno University together with KARI, the Kenya Forest Research Institute (KEFRI) and the National Museums of Kenya (NMK). In Ethiopia, the IBC organizes both long- and short-term training courses on the management of genetic resources.

Americas

In Latin America, several countries have invested in educational programmes. The Plurinational State of Bolivia, for example, has offered ten short-term university courses in PGR since 1996 and in Brazil, the Federal University of Santa Catarina started M.Sc. and Ph.D. courses in 1997 with financial support from the National Council for Scientific and Technological Development (CNPq). In Argentina, undergraduate and M.Sc. courses are available in several universities. In Costa Rica, the EARTH University offers regular courses in subjects related to genetic resources and in 2002, a postgraduate course, entitled 'Management and Sustainable Use of PGR', was conducted at CATIE with the aim of improving the use of genetic diversity of cultivated plants. A large training programme exists in Mexico, where many universities and other institutions offer courses in aspects of genetic resources, from secondary school to postgraduate levels and in Uruguay, undergraduate courses in applied science cover subjects related to conservation and sustainable use of biological diversity. According to the country reports, however, there is currently no formal training programme on genetic resources in Cuba, the Dominican Republic, Ecuador, Jamaica, Peru, Trinidad and Tobago or the Bolivarian Republic of Venezuela.

Asia and the Pacific

In recent years several regional and international short-term training courses have been conducted including: field genebank maintenance (Universiti Putra Malaysia, UPM); *in vitro* conservation and cryopreservation (NBPGR, India); documentation and bamboo genetic resources, Forest Research Institute of Malaysia (FRIM) and the Universiti Malaya (UM, Malaysia); *in vitro* conservation and cryopreservation of tropical fruit genetic resources (NBPGR, India); molecular data analysis of tropical fruit tree species diversity (Huazhong Agricultural University, China); cryopreservation of tropical fruit genetic resources (Griffith University, Australia); use of molecular markers for characterization of genetic resources (Huazhong Agricultural University, China); and on-farm and community-based conservation and the role of public awareness (Secretariat of the Pacific Community [SPC, Fiji]).

Both Bioversity International and NIAS/Japan's International Cooperation Agency (JICA) have been actively involved in training on the management of PGRFA in the region. Recently, Bioversity International has recognized NBPGR, India and the Chinese Academy of Agricultural Sciences (CAAS), Bioversity Centre of Excellence for Agrobiodiversity Resources and Development of China (CEARD) as Centres of Excellence for training on *in vitro* conservation and cryopreservation. In Nepal, LI-BIRD and the Napok Agricultural Research Centre (NARC) have been identified as Centres of Excellence for training in on-farm conservation.

The University of the Philippines Open University (UPOU) has entered into an agreement with Bioversity International to develop specialized courses on international and national policy and laws relating to the management of PGR. The Genetic Resources Policy Initiative (GPRI) of Bioversity International has published several training documents and other materials for use in education and training programmes.

Since 1996, NBPGR and the Indian Agricultural Research Institute (IARI) in New Delhi have offered joint M.Sc. and Ph.D. degree programmes in the conservation and management of genetic resources. Formal degree programmes were also initiated at the University of the Philippines Los Baños (UPLB), the Philippines in 1997 and in Malaysia and Sri Lanka in 2000.

In the Pacific Islands, the University of the South Pacific (USP), Alafua Campus, Samoa, hosted a meeting on PGR Education in 2004. Later, the Centre for Flexible and Distance Learning of USP was mandated to develop a course curriculum on genetic resources.

Europe

In Europe, many universities provide courses in agricultural sciences, plant breeding and plant science, which include aspects of PGR. Formal B.Sc., M.Sc. and Ph.D. degree programmes having special emphasis on biodiversity and genetic resources have been established in several countries as a response to calls for action by the CBD. In some countries, genebank staff are engaged as university faculty members on an adjunct or part-time basis and various institutions, societies, NGOs and a few national genebanks offer short courses (workshops, seminars) on practical aspects of PGRFA. Courses on collecting and conservation techniques are very much in demand, especially in Eastern Europe.

Near East

Universities in Egypt, Jordan and Morocco are developing master's degree programmes that focus on the conservation of genetic resources and the management of natural resources. Substantial efforts have been made in a number of countries to increase public awareness of the importance of conserving biodiversity in general and agrobiodiversity in particular. Jordan, Kazakhstan, Morocco, the Syrian Arab Republic and the West Bank and Gaza Strip, have developed educational curricula and extracurricular activities directed at increasing the awareness of students and their parents. A variety of different media (TV, radio, workshops, meetings, posters, leaflets, agricultural fairs and ecotourism) have been used by government agencies and by different biodiversity projects in the region to help educate the public. The innovative use of rural theatre by the Extension Directorate in the Syrian Arab Republic, for example, has resulted in increased general public awareness of the role and value of PGRFA.

In conclusion, while good progress has been made, there is still much to be done to provide more and better training opportunities at the local, national, regional and international levels.

5.4 National policy and legislation

While many important agreements relating to PGRFA have been negotiated and adopted at the international level (see Chapter 7), the number of national laws and regulations has also increased. Appendix 1 provides details of the status of countries with respect to their signing or ratifying major international agreements as well as the enactment of national laws relating to the conservation and use of PGRFA. The following sections describe the status of national regulations and legislation in five areas: phytosanitary regulations, seed regulations, IPRs, Farmers' Rights and biosafety. Regional approaches to phytosanitary regulations are dealt with in Section 6.4.1 and the topic of ABS is a major topic of Chapter 7.

5.4.1 Phytosanitary regulations

Most countries in all regions have adopted national phytosanitary legislation. Since the first SoW report was published, much of the new national legislation in this area has been influenced by the adoption of the revised text of the IPPC in 1997 (see Section 6.4).[10] Many countries subsequently amended their plant protection laws or enacted new ones to ensure that their legislation used the new definitions from the 1997 text and reflected the concepts and rules of the WTO Agreement on the Application of Sanitary and Phytosanitary Measures. One of the main changes that occurred is the requirement that the decision to import plants, plant products and other regulated articles should have a scientific basis.

All decisions on imports that are not based on international standards must be based on pest risk analysis.

5.4.2 Seed regulations

The seed system is highly regulated in most countries, from the release of new varieties and the quality control of seeds to the legal status of organizations that implement seed control and certification and variety release procedures. Since the first SoW report was published, three main trends have occurred: the emergence of voluntary arrangements regarding seed certification and variety release; the growing use of accreditation principles within official national rules and standards; and the regional harmonization of seed laws (see Section 4.8).

Recent years have seen a significant development of the seed trade by the public and, especially, private sectors, largely in parallel with the more traditional seed exchange arrangements of local agricultural communities. This has led governments to set up seed regulations for the protection of seed users (farmers, consumers and agrifood industries) that cover such areas as catalogues of plant varieties, marketing authorization and seed-quality control.

In some countries including Australia, Canada and New Zealand as well as some Latin American, African and Asian countries, the growth of the private seed sector has led governments to review their seed laws, resulting in many cases, in a shift away from compulsory rules on seed certification and variety release towards more voluntary arrangements. The largely self-regulated nature of variety release and seed certification in the United States of America allows for the marketing of seeds of local varieties. In India, changes have been made in the other direction, from voluntary arrangements to more compulsory rules, with a view to strengthening the protection of consumers and small farmers.

The growth of the private seed sector has also led to an increased use of accreditation principles within the national or regional seed rules and standards of a number of industrialized countries and ones with emerging economies. The introduction of private certification and testing services or in-company systems, complements or, in some cases, replaces the government's traditional role in these matters. Taking into account the evolution of seed regulations, the International Seed Federation (ISF) has regularly updated its rules dealing with contracts among seed merchants and between companies and contract growers.

The third main trend is the regional harmonization of seed laws, especially in Africa and Europe, in order to avoid disincentives to cross-border seed trade. The most far-reaching example of regional harmonization of seed laws is in the European Union where seed certification and seed quality standards[11] were adopted in the late 1960s and a common variety catalogue established in 1970. In 2008, the concept of 'conservation varieties' was introduced. These are varieties that, although having to meet quality standards, have neither to adhere to strict uniformity and stability rules nor have any proven value for cultivation and use.[12] However, such 'conservation varieties' are limited to old and locally used varieties that are threatened by genetic erosion.

In the countries of Southern Africa, the harmonization of seed laws with the assistance of FAO resulted in the adoption in the early 2000s of a joint variety list that enables varieties to be grown in the different member countries. However, a variety must be listed in at least two countries before it enters the SADC regional list. Harmonization efforts are also underway in Western Africa with the development of a joint variety list by members of the Economic Community of West African States (ECOWAS) and the adoption in 2008 of Regulation C/REG.4/05/2008 on the Harmonization of the Rules Governing Quality Control, Certification and Marketing of Plant Seeds and Seedlings in the ECOWAS Region.

In parallel with these trends and despite growing awareness of the value of informal exchange of seeds among farmers, most laws explicitly apply to packed and certified seed with only very few countries having exemptions or special arrangements for farmers' seed (see Box 5.1). Most seed laws aim to protect the seed label and are reserved for controlled seeds, labelled 'Government-certified seeds', 'Government-tested seeds', or the like. The Moroccan seed law restricts the use of the word 'seed' to controlled seed only. In many countries, the informal marketing of local varieties and landraces is illegal.

A major challenge in developing national seed laws is balancing the need to promote diversity and local varieties with systems that promote access to good quality seed of appropriate varieties. Another challenge, reported by several countries, is how to ensure the effective implementation of seed laws and regulations in situations where government funding, trained staff and infrastructure are limited.

5.4.3 Intellectual Property Rights

Systems for protecting and rewarding IP in relation to PGRFA primarily involve PBR and patents. The following sections give an overview of the state of play at the national level in both of these areas. Other forms of IPR can also play a role, for example, trade secrets for protecting inbred lines for producing hybrid varieties, geographical indications for protecting products that have a specific geographical origin and possess qualities, reputation, or characteristics that are essentially attributable to that origin and copyright for protecting databases and other information sources. However, these are not considered further in this report.

Box 5.1
Examples of developments in national legislation that support the conservation and use of traditional crop varieties

Bangladesh: the forthcoming national framework for PGRFA is expected to include, *inter alia*, the recognition of Farmers' Rights, including provisions for benefit sharing.

Ecuador: the new National Constitution approved in September 2007 strongly promotes the conservation of agricultural biodiversity and the right of people to choose their own food. In particular, Article 281.6 has the title: "promote the preservation and rehabilitation of agrobiodiversity linked to ancestral knowledge; likewise its use, conservation and free seed exchange". Several government programmes will be put in place to support small and medium farmers in the production of organic and traditional food.

Morocco: in 2008, a law was adopted covering Appellation of Origin, Geographical Indication and Agricultural Labelling of produce. It allows for the registration of products from local varieties and landraces and thus helps promote their use and conservation.

Nepal: a 2004 amendment of the 'Seed Regulatory Act' has added a new provision on plant variety registration that allows for the inclusion of farmers' field trial data and other data from participatory trials, in registration applications. This will enable farmers' varieties and landraces to be registered, thus helping to promote conservation; and it will also expand opportunities for the sharing of any benefits that result from any increased use of local genetic resources.

Tunisia: in 2008, a law was adopted to promote the *in situ* and *ex situ* conservation of date palm genetic resources. It includes the use of *in vitro* methods to multiply varieties for conservation purposes and to rehabilitate old plantations in the oases.

5.4.3.1 Plant breeders' rights

According to the UPOV, PBR allow breeders the exclusive right to sell seed or propagating material of their new varieties over a given number of years, although these varieties can still be used without restriction for research and further breeding ('breeders' exemption'). The number of countries that provide legal protection to plant varieties through PBR has increased substantially over the past ten years. While most western European countries, Australia, Canada, New Zealand and the United States of America already had PBR systems in place prior to the publication of the first SoW report, most countries in Africa, Asia, Latin America and the Caribbean, Eastern Europe and the Near East that have enacted PBR legislation have done so in the last decade.

The move to enact PBR legislation largely results from the TRIPS Agreement of the WTO that requires countries to provide for the protection of plant varieties either by patents or by an effective *sui generis* system or by any combination thereof (Article 27.3). Although there is no mention of UPOV in the TRIPS Agreement, the UPOV *sui generis* models are widely considered to meet the requirements of TRIPS and as a result, the number of countries that have joined UPOV almost doubled between 1998 and 2007, reaching 68 in February 2010.

The increasing membership of UPOV is also a consequence of a number of free-trade agreements that have been concluded that extend standards of IPR protection beyond the TRIPS requirements, for instance by making explicit reference to UPOV.

Africa, Burkina Faso, Cameroon, Kenya and South Africa, have all implemented PBR legislation, while four other countries have developed a national *sui generis* plant variety protection (PVP) system.[13] Six other countries[14] are in the process of developing or approving such regulations. At the regional level, the African Intellectual Property Organization (Organisation africaine de la propriété intellectuelle/ African Intellectual Property Organization, OAPI) revised the 1999 Bangui Agreement that governs the common intellectual property regime of its 16 Member States.[15] The new Agreement establishes, in its Annex X, a uniform PVP system that conforms with UPOV and foresees that the OAPI Member States will join UPOV by depositing an instrument of accession to the 1991 Act. In addition, the African Regional Industrial Property Organization (ARIPO) is currently drafting a regional PVP system.

In Asia and the Pacific, seven countries[16] have implemented PBR and eight other countries have developed a national *sui generis* PVP system,[17] 13 of these having done so in the last decade. The Philippines and Singapore have initiated the procedure for accession to UPOV and Nepal is currently drafting a bill on PVP.

In the Americas, 15[18] of the 34 countries in Latin America and the Caribbean have PBR legislation in place and six others[19] have developed national *sui generis* PVP systems. Guatemala and Saint Vincent and the Grenadines have developed draft legislation. In all countries except Argentina, Chile, Colombia, Cuba and Paraguay, the legislation has been adopted since the publication of the first SoW report. At the subregional level, the five Member States of the Andean Community adopted Decision 345 on Common Provisions on the Protection of the Rights of Breeders of New Plant Varieties that was modelled according to the UPOV Convention of 1991 (see Section 6.4).

All European countries have put in place or drafted national legislation on PBR or PVP except Greece, Lichtenstein, Luxembourg, Monaco and San Marino. While most Western European countries adopted such legislation before 1996, many amendments to the original laws and regulations have been made over the past decade. Most Eastern European countries have been involved more recently, with more than half of them having enacted laws in the last decade. At the European Union level, the Council Regulation No. 2100/94 on Community plant variety rights provides for the protection of PBR throughout the territory of the 27 European Union Member States in addition to national systems already in place.

Twenty-one of the 30 countries in the Near East region have adopted either PBR or a national *sui generis* PVP system,[20] the large majority having done so in the last decade. The Commonwealth of Independent States (CIS) countries adopted an agreement on the legal protection of plant varieties including the examination process in 2001 aiming to foster cooperation in that field.

5.4.3.2 Patents

At the time when the first SoW report was under preparation, the issue of patenting varieties or parts of varieties (e.g. genes or traits) and biotechnological processes (e.g. transformation), had only recently begun to emerge. Since then it has become the subject of much debate, especially as a result of increased adherence to the TRIPS Agreement. While parties are allowed to exclude from patentability "plants and animals other than microorganisms, and essentially biological processes for the production of plants and animals other than non-biological and microbiological processes", they must provide "by patents or by an effective *sui generis* system or by any combination thereof", for the protection of plant varieties. Part of the controversy arises from the fact that patents are generally claimed not for a single variety, as is the case with PBR, but for a whole class of varieties or even a trait within a whole species. Furthermore, while patents applied to plant varieties generally include a limited research exemption, unlike the situation with PBR and UPOV, they generally do not include either a breeder's exemption or a farmer's privilege. There are, however, exceptions to this, for example in France, Germany and Switzerland.

Today, relatively few countries allow patent protection for new crop varieties. However, the patent system is widely used in the United States of America, at least in part because of concerns that the UPOV 'farmers' privilege' results in insufficient protection. Australia and Japan also offer forms of patent protection for new crop varieties. In Japan, for example, the novelty requirement for patentability is interpreted in such a way that new varieties that exceptionally show breakthrough improvements can be protected with a patent, whereas others can only be protected by PBR.

In 1998, the European Union adopted Directive 98/44/EC on the Legal Protection of Biotechnological Inventions that allows patents to be awarded for a wide range of biotechnological materials and processes, including products containing or consisting of genetic information, however, it excludes plant varieties from patentability. The Directive provides for certain exemptions, in particular the farmers' exemption allowing small-scale farmers to freely use products harvested from specified plant varieties for propagation or multiplication on their own farm.

Whereas several emerging countries such as China and India have recently amended their patent laws to comply with TRIPS requirements and, in particular, to make microorganisms patentable, most developing countries, especially in Africa, consider that life forms cannot be patented and that plant varieties should be protected through *sui generis* systems. Patents on plants are not allowed in Latin American countries.

5.4.4 Farmers' Rights

While the issue of Farmers' Rights was a topic of extensive discussion prior to the publication of the first SoW report, it has since become even more hotly debated, particularly around the time of the final negotiations of the ITPGRFA (see Chapter 7). The importance of farmers as custodians and developers of genetic diversity for food and agriculture was recognized in the ITPGRFA through the provisions of Article 9 on Farmers' Rights. The Article recognizes that the responsibility for realizing Farmers' Rights, as they relate to PGRFA, rests with national governments. Such rights are seen to include: the protection of traditional knowledge relevant to PGRFA; the right of farmers to equitably share benefits that result from their use; their right to participate in making decisions at the national level on matters related to the conservation and sustainable use of PGRFA; and the right of farmers to save, use, exchange and sell farm-saved seed/propagating material, subject to national law. While all Contracting Parties of the ITPGRFA are legally bound by it, they are free to determine how they will implement the Farmers' Rights provisions at the national level.

The state of national implementation of Farmers' Rights is the focus of a recent study by the Fridtjof Nansen Institute in Norway.[21] The study describes examples of projects or activities that have resulted in substantial achievements in each of the areas referred to in the previous paragraph. Some of these involve national legislation; others focus more on civil society initiatives. Examples of such initiatives include the movement to resist increasing the scope of breeders' rights in Norway and the creation of a registry of rice varieties maintained at the community level in the Philippines, as a way of protecting traditional knowledge and farmers' varieties against misappropriation.

Although Farmers' Rights do not deal with the protection of IP *per se*, they are often regarded as a counterpart to it and countries that have enacted legislation promoting such Farmers' Rights have generally done so within their PVP legislation. At least ten countries have reported that they have adopted regulations covering one or more aspects of Farmers' Rights and several others are currently drafting legislation in this area. Many other countries do not deem it necessary to enact specific legislation of Farmers' Rights but meet their obligations under the ITPGRFA through existing mechanisms such as PBR or national participatory decision systems.

Even before the concept of Farmers' Rights was formally adopted in the ITPGRFA, a number of countries including Bangladesh, India and Thailand had already implemented legislation that protected Farmers' Rights in terms of the right to save, use, exchange and sell farm-saved seeds, participate in making decisions and, in the case of India, introduced a 'Gene Fund' financed by all users, including farmers, to support farmers who maintain genetic resources (see Box 5.2).

Africa, Ethiopia, Ghana, Malawi and Namibia are currently developing specific regulations on Farmers'

Box 5.2
India's Protection of Plant Varieties and Farmers' Rights Act of 2001

The 2001 Act protects the rights of farmers to save, use, sow, re-sow, exchange, share and sell their farm produce, including seed, of a variety protected by breeders' rights, provided that they do not sell branded seed packaged and labelled as a seed variety protected under the Act.

The Act provides for the registration of farmers' varieties on a par with breeders' varieties. Farmers' varieties are required to meet the same criteria of distinctiveness, uniformity and stability, but are not required to meet the criterion of novelty. It also protects the rights of farmers by requiring breeders and other persons applying for the registration of varieties under the Act to declare that the genetic material acquired for developing the new variety has been lawfully acquired and to disclose any use of genetic material conserved by tribal or rural families in the development of the registered variety. Claims for compensation may be made where it is found that the tribal or rural communities have contributed material used in the development of the variety. The Act provides for claims for benefit sharing to be made after the publication of certificates of registration of new varieties. Where benefit sharing is ordered by the responsible governmental authority, the money is to be paid into the National Gene Fund. Farmers who conserve or improve landraces or wild relatives of economic plants are eligible to receive an award from the Gene Fund.

Rights and Ethiopia has already implemented some aspects of Farmers' Rights in its Access to Genetic Resources and Community knowledge and Community Rights Proclamation No. 482/2006.

In the Americas, Costa Rica has addressed the issue of Farmers' Rights by establishing a Small Farmers Board in 1998 as a member of the National Commission for the Management of Biodiversity, which has the function of formulating national policies on the conservation and sustainable use of biodiversity. Other countries have addressed some aspects of Farmers' Rights, such as Brazil, in its PVP act and seed law, Cuba and Paraguay.

In Asia and the Pacific, in addition to Bangladesh, India and Thailand, Nepal and the Philippines are currently developing draft Farmers' Rights laws. In Malaysia, the Protection of New Plant Varieties Act of 2004 seeks to introduce more flexibility into the requirements for the registration of farmers' varieties. While reiterating the normal criteria for professionally bred varieties, i.e. that they must be new, distinct, uniform and stable, the Act exempts new varieties bred or discovered and developed by farmers, local communities and indigenous people, from the requirements of stability and uniformity; farmers' varieties only need to be distinct and identifiable. The Act also allows acts that are carried out privately on a non-commercial basis, thus allowing small farmers to continue their normal practices of using and exchanging farm-saved seed.

In the Near East, no country has yet enacted specific legislation on Farmers' Rights[22] although the Islamic Republic of Iran and Turkey are currently developing specific laws in this area. However, the Islamic Republic of Iran has already implemented some aspects of Farmers' Rights in broader legislation. Pakistan has drafted legislation on access to biological resources and community rights that addresses some aspects of Farmers' Rights.

In most industrialized countries, where farmers' organizations tend to be well connected to policy processes, the issue of Farmers' Rights has not taken on as much importance and the debate on the use of farm-saved seed is generally held in the framework of IPR and seed legislation. In Europe, while only Italy has adopted specific regulations on Farmers' Rights, many other countries, for example, Austria and Estonia, consider that they have adequately addressed, or are in the process of addressing, aspects of Farmers' Rights in other legislation and regulations as appropriate. However, several countries in the region are now considering how they might best support the realization of Farmers' Rights in developing countries.

5.4.5 Biosafety

Biosafety has been defined as the "the avoidance of risk to human health and safety and to the conservation of the environment, as a result of the use for research and commerce of infectious or genetically modified organisms (GMOs)".[23] Concerns over biosafety have grown substantially over the last decade, in parallel with the expanding use of GMOs and the impact of infectious agents. Factors that have contributed to this increasing concern have included outbreaks of transboundary diseases affecting animals, plants and people; heightened awareness of the potential impact of GMOs on biological diversity; increased concern over general food safety issues; and greater attention to the impact of agriculture on environmental sustainability.

Since the first SoW report was published, biosafety has emerged as an important issue and many countries in all regions have now either adopted national biosafety regulations or frameworks, or are currently developing them. At the international level, the adoption of the Cartagena Protocol on Biosafety of the CBD[24] in 2000 marked a milestone in cooperation on the safe transfer, handling and use of GMOs. The Cartagena Protocol entered into force in 2001 and as of February 2010, had been ratified by 157 countries. It now provides the international legal framework that underpins the current development of national biosafety regulations in many countries. In spite of concerns over the capacity of some developing countries to fully implement such regulations, it is likely that they will lead, in the near future, to a wider adoption of GM-varieties.

Over the past decade many countries have adopted national regulations and biosafety frameworks that aim to reduce risks to the environment and human health. The United States of America has adopted an incremental approach to the regulation of biotechnology, based on the regulation of the characteristics of a product, rather than on the assumption that products of biotechnology automatically need special regulations. In Europe, the application of the 'precautionary principle' can block use of a GMO until evidence is presented that the transgenic organism is safe. This has limited the number of approvals that have been granted for the commercial use of GMOs and even fewer approvals for their deliberate release into the environment. At the European Union level, Directive 2001/18/EC on the release of GMOs was adopted in 2001. At the national level, all 27 European Union Member States have enacted biosafety or biotechnology-related laws and among non-European Union European countries, eight[25] have done so as well. Albania, Armenia, Bosnia and Herzegovina, Croatia and Georgia are currently drafting biosafety legislation.

The development and adoption of biosafety frameworks and regulations in developing countries is increasing rapidly, supported in many cases by foreign donors or regional intergovernmental agencies. Many African countries[26] have adopted formal biosafety measures while 33 other African countries[27] are in the process of developing or adopting such regulations. In the Americas, all Central and South American countries have adopted some form of regulation or guidelines on biosafety, with the exception of Ecuador and Nicaragua and these are both currently drafting such regulations. Of the Caribbean nations, only Belize and Cuba have enacted biosafety laws, although in 12 other countries,[28] legislation is being formulated.

In Asia and the Pacific, legislation or guidelines on biosafety are in place in eleven countries[29] and draft regulations are under development in fifteen,[30] while in the Near East, Cyprus, Egypt, Israel, Kazakhstan, Malta, Pakistan, the Syrian Arab Republic and Tajikistan have adopted biosafety legislation and it is under development in twelve other countries.[31]

5.5 Changes since the first State of the World report was published

Although it has been patchy, progress has been made overall since the publication of the first SoW report in the strengthening of national programmes, the development of training capacity and particularly, in the adoption of national policies, laws and regulations relevant to the conservation and use of PGRFA. Nevertheless, as indicated above, there is still a way to go in each of these areas:

- although the first SoW report classified national programmes into three categories, since then it has become clear that such a typology is too simplistic and that there is huge heterogeneity among national programmes in terms of their goals, functions, organization and structure;
- there has been considerable progress in establishing national programmes, at least in part as a consequence of the adoption of the ITPGRFA and GPA. Of the 113 countries that provided information for both the first and second SoW reports, 54 percent had a national programme in 1996 whereas 71 percent currently have one;
- even in countries with active and well-coordinated national programmes, certain elements are still often missing. National, publicly accessible databases, for example are still comparatively rare as are coordinated systems for safety duplication and collaborative public awareness;
- the new NISM on the implementation of the GPA was mentioned by many country reports as a valuable tool for establishing and improving national programmes;
- although several countries, especially in Europe, reported that overall funding has increased since 1996, many of the country reports noted that their national programme received inadequate and unreliable funding, making it difficult to plan over multiple years;
- while in most countries national government institutions are the principal entities involved in national programmes, the inclusion of other stakeholders has expanded, especially of private for-profit companies, NGOs, farmer organizations and educational institutions;
- public-private research and development partnerships appear to have grown in importance, especially in plant breeding and biotechnology, not only in developed but also in many developing countries;
- universities have become increasingly involved in research on PGRFA, especially in the application of biotechnology to conservation and crop improvement;
- new education and training opportunities have opened up in several countries and more universities now offer M.Sc. and Ph.D. courses. Collaboration in training between national programmes and international and regional organizations has become stronger and new training materials have been developed;
- since the first SoW report was published, most countries have enacted new national phytosanitary legislation, or revised old legislation, in large part in response to the adoption of the revised IPPC in 1997;
- there have been three main trends in national seed legislation and policy over the past decade: the emergence of voluntary arrangements on seed certification and variety release; the growing use of accreditation principles alongside official national rules and standards; and the regional harmonization of seed laws;
- most developing and Eastern European countries that now provide legal protection to new plant varieties, have done so in the last decade. A few others are currently drafting legislation;
- the importance of farmers as custodians and developers of genetic diversity was recognized in the ITPGRFA through the provisions of Article 9 on Farmers' Rights. A few countries have adopted regulations covering one or more aspects of Farmers' Rights;
- since the first SoW report was published, biosafety has emerged as an important issue and many countries have now either adopted national biosafety regulations or frameworks, or are currently developing them. As of February 2010, 157 countries and the European Union had ratified the Cartagena Protocol on Biosafety.

5.6 Gaps and needs

Key gaps and needs for the future include:

- whether a national PGRFA programme is centralized, sectorial, or even regional, it is vital that there be effective coordination and collaboration among its elements, including ministries, government institutions, universities, private companies, NGOs, farmers' groups and others;

- the links between institutions concerned primarily with the conservation of PGRFA and those concerned primarily with its use are weak or even absent in many countries and need to be strengthened;
- many countries lack nationally endorsed strategies and plans for the conservation and use of PGRFA. These are important for setting priorities, distributing roles and responsibilities and allocating resources;
- almost half of the country reports indicated that they had no NISM for PGRFA, and thus lack an effective tool for promoting both internal as well as international collaboration;
- there is a need to assess human resource capacity and needs in the various aspects of conserving and using PGRFA and to use this as the basis for drawing up national (and ultimately regional and global) education and training strategies;
- in spite of the expansion of education and training opportunities over the past decade, they remain inadequate overall. More opportunities are needed both for the training of young researchers and development workers and for upgrading the knowledge and skills of existing staff;
- special efforts are needed in many countries to educate senior managers and policy-makers about the complex legal and policy issues relating to the conservation, exchange and use of PGRFA;
- greater efforts are needed to include the concept of conservation biology, especially with respect to agrobiodiversity, in biological sciences curricula at all levels;
- efforts to raise additional resources to support work on PGRFA require new and innovative approaches, better coordination in fundraising among the different institutions and sectors and greater efforts to increase awareness among policy-makers, donors and the private sector as to the actual and potential value of PGRFA;
- greater attention needs to be paid in many countries to the development of appropriate, non-conflicting and complementary national policies and legislation relating to the conservation, exchange and use of PGRFA, including such areas as phytosanitary regulations, IP protection, Farmers' Rights and biosafety taking into account the needs and concerns of all stakeholders.

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Chapter 6

The state of regional and international collaboration

6.1 Introduction

The previous chapter of this report described the current status of national programmes and trends that have occurred since the first SoW report was published. This chapter will describe and attempt to analyse developments at the international level.

Overall there has been a dramatic increase in international activities since 1996, in all fields related to the conservation and use of PGRFA. Many new regional and crop-specific networks and programmes have been set up, at least in part in response to the priorities for action contained in the GPA. The CBD and the ITPGRFA have both served to give prominence to the need for greater international collaboration. Many programmes set up to promote various aspects of the Convention or Treaty, involve collaboration among multiple partners. For example, the creation of the MLS for ABS under the ITPGRFA has greatly strengthened awareness of needs and opportunities in this area and although it is not yet possible to assess its impact quantitatively, there are signs that cooperation is expanding with respect to germplasm exchange.

Section 1.4 describes the extent of interdependence among all nations with respect to PGRFA. Such interdependence, arising from the spread of crops around the globe from their centres of origin, makes international cooperation not just desirable but essential if the full value of PGRFA is to be realized. Awareness among policy-makers and the general public of the importance of PGRFA and the extent of interdependence has grown considerably in recent years, at least in part because of high-profile initiatives such as the establishment and opening of the SGSV.

Given the very large number of regional and international networks, programmes, institutions and other cooperative initiatives involving PGRFA that are now in existence, it is not possible to mention them all and this chapter does not attempt to provide a comprehensive coverage. Indeed, given the huge diversity in types of collaborative arrangements, it is even difficult to classify them into any consistent and useful typology. This chapter thus presents major developments that have occurred since the first SoW report was published, with respect to multicrop associations and networks, crop-specific networks, thematic networks, regional and international organizations and programmes, bilateral programmes, international and regional agreements and funding mechanisms. While an attempt has been made throughout the chapter to assess the extent of progress since 1996, this is made difficult by the fact that the information in the first SoW report is all of a qualitative nature and it has not been possible to get any quantitative data on the current status of regional and international cooperation or on trends over recent years. The chapter concludes with a review of major changes that have occurred since 1996 and lists some ongoing gaps and needs for the future.

6.2 PGRFA networks

A very large number of networks currently address one or more aspects of PGRFA. Many of these have come into existence since the first SoW report was published. While all aim to promote and support collaboration among partners for a common purpose, there is a huge diversity in their objectives, size, focus, geographic coverage, membership, structure, organization, governance, funding, etc. For ease of reference, the term ‘network’ will generally be used to describe such collaborative arrangements, irrespective of whether they are formally called a network, or have adopted a different title such as association, alliance, cooperative, consortium or coalition.

Networks are very important for promoting cooperation, sharing knowledge, information and ideas, exchanging germplasm and for carrying out joint research and other activities. They support the sharing of expertise and help compensate or provide backstopping in cases where certain network participants lack the critical mass to carry out particular activities. They enable synergies to be captured when different partners have different and complementary skills and capacities. Collaboration is also critical to gaining maximum benefits under legal and policy instruments such as the CBD, GPA and ITPGRFA and to meeting associated obligations.

Networks in the PGRFA field generally fall into one of three broad categories:

a) those that focus on conservation, often regional and multicrop in nature;
b) those that focus on one of a few specific crops and may be either regional or global in scope. The primary objective of many such networks is to facilitate crop improvement;
c) those that address a particular topic or theme relating to PGRFA, across crops, such as seed systems, genomics, taxonomy, or *in situ* conservation.

Overall, good progress has been made since the first SoW report was published in all three groups of networks. The following sections do not attempt to provide comprehensive coverage or description of all relevant networks, but rather, give a snapshot of some of the more significant changes that have occurred since 1996.

6.2.1 Regional multicrop PGRFA networks

Since 1996, the number of regional and subregional PGRFA networks has grown so that all countries in all areas of the world are now eligible to join one or more of them. They bring together the heads of national genetic resources programmes, genebank managers and others concerned with conservation and in many cases also include various users of PGRFA, such as plant breeders, NGOs and the private sector. In many cases, these networks are linked to the regional fora, which in turn are key participants in the GFAR, described later. Table 6.1 lists the main PGRFA networks that fall into this category. Some of the major developments that have taken place over recent years in these networks, as well as a few other regional multicrop networks, are described for each region. Overall, the networks have tended to be most active in the areas of training and documentation and have taken on a leadership role in the development of regional PGRFA conservation strategies, under an initiative of the GCDT.

Africa

Networking in PGRFA has expanded considerably in Africa since the publication of the first SoW report. FARA[1] was created in 2002 as an umbrella organization bringing together and supporting the three African subregional associations concerned with agricultural research for development: the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), the West and Central African Council for Agricultural Research and Development (CORAF/WECARD) and the SADC, Food, Agriculture and Natural Resources Directorate (FANR). These three entities provide the umbrella for the three main PGRFA networks in Sub-Sahara Africa: EAPGREN, the Genetic Resources Network for West and Central Africa (GRENEWECA) and SADC, Plant Genetic Resources Network (PGRN):

- the East African Plant Genetic Resources Network (EAPGREN):[2] EAPGREN, hosted by ASARECA, became operational in 2003 with a membership comprising ten countries.[3] The Nordic Genebank (NGB) and Bioversity International provide technical backstopping. It has undertaken a wide range of activities in Eastern Africa including the exchange of information, training, awareness raising and policy advocacy. An information and documentation centre is currently being set up and greater collaboration among genebanks, farmers and other end-users is being promoted. A regional strategy for PGR has been developed under the GCDT initiative and key *ex situ* collections have been identified that require urgent regeneration as mentioned in the Ethiopia, Kenya and Uganda country reports;
- GRENEWECA: This network was established in 1998 under the CORAF/WECARD.[4] Various meetings have been held e.g. in Ibadan, Nigeria in 2004 and in Ouagadougou, Burkina Faso, in 2006 to discuss regional strategies. Funding support has come from Bioversity International and GCDT mainly but overall, GRENEWECA has not had the same level of external funding support as the other African regional PGRFA networks. The establishment of four nodal centres of excellence has been proposed as a means of strengthening PGR activities at the subregional level;
- SADC Plant Genetic Resources Network (SADC-PGRN):[5] Although established in 1989, the SADC-

TABLE 6.1
Regional multicrop plant genetic resources networks around the world

Region	Subregions included (all or part)	Network title (acronym)	Umbrella regional research association or forum	Institution responsible for coordination
Africa	East Africa, Madagascar	The East African Plant Genetic Resources Network (EAPGREN)	ASARECA	ASARECA
Africa	West Africa, Central Africa	Genetic Resources Network for West and Central Africa (GRENEWECA)	CORAF/WECARD	Bioversity International
Africa	Southern Africa, Madagascar, Mauritius	SADC Plant Genetic Resources Network (SADC-PGRN)	SADC	SPGRC
Americas	South America	The Andean Network on Plant Genetic Resources (REDARFIT)	PROCIANDINO	INIA-Peru (2009)
Americas	Central America	Mesoamerican Network on Plant Genetic Resources (REMERFI)	SICTA	SICTA
Americas	Caribbean	The Caribbean Plant Genetic Resources Network (CAPGERNET)	PROCICARIBE	CARDI
Americas	North America	The Plant Genetic Resources Network for North America (NORGEN)	PROCINORTE	IICA
Americas	South America	The Plant Genetic Resources Network for the Southern Cone (REGENSUR)	PROCISUR	INIA-Uruguay (2009)
Americas	South America	The Amazonian Network for Plant Genetic Resources (TROPIGEN)	PROCITROPICOS	PROCITROPICOS
Asia and the Pacific	East Asia	Regional Network for Conservation and Use of Plant Genetic Resources in East Asia (EA-PGR)	APAARI	Bioversity International
Asia and the Pacific	Pacific	The Pacific Agricultural Plant Genetic Resources Network (PAPGREN)	SPC	SPC
Asia and the Pacific	South Asia	South Asia Network on Plant Genetic Resources (SANPGR)	APAARI	Bioversity International
Asia and the Pacific	Southeast Asia	Regional Cooperation in South East Asia for PGR (RECSEA-PGR)	APAARI	Bioversity International
Europe	Europe	European Cooperative Programme for Genetic Resources (ECPGR)		Bioversity International
Europe	Nordic region	The Nordic Genetic Resources Centre (NordGen)	Nordic Council of Ministers	NordGen
Europe	Southeast Europe	South East European Development Network on Plant Genetic Resources (SeedNet)		Swedish Biodiversity Centre
Near East	Central Asia and Caucasus	The Central Asian and Caucasus Network on Plant Genetic Resources (CACN-PGR)	CACAARI	Bioversity International
Near East	West Asia and Southeast Asia	West Asia and North Africa Genetic Resources Network (WANANET)*	AARINENA	ICARDA

*Now defunct, a new PGRFA network is being established by AARINENA

PGRN has continued to grow since the publication of the first SoW report. Its membership has risen to 14 countries and the SADC SPGRC, which now comes under the responsibility of SADC-FANR, provides coordination. Major activities over the past decade have included the further development of the central base collection, capacity building in member countries and the development of a documentation and information system on the *ex situ* holdings of member countries. It has also established several working groups, and a regional conservation strategy, developed under the GCDT initiative, has been published.

Americas

The Inter-American Institute for Cooperation on Agriculture (IICA) has established a system of subregional networks to promote collaboration in agricultural research and technology development throughout the Americas. Currently these are: Programa Cooperativa de Innovación Tecnológica Agropecuaria para la Región Andina (PROCIANDINO) (Andes), Agricultural Science and Technology Networking System (PROCICARIBE) (Caribbean), Cooperative Program in Agricultural Research and Technology (PROCINORTE) (North America), Cooperative Programme for the Technological Development of the Agrofood and Agro-industry in the Southern Cone (PROCISUR), Programma Cooperativo de Investigación y Transferencia de Tecnología para los Trópicos Suramericans (PROCITROPICOS) and the Sistema de Integracion Centroamericana de Tecnologia Agricola (SICTA). They provide an umbrella for the six subregional networks on PGRFA described below and listed in Table 6.1: REDARFIT, CAPGERNET, NORGEN, Plant Genetic Resources Network for the Southern Cone (REGENSUR), TOPIGEN and Mesoamerican Network on Plant Genetic Resources (REMERFI) respectively. While many of these PGRFA networks were established prior to the publication of the first SoW report, recent years have seen relatively little major progress due to resource constraints as pointed out in the Costa Rica country report. However, new networks were established for the Caribbean (CAPGERNET) in 1998 and for North America (NORGEN) in 1999. An important development at the regional level has been the creation of the Regional Forum for Agricultural Research and Technology Development (FORAGRO):[6] Established in 1997, FORAGRO has a secretariat housed at IICA in Costa Rica. It serves all countries of the Americas and seeks to promote dialogue and cooperation in agricultural research. Its membership includes the PROCIs as well as representatives from NARS, NGOs, the private sector and others. PGRFA is an important thematic area of FORAGRO, which played a lead role in developing the PGRFA conservation strategy for the Americas under the GCDT initiative.

- the Caribbean Plant Genetic Resources Network (CAPGERNET): Established in 1998, CAPGERNET consists of 28 Caribbean countries and receives technical support from the Caribbean Agricultural Research and Development Institute (CARDI), IICA, Centre technique de coopération agricole et rurale (CTA) and Bioversity International. Activities have included capacity building, preparing PGRFA inventories, developing an information system and germplasm exchange. It held a workshop in May 2007 in Trinidad and Tobago as an input to the regional PGRFA conservation strategy. It is also coordinating the regeneration of collections of beans in Cuba, cassava in Guyana, yams in Guadeloupe and sweet potato in Trinidad and Tobago;
- the Plant Genetic Resources Network for North America (NORGEN): Operating under the aegis of PROCINORTE, Canada, Mexico and the United States of America are focusing collectively through NORGEN on information exchange, training, collecting bean wild relatives in Mexico and implementing research projects in collaboration with other networks. NORGEN has provided support to several developing countries to enable scientists and technicians to participate in meetings and training courses in North America; the Andean Network on Plant Genetic Resources (REDARFIT):[7] The Andean network involves five countries[8] and operates under the aegis of PROCIANDINO. Major activities carried out since the first SoW report was published have included (i) workshops on PGRFA management; (ii) training courses on cherimoya, GIS and characterization, risk management and

germplasm enhancement; (iii) a symposium on genetic resources in the Americas; (iv) collaborative research projects on tree tomatoes, cherimoya, native potatoes and *Lycopersicon* spp.; and (v) a programme on germplasm regeneration;

- the Plant Genetic Resources Network for the Southern Cone (REGENSUR): This network, comprising six countries,[9] is a network of PROCISUR that seeks to strengthen the work of the national programmes in the Southern Cone. Over the last decade, its activities have included: (i) training on germplasm enhancement, documentation, genebank management, *in situ* conservation and seed-pathology; (ii) hosting a workshop to develop the regional PGRFA conservation strategy for the Americas; and (iii) carrying out collaborative research on maize, wheat and vegetables.
- the Mesoamerican Network on Plant Genetic Resources (REMERFI); This network of eight countries[10] in Central America has been relatively inactive since 1996 although activities carried out in recent years have included: (i) training and capacity building on documentation; (ii) research projects on seeds; (iii) genetic resources of *Annonaceae* and *Sapotaceae*; and (iv) the conservation and use of native neo-tropical crops and their wild relatives;
- the Amazonian Network for Plant Genetic Resources (TROPIGEN): Operating under PROCITROPICOS, this network has eight member countries.[11] Activities since 1996 have included: characterization of underexploited vegetable and fruit crops; germplasm evaluation; identifying gaps in collections; prioritizing species for PGR research and management; developing a policy framework for access and benefit-sharing; information exchange and strengthening links between genebanks and breeding programmes. It has a major focus on capacity building.

Asia and the Pacific

Almost all of the subregional networks in the Asia and the Pacific region concerned with PGRFA have been initiated and/or are being facilitated by Bioversity International, in collaboration with FAO and the main regional association for agricultural research, the Asia-Pacific Association of Agricultural Research Institutions (APAARI).[12] The latter has also been active in its own right in supporting activities on PGRFA and published a regional report on PGR-related activities in 2000, provided a neutral platform for discussion of policy related issues and endorsed the regional PGRFA conservation strategy for Asia under the GCDT initiative.

Although most of the subregional PGRFA networks were established prior to the publication of the first SoW report, some, particularly the South Asia Network on Plant Genetic Resources (SANPGR), have made very substantial progress in recent years and a new network has been established for the Pacific.

- the Regional Network for Conservation and Use of Plant Genetic Resources in East Asia (EA-PGR):[13] EA-PGR promotes collaboration among its five member countries[14] in collecting, conservation, exchange, documentation/information and training. Major accomplishments since the first SoW report was published have included: (i) establishing the CAAS China-Bioversity Centre of Excellence for training on *in vitro* conservation, cryopreservation and molecular characterization; (ii) developing a subregional strategy as part of the overall South, Southeast and East Asia (SSEEA) regional conservation strategy; (iii) joint collecting, characterization and evaluation of millets in the Democratic People's Republic of Korea and Mongolia; (iv) joint studies on genetic diversity of adzuki bean, Job's tears and perilla in China, Japan and the Republic of Korea; and (v) establishing a network web site;
- the Pacific Agricultural Plant Genetic Resources Network (PAPGREN):[15] Established in 2001, PAPGREN comprises 13 nations[16] and is coordinated by the Land Resources Division of the SPC, Suva, Fiji in collaboration with Bioversity International. In addition to convening a number of key meetings and workshops, major accomplishments have included: (i) developing a directory of PGR collections; (ii) drawing up a regional conservation strategy; (iii) providing advice on policy issues; (iv) supporting emergency collecting and characterization; (v) public awareness activities; and (vi) developing a web site and blog;

- the Regional Cooperation in South East Asia for PGR (RECSEA-PGR):[17] Established in 1993, RECSEA-PGR remained active in the period following the publication of the first SoW report, although activities have tended to be somewhat curtailed in recent years due to a lack of funding as Malaysia and Thailand indicate in their country report. The network, which comprises seven member countries,[18] aims to build and enhance national research capacity in Southeast Asia through collaboration in areas such as policy, database development and sharing information and expertise. RECSEA-PGR's major recent accomplishments have included inputs to the SSEEA regional conservation strategy under the GCDT initiative and the setting up of a PGR Policy Forum together with APAARI, aimed at drafting an SMTA applicable to all materials of common interest that are not included within Annex 1 of the ITPGRFA;
- SANPGR:[19] Accomplishments of this six-country[20] network over the past decade have included: (i) training on seed genebank management, GMS software and the genetic resources of tropical fruits; (ii) establishing a regional Centre of Excellence for training on *in vitro* conservation and cryopreservation at NBPGR, India; (iii) promoting post-graduate courses on PGR in India and Sri Lanka; (iv) establishing a web site; (v) developing the South Asia component of the SSEEA regional PGRFA conservation strategy; and (vi) the joint evaluation of finger millet in Bangladesh, Bhutan, India and Nepal. Several meetings have been held and the proceedings published. A Steering Committee was constituted in 2002 to oversee network activities and the implementation of action plans.

Europe

Collaboration among European PGR programmes has further strengthened since the publication of the first SoW report, as a result of increased support from many individual countries as well as from the European Union. Bioversity International has continued to host the secretariats of the ECPGR, the main network on PGRFA in Europe, as well as the European Forest Genetic Resources Network (EUFORGEN). In addition to ECPGR, the Nordic countries have a collaborative programme on genetic resources (NordGen) that includes a common genebank and a new networking programme on PGRFA was established in 2004 in Southeastern Europe.

- ECPGR:[21] ECPGR is a joint programme of about forty European countries[22] that aims to facilitate the conservation and use of PGRFA in Europe and strengthen links between Europe and elsewhere in the world. It is structured into nine networks (six crop networks and three thematic networks) and implements activities through working groups and task forces. ECPGR collaborates with regional programmes such as the European System of Cooperative Research Networks on Agriculture (ESCORENA). ECPGR members are currently setting up AEGIS,[23] a programme that aims to rationalize collections (see Section 7.3.3.2) as well as EURISCO,[24] a globally accessible catalogue, launched in 2003, that contains information on more than 1.1 million accessions;
- NordGen:[25] NordGen is an institution under the Nordic Council of Ministers.[26] It was established in 2008 through a merger of the Nordic Gene Bank, the Nordic Gene Bank for Farm Animals and the Nordic Council for Forest Reproductive Material;
- the South East European Development Network on Plant Genetic Resources (SeedNet): This network which was set up in 2004 operates in Southeast European countries and aims to promote the long-term conservation and use of PGR through creation of national programmes and gene bank facilities. The core of the network consists of a number of crop-specific and thematic working groups.

Near East

The Near East region, which includes Central Asia, the Caucasus, West Asia and North Africa (WANA), has seen both good progress and also some stagnation in the period since the first SoW report was published. In Central Asia and the Caucasus, the regional PGRFA network CACN-PGR has been brought under the auspices of the Central Asia and the Caucasus Association of Agricultural Research Institutions (CACAARI),[27] which was established in 2004.

- the Central Asian and Caucasian Network on Plant Genetic Resources (CACN-PGR):[28] This network, established in 1999, involves eight countries[29] and has nine crop working groups. It is backstopped jointly by ICARDA and Bioversity International. A regional database has been set up that includes passport data for almost 120 000 accessions and a regional PGR strategy has been developed with support from the GCDT;
- the West Asia and North Africa Genetic Resources Network (WANANET): WANANET was originally set up as a regional network to help strengthen PGRFA activities in WANA. Unfortunately, due to lack of resources it is currently defunct. A regional strategy for the conservation of PGRFA was developed in 2006 under the GCDT initiative, with technical support from ICARDA and Bioversity International, that highlighted the importance of networking in the region. The Association of Agricultural Research Institution in the Near East and North Africa (AARINENA)[30] has established a new network on PGR in 2008.

6.2.2 Crop-specific networks

There is a vast range of international crop-specific networks operating regionally or globally. Most have some aspect of crop improvement as their primary focus, although they may also involve the conservation of PGRFA. They range from relatively straightforward mechanisms for distributing breeding materials, multilocation testing and the sharing of information and results, to fully collaborative research networks in which the comparative advantages of the participating institutions are brought to bear on a common problem or issue. Many of the networks that have international germplasm distribution and collaborative testing as their primary focus are coordinated by the IARCs and some of these are mentioned in the section on international organizations below. A few examples are given here of new, crop-specific networks that have come into existence or have developed significantly since the first SoW report was published.

The International Network for Bamboo and Rattan (INBAR)[31] was established in 1997 to promote the improved production, processing and trade of bamboo and rattan. INBAR facilitates a global network of partners from the government, private and non-profit sectors in over 50 countries. The conservation and sustainable use of bamboo and rattan genetic resources are an important part of INBAR's programme.

In 2006, the CacaoNet[32] was launched as a network of institutions that collaborate in the conservation and use of cacao genetic resources. Its membership includes a wide range of international and regional public institutions as well as the Biscuit, Cake, Chocolate and Confectionery Association (BCCCA), the Cocoa Producers Alliance (COPAL), the International Cocoa Organization (ICCO), the International Group for the Genetic Improvement of Cocoa (INGENIC) and the World Cocoa Foundation (WCF).

The INIBAP established a number of regional networks on banana and plantain in the late 1980s and early 1990s. Since the first SoW report was published, a number of important changes have taken place. The Réseau Musa pour l'Afrique Centrale et Occidentale (MUSACO) was founded in 1997 at the invitation of the CORAF/WECARD and the Banana Research Network for Eastern and Southern Africa (BARNESA) became a network under the auspices of ASARECA. The Latin America and Caribbean Network (LACNET) was renamed the Plantain and Banana Research and Development Network for Latin America and the Caribbean (MUSALAC)[33] in 2000 and now operates under FORAGRO. Likewise, the INIBAP Asia-Pacific Network (ASPNET) was renamed the Banana Asia Pacific Network (BAPNET)[34] in 2002 and now operates under the auspices of APAARI. INIBAP itself was formally incorporated, together with the International Plant Genetic Resources Institute (IPGRI), within Bioversity International in 2006.

Within the Americas, the Latin American/Caribbean Consortium on Cassava Research and Development (CLAYUCA)[35] was established in 1999 as a regional mechanism to facilitate cassava research and development through the participation of stakeholders from both the private and public sectors. Located on CIAT's campus in Colombia, CLAYUCA is also building links between Latin America and the Caribbean and African countries for technology development, training, germplasm distribution and the dissemination of information.

Within the Near East, AARINENA has sponsored various crop-specific initiatives on PGRFA since 1996, including convening networks on date palm, olive and medicinal plants. The Interregional Network on Cotton in Asia and North Africa (INCANA) was established in 2002 with support from GFAR, AARINENA, APAARI, CACAARI, ICARDA and the Agricultural Research and Education Organization (AREO), the Islamic Republic of Iran.

In addition, several new crop networks have been established at the global level that aim to generate and share genomic information on particular crops or groups of crops. These include, for example, the International Coffee Genome Network (ICGN)[37] and the collaborative international Rice Genome Sequencing Project.

6.2.3 Thematic networks

As indicated above, many new thematic networks have been established in recent years that carry out cooperative activities relating to PGRFA. Again, these are far too numerous to cover in detail and just a few examples are presented here of networks that are either new or have undergone significant change since 1996.

Since 2001, three new networks have been established specifically to promote and support the development of the seed sector in Africa: the Africa Seed Network (ASN),[38] the SADC Seed Security Network (SSSN)[39] and the West Africa Seed Network (WASNET). In 2001, the New Partnership for Africa's Development (NEPAD) was created which, among other initiatives, promoted the establishment of four biosciences networks: Biosciences East and Central Africa (BECA), the West Africa Biosciences Network (WABNET), the South African Network for Biosciences (SANBio), as well as the North Africa Biosciences Network (NABNET). SANBio, as mentioned in the Zimbabwe country report, has been particularly active in the area of PGRFA, having devoted attention to creating facilities for conserving vegetatively propagated crops, molecular characterization and promoting regional collaboration.

Within the Americas, new thematic networks established since 1996 include: the Network on Plant Biotechnology in Latin American and the Caribbean (REDBIO) which promotes the use of biotechnology for crop improvement and genetic conservation and the Agricultural Innovation Network (RedSICTA), a networking project of IICA in cooperation with the Swiss Agency for Development and Cooperation (SDC). A key aim of RedSICTA is to improve seed production in Latin America and the Caribbean as illustrated in the Nicaragua country report.

NGOs have also played a greater role over the last ten years in networking. The Community Biodiversity Development Conservation (CBDC)[40] programme, for example, which involves a number of countries in Africa, Latin America and Asia, is spearheaded by several local and international NGOs. CBDC brings governmental institutions and NGOs together at the global, regional and national level and has major focus on the conservation, use, marketing and where necessary, restoration of traditional germplasm resources.

6.3 International organizations and associations with programmes on PGRFA

There is a large range of international and regional associations that, while not exclusively focused on PGRFA, nevertheless have significant programmes that involve PGR. Arguably, the two largest and most important of these are FAO and the CGIAR and developments in each of these are given in the following sections. This is followed by a brief consideration of developments that have taken place since the first SoW report in other international and regional organizations, in international fora and associations, in bilateral arrangements and within the NGO community.

6.3.1 FAO's initiatives on PGRFA

FAO has remained very active in promoting and supporting activities on PGRFA since the first SoW report was published and it has made significant progress in a number of key areas. It provides administrative, scientific and technical support to the work of both the secretariat of the CGRFA and the secretariat of the ITPGRFA.

The CGRFA, established as an intergovernmental forum in 1983, has overseen the creation and development of the Global System for the Conservation and Sustainable Use of PGR. This system, managed and coordinated by FAO, aims to ensure the safe conservation and promote the availability and sustainable use of PGR. The first SoW report described the major elements of the system and only the most significant developments are reported below. The GPA provides the overall framework or blueprint for the Global System and the periodic SoW reports provide a mechanism for monitoring progress and evaluating the system. The basic agreement and intergovernmental policy instrument that underpinned the development of the Global System was, until 2004, the International Undertaking on Plant Genetic Resources for Food and Agriculture. This was superseded when the ITPGRFA came into force. The ITPGRFA is covered in considerable detail in Section 7.2.1 and is only mentioned briefly below:

- CGRFA:[41] It is a forum for governments to discuss and negotiate matters relevant to genetic resources for food and agriculture. It reviews and advises FAO on policy matters, programmes and activities. Currently, 168 states and the European Union are members of the CGRFA, which is the only intergovernmental body that specifically deals with all components of biological diversity for food and agriculture. The CGRFA started out as the Commission on Plant Genetic Resources and only in 1995 took on responsibility for other components of agricultural biodiversity. In 1997, recognizing the separate needs of the different components, the CGRFA established two international technical working groups, one on PGR and the other on animal genetic resources. The CGRFA provided the forum for the successful negotiation of the ITPGRFA, a legally-binding international agreement that came into force in June 2004 (see Section 7.2.1). The CGRFA acted as the Interim Committee for the ITPGRFA until 2006, when its own Governing Body was established. The CGRFA also developed the first GPA and is responsible for monitoring its implementation. At its Eleventh Regular Session in June 2007, the CGRFA adopted a rolling ten-year programme of work, which foresees the publication of the first report on the SoW's Biodiversity for Food and Agriculture and the integration of the ecosystem approach into biodiversity management in agriculture, forestry and fisheries;
- International Network of *Ex Situ* Collections: As described in the first SoW report, in 1994, eleven IARCs of the CGIAR signed agreements with FAO, acting for the CGRFA, bringing their *ex situ* germplasm collections within the International Network of *Ex Situ* Collections. These agreements and indeed the International Network as a whole, were superseded in 2006 when the centres signed further agreements with FAO, this time acting on behalf of the Governing Body of the ITPGRFA. The new agreements bring all the *ex situ* collections of PGRFA held by the centres (approximately 650 000 accessions of the world's most important crops) within the MLS of ABS of the ITPGRFA;
- GIPB:[42] launched in 2006, GIPB is an initiative whose primary aim is to strengthen and support the capacity of developing countries to conduct and benefit from plant breeding. It is a partnership that involves many agricultural research, education and development institutions. Further information on GIPB can be found in Sections 4.4 and 7.3.2;
- Agreement with the CBD: one area in which significant progress has been made is in the strengthening of the relationship with the CBD. A Memorandum of Cooperation was signed between FAO and the CBD in 2006, putting in place a practical framework for increased synergy between the two organizations in the area of biodiversity of relevance to food and agriculture.

6.3.2 The International Agricultural Research Centres of the Consultative Group on International Agricultural Research[43]

The first SoW report described the then 16 - now 15[44] - IARCs supported by the CGIAR. Over the past few years, the CGIAR System has been going through a major process of reform in its vision, governance, funding and partnerships[45] with the aim of achieving a more focused research agenda, greater coherence among the centres and increased collaboration with a wider range of partners. However, the management of the genetic resources collections is expected to remain a high priority for the system as are the genetic improvement of those food crops that are of greatest importance to the poor in the developing world.

Of the 15 centres, 11 have collections of PGRFA and are involved in one way or another with long-term conservation and plant genetic improvement (see Chapter 3). They not only make available material from their genebanks but also distribute to partners in both developing and developed countries, nurseries of advanced breeding lines, early generation segregating populations, parental materials, and lines with special characteristics (see Section 4.2). At the system level, there has been a number of significant developments since the first SoW report was published. These include greater emphasis on the breeding programmes on biotechnological tools and methods, including genomics, proteomics, MAS and the like; greater attention to participatory breeding approaches; major new partnership programmes for crop genetic improvement such as the GCP and Harvest Plus (see Section 4.7.4 and Box 4.1); and a large, system-wide initiative, now in its second phase, that aims to upgrade the collections and genebank facilities, known as "Collective Action for the Rehabilitation of Global Public Goods in the CGIAR Genetic Resources System".[46]

The centres have also continued to be heavily involved on an individual basis in a wide range of activities on the conservation and use of PGRFA. A large percentage of these involve international collaboration. By way of illustration, a few of many possible examples are given below:

- Africa Rice Center (formerly WARDA),[47] works with national programmes throughout Africa and provides leadership for the multicountry rice research network in West and Central Africa (ROCARIZ);
- Bioversity International (formerly IPGRI and INIBAP)[48] is exclusively devoted to agricultural biodiversity. It adopted a new strategy in 2006 that, while maintaining a focus on conservation, also gives greater prominence to the sustainable use of genetic resources for human well-being. Bioversity International is heavily involved with a large number of networks and partnership arrangements, e.g. it maintains an active association with all of the networks listed in Section 6.2.1;
- CIAT[49] and ILRI[50] both have major collections of tropical forages and CIAT has the largest collections in the world of cassava and beans. It facilitates a number of networks, for example the Pan-African Bean Research Alliance (PABRA);
- CIMMYT[51] maintains international germplasm collections of wheat and maize and facilitates crop improvement networks for both crops. It also plays a leading role in the Asian Maize Biotechnology Network;
- CIP[52] provides leadership for a number of regional networks on potato and/or, sweet potato as well as the Potato Gene Engineering Network (PotatoGENE);
- ICARDA[53] has helped establish genebanks in Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Morocco, Tajikistan, Turkmenistan and Uzbekistan. The significant contribution of ICARDA in the establishment of genebanks is recognized and described in the country reports of Armenia, Azerbaijan, Kazakhstan, Kyrgyzstan, Morocco, Tajikistan and Uzbekistan;
- ICRISAT[54] works closely with national programmes in both Asia and Africa to promote germplasm conservation, enhancement and use. It plays a leadership role in the CLAN;
- IITA[55] has important collections of many tropical crops and works in close collaboration with national programmes, networks and other institutions throughout Sub-Saharan Africa;
- IRRI[56] convenes the International Network for the Genetic Evaluation of Rice (INGER)[57] and the Council for Partnerships on Rice Research in Asia (CORRA);[58]
- World Agroforestry Center, (formerly ICRAF), has a Genetic Resources Unit that partners with many institutions throughout Africa and beyond, in the conservation and evaluation of species for agroforestry systems.

As an adjunct to the work of the individual centres, the SGRP has been set up as a mechanism to help coordinate policies, strategies and activities across the system. SGRP aims to optimize CGIAR's efforts in five thematic areas: genetic resources policy; public awareness; information; knowledge and technology development; and capacity building. It has provided a focus for the technical input of the CGIAR to the negotiating process of the ITPGRFA and for negotiating the agreements with FAO bringing the centres' collections under the purview of the ITPGRFA.

In 2000, the CGIAR established the Central Advisory Service on Intellectual Property (CAS-IP) to assist the centres in managing their intellectual assets in order to maximize public benefit.

6.3.3 Other international and regional research and development institutions

There are a very large number of regional and international organizations involved in one way or another with the conservation and use of PGRFA. They range from highly technical international research institutes to the SGSV, a major new safety back-up facility for the storage of duplicate samples of accessions held in seed collections (see Section 3.5). Just five examples of regional and international institutions are given below: two have been established since the first SoW report was published, two are important agricultural research institutions that have gone through significant changes over recent years and one, the CBD, has significantly expanded its work related to PGRFA:

- World Vegetable Centre (formerly AVRDC):[59] headquartered in Asia, the World Vegetable Center maintains collections of many important vegetable species and makes them and materials arising from its breeding programmes, available to the world community in a similar way to those of the CGIAR centres. Since the first SoW report was published it has greatly expanded its activities in other continents, especially in Africa. It has set up and supported a large number of different regional and international networks;
- CATIE:[60] CATIE is an intergovernmental regional research and higher education centre located in Costa Rica. While it seeks primarily to serve its member countries,[61] it maintains germplasm collections of global importance. Since the publication of the first SoW report, CATIE has signed agreements with FAO bringing the collections within the International Network of *Ex Situ* Collections (see above). Both conventional seed as well as extensive field collections are maintained, with some of the most important ones being cacao (*Theobroma* spp.), coffee (*Coffea* spp.), peach palm (*Bactris* spp.), peppers (*Capsicum* spp.), cucurbits (*Cucurbitaceae*) and tomato (*Lycopersicon* spp.);
- CBD:[62] in November 1996, the third Conference of the Parties to the CBD adopted Decision III/11: 'Conservation and sustainable use of agricultural biological diversity', which, *inter alia*, established a multi-year programme of activities on agricultural biological diversity with the following goals:
  - promote the positive effects and mitigate the negative impacts of agricultural practices on biological diversity in agro-ecosystems and their interface with other ecosystems;
  - promote the conservation and sustainable use of genetic resources of actual or potential value for food and agriculture;
  - promote the fair and equitable sharing of benefits arising out of the utilization of genetic resources.

PGRFA are also important in a number of the cross-cutting programmes of work of the CBD including the ecosystem approach, climate change and biodiversity, invasive alien species, the GSPC and ABS (see Chapter 7). In addition, the Cartagena Protocol on Biosafety, which came into force in 2003, has major implications for the conservation, management and use of PGRFA and in particular, the development and dissemination of GM-crop varieties.

- Crops for the Future:[63] created in 2008 as a result of a merger between the International Centre for Underutilized Crops and the Global Facilitation Unit for Underutilized Species, Crops for the Future seeks to promote and backstop research on those neglected and underutilized species which are considered to have a high potential for contributing to food security, poverty alleviation and protecting the environment;

- ICBA:[64] ICBA was established in 1999 to address growing concerns about water availability and quality, initially in the WANA region but more recently at the global level as well. ICBA maintains and distributes an international germplasm collection comprising more that 9 400 accessions of some 220 saline and drought-tolerant species of crops and forages.

6.3.4 International and regional fora and associations

Regional and international associations and fora are becoming an increasingly important feature of international cooperation throughout the world, and in almost all areas of society. In fields related to agriculture, and that include activities on PGRFA, they include industry associations such as the ISF[65] and CropLife International;[66] farmers' organizations such as the International Federation of Agricultural Producers (IFAP);[67] international academic institutions such as the Third World Academy of Science (TWAS);[68] and environmental networks such as the IUCN.[69] The regional associations or fora on agricultural research for development are mentioned in Section 6.2.

A particularly significant development since the first SoW report was published was the creation of GFAR in 1999.[70] GFAR is an initiative that provides a neutral platform to promote discussion and collaboration among various stakeholder groups concerned with agricultural research for development. The regional associations and fora are key members of GFAR as are FAO, the CGIAR, farmers' organizations (represented on the Steering Committee by IFAP), civil society groups, private sector organizations, donors and others. GFAR held its first international conference in Dresden, Germany, in 2000, which resulted in the Dresden Declaration that identified genetic resources management and biotechnology as one of GFAR's four priority areas. Participants also drafted a separate declaration specifically on PGR that urged governments to meet their obligations to different international instruments, legislation and policies relating to PGRFA. GFAR has also been an active partner of FAO and the CGIAR in facilitating many activities relating to the GPA.

6.3.5 Bilateral cooperation

A large number of different national institutions, in both developing and developed countries, have international programmes in the area of PGRFA and these have increased significantly since the first SoW report was published, as is evident from the country reports. Such bilateral arrangements are far too numerous to list comprehensively and it is only possible to give a very general overview here. Institutions involved in regional and international bilateral activities include universities, national plant breeding and research institutes, genebanks, botanical gardens, etc.

Several developed countries have specialized governmental organizations devoted to providing technical assistance to developing countries. Many of these are involved in agricultural research and development, and initiatives involving the conservation and sustainable use of PGRFA have generally increased over the past decade. Examples include: the Cirad in France, the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) in Germany, the Istituto Agronomico per l'Oltremare (IAO) in Italy and the Japan International Research Centre for Agricultural Sciences (JIRCAS).

The growing importance of South-South Cooperation is pointed out in a number of country reports. Increasingly, institutions in developing countries are taking on international responsibilities, within the context of regional and international networks as well as in their own right. This is particularly true of universities and two examples are given in Chapter 4 Box 4.1: the ACCI established by the University of KwaZulu-Natal and the WACCI established by the University of Ghana. Some government institutions in developing countries are also expanding their international operations, for example the CAAS is increasingly posting staff overseas, and Embrapa has set up offices/laboratories in France, Ghana, the Netherlands, the Republic of Korea and the United States of America.

6.3.6 Non-governmental organizations

Over the last ten years, the involvement of NGOs has increased substantially in various aspects of PGRFA and, as with other types of institutions, it is impossible to inventory them all. While activities have largely taken place at the national level, international activities have also expanded. For example, NGOs such as the Gene Campaign in India, the Action Group on Erosion Technology and Concentration (ETC Group) and Grain, among many others, were particularly active internationally when negotiations were in process for the ITPGRFA and in the context of various initiatives of the CBD such as those relating to indigenous knowledge and ABS.

Since the first SoW report was published, a number of new national NGOs have been set up concerned with conserving old varieties, especially 'heritage' or 'heirloom' varieties of fruits and vegetables. This has in turn, led to the creation of umbrella organizations and networks such as Safeguard for Agricultural Varieties in Europe (SAVE Foundation). Botanical gardens have also grown in number and strength over the past decade (see Section 3.9) and this has been reflected in the growth in membership of the umbrella organization, BGCI, which today includes some 700 members from almost 120 countries.

In addition to NGOs that focus primarily on plant diversity such as those previously mentioned, many developmental NGOs, both national and international, are also involved in the conservation and use of PGRFA, for example through projects that promote the management of PGRFA on farm or that promote traditional and high value crops and value added products. In an attempt to promote greater collaboration among such NGOs, a number of regional and international networks have been established, or expanded in scope, since the first SoW report was published. These include, for example, the Asian NGO Coalition for Agrarian Reform and Rural Development (ANGOC) and the CBDC mentioned earlier.

6.4 International and regional agreements

Arguably the most important international events associated with PGRFA since the publication of the first SoW report was the adoption in 2001 and entry into force in 2004 of the ITPGRFA.[71] As of August 2010, the ITPGRFA had been ratified by 125 countries and the European Union. Article 1.1 of the ITPGRFA states its objectives as, "the conservation and sustainable use of PGR for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security."

The ITPGRFA covers all PGRFA and promotes, *inter alia*: conservation, exploration, collection, characterization, evaluation and sustainable use. It promotes action at the national level as well as international cooperation and technical assistance. One article is devoted to Farmers' Rights (see Sections 5.4.4 and 7.4) and a centrepiece of the ITPGRFA is the creation of an MLS for ABS that covers the 35 food crops and 29 forage genera listed in Annex 1 of the ITPGRFA. Developments with respect to ABS are described in detail in Chapter 7.

The ITPGRFA also promotes the implementation of the GPA and recognizes several other supporting components including the *ex situ* collections held by the IARCs, international PGR networks and the global information system on PGRFA. The Contracting Parties undertake to implement a funding strategy for the implementation of the ITPGRFA with the objective of enhancing the availability, transparency, efficiency and effectiveness of the provision of financial resources to implement activities under the ITPGRFA.

In addition to the ITPGRFA, a trend towards stronger regional cooperation in matters relating to PGRFA is also reflected in the growing number of regional agreements covering such areas as conservation, PVP, access to genetic resources and benefit-sharing. One area that has seen particular progress is phytosanitary regulations and these are covered separately below.

In Africa, regional agreements have been signed on PVP,[72] access and benefit-sharing, Farmers' Rights,[73] the conservation of natural resources,[74] and safety in the application of biotechnology.[75]

In the Americas, the Andean Community countries have adopted several regional agreements regarding PGR, two of the most important being the 1996 Decision 391 on a Common Regime on Access to Genetic Resources and the 1993 Decision 345 on Common Provisions on the Protection of the Rights of Breeders of New Plant

Varieties. Central American countries have also drafted an agreement on access to genetic and biochemical resources and related traditional knowledge.

In Asia, in 2000, the Association of Southeast Asian Nations (ASEAN) countries agreed on a framework on access to biological and genetic resources and in 1999 the CIS countries adopted a multilateral agreement on cooperation in the sphere of conservation and management of cultivated PGR. In 2001, they also adopted an agreement on the legal protection of plant varieties.

In Europe, the European Union has adopted numerous European Community regulations and directives regulating such areas as seed production and distribution, IP and biosafety. National laws on PBR have, for example, been harmonized and a European Commission variety register established.[76] In the Nordic countries, the Nordic Council of Ministers adopted a Ministerial Declaration on Access and Rights to Genetic Resources in 2003.

6.4.1 Regional and international collaboration regarding phytosanitary issues

In 1997, a new text of the IPPC[77] was adopted. The number of members of IPPC has also risen considerably over the last decade, with 69 countries and the European Union out of the total membership of 172 having joined since 1996.

The 1997 revision of the IPPC was substantial and aimed to bring it up to date with current phytosanitary practices and in line with the concepts contained in the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) Agreement.[78] In addition to its implications for international trade, the 1997 text of the IPPC promotes the harmonization of phytosanitary measures and creates a procedure to develop International Standards for Phytosanitary Measures. It also introduces new phytosanitary concepts such as the designation of pest-free areas, the phytosanitary security of export consignments after certification and pest risk analysis.

The role of regional plant protection organizations (RPPOs) was also strengthened in 1997. In addition to promoting the objectives of the IPPC, RPPOs act as phytosanitary coordinators for their respective regions, promote harmonization of phytosanitary regulations and develop regional standards based on science and in harmony with international standards.

The first SoW report lists eight regional organizations; there are now ten. Although established in 1994, the Pacific Plant Protection Organization was not mentioned in the first report and the Near East Plant Protection Organization was established in 2009.

6.5 International funding mechanisms

With the growing recognition of the importance and value of PGRFA, an increasing number of donors have provided funds to support activities in this area, some in substantial amounts. One of the most significant funding developments since the first SoW report published was the creation of the GCDT. This specialized funding mechanism, that is also part of the funding mechanism of the ITPGRFA, is described in more detail below, followed by an update on the situation with respect to other multilateral and bilateral funding agencies.

- GCDT:[79] it has long been argued that in order to provide long-term sustainable funding for the conservation of PGRFA, an endowment fund is needed. Such a fund would build, preserve and invest its capital assets while using the interest generated to support conservation efforts around the world. With the adoption of the ITPGRFA in 2001, the way was opened up for the creation of such a dedicated funding mechanism, linked to the ITPGRFA. Thus, in 2004, FAO and Bioversity International (acting on behalf of the CGIAR centres) spear-headed the establishment of the GCDT. With its own Executive Board, acting under the overall guidance of the Governing Body of ITPGRFA and the advice of a Donor Council, the GCDT had, by early 2009, obtained total funding pledges amounting to more than USD 150 million. Funds have been provided by national governments, including some developing country governments, multilateral donors, foundations, corporations and private individuals.

In addition to managing the endowment, the GCDT has also raised funds to support the upgrading of collections and facilities, building human capacity, strengthening information systems, evaluating collections and targeted collecting. Efforts to date have concentrated on *ex situ* conservation and evaluation and a sizeable initiative has been undertaken, referred to earlier in this chapter, to formulate regional and global collaborative crop conservation strategies. These strategies are used to guide the allocation of the resources made available by the GCDT.

In spite of the success of the GCDT, there is still some way to go before the endowment fund can be considered large enough for the interest derived from it to be able to ensure that all the world's most important PGRFA are securely conserved;

- Multilateral and bilateral funding agencies: while it has not been possible to carry out a detailed inventory and analysis of trends in funding for PGRFA, it is evident that the number of agencies which support the conservation and sustainable use of PGRFA, including plant breeding, has grown somewhat since the first SoW report was published. The CGIAR, for example, now numbers some 47 countries as donors (including 21 developing countries) plus 4 foundations and 13 international and regional donor agencies. The large majority of these funders, directly or indirectly support research and development activities involving PGRFA. GEF remains a major funder of *in situ* conservation, including the conservation of CWR and is the principal funding mechanism of the CBD. The World Bank, a major supporter of the CGIAR, has provided funding not only for the centres' research programmes but has also provided a substantial injection of funds to bring the genebanks up to standard. Other multilateral funding agencies have also been active in supporting national and international projects and programmes that include activities on PGRFA. These include the Regional Development Banks, European Commission, International Fund for Agricultural Development (IFAD), Islamic Development Bank (IsDB), Organization of the Petroleum Exporting Countries) OPEC Fund for International Development, UNDP and UNEP.

Special mention should also be made of the FONTAGRO,[80] an alliance of Latin American and Caribbean countries together with the Inter-American Development Bank (IDB) and IICA, that provides funds to support agricultural research and innovation in member countries. Established in 1998, the Fund currently supports 65 projects, many of which, have a genetic resources component.

The number of foundations involved in funding PGRFA, especially those in the United States of America, has also increased in line with the overall growth of the philanthropic sector. Foundations that are involved in one way or another with funding international activities on PGRFA include the Bill and Melinda Gates Foundation, Gatsby Charitable Trust, Gordon and Betty Moore Foundation, Lillian Goldman Charitable Trust, Kellog Foundation, MacArthur Foundation, Nippon Foundation, Rockefeller Foundation, Syngenta Foundation and the United Nations Foundation.

In addition to multilateral agencies and foundations, many countries provide bilateral support for projects that include activities on the conservation and use of PGRFA. Most of the national development assistance agencies of the Organisation for Economic Co-operation and Development (OECD) countries, for example, are active in this area. Some countries also have specialized agencies dedicated to supporting research in developing countries, e.g. the International Development Research Centre (IDRC) of Canada, the Australian Centre for International Agricultural Research (ACIAR), the Swedish Agency for Research Cooperation (SAREC – now incorporated in the Swedish International Development Cooperation Agency, Sida) and the International Foundation for Science (IFS) of Sweden.

6.6 Changes since the first State of the World report was published

It is evident from the information presented in this chapter that in general, regional and international collaboration have advanced considerably since the first SoW report was published. While some networks are still under-resourced, a number of new institutions and partnerships have been established and old mechanisms strengthened. The ITPGRFA's MLS provides a mechanism that makes it easier for countries to share the burden of conservation, leading over time to a greater rationalization of collections (including the elimination of inadvertent duplication) and safety backup duplication and making it easier for countries to work together to conserve and use a wider range of genetic diversity. Key changes that have taken place include:

- the entry into force of the ITPGRFA in 2004 which marks what is probably the most significant development relating to PGR since the publication of the first SoW report. The ITPGRFA is a legally binding international agreement that promotes the conservation and sustainable use of PGRFA and the fair and equitable sharing of the benefits arising out of their use, in harmony with the CBD;
- several new regional PGRFA networks have been established, including GRENEWECA for West and Central Africa, NORGEN for North America, CAPGERNET for the Caribbean, PAPGREN for the Pacific, SeedNet for Southwestern Europe and CACN-PGR for the Central Asia and Caucasus region;
- other regional PGRFA networks have significantly strengthened their activities, e.g. SANPGR in South Asia, SADC-PGRN in southern Africa and the AEGIS and EURISCO initiatives of the European network ECPGR;
- many other regional PGRFA networks have not fared as well. While almost all networks need additional resources, insufficient funding was a major factor in the demise of WANANET and represents a major constraint for most of the networks in the Americas as well as Southeast Asia and West Africa;
- several new crop-specific networks have been established that have significant activities on PGRFA. These include, for example, international networks on cacao, the coffee genome, the rice genome and bamboo and rattan. New or reformed regionally-focused crop networks include ones on banana and plantain, cassava in the Americas, cereals and legumes in Asia, cassava in the Pacific and cotton in Asia and North Africa;
- several new thematic networks have been established, focusing on a range of different topics. For example, a number of networks have been created on biotechnology, both globally (e.g. the GCP) and in many regions. Other topics have included the on-farm management of genetic diversity and seed production. Three seed networks have been established in Africa alone;
- FAO supports the secretariats of both the ITPGRFA and the CGRFA. Relationships with the CBD were strengthened with the signing of a joint Memorandum of Cooperation in 2006;
- FAO has further strengthened its activities in the PGRFA area, for example, it established the GIPB in 2006;
- the international centres of the CGIAR have concluded new agreements with FAO, acting on behalf of the Governing Body of the ITPGRFA, bringing their collections within ITPGRFA's MLS of ABS. The CGIAR itself has been going through a period of major reform;
- the CGIAR centres have continued to work collaboratively with a very large number of partners, especially in developing countries and have continued to make available a wide range of genetic materials. A major programme has been undertaken to upgrade the collections and genebank facilities. In 2000, the CGIAR centres established the CAS-IP;
- several other new international institutes have been established that undertake research involving PGRFA. These include Crops for the Future and the ICBA;
- the SGSV, which opened in 2008, represents a major new international collaborative initiative to improve the safety of germplasm collections, through providing secure facilities for storing duplicate samples of seed accessions;
- another significant development since the first SoW report was published is the creation in 1999 of the GFAR. The Forum promotes discussion and collaboration among different stakeholder groups concerned with agricultural research. GFAR has identified genetic resources management and biotechnology as one its four priority areas;
- the trend towards stronger cooperation is reflected in the growing number of regional agreements

covering such areas as conservation, PVP, access to genetic resources and benefit sharing. One area that has seen particular progress is in phytosanitary regulations;
- several new foundations now support activities in PGRFA internationally. A special fund to support agricultural research in Latin America (FONTAGRO) was set up in 1998 and in 2004 the GCDT was established as a specialized fund dedicated to supporting the conservation of PGRFA and promoting its use worldwide.

6.7 Gaps and needs

In spite of the impressive progress made since the first SoW report was published, there are still a number of gaps and concerns that need to be addressed as a matter of urgency. These include:
- many networks have suffered from a lack of funds although several new networks have been formed. At least one has ceased to function. New and innovative funding strategies and mechanisms are needed;
- in order to underpin such funding strategies, increased efforts are needed to raise awareness among policy-makers and the general public of the value of PGRFA, the interdependence of nations and the importance of supporting increased international collaboration;
- greater collaboration is also needed among policy and funding bodies at the international level, and a greater awareness of the need for long-term financial support;
- with the strengthening of the regional and global fora on agricultural research, their influence with national policy-makers has grown and they offer valuable opportunities for promoting appropriate national and regional policies in areas of importance to the conservation and use of PGRFA;
- given that international germplasm exchange is a key motivation behind many networks, additional attention is needed both to promote the effective implementation of ITPGRFA and in particular, its MLS of ABS, as well as to develop arrangements for those other crops that are not currently included in the system but that are within the overall scope of the ITPGRFA;
- in order to benefit from many of the regional and international opportunities for collaboration, there is a need in many countries for greater internal coordination among different ministries and institutions and between the public and private sectors.

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Chapter 7

Access to Plant Genetic Resources, the sharing of benefits arising out of their utilization and the realization of Farmers' Rights

7.1 Introduction

Access and benefit-sharing (ABS), together with conservation and sustainable use, are at the heart of both the CBD and the ITPGRFA. In a world where countries are interdependent among each other for the plant genetic resources they need to sustain food production and to meet the increasing challenges of disease and climate change, access to those resources is essential for achieving world food security. This chapter reviews the changes that have taken place since the first SoW report was published. It covers the international legal and policy framework relevant to ABS and developments in ABS at the national level. It then reviews developments in the realization of Farmers' Rights under the ITPGRFA.

7.2 Developments in the international legal and policy framework for access and benefit-sharing

The international legal and policy framework is an area that has undergone and is still undergoing, very significant change since the first SoW report was published. Its dynamic nature has influenced and will continue to have a major influence on progress in all areas of the conservation and use of PGRFA.

7.2.1 The ITPGRFA

One of the most important developments in the PGR sector since the first SoW report was published has been the adoption and entry into force of the ITPGRFA. On the issue of ABS, the ITPGRFA draws together the threads of the International Undertaking on PGR, a non-binding international instrument that provides for 'unrestricted' availability of PGR as a common heritage of humankind and those of the CBD which is based on the principle of national sovereignty over genetic resources and access on the basis of prior informed consent and mutually agreed terms. The ITPGRFA establishes an MLS of ABS for those PGR that are most important for food security and on which countries are most interdependent. For such genetic resources, which are listed in Annex 1 of the ITPGRFA, the Contracting Parties have agreed on standard terms and conditions that will govern their transfer for the purpose of research, breeding and training. These standard terms and conditions are set out in the SMTA, adopted by the Governing Body at its First Session in June 2006. In this way, the MLS reduces the transaction costs inherent in bilaterally negotiated exchanges. The MLS automatically covers all PGRFA of Annex 1 crops that are "under the management and control of the Contracting Parties and in the public domain". Provision is made for the voluntary inclusion of other materials in the MLS by their holders.

7.2.1.1 Benefit-sharing under the Multilateral System

Benefit-sharing under the MLS takes place at the multilateral level. Facilitated access to genetic resources that are included in the MLS is, itself, recognized as a major benefit of the system. Other benefits arising from the use of PGRFA that are to be shared on a 'fair and equitable' basis, include the exchange of information, access to and transfer of technology, capacity building and the sharing of monetary and other benefits arising from commercialization (see Box 7.1). The Benefit-Sharing Fund that has been established for the purpose of receiving revenues arising from commercialization will also accept voluntary contributions received from the Contracting Parties, non-contracting parties and the private sector[1] as part of the benefit-sharing system. As of mid-2009, voluntary contributions to the fund have been made by a number of governments, including a commitment by the Government of Norway to make a voluntary contribution to the Benefit-Sharing Fund equal to 0.1 percent of the value of all seeds sold in Norway. The ITPGRFA Secretariat's first call for proposals under the Benefit-Sharing Fund closed in January 2009 and the first 11 project grants were awarded before the Third Session of the Governing Body in June 2009.

The financial benefits arising from commercialization form part of the ITPGRFA's Funding Strategy under Article 18. The strategy also includes the mobilization of funding from other sources outside the ITPGRFA. An essential element of the Strategy is the GCDT, an

Box 7.1
Benefit-sharing under the ITPGRFA

Under the ITPGRFA, facilitated access to genetic resources that are included in the MLS is itself recognized as a major benefit of the system. Other benefits arising from the use of PGRFA that are to be shared on a 'fair and equitable' basis include:

- **the exchange of information**: this includes catalogues and inventories, information on technologies and results of technical, scientific and socio-economic research on PGRFA including data on characterization, evaluation and information on use.
- **access to and transfer of technology**: Contracting Parties agree to provide or facilitate access to technologies for the conservation, characterization, evaluation and use of PGRFA. The ITPGRFA lists various means by which transfer of technology is to be carried out, including participation in crop-based or thematic networks and partnerships, commercial joint ventures, human resource development and through making research facilities available. Access to technology, including that protected by IPR, is to be provided and/or facilitated under fair and most-favourable terms, including on concessional and preferential terms where mutually agreed. Access to these technologies is provided while respecting applicable property rights and access laws.
- **capacity building**: the ITPGRFA gives priority to programmes for scientific education and training in the conservation and use of PGRFA, to the development of facilities for conserving and using PGRFA and to the carrying out of joint scientific research.
- **sharing of monetary and other benefits arising from commercialization**: monetary benefits include payment into a special Benefit-Sharing Fund of the MLS of a share of the revenues arising from the sale of PGRFA products that incorporate material accessed from the MLS. Such payment is mandatory where the product is not available for further research and breeding, for example, as a result of certain types of patent protection. In the SMTA, adopted by the Governing Body at its First Session in 2006, the payment is set at 1.1 percent of the gross sales generated by the product less 30 percent (i.e. 0.77 percent).

international fund that was established in 2004 to help ensure the long-term *ex situ* conservation and availability of PGRFA (see Section 6.5).

7.2.1.2 Enforcement of the terms and conditions of the Standard Material Transfer Agreement

The SMTA provides a mechanism for overcoming potential difficulties of enforcement by empowering FAO, as the entity chosen by the Governing Body, to represent its interests as a third party beneficiary under the SMTA, and to initiate action where necessary to resolve disputes.

7.2.2 The Convention on Biological Diversity

The CBD continues to provide the legal and policy framework for ABS with regards to genetic resources in general. The main developments in the CBD framework since the first SoW report was published have been in the context of the work on ABS initiated by the Fourth Conference of the Parties on Biological Diversity (COP 4) in 1999 and carried out principally by a Working Group on ABS established in 2000. The first product was the non-binding Bonn Guidelines on ABS adopted at COP 6 in 2001. The Bonn Guidelines were designed to assist countries in developing and drafting policies,

Box 7.2
Potential benefits from access and benefit-sharing as listed in the Bonn Guidelines

1. Monetary benefits may include, but not be limited to:

(a) access fees/fee per sample collected or otherwise acquired;
(b) up-front payments;
(c) milestone payments;
(d) payment of royalties;
(e) license fees in case of commercialization;
(f) special fees to be paid to trust funds supporting conservation and sustainable use of biodiversity;
(g) salaries and preferential terms where mutually agreed;
(h) research funding;
(i) joint ventures;
(j) joint ownership of relevant IPRs.

2. Non-monetary benefits may include, but not be limited to:

(a) sharing of research and development results;
(b) collaboration, cooperation and contribution in scientific research and development programmes, particularly biotechnological research activities, where possible in the provider country;
(c) participation in product development;
(d) collaboration, cooperation and contribution in education and training;
(e) admittance to *ex situ* facilities of genetic resources and to databases;
(f) transfer to the provider of the genetic resources of knowledge and technology under fair and most-favourable terms, including on concessional and preferential terms where agreed; in particular, knowledge and technology that make use of genetic resources, including biotechnology, or that are relevant to the conservation and sustainable use of biological diversity;
(g) strengthening capacities for technology transfer to user developing country Parties and to Parties that are countries with economies in transition and technology development in the country of origin that provides genetic resources. Also to facilitate abilities of indigenous and local communities to conserve and sustainably use their genetic resources;
(h) institutional capacity building;
(i) human and material resources to strengthen the capacities for the administration and enforcement of access regulations;
(j) training related to genetic resources with the full participation of providing Parties and, where possible, in such Parties;
(k) access to scientific information relevant to conservation and sustainable use of biological diversity, including biological inventories and taxonomic studies;
(l) contributions to the local economy;
(m) research directed towards priority needs, such as health and food security, taking into account domestic uses of genetic resources in provider countries;
(n) institutional and professional relationships that can arise from an access and benefit-sharing agreement and subsequent collaborative activities;
(o) food and livelihood security benefits;
(p) social recognition;
(q) joint ownership of relevant IPRs.

laws, regulations and contracts on ABS to be applied to all genetic resources and associated traditional knowledge, innovation and practices covered by the CBD and benefits arising from the commercial and other utilization of such resources, with the exclusion of human genetic resources (see Box 7.2).

In 2004, the Working Group on ABS was mandated by COP 7 to elaborate and negotiate an international regime on access to genetic resources and benefit-sharing, with the aim of adopting an instrument/instruments to effectively implement the provisions in Article 15 and 8(j) of the CBD and the three objectives of the CBD. In 2008, COP 9 agreed on a road map and a basic framework including the main components of the international regime and called for the Working Group to complete its negotiations at the earliest time possible before COP 10 in 2010. The relationship of the international regime to more sector-specific regimes such as the MLS for ABS in the ITPGRFA, is also an important issue that needs to be further addressed.

7.2.3 Access and benefit-sharing in relation to WTO, UPOV and WIPO

IPR offer one means to facilitate the sharing of benefits arising from the use of genetic resources equitably among innovators and users of innovations. Recognizing this, the relationship between ABS regimes for genetic resources, traditional knowledge and the IPR system, have been a focus of discussion in the WTO and in particular in the TRIPS Council. It has also been under discussion in UPOV and WIPO.

The TRIPS Agreement provides for periodical reviews of its implementation and other reviews in the light of any relevant new developments that might warrant modifications of the Agreement. It has become apparent that there is a difference of opinion among TRIPS Council Members as to whether there is any inherent conflict between the TRIPS Agreement and the CBD and if so, how it could be resolved. One proposal that has been made in the TRIPS Council is to amend the TRIPS Agreement to add the requirement in national patent legislation of disclosure of the origin of genetic resources and/or associated traditional knowledge in patent applications.

Article 27.3(b) of the TRIPS Agreement authorizes TRIPS members to exclude plants and animals other than microorganisms from patentability, as well as essentially biological processes for the production of plants or animals. However, TRIPS members are required to grant protection to plant varieties, either through patents, through an effective *sui generis*[2] system, or through a combination of both. The Article refers in general terms only to an effective *sui generis* system of protection for plant varieties, leaving it open for countries to devise their own *sui generis* system, should they so desire. In practice, most countries have based their protection of plant varieties on the UPOV Convention, which offers the advantage of mutual recognition among all UPOV members.[3] The UPOV Convention incorporates the principle of free access to improved varieties for further research and breeding (breeders' exemption). In its present form, the UPOV model would exclude the imposition of a requirement to disclose the origin of genetic resources as a condition for the granting of PBR, since the UPOV Convention precludes the imposition of any conditions other than novelty, distinctness, uniformity and stability.

WIPO is the United Nations (UN) specialized agency dedicated to developing a balanced and accessible international intellectual property (IP) system. In 2000, the WIPO General Assembly established an Intergovernmental Committee on IP and Genetic Resources, Traditional Knowledge and Folklore (IGC), to examine, among other things, intellectual property issues arising in the context of ABS and traditional knowledge. At the request of COP 7, WIPO was invited to examine issues regarding the inter-relationship of access to genetic resources and disclosure requirements in patent applications: the results of the examination were officially transmitted to COP 8.

7.2.4 FAO and access and benefit-sharing

The FAO CGRFA at its Eleventh Regular Session in 2007, adopted a Multi-Year Programme of Work which recommended that "FAO continue to focus on ABS for genetic resources for food and agriculture in an integrated and interdisciplinary manner…".[4] It decided that its "work in this field should be an early task within its Multi-Year Programme of Work". In light of this decision, the CGRFA considered policies and arrangements for ABS for genetic resources at its 12th Session in 2009. ABS is a cross-cutting issue in the CGRFA, which also addresses the genetic resources of farm animals, microbial and insect genetic resources for food and agriculture, fish genetic resources and forest genetic resources.

7.3 Developments in access and benefit-sharing at the national and regional levels

7.3.1 Accessing germplasm

There are no reliable figures on the worldwide movement of germplasm for the period since the preparation of the first SoW report. However, figures are available for acquisition and distribution of PGRFA by and from the CGIAR centres (see Chapters 3 and 4).

Little information is contained in country reports on the actual flows of PGRFA to and from individual countries. Ethiopia reports that its national genebank dispatches annually about 5 000 samples nationally and internationally and the Bolivarian Republic of Venezuela reports that it has received 64 applications for access to PGRFA under the Law on Biological Diversity adopted in 2000.

Such information is still not readily available from public databases, although work is progressing on the establishment of a global accession level information system. Several country reports, for example Azerbaijan, New Zealand and Sri Lanka, indicated that having access to PGRFA held by the centres of the CGIAR was important to them, although India reported a decline in PGRFA from CGIAR centres and other national genebanks after the entry into force of the CBD. Several country reports[5] indicated that access to PGRFA from other sources is becoming more difficult, due in part to a lack of clarity over issues such as ownership and IPR and a need for clearer procedures.

7.3.2 Benefits derived from the conservation and use of PGRFA

As discussed in Chapter 4, to take full advantage of the benefits provided by access to PGRFA requires that developing countries have access to plant breeding capacity. To some extent, such capacity is being provided through the breeding programmes of the CGIAR centres, which operate in close cooperation with the NARS they serve. But there is a need for greater breeding capacity in many developing countries, a need that new programmes, such as the GIPB,[6] are helping to address. There is also a need for more fully integrated systems at the national level that provide for effective linkages between conservation, breeding and seed production and distribution, in order to bring the benefits to the farmers themselves, in the form of improved seeds.

7.3.3 Development of access and benefit-sharing arrangements at the national level

An overview of the status of ABS legislation and regulations is included in Appendix 1. More general problems and issues are discussed in the sections below.

7.3.3.1 General problems and approaches at the national level

One obstacle to regulating access to genetic resources and achieving a fair and equitable sharing of benefits has been the nature of such resources and difficulties in establishing rights over them. These difficulties stem from the intangible nature of genetic resources as compared with physical biological resources.[7]

Traditionally, ownership of genetic resources, in so far as any such ownership was recognized, has been linked to ownership of the biological resource, such as wheat in farmers' fields, or samples in *ex situ* genebanks. Ownership of the intangible genetic resource *per se* was recognized only where they were the consequence of an act of creation, as for example through the granting of IPR over new plant varieties that are the result of breeding processes. The ITPGRFA

Box 7.3
Implementing the Multilateral System through administrative measures – the experience of one Contracting Party

The following account is drawn from the experience of one Contracting Party, but reflects the experience of a number of countries. In the example cited, the responsibility for PGRFA is shared between the federal and state authorities and PGRFA is also held in private institutions. The focal point for the ITPGRFA is the Federal Ministry of Agriculture. The framework for the implementation of the MLS, including activities of both governmental and private institutions, is provided by a National Programme on PGR, by an Advisory and Coordinating Committee and by a National Inventory for PGR.

As a **first step** in implementation of the MLS, information on the system was provided to all relevant stakeholders, both in the public and the private sectors, including the preparation of explanatory notes on the SMTA and Frequently Asked Questions (FAQs). Public and private institutions have been informed of the SMTA and the rights and obligations arising from its use. The private sector has also been encouraged to make voluntary payments when a product that incorporates material accessed from the MLS is commercialized without restrictions.

As a **second step**, existing collections of Annex 1 PGRFA were examined against the criteria of governmental 'management and control'. As a result of this examination:

- collections under the direct control of the Federal Ministry were instructed to introduce the SMTA;
- collections under the control of the states and/or local authorities were requested to introduce the SMTA;
- all other collections (mixed, private) were invited to introduce the SMTA.

The **third step** was the identification of Annex I material in the genebanks that are in the public domain, excluding both material held under black-box arrangements, for example and protected varieties, which are available for further research and breeding from the individual breeders.

The fourth and **final step** was to include the identified material formally in the MLS and to identify such material in the databanks by an MLS flag.

The case study draws the following lessons from the national experience:

- early and comprehensive information of the relevant stakeholders on the national implementation of the MLS and the SMTA by the respective authorities is important;
- existing "infrastructure" for cooperation such as a national programme for PGRFA with a national coordination committee and a national inventory (documentation system) should be used as much as possible;
- the text of the SMTA is not self-explanatory, especially for users not speaking UN languages. There is a need for assistance through experts giving guidance and/or a courtesy translation in the national language. Explanatory notes, FAQs, etc. are useful in order to facilitate the implementation of the MLS and the SMTA at national level;
- general guidelines on how to include material in the MLS at the collection level (e.g. identification of public domain accessions) could be helpful.

avoids the issue of ownership entirely, by focusing on terms of access and provisions for benefit-sharing.

The recognition of national sovereignty over genetic resources implies that countries have the power to manage those resources and to regulate access to them, but it does not address the issue of ownership *per se*. While in many countries legal ownership of genetic resources still follows the ownership of land and the biological resources on that land, an increasing number of countries are affirming the separate ownership of genetic resources by the State. Decision 391 of the Andean Community, for example, provides that genetic resources are the property or heritage of the nation or state. Article 5 of the Ethiopian Proclamation No. 482 of 2006 provides that "the ownership of genetic resources shall be vested in the state and the Ethiopian people". The practical consequences of these ownership claims are as yet unclear.

Another obstacle frequently cited by countries in their national reports (more than 35 countries) is the lack of the necessary multidisciplinary scientific, institutional and legal capacity to develop a satisfactory system of ABS, given the interrelated dimensions of access, benefit-sharing, local community rights and traditional knowledge and the connected problems of IP and economic development.[8]

Other difficulties include the overlapping competences of different ministries. The implementation of the ITPGRFA, for example, normally requires coordination between the Ministry responsible for agricultural policies and that responsible for environmental matters, as well as coordination with ministries responsible for trade, land, forests and national parks where access to PGRFA *in situ* is concerned.

In the case of federal states or similar decentralized governmental systems, the allocation of responsibilities between a central or federal government and its individual states, regions or provinces may also provide a challenge. In Malaysia, for example, the difficulties caused by the division of responsibilities between the state and federal authorities with respect to genetic resources are specifically noted in the 1998 National Policy on Biological Diversity (paragraphs 16-20). The Malaysia country report notes that while national legislation on ABS was being developed, the States of Sabah and Sarawak had their own process underway which resulted in two state enactments on this matter. In Australia, discussions are in progress between the national government and states regarding the way in which Australia will implement the ITPGRFA. In Brazil, competence over genetic resources is shared at both federal and state levels and state laws have been enacted on access to genetic resources.[9] The federal government is responsible for establishing standards and granting import and export permits.

7.3.3.2 National and regional implementation of access and benefit-sharing under the ITPGRFA

Placing of PGRFA in the MLS: to date, the major collections formally placed in the MLS are those held by the international institutions that have signed agreements with the Governing Body of the ITPGRFA.[10]

As far as national collections are concerned, Article 11.2 of the ITPGRFA provides that PGRFA of crops and forages listed in its Annex 1 that are under the management and control of the Contracting Parties and in the public domain, are to be included automatically in the MLS. Other holders of PGRFA listed in Annex 1 are invited to place them in the MLS and Contracting Parties agree to take appropriate measures to encourage them to do so. While the ITPGRFA itself does not clearly and explicitly place an obligation on Contracting Parties to disseminate information on the material included automatically or voluntarily in the MLS, it is clear that the accessibility of such material will depend, in practice, on the relevant information being available. For this purpose, the ITPGRFA Secretariat has formally requested Contracting Parties to provide information on the materials within the MLS in their jurisdictions.[11] Updated information on the accessions included in the MLS is available at the Secretariat of the ITPGRFA.[12] A number of countries, including both developed and developing countries, as well as countries with economies in transition, have provided information on material included in the MLS.[13] The material includes some PGRFA held by private entities including, for example, at least two private breeders' associations in France.[14] EURISCO, the European catalogue of *ex situ* PGR collections, has been adapted to incorporate the inclusion of each accession in the MLS.

From the information available, it appears that there may be differences in the interpretation of the criteria of 'under the management and control of Contracting Parties' and 'in the public domain'. This matter may need to be referred to the Governing Body for clarification. In the meantime, it appears that wide use is being made of the persuasive powers of governments to encourage holders of non-governmental collections of Annex 1 PGRFA to place their collections in the MLS.[15]

Implementing the MLS through administrative measures: to date a number of countries are choosing to implement the MLS of the ITPGRFA through administrative measures rather than through the adoption of new national legislation. This is the case, for example, in both Germany and the Netherlands. The implementation of the MLS in Germany is illustrative of the type of administrative measures taken.

Implementing the MLS through legislative measures: while some countries consider that the MLS can be implemented solely through administrative measures, other countries have found that more formal legislative action may be necessary, in order to provide legal space in which the implementation can operate, provide for legal authority for the implementation of the system and/or provide legal certainty as to the procedures to be followed.

The need to provide legal space may be necessary where legislation is already in place for the implementation of ABS procedures under the CBD. Legislative action in this context may be limited to the recognition that ABS under the MLS should follow different and simplified procedures, leaving those procedures to be defined by administrative measures or by further legislative action, or else it may enter into the detailed procedures applicable as with other genetic resources or uses. The legislation of Ethiopia is one example of the first approach, where the legislation provides that access to genetic resources under an MLS is to be made in accordance with the procedure specified in the MLS and in accordance with future regulations to be issued on the subject.[16] There are to date no instances of national legislation that set out detailed procedures for dealing with ABS under the MLS. It is known however that a number of countries are considering, or in the process of drafting, such legislation, whether as part of stand-alone legislation on PGRFA, or in the context of national legislation on genetic resources in general.[17]

Regional cooperation in the implementation of the MLS: reference has already been made to regional initiatives in the implementation of ABS. A number of regions are also taking cooperative action for the implementation of the MLS. One such initiative is that launched by the Arab Organization for Agricultural Development (AOAD) with the support of FAO and Bioversity International for the development of guidelines and model legislation on the implementation of the ITPGRFA and its MLS in the countries of the Near East region. A workshop held in Cairo in March/April 2009 agreed on a roadmap for the development of the guidelines and their implementation in selected countries in the region.

A second example is the European initiative to establish AEGIS. This system, which has been developed within the framework of the ECPGR, would provide for the establishment of a European Collection, consisting of selected accessions designated by the individual countries. Material designated as part of the European Collection would continue to be conserved in the individual genebanks concerned, but would be maintained in accordance with agreed quality standards and would be made freely available, both within Europe and outside, in accordance with the terms and conditions set out in the ITPGRFA using the SMTA. In so doing, the countries plan to share responsibilities relating to the conservation and sustainable use of PGRFA and thus to develop a more efficient regional system in Europe. Both Annex 1 and non-Annex 1 materials can be designated as part of the European Collection.[18]

A third regional: initiative is that underway in the Pacific Region, where the Pacific Island countries have agreed to make Annex 1 material available through their regional genebank, CePaCT, run by the SPC. The SPC is in the process of concluding an Agreement with the Governing Body under Article 15.5 of the ITPGRFA, placing the regional germplasm collection within the purview of the ITPGRFA.

Access and Availability of PGRFA under the MLS: Table 7.1 provides information on rates of acquisition and distribution by CGIAR centres during the first seven months of operation of the system as reported to its Governing Body at its Second Session in 2007.[19] Further information is provided on acquisition and distribution by CGIAR centres during the year commencing 1 August 2007 as reported to the Third Session of the Governing Body.[20] Seventy-four percent of the materials were distributed to developing countries and six percent to developed countries.

So far, there is still little quantifiable information on the flow of germplasm from national sources, although it is clear that an increasing amount of PGRFA is now circulating under the MLS. In particular, it is understood that a number of countries, such as Canada, Egypt, Germany, the Islamic Republic of Iran, the Netherlands, the Nordic countries and the Syrian Arab Republic, are now distributing Annex 1 materials widely under the SMTA. The ITPGRFA Secretariat's report to the Third Session of the Governing Body on the implementation of the MLS also provides information on materials made available under emergency disaster situations over the last decade or so.[21]

7.3.3.3 *National and regional implementation of access and benefit-sharing under the Convention on Biological Diversity*

The implementation of ABS does not necessarily require the adoption of a legislative framework. Indeed, the number of national instruments implementing ABS under the CBD is still relatively limited. Several countries, particularly developed countries, tend to favour a strategy of using administrative policies and placing few if any legal or regulatory conditions on access to genetic resources, other than those inherent in general property laws (real and intellectual), contract law, forest and wildlife protection laws and/or under international agreements such as the ITPGRFA. The Nordic Ministerial Declaration of 2003 'Access and Rights to Genetic Resources'[22] is an example of this approach.

The number of laws regulating ABS is, however, increasing. As of February 2010, the CBD Database on ABS Measures[23] listed 32 countries[24] that had some legislation or regulations addressing ABS, of which 22 had adopted new laws or regulations since 2000. The laws are either part of general legislation on the environment or free-standing legislation on biodiversity or genetic resources.

For the most part, ABS legislation tends to be drafted primarily to cover the issues raised by *in situ* bioprospecting including, in particular, access to genetic resources and associated traditional knowledge in indigenous and local communities, although the legislation also applies, sometimes expressly, to accessing genetic resources in *ex situ* conditions.

So far as access regimes are concerned, provisions in national legislation are fairly standard, requiring application to a central authority for permission to access genetic resources and associated local knowledge, prior informed consent of the national authority and the indigenous and local landowners or communities where access is to take place, and arrangements for benefit-sharing with both the central authority and the indigenous or local communities concerned. In an increasing number of countries,[25] a distinction is being made between access for research and access for commercial purposes, although the borderline is very difficult to establish. Where the use

TABLE 7.1
Experience of the CGIAR centres with the SMTA from 1 January 2007 to 31 July 2007 (first line) and 1 August 2007 to 1 August 2008 (second line)

Acquisitions	Transfers of raw PGRFA	Transfers of PGRFA under development	Total transfers	Shipments	Countries	Rejections
3 988	38 210	48 848	97 669	833	155	3
7 264	95 783	348 973	444 824	3 267	-	0

changes after the initial research, then a new ABS agreement is required, but many innovators hesitate to access genetic resources if they have to renegotiate ABS as soon as a profitable product appears on the horizon.

Many countries have no national ABS legislation or policies in place and a constant theme in many of the reports from developing countries is the need to develop them.[26] It is not possible to describe all aspects of national arrangements for ABS. This section will therefore concentrate on the following four issues: benefit-sharing arrangements, traditional knowledge and the rights of indigenous and local communities, as well as regional cooperation and compliance.

Benefit-sharing arrangements: in general, there are few, if any, examples of laws and policies that are broadly acknowledged to be successful in generating tangible benefits and that could provide a model for other countries.[27] Most countries with ABS arrangements in place allow for flexibility in the actual nature of the benefits. This is in line with the thrust of recent studies indicating wide divergences in the practices and interests involved in different sectors that depend on access to genetic resources.[28] There is clearly a need for better market information on the valuation of genetic resources used in different sectors. Recent legislation in some Latin American countries, however, seems to take a different approach, requiring fixed percentages of payments to be made under benefit-sharing arrangements, in addition to non-monetary benefits.

Costa Rica, for example, requires that up to 10 percent, of the budget for research and bioprospecting and up to 50 percent of the royalties obtained from commercialization be paid by the applicant (the actual amounts to be agreed in advance). Under prior informed consent agreements entered into in the period 2004-2006 between the National System of Conservation Areas (SINAC) as provider and the National Institute for Biodiversity as user, SINAC obtained monetary benefits of approximately USD 38 387 of which 89.3 percent resulted from the percentage of the research budget and 10.7 percent from royalties.

Peru requires that the ABS agreement foresee an initial monetary payment or equivalent to the providers of traditional knowledge, to be applied to sustainable development and not less than five percent of the value of the gross sales of products developed from the direct or indirect use of such knowledge. A percentage of not less than 10 percent of the gross value of the sales of those products must also be paid into the Fund for the Development of Indigenous Peoples.[29]

Traditional knowledge and the rights of indigenous and local communities: specific recognition of the rights of holders of traditional knowledge or community knowledge is given in many new ABS enactments. Examples are the African Model Legislation,[30] a proclamation in Ethiopia,[31] and a law in Peru. One new approach has been to provide for the registration of traditional knowledge and to take action against acts of misappropriation. In Peru, this is done through the dissemination of information on the registered rights to patent offices around the world and by taking legal action to oppose IPR being awarded for inventions based on traditional knowledge that has been misappropriated.[32] A new law in Portugal provides for the registration of local varieties and other indigenous material and of associated traditional knowledge, developed in a non-systematic manner by local populations.[33] Registration allows for the sharing of benefits and some protection against misappropriation. It also implies a corresponding responsibility on the rights' holders for the continued *in situ* maintenance of the registered plant material.

Regional Cooperation in the implementation of ABS: the Conference of Parties to the CBD has, on a number of occasions, stressed the importance of regional cooperation on ABS.[34] A number of initiatives have been taken at the regional level in this respect. Examples are Decision 391 of the Andean Community of 1996 establishing a Common Regime on Access to Genetic Resources, the ASEAN Framework Agreement on Access to Biological and Genetic Resources of 2000 and the African Model Legislation for the Protection of the Rights of Local Communities, Farmers and Breeders and for the Regulation of Access to Biological Resources (the Organization of African Unity [OAU] Model Legislation), also of 2000. Each of these regional initiatives takes as its starting point the sovereign rights of states over their genetic resources and sets out basic principles for access to genetic resources, including prior informed consent of the national government providing access and of the local communities involved, along the lines of the Bonn Guidelines adopted in 2001. The OAU Model Legislation deals in more detail with the rights of local communities and Farmers' Rights and also covers PBR. Both the OAU Model legislation and the ASEAN Framework Agreement take the form of guidelines for the establishment of ABS regimes by national governments in the region; however no African country has yet enacted law following the OAU model. The Andean Community Decision 391, on the other hand, requires each Andean Community member to enact legislation that is consistent with it. To the extent that the regional initiatives set out detailed procedures for ABS based on the bilateral model, there may well be a need for Parties to the ITPGRFA to consider revising them to take into account the MLS of ABS established under the ITPGRFA.

Compliance: one of the problems facing national ABS regimes has been difficulty in ensuring compliance with and enforcing the conditions placed on the use of the genetic resources, especially once the material has been accessed and has left the country. Taking legal action to enforce the agreed conditions of ABS in foreign courts is very expensive and can be beyond the resources of many countries. Legal recourse may be necessary not only where genetic resources have been accessed in contravention of national legislation or used in contravention of the agreed conditions but also when, following initial research, the material is used for purposes that were not covered in the original agreement, such as commercial exploitation. It was partly for these reasons that the role of the Third Party Beneficiary was conceived in the SMTA under the MLS established under the ITPGRFA.[35]

While the issue of compliance remains complex, the proposal for a certificate of origin/source/legal provenance is one approach being suggested in international fora as a means of alleviating at least some of the concerns, although its feasibility remains in some doubt. The requirement for such a certificate has been taken up in the ABS legislation of a number of developing countries, for example Costa Rica and Panama.

Disclosure of origin requirements have been enacted in the patent legislation of a number of European countries, including Belgium, Denmark, Germany, Norway, Sweden and Switzerland.

7.4 Farmers' Rights under the ITPGRFA

The ITPGRFA deals with the issue of the realization of Farmers' Rights, a concept originally launched in the interpretations of International Undertaking on PGR. Recognizing that the responsibility for realizing Farmers' Rights rests with national governments, Article 9 of the ITPGRFA calls on Contracting Parties to take appropriate measures to protect and promote Farmers' Rights. For the first time in an international instrument, the possible scope of Farmers' Rights is clarified, as including: the protection of traditional knowledge relevant to PGRFA; the right of farmers to equitably share benefits that result from their use; and their right to participate in making decisions, at the national level, on matters related to the conservation and sustainable use of PGRFA. The ITPGRFA does not limit any rights that farmers have to save, use, exchange and sell farm-saved seed/propagating material, subject to national law.

Recent debates on the implementation of Farmers' Rights have focused on the distinction between the 'ownership' approach and the 'stewardship' approach. The former places emphasis on the right of farmers to be rewarded for genetic material obtained from their fields and used in commercial varieties and the latter places emphasis on the rights that farmers need to have in order to allow them to continue as stewards and innovators of agrobiodiversity. Both approaches are clearly reflected in the present state of national implementation of Farmers' Rights as described in Chapter 5.

The Third Meeting of the Governing Body of the ITPGRFA, held in Tunis in 2009,[36] reviewed the state of implementation of Article 9 of the ITPGRFA dealing with Farmers' Rights. As Contracting Parties had provided only a small number of submissions, describing the status of implementation, the Secretariat of the ITPGRFA was requested to convene regional workshops on Farmers' Rights to discuss national experiences in implementing the Article.

7.5 Changes since the first State of the World report was published

Since the publication of the first SoW report, there has been a great deal of activity with respect to the development of the international and national legal and policy frameworks for ABS. Less progress has been made overall in the implementation of Farmers' Rights. Major changes that have occurred in these areas include:

- perhaps the most far-reaching development has been the entry into force of the ITPGRFA in 2004. This International Treaty establishes an MLS of ABS that facilitates access to PGRFA of the most important crops and forages for food security; as of February 2010, there were 123 Parties to the ITPGRFA;
- negotiations have been initiated by the Contracting Parties to the CBD aimed at developing an international regime on ABS. These are scheduled to be finalized before the 10th Meeting of the Conference of Parties in 2010;
- discussions on certain matters related to ABS are also taking place in other fora such as the TRIPS Council, WIPO and WHO;
- the FAO CGRFA adopted a Multi-Year Programme of Work in 2007 and recommended that "FAO continue to focus on ABS for genetic resources for food and agriculture in an integrated and interdisciplinary manner…", including PGRFA, along with genetic resources of farm animals, microbes and beneficial insects, fish and forest species;
- in February 2010, the CBD Database on ABS Measures listed 32 countries with legislation or regulations addressing ABS. Of these, 22 had adopted new laws or regulations since 2000. Most of these have been developed in response to the CBD rather than the ITPGRFA.

7.6 Gaps and needs

While much has been achieved, the following is a list of some of the areas that still require attention:

- at the global level, there is still a great deal of work to be done in international fora on defining a comprehensive international ABS regime. Any new international regime needs to take into account the specific needs of the agriculture sector and other sectors;
- while the special requirements of PGRFA are provided for in the ITPGRFA, more needs to be done to raise awareness of the importance of the ITPGRFA among governments and to encourage wider participation therein;
- many countries have expressed the need for assistance, both with regards to advice and capacity building for the implementation of the ITPGRFA and its MLS for ABS. Assistance is also needed in ensuring a proper interface between the ITPGRFA and the CBD;
- potential difficulties remain in implementing ABS in the context of material found in *in situ* conditions, even when that material falls within the MLS;
- there is a need for stronger coordination in the development of policies, legislation and regulations among the various ministries, state, regional or provincial governments and other institutions having responsibility for different aspects of PGRFA;
- several countries have expressed the need for assistance in developing policies, legislation, regulations and practical measures for implementing Farmers' Rights. While a few countries are experimenting in this area, to date there are no well-proven models that could be widely adopted. Existing examples of such legislation need to be evaluated and information made available on their effectiveness and how they function in practice;
- one way to realize Farmers' Rights is through making available better varieties. Plant breeding and seed dissemination systems need to be strengthened and greater attention paid to the needs and circumstances of resource-poor farmers, the guardians of much genetic diversity. Regulatory systems also need to be responsive to the needs of farmers.

References

1 Article 13.6 requires the Contracting Parties to consider modalities of a strategy of voluntary benefit-sharing contributions from Food Processing Industries that benefit from plant genetic resources for food and agriculture.

2 The term *sui generis* is used in the legal sense of an instrument that is designed for a specific purpose, in this case a legal instrument specifically designed to protect plant varieties.

3 Article 5.2 of the International Convention for the Protection of New Varieties of Plants, 1961, as revised in 1972, 1978 and 1991.

4 **CGRFA-**11/07/Report. Available at: ftp://ftp.fao.org/docrep/fao/meeting/014/k0385e.pdf

5 Country reports: Morocco, Nepal, Spain, Sri Lanka and Uruguay.

6 Available at: http://km.fao.org/gipb/

7 **Young, T.** 2004. Legal issues regarding the international regime: objectives, options and outlook. *In* Carriosa, S., Brush, S., Wright, B. and McGuire, P. (Eds.) *Accessing Biodiversity and Sharing the Benefits: Lessons from Implementing the Convention on Biological Diversity.* IUCN Environmental Policy and Law Paper No. 54, 2004, pp. 271-293.

8 Some assistance is already being offered by FAO and Bioversity International under their Joint Programme of Assistance to countries who request it in the implementation of the ITPGRFA and its MLS. See ftp://ftp.fao.org/ag/agp/planttreaty/noti/NCP_GB3_JIP1_e.pdf

9 For example, the Acre State Law, Accesso a recursos genéticos lei estadual, 1997, and Amapá State Law on Access to Genetic Resources, 1997.

10 These include the 11 CGIAR centres holding in trust collections, CATIE, the COGENT coconut collection for Africa and the Indian Ocean, the COGENT coconut collection for the South Pacific, and the Mutant Germplasm Repository of the FAO/IAEA Joint Division. Agreements are expected to be signed in the near future with the International Cocoa Genebank of the University of the West Indies, and the Secretariat of the Pacific Community (SPC).

11 Notification from the ITPGRFA Secretariat dated 11 June 2008. Available at: ftp://ftp.fao.org/ag/agp/planttreaty/noti/csl806e.pdf

12 Available at: http://www.planttreaty.org/inclus_en.htm

13 Op cit. Endnote 12.

14 Review of the Implementation of the MLS, FAO Doc. IT/GB-3/09/13.

15 Country reports: Germany and Netherlands. It is also reported that United Kingdom has also successfully encouraged government-supported institutions to place their collections in the MLS.

16 Ethiopia, Proclamation No. 482/2006 on Access to Genetic Resources and Community Knowledge, and Community Rights, 2006, Article 15. The Proclamation provides for a Special Access Permit.

17 Country reports: Morocco, Sudan and Syrian Arab Republic.

18 For an account of AEGIS, see http://www.ecpgr. cgiar.org/AEGIS/AEGIS_home.htm

19 Experience of the centres of the CGIAR with the implementation of the agreements with the Governing Body, with particular reference to the SMTA, FAO Doc. IT/GB-2/07/Inf. 11.

[20] Experience of the International Agricultural Research Centres of the CGIAR with the Implementation of the Agreements with the Governing Body, with particular reference to the use of the SMTA for Annex 1 and Non-Annex 1 Crops, FAO Doc. IT/GB-3/09/Inf.15.

[21] Review of the Implementation of the MLS, FAO Doc. IT/GB-3/09/13.

[22] Available at: http://www.norden.org/pub/miljo/jordogskov/sk/ANP2004745.pdf

[23] Available at: http://www.cbd.int/abs/measures.shtml

[24] Country reports: Afghanistan, Argentina, Australia, Bhutan, Brazil, Bulgaria, Cameroon, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Ethiopia, Gambia, Guatemala, Guyana, India, Kenya, Malawi, Mexico, Nicaragua, Panama, Peru, Philippines, Portugal, South Africa, Uganda, Vanuatu, Venezuela (Bolivarian Republic of) and Zimbabwe.

[25] Country reports: Bhutan, Brazil, Bulgaria, Costa Rica, Ethiopia, Malawi and Philippines.

[26] Country reports: Afghanistan, Algeria, Albania, Armenia, Dominica, Dominican Republic, Fiji, Ghana, Jordan, Lao People's Democratic Republic, Lebanon, Madagascar, Malawi, Malaysia, Mali, Morocco, Namibia, Nepal, Nigeria, Oman, Pakistan, Palau, Russian Federation, Tajikistan, United Republic of Tanzania, Thailand, Trinidad and Tobago, Uruguay, Viet Nam and Zambia.

[27] Op cit. Endnote 7, p. 275.

[28] For example, **Laird, S. & Wynberg, R.** 2008. Study on access and benefit-sharing arrangements in specific sectors, UNEP/CBD/WG-ABS/6/INF/4/Rev.1. Document presented to the Sixth Meeting of the Ad Hoc Open-ended Working Group on Access and Benefit-sharing, Geneva, 21-25 January 2008.

[29] Law No. 27811 of August 2002, Articles 8 and 27 (c).

[30] African Model Legislation for the Protection of the Rights of Local Communities, Farmers and Breeders. and for the Regulation of Access to Biological Resources, OAU Model Law, Algeria, 2000. Available at: http://www.opbw.org/nat_imp/model_laws/oau-model-law.pdf

[31] Proclamation No. 482/2006 on Access to Genetic Resources and Community Knowledge, and Community Rights.

[32] Law No. 27811 establishing the Protection Regime for Collective Knowledge of Indigenous Peoples Connected with Biological Resources, 2002.

[33] Decree-Law No. 118/2002.

[34] For example, COP decisions II/11 and III/15.

[35] The primary role of the Third Party Beneficiary is to initiate dispute-resolution proceedings under the SMTA where necessary to protect the interests of the MLS. However, the concept originally arose during the negotiations of the SMTA in part out of concern by developing countries for an international mechanism to ensure compliance with the terms and conditions of the SMTA.

[36] **FAO.** 2009. Report of the Governing Body of the ITPGRFA, Third Session. Tunis, Tunisia, 1-5 June 2009 IT/GB-3/09/Report.

Chapter 8

The contribution of Plant Genetic Resources for Food and Agriculture to food security and sustainable agricultural development

8.1 Introduction

Over recent decades, agriculture has undergone enormous changes as a result of both technological advances and changing human needs and desires. On the one hand, yields per unit area have increased dramatically through a combination of improved crop varieties and a greater use of external inputs.[1] On the other hand, there has been increasing pressure on land for uses other than the production of food, as well as growing concerns about the sustainability and safety of some modern practices.

In spite of advances in food production, food insecurity and malnutrition are still widespread. The latest FAO figures indicate that in 2009 there were around 1 billion chronically hungry people in the world, an increase of about 200 million since the World Food Summit in 1996. It is estimated that the number of hungry people increased by over 100 million due to the food price crisis of 2007-2008 alone. Most of the worst affected people (about 75 percent) live in rural areas of developing countries and depend directly or indirectly on agriculture for a large part of their livelihoods. A 70 percent increase in world agricultural production over today's levels will be required to meet the food demands of the estimated 9.2 billion people in 2050. A major share of this productivity increase will have to come from the use of PGRFA to produce higher yielding, more nutritious, more stable and more eco-efficient crop varieties.

In 2000, the United Nations Millennium Declaration was adopted, committing nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets, with a deadline of 2015, that have become known as the Millennium Development Goals (MDG) (see Box 8.1). All countries and all of the world's leading development institutions have agreed to these goals, two of which, in particular, will require the conservation and use of PGRFA if they are to be reached: the eradication of poverty and hunger and the achievement of environmental sustainability.

The aim of this chapter is to discuss the role and contribution of PGRFA to food security, sustainable agriculture, economic development and poverty alleviation. The chapter will not review or interpret these four concepts or their inherent complexity and interlinkages. Instead, it will look at the role of PGRFA in the context of some of the emerging and difficult challenges now facing agriculture. Unlike the other seven chapters, this one does not have a counterpart in the first SoW report and so there is no baseline upon which to build. It thus aims to provide an overall review of the current status of PGRFA in relation to sustainable agriculture, food security and economic development, concludes with a summary of some of the main changes that have occurred in recent years and identifies some of the key gaps and needs for the future.

Box 8.1
The Millennium Development Goals

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria and other diseases.
7. Ensure environment sustainability.
8. Develop a global partnership for development.

8.2 Sustainable agriculture development and PGRFA

Since the United Nations Conference on Environment and Development (UNCED) in 1992 and the subsequent World Summit on Sustainable Development (WSSD) in 2002, 'sustainable development' has grown from being a concept focusing mainly on environmental concerns, to a widely recognized framework that attempts to balance economic, social, environmental and intergenerational concerns in decision-making and action at all levels.[2]

Within the context of overall sustainable development, agricultural systems are extremely important. There are, however, many concerns about the non-sustainability of many agricultural practices, for example: the overuse or misuse of agrochemicals, water, fossil fuels and other inputs; the shifting of production to more marginal land and encroachment into forested areas; and the increased use of monocropping, more uniform varieties and a reduced use of crop rotations. MEA[3] undertaken between 2001 and 2005 reported that about 60 percent of the ecosystems studied were being degraded or used unsustainably, while the demands of a continually expanding human population, climate change and increasing demand for biofuels are all putting new additional pressure on land. The wise use of agricultural biodiversity in general and PGRFA in particular, offers a way forward on many of these inter-related issues. The following sections look at two aspects: the role of genetic diversity in sustainable agriculture and the role of PGRFA in the provision of ecosystem services.

8.2.1 Genetic diversity for sustainable agriculture

PGR are a strategic resource and lie at the heart of sustainable agriculture. The link between genetic diversity and sustainability has two main dimensions: firstly the deployment of different crops and varieties and the use of genetically heterogeneous varieties and populations, can be adopted as a mechanism to reduce risk and increase overall production stability; and secondly, genetic diversity is the basis for breeding new crop varieties to meet a variety of challenges.

A large number of the country reports expressed concern about the increasing use of genetically uniform varieties and the trend for them to be grown on ever larger areas, resulting in increased genetic vulnerability (see Section 1.3). Many called for a greater use of genetic diversity to counter this. The deployment of diversity at the farm and field level helps provide a buffer against the spread of new pests and diseases and the vagaries of weather. In the case of pests and diseases, for example, while some individual component might be susceptible, there is a strong possibility that other components will be partially or totally resistant or tolerant. In such situations, the resistant or tolerant component can produce some yield, thus avoiding total crop failure, and in many circumstances such genetic diversity can also significantly slow the overall rate of spread of a disease or pest. Thus, production strategies that include the deployment of diversity are likely to be more stable overall than monocultures of uniform varieties, they reduce the risk of crop failure and require fewer pesticides. There is also evidence that in cases where heterogeneous varieties are able to exploit a given environment more efficiently and effectively, this can even result in higher yields.

The development and production of appropriate crop varieties provides one of the best mechanisms for addressing many of the most important agricultural challenges related to sustainability. Varieties that are pest and disease resistant require fewer fungicide and insecticide applications; varieties that compete better with weeds require less herbicide; varieties that use water more efficiently can produce higher yields with less water; and varieties that use nitrogen more efficiently require less nitrogenous fertilizer, with a concomitant saving in fossil fuel. While varieties having many of these characteristics already exist, the situation is far from static. Agricultural environments change as do farming systems; new pests and diseases arise and the demand for specific products is constantly shifting. The result is that there is a continual need for new varieties. A variety that performs well in one location may not do so in another and a variety that produces a good yield this year may be knocked out by a new pest next year. In order to be able to continually adapt agriculture to ever changing conditions, plant breeders need to develop and maintain a pipeline of new varieties. Genetic diversity underpins the whole process of producing new varieties; it is the reservoir that enables breeders to maintain a full pipeline.

The country reports cite several examples of the use of PGRFA to improve pest and disease resistance. In Pakistan, for example, two million cotton bales were lost from 1991 to 1993 due to a crop failure caused by Cotton Leaf Curl Virus. Resistant cotton types were subsequently identified and were used to develop new virus resistant cotton varieties adapted to the growing conditions in Pakistan.[4] Morocco was able to release the first Hessian fly resistant durum wheat varieties, derived from interspecific crosses with wild relatives.[5] There are countless such examples and all depend on the existence of PGRFA and the ability of plant breeders to access and use it. While genetic diversity represents a 'treasure chest' of potentially valuable traits, as shown elsewhere in this report, it is under threat and special efforts are needed to conserve it both *in situ* (see Chapter 2) and *ex situ* (see Chapter 3), as well as to develop a strong capacity to use it, especially in the developing world (see Chapter 4).

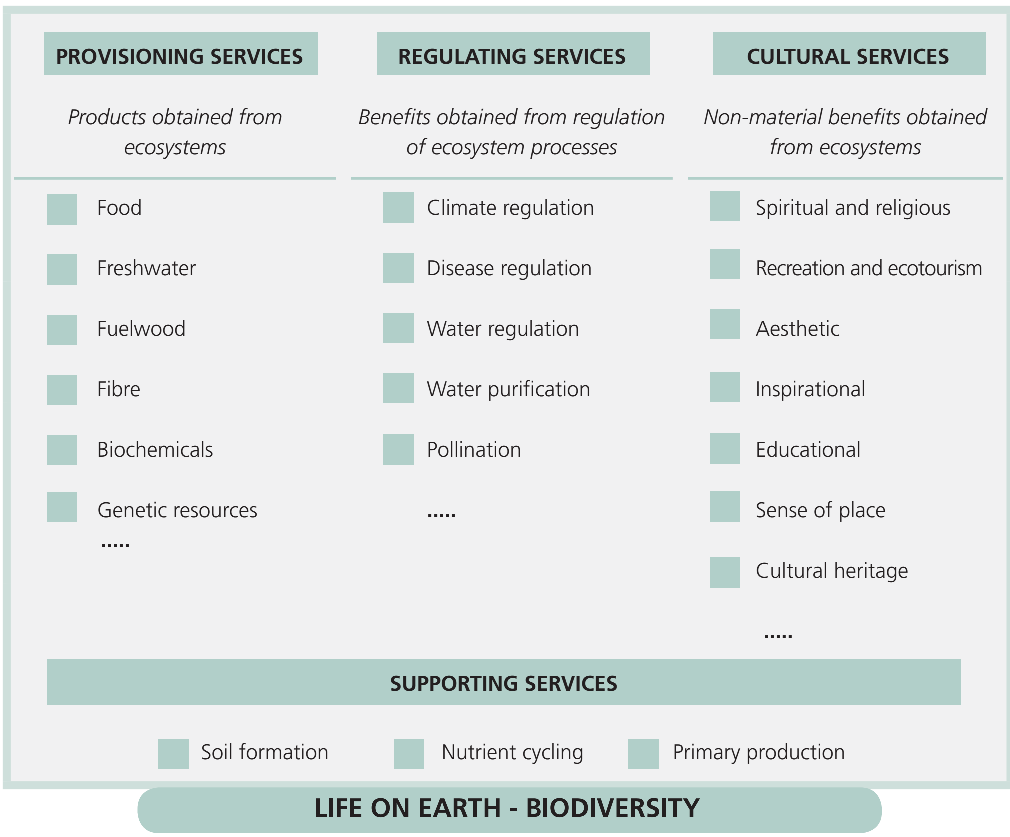
8.2.2 Ecosystem services and PGRFA

Agriculture contributes to development not only as an economic activity and as a source of livelihoods, but is also an important provider of environmental services.

Figure 8.1 illustrates the four broad categories of services provided by ecosystems:

- provisioning services: the supply of products from ecosystems, such as food and genetic resources;
- regulating services: the benefits, such as water purification obtained from the regulation of ecosystem processes;
- cultural services: non-material benefits obtained from ecosystems such as recreation, education and ecotourism;
- supporting services: the services needed for the production of all other ecosystem services. These

FIGURE 8.1
Categories of ecosystem services



Source: Adapted from Ecosystem and Human Well-being: a framework for assessment by the MEA. Copyright © 2003 World Resources Institute. Reproduced by permission of Island Press, Washington, DC.

include such things as nutrient recycling and soil formation.

PGRFA plays an important role in all of the four categories. In addition to being a direct 'provisioning service', genetic resources provide the raw material for improving the production of more and better food, either directly or through providing better feed for livestock. They are also important as the basis for improving fibre, fuel or any other crop product. In the area of 'regulating services,' PGRFA are the basis for improving such services as carbon sequestration by crops, for example, deeper-rooted rangeland species and the control of water run-off and soil erosion. The diversity of traditional crops and foods can provide an important cultural service, e.g. through its importance in agrotourism or ecotourism; and as a 'supporting service' PGRFA can underpin the development of new varieties, for example food and forage legumes, having an enhanced ability to recycle nutrients such as nitrogen within an agro-ecosystem.

In recent years, many programmes have been initiated that seek to enhance these services, in particular, through rewarding those responsible for managing the underlying resource through PES schemes. However, implementing PES is a challenge as many of the services arise from complex processes, making it difficult to determine which actions affect their provision, who is responsible for these actions and who are the beneficiaries who should pay for them. This is particularly true in the case of agrobiodiversity. If, for instance, the on-farm conservation of a particular traditional crop variety is considered eligible for PES, the challenge is to determine which farmer or farmers should be compensated for its conservation. How much should they receive, for how long, who should pay and what mechanisms are in place for monitoring and ensuring that payments are actually made and that the expected service is actually provided? This is a dilemma that also underlies the debate over how to implement farmers' rights (see Chapters 5 and 7). Nevertheless, PES raises hopes and expectations for the development of a more environmentally-friendly agriculture and the PGRFA sector has a critical role and a responsibility to be part of the debate and action.

8.3 PGRFA and food security

Food security and related issues were put firmly on the global agenda in the Rome Declaration on World Food Security in 1996, which called for "the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger." Later, in 2002, the 'World Food Summit:*five years later*' led to the development of voluntary guidelines to support the progressive realization of the right to adequate food in the context of national food security.[6] These guidelines were adopted by the 127th Session of the FAO Council in 2004.

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The four pillars of food security are: availability, stability of supply, access and utilization.[7] The PGRFA sector has multiple roles to play in helping ensure food security, for example: producing more and better food for rural and urban consumers; providing healthy and more nutritious food; and enhancing income generation and rural development. There is, however, need for a greater recognition of the multiple roles and contributions that PGRFA can play and for a strengthening of the linkages among all relevant institutions dealing with food security at the global, regional, national and local levels.

8.3.1 Crop production, yields and PGRFA

Agricultural production in general and crop production in particular, must increase substantially in order to meet the rising food demand of a population that is projected to expand by some 40 percent over the period from 2005 to 2050. According to one projection by FAO, an additional billion tonnes of cereals will be needed annually by 2050. As on average, only 16 percent[8] (15 percent of cereals and 12 percent of meat) of the world's agricultural production enters international trade, much of the increase will have to be met through expanding production in those, mainly developing countries that experience the greatest increase in demand.

Many country reports from all regions have documented the vital role of sound PGRFA management in strengthening national food security and improving livelihoods. In China, for example, varieties of rice, cotton and oilseed crops have all been replaced four to six times throughout the country since 1978, each replacement representing the introduction of a new variety that was an improvement over the one it replaced. Yield increases of 10 percent and more were associated with each replacement and with every 10 percent yield increase, the level of poverty was reduced by six to eight percent.[9] According to Malawi's country report, adoption of improved varieties of sorghum and cassava has led to higher yields and greater food security at both the household and national level. The increased use of improved varieties has also opened up business opportunities for farmers and the extra income derived from marketing cash crops and value added products, such as cassava snacks, has helped to boost local industry such as the fabrication of cassava processing equipment, increased the use of cassava in livestock feed and provided funds for the development of local on-farm seed programmes.[10]

Recent experience with crop productivity growth gives reason for both optimism and concern. When growth in yield per unit area has been assessed for key staple crops over the past several decades, it is apparent, particularly for wheat, that productivity growth has levelled off in recent years (see Figure 8.2). Rice and maize productivity have continued to increase on a world scale, although rice yield increases have also levelled off in East and Southeast Asia. In Africa, yields of major crops like rice, maize and wheat are still far below those typically seen in other regions. However, good progress is being made, for example through the development and fast dissemination of NERICA[11] rice (see Box 8.2). While much of the yield increase is attributable to a combination of factors including an increased use of inputs and good weather conditions, a major factor has been the development and dissemination of improved crop varieties.

The production of staple food crops remains the largest agricultural subsector in most countries and will continue to play an important role in meeting food security and agricultural development objectives in the future. Sustaining productivity growth in 'breadbasket' zones, where new, high-yielding varieties and associated practices have already been widely adopted, will remain an important strategy for meeting future

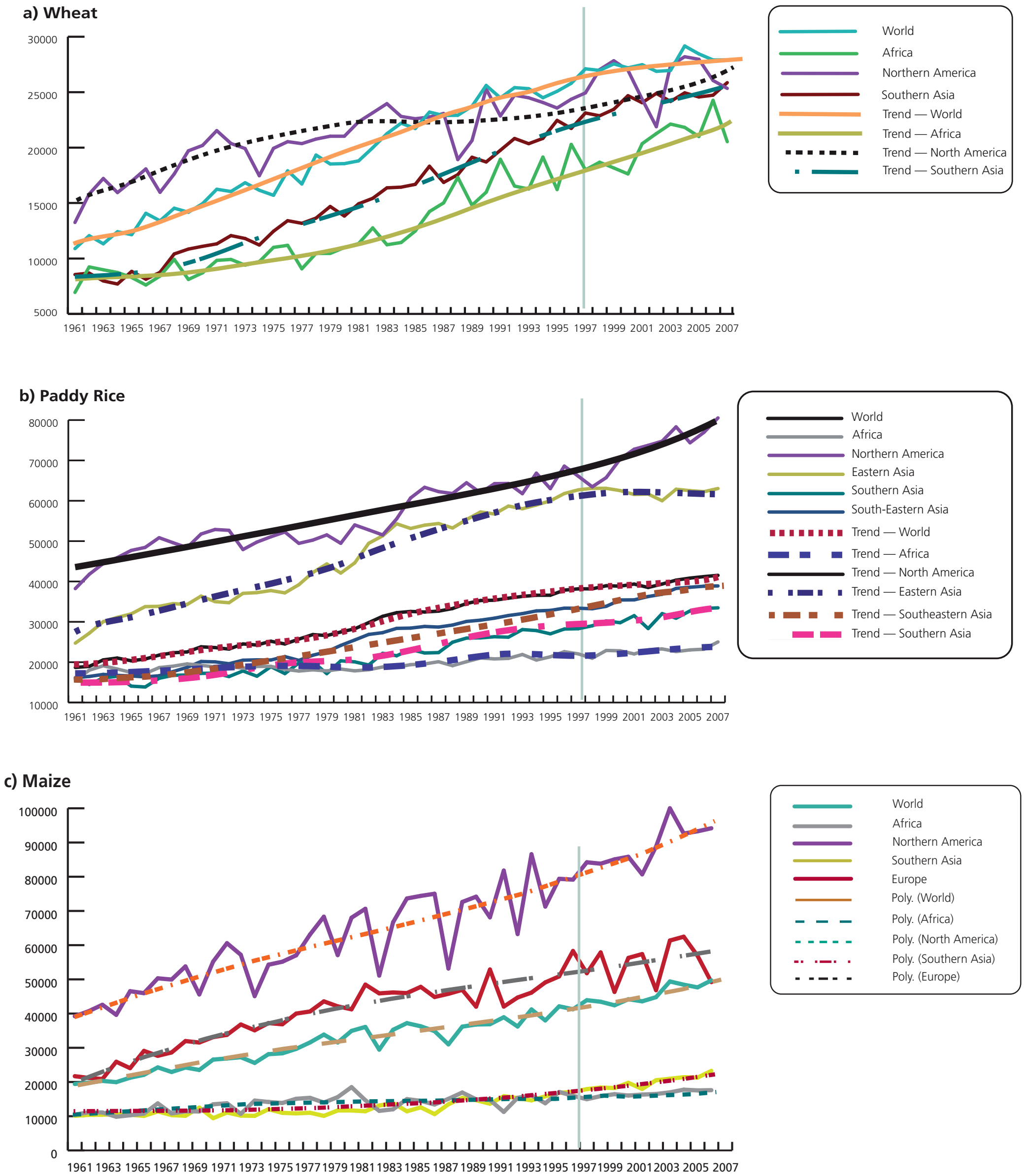
Box 8.2
NERICA Rice

The term NERICA, 'New Rice for Africa', is used to refer to the genetic material derived from the successful crossing by WARDA in the early 1990s, of the two species of cultivated rice, the African rice (*O. glaberrima* Steud.) and the Asian rice (*O. sativa* L.), to produce progeny that combine the high yielding traits from the Asian parent and the ability to thrive in harsh environments from the African parent. The *O. glaberrima* accessions used in the breeding programme came from the WARDA genebank and simple biotechnological techniques (anther culture and doubled haploids) were used to overcome sterility barriers with *O. sativa*.

NERICA is a new group of rice varieties that adapt well to rainfed ecologies in Sub-Sahara Africa, where 70 percent of smallholder farmers cultivate rice. The new varieties have a higher yield potential than the traditional varieties grown and have spread at record rates, covering more than 200 000 hectares in West, Central, East and Southern Africa by 2006. The NERICA varieties offer hope to millions of poor rice farmers and consumers.

FIGURE 8.2

Average yields (kg/ha) for a) wheat; b) paddy rice (1961-2007); and c) maize (1997-2007) by major regions (the vertical bar marks the date on which the first SoW report was published)



Source: Faostat (http://faostat.fao.org) food needs, particularly for rapidly growing urban populations. This will require a continued stream of new varieties to meet the changing needs and environments in these 'breadbasket' areas. A significant share of the increase in staple foods will also have to come from more marginal environments, home to many of the world's poorest people. A pipeline of new varieties will also be needed for these areas.

8.3.2 Use of local and indigenous PGRFA

While local landraces and farmers' varieties provide the genetic diversity that underpins much modern plant breeding, for many agrarian countries, such varieties still provide the basis for local food production and security. Indeed, this generally remains their main use in situations where they are still grown by the communities that developed them. Furthermore, they may have a number of advantages, especially in the absence of appropriate alternatives: they are adapted to local environmental conditions, fit in with local farming systems, meet local taste and other preferences and their diversity can bring greater production stability. Local varieties may also command premium prices in niche markets and for agrotourism. There are many examples to illustrate this in the country reports and in other publications. In lowland areas of Viet Nam, for example, many traditional varieties are maintained because of their adaptation to local climate, soils and other conditions and are appreciated for their cultural value, productivity, taste and cooking qualities.[12] An analysis of maize landraces in Mexico[13] found that even though new, high yielding varieties were available and supported by the Government, farmers maintained complex populations of landraces in order to cope with environmental heterogeneity, combat the effects of pests and diseases, meet cultural and ritual needs and satisfy dietary and food preferences. There are a number of programmes, such as the "Programa Nacional do Desenvolvimento Rural do Continente" of Portugal,[14] that support on-farm conservation of PGRFA, promote the use of local varieties and build on local and indigenous knowledge to add value. Latin America has reported several programmes[15] that link small farmers and indigenous communities with governmental agricultural research institutions and genebanks to carry out joint activities on collecting PGRFA, on-farm conservation, reintroduction, evaluation and participatory breeding.

Niche markets for regional and local products have expanded and with them, the role and importance of local crops. The international Slow Food movement,[16] for example, has had a significant impact on raising awareness in many developed countries of the role of traditional food in local culture, the nutritional value of many local foods and the importance of dietary diversity and reduction of 'food miles'. Several international initiatives have also supported this trend, such as the growth of 'fair trade' systems and the increasing use of 'geographical indications' to designate the specific geographical origin of a food item possessing qualities or a reputation that are related to the place of origin.[17] Finally, organic crop production, requiring varieties that are adapted to organic growing conditions, has gained in importance globally and is often associated with initiatives aimed to promote traditional and local food.

8.3.3 Climate change and PGRFA

While the effects of climate change are only now beginning to be felt, there is a growing consensus that unless drastic measures are taken its future impact could be enormous. This topic was the main theme of a seminar held in 2009 on the occasion of the First Anniversary of the SGSV. The importance of taking immediate action was addressed in a Summary Statement arising from the seminar[18] that concluded: "*…we ask the nations of the world to recognize the urgency of adapting agriculture to climate change, that crop diversity is a prerequisite for this adaptation and therefore that the importance of ensuring that the genetic diversity of our crops is properly conserved and available is a basic prerequisite for feeding a warming world*".

Prediction models of the IPCC[19] as well as other reports[20] indicate that there will be severe effects on agricultural productivity in many parts of the world. The news is not all bad, however; some regions, especially those further away from the equator, are expected to have longer growing seasons and will become more productive, as long as high yielding varieties that are adapted to the new environmental conditions are available.

Unfortunately, it is expected that regions such as South Asia and Southern Africa are likely to be most affected by climate change; areas of the world that are home to the largest number of poor people and that are least able to cope.[21] In many regions, adapting agriculture to the new conditions will require a shift to more drought-tolerant or heat-tolerant varieties or even to other crops. Changes in pest and disease patterns are likely to take place and indeed may be already happening, resulting in the need for new resistant or tolerant varieties. Less predictable weather patterns may also require the development of new varieties that are adapted to a wider range of more extreme conditions.

New varieties will also be needed for agriculture to be able to play a greater role in mitigating climate change. For example, varieties with greater biomass, e.g. that have deeper rooting, coupled with appropriate agronomic practices, can result in the capture of more carbon in the soil. Feed and forage varieties that result in less methane being emitted by ruminants can be bred as well as varieties that are able to use nitrogen more efficiently and need less fertilizer and hence less total energy, but also result in reduced emissions of the potent greenhouse gas nitrous oxide. Although bioenergy crops were mentioned in only relatively few country reports, there have been significant moves to increase the production of biofuels in many countries in response to growing concerns about climate change and in the face of fossil fuel scarcity.

Overall, the difficulties of mitigating against and adapting to climate change are likely to make it considerably more difficult to meet the increased demand for food in the future. The challenge will be exacerbated further by growing competition for land for other uses, such as urban development or for growing new crops. In order to meet such challenges it is essential that greater attention be devoted to conserving genetic diversity and in particular, to targeting the collection and conservation of landraces and CWR that have traits that are likely to become more important in the future. Coupled with this, it is essential that plant breeding efforts be stepped up around the world, especially in those developing countries likely to be hardest hit by climate change. This will require greatly enhanced attention to capacity building in traditional as well as modern crop improvement techniques.

8.3.4 Gender dimensions of PGRFA

Gender is an important determinant of the extent and nature of the diversity of crops and varieties grown and is a key aspect of sustainable crop production and food security. Rural women are responsible for half of the world's food production and produce between 60 and 80 percent of the food in many developing countries. Women often have a particular responsibility for managing home gardens and these tend to include a wider variety of vegetables, fruit, spices, medicinal and other crops than is generally the case for fields producing staple-crops and for which men often have a primary responsibility.[22] Gender differences are further evident in varietal choices and the importance placed on different traits. Research in the United Republic of Tanzania, for example, showed differences between male and female farmers in the different importance and ranking they gave to various traits in sorghum.[23]

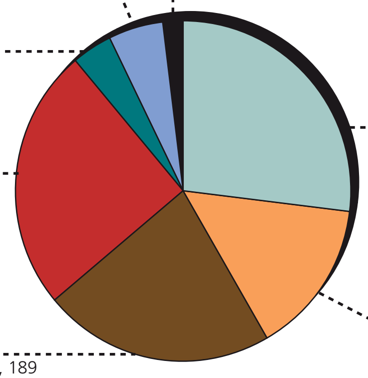
While overall this did not come across clearly in the country reports, it is critical that the role of rural women be better understood and taken into account in policy-making and in all relevant PGRFA initiatives.

8.3.5 Nutrition, health and PGRFA

The majority of food-insecure and undernourished people live in rural areas. They are most numerous in Asia and Sub-Sahara Africa. Seven countries comprising Bangladesh, China, the Democratic Republic of the Congo, Ethiopia, India, Indonesia and Pakistan account for 65 percent of the world's food insecure people (see Figure 8.3).

PGRFA underpin not only total food production but also nutritional well-being (see Section 4.9.4). The best insurance against nutrient deficiencies is through eating a varied diet, thereby ensuring an adequate intake of all the macro and micronutrients needed for good health. However, many poor people

FIGURE 8.3
Number of undernourished people in the world, 2003-2005 (millions)



Source: FAO, 2008, The State of Food Insecurity in the World, Rome

do not have access to, or are unable to afford, an adequately diverse diet and have to rely heavily on just a few staple food crops for most of their food. In recognition of this, a number of breeding efforts are underway to improve the nutritional quality of staple crops, for example, by producing rice, maize, cassava and sweet potato with higher levels of beta–carotene (the precursor of Vitamin A), pearl millet and beans with higher levels of available iron and rice, wheat and beans with higher levels of zinc.[24]

In addition to the important direct relationship between PGRFA, nutrition and human health, there are various indirect effects. For example, for resource poor populations in countries faced with the problems caused by HIV/AIDS, the consumption of diverse diets represents an important way of boosting human resistance and tolerance.

Plants are also an extremely important source of pharmaceutical products and, as for all crops, the current production of medicinal crops as well as their future improvement is dependent on their genetic diversity. In some African and Asian countries, up to 80 percent of the population depends on traditional, mainly herbal, medicine. In Kenya, for example, a recent World Bank study indicated that 70 percent of the population is not covered by the national healthcare system and depend on traditional forms of medication.[25] Herbal medicines are highly lucrative: annual revenues in Western Europe reached USD 5 billion in 2003-2004, in China sales totalled USD 14 billion in 2005 and revenues of USD 160 million were generated from herbal medicines in Brazil in 2007.[26]

8.3.6 Role of underutilized and neglected PGRFA

Since the first SoW report was published, many studies have documented the importance of neglected and underutilized species for the food security and income of local communities (see Section 4.9.2). By definition, the area sown to these crops is relatively small worldwide;[27] there are few marketing opportunities and relatively little effort at crop improvement. Nevertheless, country reports from all regions have described the role and uses of different species, ranging from those that are important for dietary diversity or have the potential to make a greater contribution to generating income, to those that are likely to become more important in local farming systems as climate changes.[28] They emphasize the importance of many of these species in the social and cultural fabric of local societies and call for increased efforts to conserve and use them. Many countries have reported efforts made over the past decade to collect, characterize, evaluate and conserve samples of underutilized species in their NPGS[29] as well as efforts to promote and market them.[30]

While much has been done in this area, much more still needs to be done, in particular, in developing markets for the products of neglected species. Efforts of institutions such as Crops for the Future (see Section 6.3.3)[31] can make a very valuable contribution to ensuring that neglected and underutilized crops play a greater role in sustainable agriculture and livelihood systems in the future.

8.4 Economic development, poverty and PGRFA

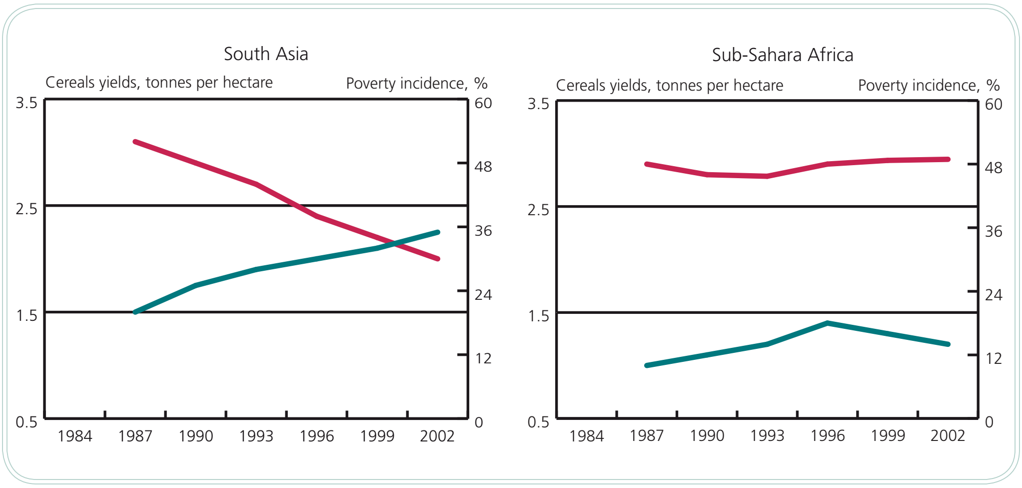
The economic health and prosperity of a country depends on a large number of factors of which agricultural productivity and growth is one. The importance of agriculture varies by region, from only 1.9 percent of the population dependent on agriculture in North America to over 50 percent in Africa and Asia. However, taken overall, agricultural production is the main source of income for about half of the world's population. The choice of crops, varieties, planting materials and associated production methods have a significant influence on productivity and livelihoods. Generally, farmers grow a number of different crops and varieties, each of which provides a set of benefits in the form of income, food and other products. In addition, benefits may arise from the overall portfolio of crops and varieties, including mitigation against the effects of failure of any one crop or variety, spreading production through the year and achieving a greater intensity of land use.

Marketed values vary by crop, variety and marketing channel. In many countries the growth of a dynamic food-marketing sector has created high-value potential market outlets, representing an important means of increasing farm incomes and achieving food security. Several studies have indicated that agricultural productivity growth has had an important effect on poverty reduction[32] and plant breeding has played a predominant role in this. Nonetheless, while this is certainly the case for Asia and Latin America, the relationship is less clear in Sub-Sahara Africa where agricultural yields have generally stagnated, making it more difficult to clearly establish a relationship with poverty reduction (see Figure 8.4).

Many small farmers experience difficulties in accessing both input and output markets and several country reports indicated that this is one of the most serious constraints to diversifying crop production. Lack of access to good quality seeds of appropriate varieties can prevent farmers from entering specific markets. Numerous country reports, particularly from Africa, referred to the suboptimal state of seed production and distribution systems, noting widespread problems with insufficient availability of seeds of new and appropriate varieties. Overcoming input and output bottlenecks and inequalities in the value chain is a key strategy for increasing the market value of crops and one that has important implications for the management of PGRFA.

While sound crop management (together with land and water management) is critical for success, it is very difficult to place an exact economic value on the underlying genetic resources. Estimating the value of PGRFA by rigorous economic methods summing their direct use, indirect use, option and non-use values underestimates their overall value.[33] This problem hampers efforts to make a case for investing more in PGRFA and is a significant impediment to securing adequate funding. However, some of the most convincing data come from impact studies based on tracing germplasm flows. In one study,[34] for example, it was estimated that conserving 1 000 accessions of rice generates an annual income stream for developing countries that has a direct use value of USD 325 million at a 10 percent discount rate. This calculation also serves to highlight the need for better integration and linkages between conservation, plant breeding and seed delivery for realizing the full potential of PGRFA.

FIGURE 8.4
Cereal yield and poverty in South Asia and Sub-Saharan Africa



Source: Ravallion, M. & Chen, S. 2004. World Bank, 2006

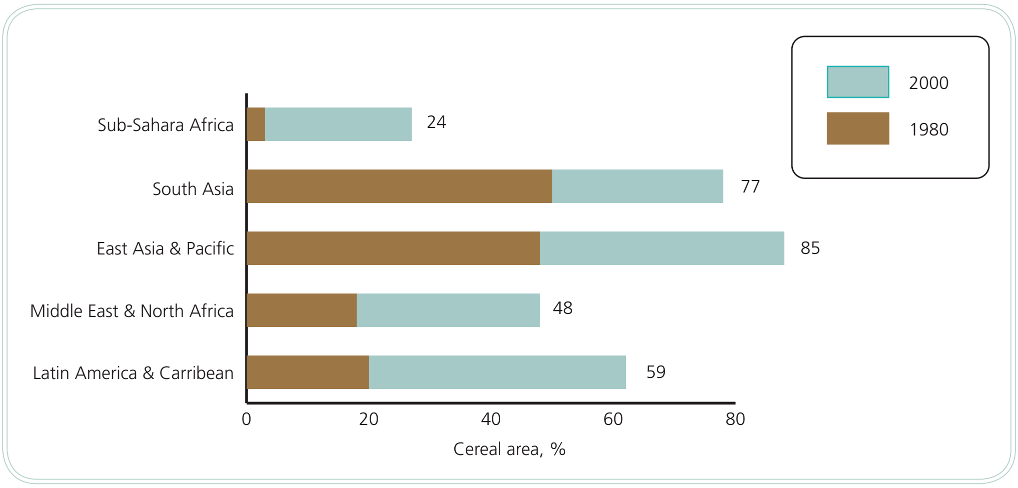
8.4.1 Modern varieties and economic development

Overall, the contribution of modern varieties to agricultural growth and poverty reduction has been very impressive.[35] The impact has been both direct and indirect: high yields generating higher incomes, but also generating employment opportunities and lower food prices.[36]

However, in a study across 11 food crops in four regions over the period 1964-2000,[37] it was concluded that the contribution of modern varieties to productivity increases was a 'global success, but for a number of countries a local failure.' Many of these countries are located in Sub-Sahara Africa where adoption of improved varieties of cereal crops was very low during the initial phases of the Green Revolution and only began to reach significant levels in the late 1990s (see Figure 8.5). It is interesting to note, in this respect, that the yield growth experienced by Sub-Sahara Africa, although relatively small, has been almost completely attributable to modern varieties, with little contribution from fertilizer and other inputs.[38]

There is considerable variability in adoption patterns of modern varieties within regions as well as across crops. In Latin America, for example, farmer-saved maize seed was grown by 60 to 100 percent of farmers in most Central American countries (with the exception of El Salvador) and by more than 50 percent of the farmers in the Plurinational State of Bolivia, Colombia, Paraguay and Peru.[39] However, hybrid seed maize was more widely used in Argentina, Brazil, Ecuador, Uruguay and the Bolivarian Republic of Venezuela. Similar patterns were evident in Eastern and Southern Africa, where the adoption of modern semi-dwarf varieties of wheat was high in most countries, but adoption of hybrid maize was far patchier (e.g. 91 percent adoption in Zimbabwe compared with 3 percent in Mozambique). Several factors help to explain these trends. One is environmental heterogeneity – e.g. in the harsh and variable highland regions of the Andes, local maize varieties may be better suited than improved hybrids. Another factor may be the availability of a large range of alternative types. Ethiopia, for example, which had lower levels of adoption of semi-dwarf wheat than other countries in the region, is a secondary centre of diversity for durum

FIGURE 8.5
The growth in area under improved cereal varieties in 1980 and 2000



Source: Evenson, R.E. & Gollin, D. (eds.).

wheat and thus greater genetic diversity was available to help farmers in their heterogeneous and difficult growing environments.

Studies at the household level paint a varied picture. Adoption tends to vary by crop rather than by household and depends on such factors as the sources of seed and its cost, the specific agro-ecological conditions encountered and on the demands of the farm and consumption system. In an analysis of modern variety adoption of sorghum and bread wheat in low-income farming communities of Eastern Ethiopia,[40] it was found that the poorest people were significantly less likely to adopt modern varieties of either crop, although higher adoption levels were found for wheat than sorghum. Sorghum is a crop with considerable local diversity available through local seed systems; it is grown for multiple purposes and on-farm seed-storage techniques are well developed. In contrast, bread wheat, unlike durum wheat, is a relatively recently introduced crop in this area of Ethiopia and as a result, the genetic diversity available locally is quite limited.

While modern varieties have been shown to contribute significantly to poverty reduction, they have arguably been less successful in enhancing the sustainable agricultural development of small-farm systems, especially in more marginal production environments. Key shortcomings cited have been a lack of adaptation to heterogeneous and harsh production areas[41] and the failure, cited in several country reports, of many centralized plant breeding programmes to breed for traits of concern to small-scale and resource poor farmers.

8.4.2 Diversification and the use of genetic diversity

The choice of which crops and varieties to plant is driven by a range of economic, social and agronomic factors, including the availability of suitable market outlets, prices, familiarity and societal acceptance, costs of production, the need for and availability of production inputs (including seeds, water, fertilizers, pesticides, labour, etc.), climate, soils and topography.

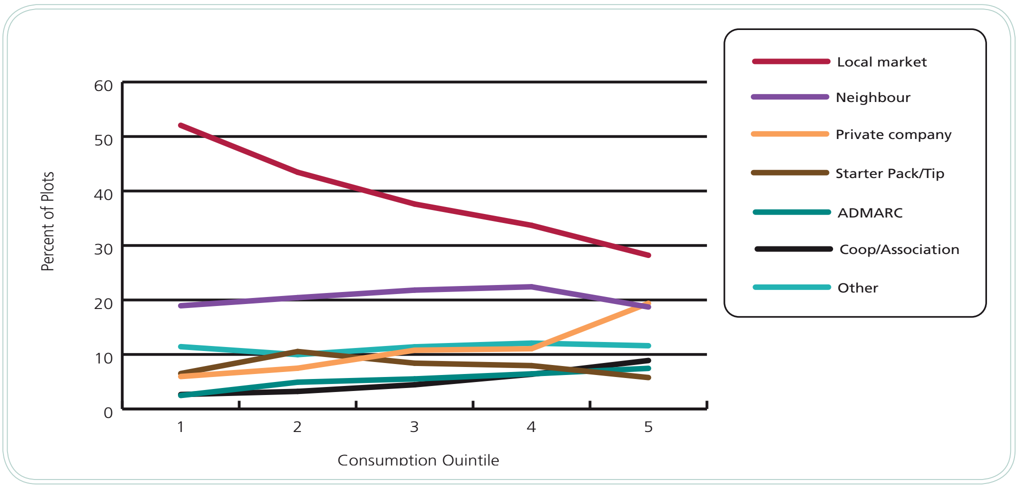
While for the more market-oriented producers varietal choice is largely driven by yield and market demand, this is not the case for most food-insecure farmers. Studies[42] have shown that household farms in most developing countries produce both for their own consumption as well as for sale,[43,44] and that when farmers are both consumers and producers of food, this has a major impact on which crops are grown.

Farm households also tend to draw on a variety of activities to achieve food and income security.[45] Diversification across activities is an important risk management strategy, often one of the very few available to poor farmers. At the crop level, farmers can diversify with respect to the crops and varieties they grow and at the farm level, a diversity of enterprises can be undertaken, e.g. food processing, meat or egg production, agroforestry or agrotourism. Many of these strategies have important implications for genetic diversity and the crops and varieties grown. Households are also increasingly relying on off-farm employment, often with one or more family members taking on paid employment away from the farm and remitting money back home. A recent study looked at data from the FAO Rural Income Generation Project (RIGA) across sixteen developing countries in Africa, Latin America, Asia and Eastern Europe.[46] The study found that income diversification was generally the norm for most of the countries, although less so for those in Africa where off-farm opportunities are normally fewer. Different income diversification strategies, within and outside of agriculture, obviously have different implications for PGRFA management.

8.4.3 Access to seed

Section 4.8 emphasized how, for agriculture to be successful and sustainable, sufficient good quality seed has to be available to farmers at the right time and at the right price. Recent evidence underscores the importance of markets in providing seed to poor farmers.[47] Analysis of the FAO RIGA data for Ghana, Malawi and Nigeria confirms this. In Malawi, for example, purchased seed was used on 30 percent of the plots, a percentage that was essentially the same across all income groups (see Figure 8.6). However, the source of purchased seed varied significantly. While local markets were the most important source of seed for all groups, their relative importance diminished as farmers' wealth status increased and private companies played an increasingly important role in providing seeds to better-off farmers.

FIGURE 8.6
Seed sources by consumption group in Malawi (1=poor; 5=rich)



Source: RIGA Database (available at: http://www.fao.org/es/esa/RIGA/English/Index_en.htm).

Box 8.3
FAO Initiative on Soaring Food Prices

FAO launched the Initiative on Soaring Food Prices (ISFP) in 2007 with the immediate goal of raising USD 1.7 billion for rapidly increasing food production in 2008 and 2009, mainly through supporting direct access to inputs for smallholders in the most affected countries. FAO's assistance has taken the form of:

(i) interventions to increase access by small-scale farmers to inputs (e.g. seeds, fertilizer, animal feed) and improve agricultural practices (e.g. water and soil management, reduction of post-harvest losses);
(ii) policy and technical support;
(iii) measures to increase smallholder access to markets;
(iv) a strategic response to cushion the effects of rising food prices in the short, medium and long term, through increased and sustainable investment in agriculture.

Farmers tend to favour local markets for purchasing seed because 1) locally traded seed is less expensive than seed from industry; and 2) there is a ready availability of locally adapted materials.[48] Many country reports stressed the need for stronger seed production and distribution systems as well as for greater harmonization between the commercial and farmers' seed sectors.

8.4.4 Globalization and PGRFA

Globalization and trade liberalization have increased substantially since the first SoW report was published, leading to rapid economic expansion in many but by no means all countries. Market opportunities have opened up for new products, with the result that the demand for particular crops and varieties has shifted. Many small-scale farming systems that were traditionally self-reliant for seed have increasingly had both the need and the resources to access new varieties. Moreover, a growing share of produce from the small-scale sector is now reaching local, national and even international markets. The privatization of breeding has continued (see Section 4.4) and the commercial plant breeding sector has become markedly more concentrated in the hands of fewer multinational companies.

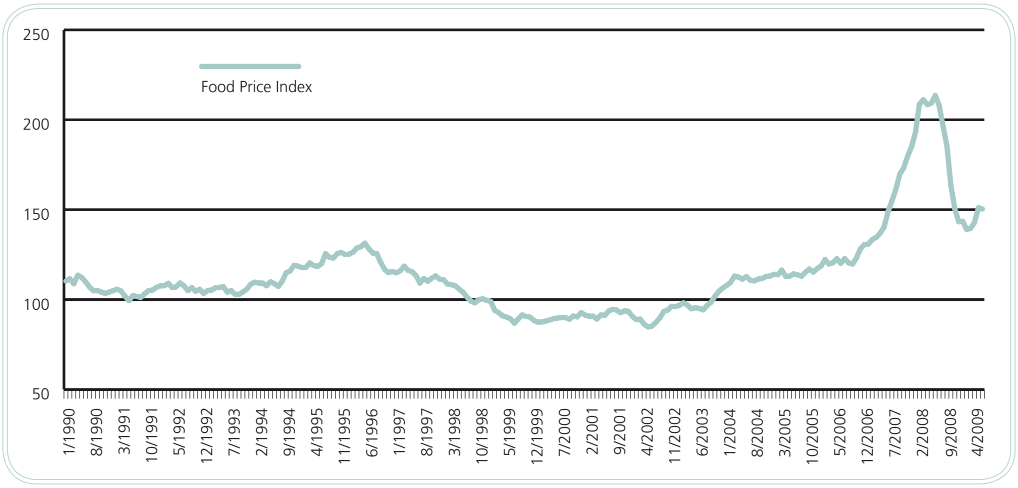
In the first three months of 2008, international food prices of all major food commodities reached their highest level in nearly 30 years (see Figure 8.7). This was the result of a number of factors including: poor harvests in several major producing countries; a marked decline in food stocks; high energy prices; subsidized production of biofuels; speculation on futures markets; the imposition of export restrictions and a lack of investment in the agricultural sector.[49] Although prices of agricultural commodities have come down since then, they remain volatile and as of mid-2009 food prices in the most vulnerable countries remain high, in some cases double what they were just two years before. This has thrown into reverse earlier progress towards achieving the first MDG of eradicating poverty and hunger. In late 2007 FAO launched the ISFP in response to these sudden price increases (see Box 8.3).

While there is no single and easy solution, the wise use of PGRFA, particularly to underpin the breeding of new varieties, can make a very significant contribution to helping the world's poorest people survive and thrive in a world of increasing globalization through helping to expand and stabilize food production and increase the incomes of many of the world's poorest people.

8.5 Changes since the first State of the World report was published

Since the first SoW report was published, a number of trends relating to food security and sustainable

FIGURE 8.7
Volatility of international cereal prices



Source: RIGA Database (available at: http://www.fao.org/es/esa/RIGA/English/Index_en.htm).

agriculture have become more visible and new issues have emerged. Those having the greatest implications for and impact on, the conservation and use of PGRFA include:

- sustainable development has grown from being a movement focusing mainly on environmental concerns, to a widely recognized framework that aims to balance economic, social, environmental and intergenerational concerns in decision-making and action at all levels;
- there have been growing efforts to strengthen the relationship between agriculture and the provision of ecosystem services. Schemes that promote PES, such as the *in situ* or on-farm conservation of PGRFA, are being set up in an attempt to encourage and reward farmers and rural communities for their stewardship of the environment. However, the fair and effective implementation of such schemes remains a major challenge;
- concerns about the potential impact of climate change have grown substantially over the past decade. Agriculture is both a source and a sink for atmospheric carbon. PGRFA are becoming recognized as being critically important for the development of farming systems that capture more carbon and emit fewer greenhouse gasses and for underpinning the breeding of the new varieties that will be needed for agriculture to adapt to the anticipated future environmental conditions;
- strong consumer demand for cheap food has continued, resulting in a sustained focus on the development of more cost-efficient production systems. Multinational food companies have gained in influence and, especially in industrialized countries, food is increasingly being produced beyond national borders in order to keep prices low;
- a simultaneous trend has seen the share of so-called niche or high-value markets expand. In many countries, consumers are increasingly willing to pay higher prices for better quality or novel food, from sources they know and trust. Certification schemes such as 'fair trade' and 'organic' or 'protected designation of origin' (PDO) have been established to help ensure standards and provide reliable source information;
- in most developed countries and in a growing number of developing countries, commercial food

production is responsible for the supply of most food products to the majority of people. Crop varieties have been bred to meet the needs of high-input production systems, industrial processing and strict market standards. There has increasingly been a disconnection between rural producers and growing numbers of predominantly urban consumers;

- in many developing countries, incentives are provided for farmers to shift to more commercial agricultural systems. This is having a major impact on livelihood strategies, culture and on the genetic resources managed by farmers. Initiatives such as the establishment of commodity exchanges in an increasing number of countries, are also resulting in more farming communities being linked to world markets;
- organic agricultural production is receiving greater attention in response to increasing concerns by consumers regarding their diet, health and the environment;
- in spite of the ongoing controversy, GM-crops are being grown on an expanding area in a growing number of countries, but for a limited number of species and traits.

8.6 Gaps and needs

Much progress has been made over recent years in linking the conservation and use of PGRFA with endeavours to increase food security and develop more sustainable agricultural systems. However, there are still many gaps in our knowledge and in the range of action required to improve the situation. Attention is needed, for example, in the following areas:

- the growing consensus on the nature, extent and rate of climate change makes it imperative that far greater attention be paid to anticipating and preparing for its effects. Given the time needed to breed a new crop variety (around ten years), it is essential that additional plant breeding capacity be built now, especially in developing countries and that breeding programmes expand their efforts to develop the traits and varieties needed to meet the challenge;
- there is also a need to step up efforts to conserve landraces, farmers' varieties and CWR before they are lost as a result of changing climates. Special efforts are needed to identify those species and populations that are most at risk and that are most likely to harbour traits that will be important in the future;
- there is a need for more efficient, strategic and integrated approaches to the management of PGRFA at the national level. Links need to be strengthened between those individuals and institutions in both the private and public sectors who are primarily responsible for conservation and those who are primarily concerned with genetic improvement and seed production and distribution;
- at the international level there is also a need for greater coordination and cooperation among agencies and institutions concerned with international and intergovernmental aspects of the conservation and use of PGRFA and those concerned with agricultural production, protection, sustainability and food security, as well as related areas such as health and the environment;
- although much progress has been made, enhanced South-South Cooperation has the potential to contribute much more to the conservation and use of PGRFA, and to strengthening its role in achieving food security and sustainable agricultural development;
- in spite of the enormous contribution by PGFRA to global food security and sustainable agriculture, its role is not widely recognized or understood. Greater efforts are needed to estimate the full value of PGRFA, to assess the impact of its use and to bring this information to the attention of policy-makers and the general public so as to help generate the resources needed to strengthen programmes for its conservation and use;
- there is a need for more accurate and reliable measures, standards, indicators and baseline data for sustainability and food security that will enable better monitoring and assessment of the progress made in these areas. Of particular need are standards and indicators that will enable the monitoring of the specific role played by PGRFA;

- greater attention needs to be given to the development of more decentralized, participatory and gender sensitive approaches to plant breeding in order to more effectively generate varieties that are specifically adapted to the particular production environments and socio-economic situations of the poor in less favoured environments;
- agricultural markets play a vital role in helping achieve food security and sustainable agricultural development. They can help increase the diversity of PGRFA in the seed supply chain and provide outlets for the products of neglected and underutilized crops, leading to greater dietary diversity. Better access by resource poor farmers to markets and strengthened market information systems are needed.

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Annex 1

List of countries that provided information for the preparation of the Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture

List of countries that provided information for the preparation of the SoWPGR-2

Countries	Country reports (111)	Country information other than country reports (12)	NISM (64)
Afghanistan	X		
Albania	X		
Algeria	X		X
Angola		X	
Argentina	X		X
Armenia	X		X
Azerbaijan	X		X
Bangladesh	X		X
Belgium	X	X	
Benin	X		X
Bolivia (Plurinational State of)	X		X
Bosnia and Herzegovina	X		
Brazil	X		
Burkina Faso	X		X
Cameroon	X		X
Chile	X		X
China	X		
Democratic Repubic of the Congo	X		X
Congo	X		X
Cook Islands	X		
Costa Rica	X		X
Cote d'Ivoire	X		
Croatia	X		
Cuba	X		X
Cyprus	X		
Czech Republic	X		X
Denmark	X	X	
Djibouti	X		
Dominica	X		
Dominican Republic	X		X
Ecuador	X		X
Egypt	X		X
El Salvador	X		X
Estonia	X		

ANNEX 1

List of countries that provided information for the preparation of the SoWPGR-2

Countries	Country reports	Country information other than country reports	NISM
Ethiopia	X		X
Fiji	X		X
Finland	X	X	
Georgia	X		X
Germany	X		
Ghana	X		X
Greece	X		
Grenada	X		
Guatemala	X		X
Guinea	X		X
Hungary	X	X	
Iceland	X		
India	X		X
Indonesia	X		
Iraq	X		
Ireland	X	X	
Italy	X		
Jamaica	X		X
Japan	X		
Jordan	X		X
Kazakhstan	X		X
Kenya	X		X
Korea, Republic of	X		
Kyrgyzstan	X		X
Lao People's Democratic Republic	X		X
Lebanon	X		X
The former Yugoslav Republic of Macedonia	X		
Madagascar	X		
Malawi	X		X
Malaysia	X		X
Mali	X		X
Mexico	X		
Morocco	X		X
Namibia	X		

List of countries that provided information for the preparation of the SoWPGR-2

Countries	Country reports	Country information other than country reports	NISM
Nepal	X		
Netherlands	X		
New Zealand	X		
Nicaragua	X		X
Niger	X		X
Nigeria	X		X
Norway	X		
Oman	X		X
Pakistan	X		X
Palau	X		X
Papua New Guinea	X		X
Paraguay	X		X
Peru	X		X
Philippines	X		X
Poland	X		
Portugal	X		X
Romania	X	X	
Russian Federation	X		
Saint Vincent and the Grenadines	X		
Samoa	X		X
Senegal	X		X
Serbia	X		
Slovakia	X	X	
Slovenia		X	
Spain	X		
Sri Lanka	X		X
Suriname	X		
Sweden	X	X	
Switzerland	X	X	
Tajikistan	X		X
United Republic of Tanzania	X		X
Thailand	X	X	X
Togo	X		X
Trinidad and Tobago	X		

ANNEX 1

List of countries that provided information for the preparation of the SoWPGR-2

Countries	Country reports	Country information other than country reports	NISM
Turkey	X		X
Uganda	X		X
Ukraine	X		
United Kingdom	X		
Uruguay	X		X
Uzbekistan	X		X
Venezuela (Bolivarian Republic of)	X		X
Viet Nam	X		X
Yemen	X		X
Zambia	X		X
Zimbabwe	X		X

Annex 2

Regional distribution of countries*

* This report follows the regional distribution of countries used for the preparation of the first State of the World's Plant Genetic Resources for Food and Agriculture published in 1998. It should be noted, however, that this regional distribution does not necessarily follow the regional distribution of countries as determined for the election of Members of the FAO Council.

AFRICA

Subregion	Country
Central Africa	Cameroon, Central African Republic, the Democratic Republic of the Congo, the Republic of the Congo, Equatorial Guinea, Gabon, Sao Tome and Principe
East Africa	Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Uganda
Indian Ocean Islands	Comoros, Madagascar, Mauritius, Seychelles
Southern Africa	Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, United Republic of Tanzania, Zambia, Zimbabwe
West Africa	Benin, Burkina Faso, Cape Verde, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo

AMERICAS

Subregion	Country
Caribbean	Antigua and Barbuda, Bahamas, Barbados, Belize, Cuba, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago
Central America and Mexico	Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
North America	Canada, United States of America
South America	Argentina, Bolivia (Plurinational State of), Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela (Bolivarian Republic of)

ANNEX 2

ASIA AND THE PACIFIC

Subregion	Country
East Asia	China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea
Pacific Region	Australia, Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, New Zealand, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu
South Asia	Bangladesh, Bhutan, India, Maldives, Nepal, Sri Lanka
Southeast Asia	Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor Leste, Viet Nam

EUROPE

Subregion	Country
Eastern Europe	Albania, Armenia, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Montenegro, Poland, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, The former Yugoslav Republic of Macedonia, Ukraine
Western Europe	Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom

NEAR EAST

Subregion	Country
Central Asia	Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
South/East Mediterranean	Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Libyan Arab Jamahiriya, Malta, Morocco, Syrian Arab Republic, Tunisia, West Bank and the Gaza Strip
West Asia	Afghanistan, Bahrain, Iran (Islamic Republic of), Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, Turkey, United Arab Emirates, Yemen

Appendix 1

Status by country of national legislation related to plant genetic resources for food and agriculture

LEGEND:

X	Legislation adopted before 1 January 1996
X	Legislation adopted after 1 January 1996
Y	Part of broader legislation adopted before 1 January 1996
Y	Part of broader legislation adopted after 1 January 1996
O	Draft or ongoing legislation
Z	Part of a broader draft or ongoing legislation
P	Party to the treaty or convention before 1 January 1996
P	Party to the treaty or convention after 1 January 1996
S	Signatory of the treaty or convention before 1 January 1996
S	Signatory of the treaty or convention after 1 January 1996
Regional	Regional agreement (this information is given only when the country that has signed the regional agreement has not adopted national legislation)

Selected information sources:
- http://www.cbd.int/abs/measures/
- http://www.cbd.int/biosafety/parties/reports.shtml
- http://www.ecolex.org/start.php
- http://faolex.fao.org/faolex/index.htm
- https://www.ippc.int/index.php?id=1110520&no_cache=1&type=legislation&cat=4&L=0
- http://www.unep.org/biosafety/National%20Biosafety%20frameworks.aspx
- http://www.upov.int/en/publications/npvlaws/index.html
- http://www.wipo.int/clea/en/

APPENDIX 1

AFRICA
WEST AFRICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Benin	P	P			X		X		P	Regional		P	X
Burkina Faso	P	P			X	P	X		P	Y		P	X
Cape Verde	S	P				P	X		P			P	O
Chad	P	P				P	X		P	Regional		P	O
Côte d'Ivoire	P	P			X	P	X		P	Regional			O
Gambia		P	Y				X		P			P	O
Ghana	P	P		O	X	P	X		P	O		P	O
Guinea-Bissau	P	P			X	P	X		P	Regional		P	O
Guinea	P	P				P	X		P	Regional		P	O
Liberia	P	P				P	X					P	O
Mali	P	P			X	P	X		P	Regional		P	O
Mauritania	P	P			X	P	X		P	Regional		P	
Niger	P	P			X	P	X		P	Regional		P	O
Nigeria	S	P	Y		X	P	X		P			P	O

1 No information was available for Andorra, and the West Bank and Gaza Strip.

2 Legislation on ABS also includes national approaches, policies, frameworks and guiding principles on ABS as well as regulations governing genebanks.

3 Only the latest Act to which the country adhered is indicated. However, the colour of the case does not refer to the date on which the country adhered to the latest Act but to the date on which the country joined UPOV (before or after 1996).

4 PBR legislation does comply with UPOV.

5 PVP legislation does not comply with UPOV.

AFRICA
WEST AFRICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Senegal	P	P			X	P	X		P	Regional		P	O
Sierra Leone	P	P				P	X		P				O
Togo	P	P				P	X		P	Regional		P	O

AFRICA
CENTRAL AFRICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Cameroon	P	P			X	P	X		P	Y		P	X
Central African Republic	P	P				p	X		p	Regional		p	O
Congo	p	p				P	X		p	Regional		p	O
Democratic Rep. of the Congo	p	p					X		p			P	O
Equatorial Guinea		P				P				Regional			
Gabon	P	P				P	X		P	Regional		P	O
Sao Tome and Principe	P	P				P	X						O

APPENDIX 1

AFRICA
SOUTHERN AFRICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS[2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act)[3]	TRIPS - WTO	PBR[4]	PVP[5]	Cartagena Protocol on Biosafety	Biosafety regulations
Angola	P	P	X		X				P			P	
Botswana		P			X	P	X		P			P	O
Lesotho	P	P	Y						P			P	O
Malawi	P	P	X	O	X	P	X		P	O		P	X
Mozambique		P			X	P	X		P			P	O
Namibia	P	P	O	O	Z	P	O		P	O		P	X
South Africa		P	X		X	P	X	1978	P	X		P	X
Swaziland	S	P			X	P	X		P		X	P	O
United Republic of Tanzania	P	P	O		X	P	X		P		X	P	X
Zambia	P	P	O		X	P	X		P		X	P	X
Zimbabwe	P	P	Y		X		X		P		X	P	X

AFRICA
EAST AFRICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Burundi	P	P			X	P	X		P			P	O
Djibouti	P	P				P			P			P	O
Eritrea	P	P			X	P	X					P	O
Ethiopia	P	P	X	O	X	P	X			O		P	O
Kenya	P	P	X		X	P	X	1978	P	X		P	O
Rwanda		P			X	P	X		P			P	O
Somalia		P											
Sudan	P	P			X	P	X					P	O
Uganda	P	P	X		X	P	X		P	O		P	X

APPENDIX 1

AFRICA
INDIAN OCEAN ISLANDS

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Comoros		P				P	O					P	O
Madagascar	P	P	O		X	P	X		P			P	O
Mauritius	P	P				P	X		P	O		P	X
Seychelles	P	P	O			P	X					P	O

AMERICAS
SOUTH AMERICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	Access and benefit-sharing [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Argentina	S	P	O		X	P	X	1978	P	X		S	Y
Bolivia (Plurinational State of)		P	X		X	P	X	1978	P	X		P	X
Brazil	P	P	X	Y	X	P	X	1978	P	X		P	X
Chile	S	P	O		X	S	X	1978	P	X		S	X
Colombia	S	P	X		X	P	X	1978	P	X		P	X
Ecuador	P	P	Z		X	P	X	1978	P	X		P	O
Paraguay	P	P	Y	Y	X	P	X	1978	P	X		P	X
Peru	P	P	X		X	P	X		P	X		P	X
Uruguay	P	P	O		X	P	X	1978	P	X		S	X
Venezuela (Bolivarian Republic of)	P	P	X		X	P	X		P		X	P	X

APPENDIX 1

AMERICAS
CENTRAL AMERICA AND MEXICO

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Costa Rica	P	P	X	Y	X	P	X	1991	P	X		P	X
El Salvador	P	P			X	P	X		P		X	P	X
Guatemala	P	P	Y		X	P	X		P	O		P	X
Honduras	P	P			X	P	X		P			P	X
Mexico		P	X		X	P	X	1978	P	X		P	X
Nicaragua	P	P	Y		X	P	X	1978	P	X		P	O
Panama	P	P	X		X	P	X	1978	P	X		P	X

AMERICAS
CARIBBEAN

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Antigua and Barbuda		P				P	X		P			P	O
Bahamas		P				P	X					P	O
Barbados		P				P	X		P		X	P	O
Belize		P				P	X		P		X	P	X
Cuba	P	P	Y	Y	X	P	X		P		X	P	X
Dominica		P				P	X		P		X	P	O
Dominican Republic	S	P	O		X	P	X	1991	P	X		P	O
Grenada		P				P	X		P			P	O
Guyana		P	O		O	P	X		P			P	O
Haiti	S	P				P	X		P			S	
Jamaica	P	P				P	X		P			S	O
Saint Kitts and Nevis		P				P	X		P			P	O
Saint Lucia	P	P				P	X		P			P	O
Saint Vincent and the Grenadines		P				P	X		P		O	P	O

APPENDIX 1

AMERICAS
CARIBBEAN (continued)

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	iTPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Suriname		P				S	X		P			P	O
Trinidad and Tobago	P	P				P	X	1978	P	X		P	

AMERICAS
NORTH AMERICA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Canada	P	P			X	P	X	1978	P	X		S	Y
United States of America	S	S			X	P	X	1991	P	X			X

ASIA AND THE PACIFIC

SOUTH ASIA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		Inter-national	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Bangladesh	P	P	X	X	X	P	X		P		X	P	O
Bhutan	P	P	X		X	P	X				X	P	O
India	P	P	X	X	X	P	X		P		X	P	X
Maldives	P	P				P			P			P	
Nepal	P	P	O	O	X	P	X		P		O	S	X
Sri Lanka		P	O		X	P	X		P		X	P	O

APPENDIX 1

ASIA AND THE PACIFIC
SOUTHEAST ASIA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Brunei Darussalam		P	Regional				X		P				
Cambodia	P	P	Regional			P	X		P			P	O
Indonesia	P	P	Y		X	P	X		P		X	P	X
Lao People's Demo→ctratic Republic	P	P	Regional		X	P	X					P	
Malaysia	P	P	O	Y	X	P	X		P	X		P	X
Myanmar	P	P	Regional		O	P			P			P	O
Philippines	P	P	X	O	X	P	X		P	O	X	P	X
Singapore		P	Regional		X		X	1991	P	O	X		
Thailand	S	P	Y	Y	X	P	X		P		X	P	O
Timor Leste		P											
Viet Nam		P	Y		X	P	X	1991	P	X		P	X

ASIA AND THE PACIFIC

EAST ASIA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			International	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phytosanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
China		P	Y		X	P	X	1978	P	X		P	X
Democratic People's Republic of Korea	P	P				P	X					P	O
Japan		P			X	P	X	1991	P	X		P	X
Mongolia		P				P			P			P	O
Republic of Korea	P	P	Y		X	P	X	1991	P	X		P	X

APPENDIX 1

ASIA AND THE PACIFIC

PACIFIC

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Australia	P	P	Y		X	P	X	1991	P	X			X
Cook Islands	P	P				P	X					S	O
Fiji	P	P				P	X		P			P	
Kiribati	P	P					X					P	
Marshall Islands	S	P					X					P	
Micronesia (Federated States of)		P				P	X						
Nauru		P				P						P	
New Zealand		P	O			P	X	1978	P	X		P	X
Niue		P				P	X					P	O
Palau	P	P				P	X					P	O
Papua New Guinea		P				P	X		P			P	O
Samoa	P	P				P	X					P	O
Solomon Islands		P				P	X		P			P	
Tonga		P				P	X		P			P	O
Tuvalu		P				P	X						
Vanuatu		P	Y			P	X						O

EUROPE

WESTERN EUROPE

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Austria	P	P	Y	Y	X	P	X	1991	P	X		P	X
Belgium	P	P			X	P	X	1972	P	X		P	X
Denmark	P	P	Regional		X	P	X	1991	P	X		P	X
Finland	P	P	Regional		X	P	X	1991	P	X		P	X
France	P	P		Y	X	P	X	1978	P	X		P	X
Germany	P	P	Y	Y	X	P	X	1991	P	X		P	X
Greece	P	P	X		X	P	X		P	Regional		P	Y
Iceland	P	P	Regional			P	X	1991	P	O	X	S	
Ireland	P	P			X	P	X	1978	P	X		P	X
Italy	P	P	X	X	X	P	X	1978	P	X		P	X
Liechtenstein		P							P				
Luxembourg	P	P			X	P	X		P	Regional		P	X
Monaco		P										S	
Netherlands	P	P			X	P	X	1991	P	X		P	X
Norway	P	P	Z		X	P	X	1978	P	X		P	X

APPENDIX 1

EUROPE
WESTERN EUROPE

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Portugal	P	P	X		X	P	X	1978	P	X		P	X
San Marino		P											
Spain	P	P			X	P	X	1991	P	X		P	X
Sweden	P	P	Regional		X	P	X	1991	P	X		P	X
Switzerland	P	P			X	P	X	1991	P	X		P	X
United Kingdom	P	P			X	P	X	1991	P	X		P	X

EUROPE
EASTERN EUROPE

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Albania	P	P	Y		X	P	X	1991	P	X		P	O
Armenia	P	P			X	P	X		P		X	P	O
Belarus		P			X	P	X	1991		X		P	X
Bosnia and Herzegovina		P				P				O	X	P	O
Bulgaria	P	P	Y			P	X	1991	P	X		P	X
Croatia	P	P			X	P	X	1991	P	X		P	O
Czech Republic	P	P	X		X	P	X	1991	P	X		P	X
Estonia	P	P		Y	X	P	X	1991	P	X		P	X
Georgia		P			X	P	X	1991	P	X		P	O
Hungary	P	P	X		X	P	X	1991	P	X		P	X
Latvia	P	P			X	P	X	1991	P	X		P	X
Lithuania	P	P	Y		X	P	X	1991	P	X		P	X
Montenegro		P				P				O	X	P	
Poland	P	P			X	P	X	1991	P	X		P	X

APPENDIX 1

EUROPE
EASTERN EUROPE

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Republic of Moldovia		P			X	P	X	1991	P	X		P	X
Romania	P	P			X	P	X	1991	P	X		P	X
Russian Federation		P			X	P	X	1991		X			X
Serbia	S	P			X	P	X			O	X	P	X
Slovakia		P	X		X	P	X	1991	P	X		P	X
Slovenia	P	P			X	P	X	1991	P	X		P	X
The former Yugoslav Republic of Macedonia	S	P			X	P	X		P	O		P	X
Ukraine		P	O		X	P	X	1991	P	X		P	X

NEAR EAST
SOUTH/EAST MEDITERRANEAN

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			International	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Algeria	P	P			X	P	X				X	P	O
Cyprus	P	P			X	P	X		P		X	P	X
Egypt	P	P	Y		X	P	X		P	O	X	P	X
Israel		P			X	P	X	1991	P	X			X
Jordan	P	P	O		X	P	X	1991	P	X		P	O
Lebanon	P	P	O		X	P	X						O
Libyan Arab Jamahiriya	P	P				P	X					P	O
Malta	S	P			X	P	X		P		X	P	X
Morocco	P	P	O		X	P	X	1991	P	X		S	O
Syrian Arab Republic	P	P	O		X	P	X					P	X
Tunisia	P	P	O		X	P	X	1991	P	X		P	O

APPENDIX 1

NEAR EAST
WEST ASIA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Afghanistan	P	P	Y		X								
Bahrain		P				P	X		P		X		
Iran (Islamic Republic of)	P	P		O	X	P	X				X	P	O
Iraq		P			X	P					X		
Kuwait	P	P				P			P				
Oman	P	P				P	X	1991	P	X		P	O
Pakistan	P	P	O	O	X	P	X		P		X	P	X
Qatar	P	P				P	X		P			P	O
Saudi Arabia	P	P				P			P		X	P	
Turkey	P	P	Y	O	X	P	X	1991	P	X		P	O
United Arab Emirates	P	P			X	P	X		P				
Yemen	P	P			X	P	X				X	P	O

NEAR EAST
CENTRAL ASIA

Countries[1]	Agricultural biodiversity including access to plant genetic resources and seeds					Plant Protection		Intellectual Property Rights				Biosafety	
	International		National			Inter-national	National	International		National		International	National
	ITPGRFA	CBD	ABS [2]	Farmers' Rights	Seed certification	IPPC	Phyto-sanitary	UPOV (Latest Act) [3]	TRIPS - WTO	PBR [4]	PVP [5]	Cartagena Protocol on Biosafety	Biosafety regulations
Azerbaijan		P			X	P	X	1991		X		P	
Kazakhstan		P			X		X				X	P	X
Kyrgyzstan	P	P			X	P	X	1991	P	X		P	O
Tajikistan		P			X		X			O	X	P	X
Turkmenistan		P			X						Regional	P	
Uzbekistan		P			X		X	1991		X			

Appendix 2

Major germplasm collections by crop and institute

LEGEND:

Collections of germplasm accessions of major crops are grouped by main crop categories (cereals; food legumes; roots and tubers; vegetables; nuts, fruits and berries; oil crops; forage crops; sugar crops; fibre crops; medicinal, aromatic plants, spices and stimulants crops and industrial and ornamental crops). The collections are listed by institutes (indicated by an acronym and the WIEWS institution code) in descending order of the collection size. The percentage of accessions is the percentage of the genus total.

Accessions are categorized by type, expressed as a percentage of the institute's collection: wild species; landraces/old cultivars; advanced cultivars; breeding lines.

WS: wild species.
LR: landraces/old cultivars.
BL: research materials/breeding lines.
AC: advanced cultivars.
OT: (others) the type is unknown or a mixture of two or more types.

The information in this Appendix is based on numbers of accessions, or samples, of germplasm.

Full names of the institutes mentioned in the following table are given in section 'Acronyms and Abbreviations' at the end of this document.

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Wheat	*Triticum*	MEX002	CIMMYT	110 281	13	6	31	50	7	6
Wheat	*Triticum*	USA029	NSGC	57 348	7	4	57	24	14	<1
Wheat	*Triticum*	CHN001	ICGR-CAAS	43 039	5	5				95
Wheat	*Triticum*	IND001	NBPGR	35 889	4	4	2	9	1	84
Wheat	*Triticum*	SYR002	ICARDA	34 951	4	5	75		<1	21
Wheat	*Triticum*	JPN003	NIAS	34 652	4	3	4	31		61
Wheat	*Triticum*	RUS001	VIR	34 253	4	1	43	20	35	<1
Wheat	*Triticum*	ITA004	IGV	32 751	4	2	98			
Wheat	*Triticum*	DEU146	IPK	26 842	3	4	49	12	32	4
Wheat	*Triticum*	AUS003	TAMAWC	23 811	3		3	50	32	16
Wheat	*Triticum*	IRN029	NPGBI-SPII	18 442	2					100
Wheat	*Triticum*	KAZ023	RIA	18 000	2					100
Wheat	*Triticum*	BRA015	CNPT	13 464	2					100
Wheat	*Triticum*	ETH085	IBC	13 421	2		100			<1
Wheat	*Triticum*	BGR001	IPGR	12 539	1	<1	9	7	2	82
Wheat	*Triticum*	POL003	IHAR	11 586	1		3	88	7	3
Wheat	*Triticum*	FRA040	INRA-CLERMON	10 715	1					100
Wheat	*Triticum*	CAN004	PGRC	10 514	1	19	14	35	28	3
Wheat	*Triticum*	CZE122	RICP	10 419	1	2	7	27	64	<1
Wheat	*Triticum*	GBR011	IPSR	9 462	1		11	28	25	36
Wheat	*Triticum*	CHL008	INIA QUIL	9 333	1					100
Wheat	*Triticum*	UZB006	UzRIPI	9 277	1					100
Wheat	*Triticum*	HUN003	RCA	8 569	1		2	<1	12	86
Wheat	*Triticum*	CYP004	ARI	7 696	1		1	99		
Wheat	*Triticum*	CHE001	RAC	7 266	1					100
Wheat	*Triticum*	UKR001	IR	7 220	1		4	42	53	1
Wheat	*Triticum*	PER002	UNALM	7 000	1					100
Wheat	*Triticum*		Others (202)	237 428	28	5	14	15	22	44
Wheat	***Triticum***		**Total**	**856 168**	**100**	**4**	**24**	**20**	**13**	**39**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Rice	*Oryza*	PHL001	IRRI	109 136	14	4	44	9	3	39
Rice	*Oryza*	IND001	NBPGR	86 119	11	1	18	<1	12	69
Rice	*Oryza*	CHN121	CNRRI	70 104	9	1	70	13	9	7
Rice	*Oryza*	JPN003	NIAS	44 489	6	<1	22	19		59
Rice	*Oryza*	KOR011	RDAGB-GRD	26 906	3	5	5	13	4	74
Rice	*Oryza*	USA970	DB NRRC	23 090	3	<1	5	93	2	
Rice	*Oryza*	CIV033	WARDA	21 527	3	1	47	51		1
Rice	*Oryza*	THA399	BRDO	20 000	3		100			
Rice	*Oryza*	LAO010	NARC	13 193	2		100			
Rice	*Oryza*	MYS117	SR, MARDI	11 596	1	1	99			
Rice	*Oryza*	BRA008	CNPAF	10 980	1					100
Rice	*Oryza*	CIV005	IDESSA	9 675	1					100
Rice	*Oryza*	FRA014	Cirad	7 306	1					100
Rice	*Oryza*	BGD002	BRRI	6 259	1	2	79	14		5
Rice	*Oryza*	VNM049	PRC	6 083	1					100
Rice	*Oryza*	IDN009	CRIA	5 917	1					100
Rice	*Oryza*	PHL158	PhilRice	5 000	1		100			
Rice	*Oryza*	PAK001	PGRI	4 949	1		100			
Rice	*Oryza*	PER017	INIA-EEA.POV	4 678	1				100	
Rice	*Oryza*		Others (160)	286 941	37	3	26	6	11	54
Rice	***Oryza***		**Total**	**773 948**	**100**	**2**	**35**	**11**	**7**	**45**
Barley	*Hordeum*	CAN004	PGRC	40 031	9	12	41	27	13	7
Barley	*Hordeum*	USA029	NSGC	29 874	6	7	56	23	15	
Barley	*Hordeum*	BRA003	CENARGEN	29 227	6					100
Barley	*Hordeum*	SYR002	ICARDA	26 679	6	7	67		<1	25
Barley	*Hordeum*	JPN003	NIAS	23 471	5	<1	6	15		79
Barley	*Hordeum*	DEU146	IPK	22 093	5	6	56	12	24	2
Barley	*Hordeum*	CHN001	ICGR-CAAS	18 617	4					100
Barley	*Hordeum*	KOR011	RDAGB-GRD	17 660	4		25	10	<1	64
Barley	*Hordeum*	RUS001	VIR	16 791	4		25			75
Barley	*Hordeum*	ETH085	IBC	16 388	4		94			6

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Barley	*Hordeum*	MEX002	CIMMYT	15 473	3	<1	3	77	11	9
Barley	*Hordeum*	SWE054	NORDGEN	14 109	3	5	5	84	4	2
Barley	*Hordeum*	GBR011	IPSR	10 838	2		17	30	23	29
Barley	*Hordeum*	IND001	NBPGR	9 161	2	11	3	13	2	71
Barley	*Hordeum*	AUS091	SPB-UWA	9 031	2					100
Barley	*Hordeum*	IRN029	NPGBI-SPII	7 816	2					100
Barley	*Hordeum*	ISR003	ICCI-TELAVUN	6 658	1	100	<1			<1
Barley	*Hordeum*	POL003	IHAR	6 184	1		2	94	2	2
Barley	*Hordeum*	BGR001	IPGR	6 171	1	<1	<1	4	7	88
Barley	*Hordeum*		Others (180)	140 259	30	4	12	13	11	60
Barley	***Hordeum***		**Total**	**466 531**	**100**	**5**	**23**	**17**	**8**	**47**
Maize	*Zea*	MEX002	CIMMYT	26 596	8	1	89	2	8	
Maize	*Zea*	PRT001	BPGV-DRAEDM	24 529	7		8	91	1	
Maize	*Zea*	USA020	NC7	19 988	6	2	79	17	2	1
Maize	*Zea*	CHN001	ICGR-CAAS	19 088	6					100
Maize	*Zea*	MEX008	INIFAP	14 067	4	1				99
Maize	*Zea*	RUS001	VIR	10 483	3		31			69
Maize	*Zea*	IND001	NBPGR	6 909	2	6	16	15	2	61
Maize	*Zea*	JPN003	NIAS	5 935	2		7	4		88
Maize	*Zea*	SRB001	MRIZP	5 475	2		55	45		
Maize	*Zea*	COL029	CORPOICA	5 234	2					100
Maize	*Zea*	ROM007	BRGV Suceava	4 815	1		69	28	3	<1
Maize	*Zea*	BGR001	IPGR	4 700	1		23	14	<1	63
Maize	*Zea*	FRA041	INRA-MONTPEL	4 139	1		28	72		
Maize	*Zea*	BRA003	CENARGEN	4 112	1					100
Maize	*Zea*	UKR001	IR	3 974	1		13	83	5	<1
Maize	*Zea*	PER002	UNALM	3 023	1		100			
Maize	*Zea*	VNM237	SSJC	2 914	1			100		
Maize	*Zea*	HUN003	RCA	2 765	1		38	8	3	51
Maize	*Zea*	ARG1346	BAP	2 584	1		100			
Maize	*Zea*	ESP004	INIACRF	2 344	1	<1	95	1		4

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Maize	*Zea*	UZB006	UzRIPI	2 200	1					100
Maize	*Zea*	GRC001	CERI	2 048	1			85	14	<1
Maize	*Zea*	PHL130	IPB-UPLB	2 013	1	<1	100			
Maize	*Zea*	ECU021	EETP	2 000	1				100	
Maize	*Zea*		Others (257)	145 997	45	<1	29	17	5	49
Maize	***Zea***		**Total**	**327 932**	**100**	**1**	**33**	**21**	**4**	**42**
Sorghum	*Sorghum*	IND002	ICRISAT	37 904	16	1	86	13	<1	
Sorghum	*Sorghum*	USA016	S9	36 173	15	1	41	8	3	48
Sorghum	*Sorghum*	CHN001	ICGR-CAAS	18 263	8					100
Sorghum	*Sorghum*	IND001	NBPGR	17 466	7	15	73	1	1	10
Sorghum	*Sorghum*	ETH085	IBC	9 772	4		100			<1
Sorghum	*Sorghum*	BRA001	CNPMS	7 225	3					100
Sorghum	*Sorghum*	KEN015	KARI-NGBK	5 866	2	2	52	<1	1	44
Sorghum	*Sorghum*	JPN003	NIAS	5 074	2	<1	6	12		81
Sorghum	*Sorghum*	AUS048	ATCFC	4 487	2	8	2	70	6	15
Sorghum	*Sorghum*	MEX008	INIFAP	3 990	2					100
Sorghum	*Sorghum*	RUS001	VIR	3 963	2		16	3	1	81
Sorghum	*Sorghum*	FRA202	ORSTOM-MONTP	3 859	2	1			99	
Sorghum	*Sorghum*	ZMB030	SPGRC	3 720	2	1	99			<1
Sorghum	*Sorghum*	ARG1342	BBC-INTA	3 249	1					100
Sorghum	Sorghum	SDN001	ARC	3 145	1					100
Sorghum	Sorghum	MLI070	URG	2 673	1		100			
Sorghum	Sorghum	UGA001	SAARI	2 635	1					100
Sorghum	Sorghum	VEN152	DANAC	2 068	1			100		
Sorghum	Sorghum	HND005	EAPZ	2 000	1					100
Sorghum	Sorghum		Others (153)	62 156	26	<1	14	10	11	63
Sorghum	***Sorghum***		**Total**	**235 688**	**100**	**2**	**38**	**9**	**5**	**47**
Oat	*Avena*	CAN004	PGRC	27 676	21	55	12	20	12	1
Oat	*Avena*	USA029	NSGC	21 195	16	49	14	24	13	

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Oat	*Avena*	RUS001	VIR	11 857	9	19	41	<1	1	39
Oat	*Avena*	DEU146	IPK	4 799	4	15	33	9	38	4
Oat	*Avena*	KEN015	KARI-NGBK	4 197	3	<1				100
Oat	*Avena*	AUS003	TAMAWC	3 674	3			<1	<1	99
Oat	*Avena*	CHN001	ICGR-CAAS	3 357	3					100
Oat	*Avena*	GBR011	IPSR	2 598	2	<1	17	22	53	8
Oat	*Avena*	POL003	IHAR	2 328	2	<1	5	44	48	3
Oat	*Avena*	BGR001	IPGR	2 311	2	<1	1	6	2	91
Oat	*Avena*	MAR088	INRA CRRAS	2 133	2		<1			100
Oat	*Avena*	CZE047	KROME	2 011	2	<1	3	1	53	42
Oat	*Avena*	ISR003	ICCI-TELAVUN	1 604	1	100				
Oat	*Avena*	JPN003	NIAS	1 540	1		2	6		92
Oat	*Avena*	FRA010	INRA-RENNES	1 504	1					100
Oat	*Avena*	ESP004	INIACRF	1 318	1	<1	97		1	1
Oat	*Avena*	HUN003	RCA	1 301	1	<1	6		8	86
Oat	*Avena*	ARG1224	EEA INTA Bordenave	1 287	1			100		
Oat	*Avena*	PER002	UNALM	1 200	1					100
Oat	*Avena*	IND027	IGFRI	1 125	1					100
Oat	*Avena*		Others (104)	31 638	24	3	12	7	13	66
Oat	***Avena***		**Total**	**130 653**	**100**	**24**	**14**	**13**	**12**	**37**
Pearl millet	*Pennisetum*	IND002	ICRISAT	21 583	33	3	86	9	1	1
Pearl millet	*Pennisetum*	BRA001	CNPMS	7 225	11					100
Pearl millet	*Pennisetum*	IND064	NBPGR	5 772	9		100			
Pearl millet	*Pennisetum*	FRA202	ORSTOM-MONTP	4 405	7	8		10	82	
Pearl millet	*Pennisetum*	CAN004	PGRC	3 816	6	1	98	<1	<1	1
Pearl millet	*Pennisetum*	NER047	ICRISAT	2 817	4		100			
Pearl millet	*Pennisetum*	UGA001	SAARI	2 142	3					100
Pearl millet	*Pennisetum*	USA016	S9	2 063	3	1	28	3	1	68
Pearl millet	*Pennisetum*		Others (96)	15 624	24	10	57	3	1	29
Pearl millet	***Pennisetum***		**Total**	**65 447**	**100**	**4**	**62**	**4**	**6**	**24**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Millet	*Setaria*	CHN001	ICGR-CAAS	26 233	56					100
Millet	*Setaria*	IND001	NBPGR	4 392	9	<1	17		<1	82
Millet	*Setaria*	FRA202	ORSTOM-MONTP	3 500	8					100
Millet	*Setaria*	JPN003	NIAS	2 531	5	1	38	1		60
Millet	*Setaria*	IND002	ICRISAT	1 535	3	4	96			
Millet	*Setaria*	USA020	NC7	1 010	2	2	11	1	2	84
Millet	*Setaria*		Others (74)	7 405	16	8	51	1	2	38
Millet	***Setaria***		**Total**	**46 606**	**100**	**1**	**15**	**<1**	**<1**	**83**
Wheat	*Aegilops*	ISR003	ICCI-TELAVUN	9 146	22	100				<1
Wheat	*Aegilops*	SYR002	ICARDA	3 847	9	100				<1
Wheat	*Aegilops*	IRN029	NPGBI-SPII	2 653	6	99				1
Wheat	*Aegilops*	JPN003	NIAS	2 433	6	5				95
Wheat	*Aegilops*	RUS001	VIR	2 248	5					100
Wheat	*Aegilops*	USA029	NSGC	2 207	5	100				
Wheat	*Aegilops*	ARM035	LPGPB	1 827	4	100		<1		
Wheat	*Aegilops*	DEU146	IPK	1 526	4	100				<1
Wheat	*Aegilops*	MEX002	CIMMYT	1 326	3	99		<1		<1
Wheat	*Aegilops*	FRA010	INRA-RENNES	1 070	3					100
Wheat	*Aegilops*		Others (52)	12 643	31	81	3	2		14
Wheat	***Aegilops***		**Total**	**40 926**	**100**	**80**	**1**	**1**		**18**
Wheat	*Triticosecale*	MEX002	CIMMYT	17 394	46	<1		97	3	<1
Wheat	*Triticosecale*	RUS001	VIR	2 030	5					100
Wheat	*Triticosecale*	USA029	NSGC	2 009	5		1	83	16	
Wheat	*Triticosecale*	CAN091	SCRDC-AAFC	2 000	5					100
Wheat	*Triticosecale*	UKR001	IR	1 748	5			86	13	1
Wheat	*Triticosecale*	POL025	LUBLIN	1 748	5			63	33	3
Wheat	*Triticosecale*	DEU146	IPK	1 577	4		2	81	17	<1
Wheat	*Triticosecale*		Others (62)	8 934	24	4	<1	36	11	49
Wheat	***Triticosecale***		**Total**	**37 440**	**100**	**1**	**<1**	**68**	**8**	**23**

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Millet	*Eleusine*	IND001	NBPGR	9 522	27	<1	18	<1	1	80
Millet	*Eleusine*	IND002	ICRISAT	5 949	17	2	95	1	2	
Millet	*Eleusine*	KEN015	KARI-NGBK	2 931	8	3	61	1		35
Millet	*Eleusine*	ETH085	IBC	2 173	6	<1	100			<1
Millet	*Eleusine*	UGA001	SAARI	1 231	3					100
Millet	*Eleusine*	ZMB030	SPGRC	1 040	3	<1	100			<1
Millet	*Eleusine*	NPL055	CPBBD	869	2		100			
Millet	*Eleusine*	USA016	S9	766	2		<1			100
Millet	*Eleusine*		Others (38)	10 901	31	1	71	<1	<1	28
Millet	***Eleusine***		**Total**	**35 382**	**100**	**1**	**59**	**<1**	**1**	**39**
Amaranth	*Amaranthus*	IND001	NBPGR	5 760	20	6	25		5	65
Amaranth	*Amaranthus*	USA020	NC7	3 341	12	11	22	4	4	59
Amaranth	*Amaranthus*	BRA003	CENARGEN	2 328	8					100
Amaranth	*Amaranthus*	PER027	UNSAAC/CICA	1 600	6		100			
Amaranth	*Amaranthus*	CHN001	ICGR-CAAS	1 459	5					100
Amaranth	*Amaranthus*		Others (106)	13 825	49	6	47	3	1	42
Amaranth	***Amaranthus***		**Total**	**28 313**	**100**	**5**	**36**	**2**	**2**	**54**
Rye	*Secale*	RUS001	VIR	2 928	14		34			66
Rye	*Secale*	DEU146	IPK	2 392	11	9	27	27	30	7
Rye	*Secale*	POL003	IHAR	2 266	11	<1	12	86		2
Rye	*Secale*	USA029	NSGC	2 106	10	4	77	3	16	1
Rye	*Secale*	CAN004	PGRC	1 446	7	10	23	16	47	3
Rye	*Secale*	BGR001	IPGR	1 248	6	<1	3	61	<1	35
Rye	*Secale*		Others (88)	8 806	42	9	26	12	17	36
Rye	***Secale***		**Total**	**21 192**	**100**	**6**	**29**	**22**	**15**	**27**
Chenopodium	*Chenopodium*	BOL138	BNGGA-PROINPA	4 312	27	9	91			
Chenopodium	*Chenopodium*	PER014	INIA-EEA.ILL	1 396	9		18			82
Chenopodium	*Chenopodium*	DEU146	IPK	1 056	6	93	1		<1	6

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Cereals										
Chenopodium	*Chenopodium*	ECU023	DENAREF	681	4	2	62	2	3	32
Chenopodium	*Chenopodium*	ARG1191	UBA-FA	500	3		100			
Chenopodium	*Chenopodium*	COL006	U.NACIONAL	300	2					100
Chenopodium	*Chenopodium*		Others (69)	8 018	49	6	49	<1	1	44
Chenopodium	***Chenopodium***		**Total**	**16 263**	**100**	**11**	**55**	**<1**	**1**	**32**
Tef	*Eragrostis*	ETH085	IBC	4 741	54		100			
Tef	*Eragrostis*	USA022	W6	1 302	15	44	15	<1	4	37
Tef	*Eragrostis*	KEN015	KARI-NGBK	1 051	12	5	<1			95
Tef	*Eragrostis*	JPN003	NIAS	327	4	8	2	1		89
Tef	*Eragrostis*	IND001	NBPGR	269	3	6				94
Tef	*Eragrostis*	MEX035	CIFAP-CAL	258	3					100
Tef	*Eragrostis*		Others (42)	872	10	60	13	1	1	24
Tef	***Eragrostis***		**Total**	**8 820**	**100**	**14**	**57**	**<1**	**1**	**28**
Food legumes										
Bean	*Phaseolus*	COL003	CIAT	35 891	14	6	85	2	7	
Bean	*Phaseolus*	USA022	W6	14 674	6	6	67	3	21	4
Bean	*Phaseolus*	BRA008	CNPAF	14 460	6					100
Bean	*Phaseolus*	MEX008	INIFAP	12 752	5	17				83
Bean	*Phaseolus*	DEU146	IPK	8 680	3	1	66	4	28	1
Bean	*Phaseolus*	CHN001	ICGR-CAAS	7 365	3					100
Bean	*Phaseolus*	RUS001	VIR	6 144	2		22	20	3	55
Bean	*Phaseolus*	MWI004	BCA	6 000	2		100			
Bean	*Phaseolus*	HUN003	RCA	4 350	2		70	<1	<1	30
Bean	*Phaseolus*	IDN002	LBN	3 846	1					100
Bean	*Phaseolus*	KEN015	KARI-NGBK	3 534	1	<1	34	3	35	28
Bean	*Phaseolus*	BGR001	IPGR	3 220	1		32		<1	68
Bean	*Phaseolus*	ECU023	DENAREF	3 102	1	2	6	17	<1	75
Bean	*Phaseolus*	RWA002	ISAR	3 075	1					100
Bean	*Phaseolus*	ESP004	INIACRF	3 038	1		98	<1	<1	1

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Food Legumes										
Bean	*Phaseolus*		Others (231)	131 832	50	1	30	5	13	52
Bean	***Phaseolus***		**Total**	**261 963**	**100**	**2**	**39**	**4**	**10**	**45**
Soybean	*Glycine*	CHN001	ICGR-CAAS	32 021	14	21				79
Soybean	*Glycine*	USA033	SOY	21 075	9	10	80	5	4	1
Soybean	*Glycine*	KOR011	RDAGB-GRD	17 644	8	<1	45	5	1	50
Soybean	*Glycine*	TWN001	AVRDC	15 314	7		<1		<1	100
Soybean	*Glycine*	BRA014	CNPSO	11 800	5					100
Soybean	*Glycine*	JPN003	NIAS	11 473	5	5	33	21		40
Soybean	*Glycine*	RUS001	VIR	6 439	3		9	40	41	11
Soybean	*Glycine*	IND016	AICRP-Soybean	4 022	2	<1				100
Soybean	*Glycine*	CIV005	IDESSA	3 727	2					100
Soybean	*Glycine*	TWN006	TARI	2 745	1					100
Soybean	*Glycine*	DEU146	IPK	2 661	1	1	23	53	23	
Soybean	*Glycine*	ZWE003	CBICAU	2 236	1					100
Soybean	*Glycine*	IDN182	ICRR	2 198	1	<1				100
Soybean	*Glycine*	AUS048	ATCFC	2 121	1	3	<1	38	52	6
Soybean	*Glycine*	NGA039	IITA	1 909	1		5	4	1	90
Soybean	*Glycine*	FRA060	AMFO	1 582	1					100
Soybean	*Glycine*	THA005	FCRI-DA/TH	1 510	1			100		
Soybean	*Glycine*	MEX001	INIA-Iguala	1 500	1					100
Soybean	*Glycine*	PHL130	IPB-UPLB	1 381	1		100			
Soybean	*Glycine*	UKR001	IR	1 288	1	3	1	21	72	3
Soybean	*Glycine*	COL017	ICA/REGION 1	1 235	1		<1	64	13	22
Soybean	*Glycine*	SRB002	IFVCNS	1 200	1				100	
Soybean	*Glycine*	ROM002	ICCPT Fundul	1 024	<1			62	38	<1
Soybean	*Glycine*		Others (166)	81 839	36	7	11	4	27	51
Soybean	***Glycine***		**Total**	**229 944**	**100**	**6**	**17**	**7**	**13**	**56**
Groundnut	*Arachis*	IND002	ICRISAT	15 419	12	3	46	32	7	13
Groundnut	*Arachis*	IND001	NBPGR	13 144	10	7	15	1	5	72
Groundnut	*Arachis*	USA016	S9	9 964	8	2	19	15	3	61

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Food Legumes										
Groundnut	*Arachis*	ARG1342	BBC-INTA	8 347	6	4				96
Groundnut	*Arachis*	NER047	ICRISAT	7 262	6		100			
Groundnut	*Arachis*	CHN001	ICGR-CAAS	6 565	5					100
Groundnut	*Arachis*	BRA214	CENARGEN	2 042	2					100
Groundnut	*Arachis*	THA005	FCRI-DA/TH	2 030	2			100		
Groundnut	*Arachis*	IDN179	ICABIOGRAD	1 730	1					100
Groundnut	*Arachis*	RUS001	VIR	1 667	1		41	40	19	
Groundnut	*Arachis*	ZMB014	MRS	1 500	1					100
Groundnut	*Arachis*	UZB006	UzRIPI	1 438	1					100
Groundnut	*Arachis*	PHL130	IPB-UPLB	1 272	1		100			
Groundnut	*Arachis*	AUS048	ATCFC	1 196	1	5	14	61	11	8
Groundnut	*Arachis*	JPN003	NIAS	1 181	1	1	22	13		64
Groundnut	*Arachis*	BOL160	CIFP	1 040	1	2	98			
Groundnut	*Arachis*		Others (130)	52 638	41	3	34	6	6	51
Groundnut	***Arachis***		**Total**	**128 435**	**100**	**3**	**31**	**10**	**4**	**52**
Chickpea	*Cicer*	IND002	ICRISAT	20 140	20	1	91	6	<1	1
Chickpea	*Cicer*	IND001	NBPGR	14 704	15	2	13	<1	13	72
Chickpea	*Cicer*	SYR002	ICARDA	13 219	13	2	52		<1	46
Chickpea	*Cicer*	AUS039	ATFCC	8 655	9	3	28	38	30	2
Chickpea	*Cicer*	USA022	W6	6 195	6	3	91	1	5	<1
Chickpea	*Cicer*	IRN029	NPGBI-SPII	5 700	6					100
Chickpea	*Cicer*	PAK001	PGRI	2 146	2	1	99			
Chickpea	*Cicer*	RUS001	VIR	2 091	2		5			95
Chickpea	*Cicer*	TUR001	AARI	2 075	2	1	99		<1	
Chickpea	*Cicer*	MEX001	INIA-Iguala	1 600	2					100
Chickpea	*Cicer*	ETH085	IBC	1 173	1		99			1
Chickpea	*Cicer*	HUN003	RCA	1 170	1	<1	2	14		83
Chickpea	*Cicer*	UZB006	UzRIPI	1 055	1					100
Chickpea	*Cicer*	UKR001	IR	1 021	1		16	73	11	<1
Chickpea	*Cicer*		Others (104)	17 369	18	1	50	7	4	38
Chickpea	***Cicer***		**Total**	**98 313**	**100**	**1**	**50**	**7**	**6**	**36**

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Food legumes										
Pea	*Pisum*	AUS039	ATFCC	7 230	8	1	36	20	13	31
Pea	*Pisum*	RUS001	VIR	6 653	7	<1	13	<1		87
Pea	*Pisum*	SYR002	ICARDA	6 129	7	4	27		<1	69
Pea	*Pisum*	DEU146	IPK	5 508	6	1	33	6	55	6
Pea	*Pisum*	USA022	W6	5 399	6	3	53	2	27	14
Pea	*Pisum*	ITA004	IGV	4 090	4					100
Pea	*Pisum*	CHN001	ICGR-CAAS	3 825	4					100
Pea	*Pisum*	GBR165	SASA	3 302	4	3	<1	5		92
Pea	*Pisum*	IND001	NBPGR	3 070	3	<1	9	<1	5	86
Pea	*Pisum*	POL033	SHRWIAT	2 960	3	<1				100
Pea	*Pisum*	SWE054	NORDGEN	2 821	3	2	16	54	15	14
Pea	*Pisum*	BRA012	CNPH	1 958	2					100
Pea	*Pisum*	ETH085	IBC	1 768	2		99			1
Pea	*Pisum*	UKR001	IR	1 671	2	<1	4	3	46	47
Pea	*Pisum*	BGR001	IPGR	1 589	2	<1	<1	17	3	79
Pea	*Pisum*	SRB002	IFVCNS	1 578	2				100	
Pea	*Pisum*	CZE090	SUMPERK	1 276	1	2	4	19	74	1
Pea	*Pisum*	HUN003	RCA	1 199	1		6	<1	3	90
Pea	*Pisum*	CHL004	INIA CARI	1 142	1		100			
Pea	*Pisum*	NLD037	CGN	1 002	1	2	34	9	50	5
Pea	*Pisum*	FRA065	INRA-VERSAIL	1 000	1					100
Pea	*Pisum*		Others (149)	28 831	31	3	14	12	20	51
Pea	***Pisum***		**Total**	**94 001**	**100**	**2**	**19**	**8**	**17**	**54**
Cowpea	*Vigna*	NGA039	IITA	15 588	24	4	64	8	<1	24
Cowpea	*Vigna*	USA016	S9	8 043	12	2	62	<1	<1	35
Cowpea	*Vigna*	BRA003	CENARGEN	5 501	8					100
Cowpea	*Vigna*	IDN002	LBN	3 930	6					100
Cowpea	*Vigna*	IND001	NBPGR	3 317	5	<1	9	<1	12	79
Cowpea	*Vigna*	CHN001	ICGR-CAAS	2 818	4					100
Cowpea	*Vigna*	JPN003	NIAS	2 431	4	<1	13	<1		86
Cowpea	*Vigna*	PHL130	IPB-UPLB	1 821	3		100			

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Food Legumes										
Cowpea	*Vigna*	BWA002	DAR	1 435	2	<1	4			95
Cowpea	*Vigna*	RUS001	VIR	1 337	2		9			91
Cowpea	*Vigna*	TWN001	AVRDC	1 152	2		28		3	69
Cowpea	*Vigna*		Others (114)	17 950	27	7	46	6	3	38
Cowpea	***Vigna***		**Total**	**65 323**	**100**	**3**	**40**	**4**	**2**	**52**
Lentil	*Lens*	SYR002	ICARDA	10 864	19	5	41		<1	54
Lentil	*Lens*	IND001	NBPGR	9 989	17	<1	2	<1	1	97
Lentil	*Lens*	AUS039	ATFCC	5 251	9	4	54	10	5	26
Lentil	*Lens*	IRN029	NPGBI-SPII	3 011	5	11	52			37
Lentil	*Lens*	USA022	W6	2 874	5	5	79	1	6	10
Lentil	*Lens*	RUS001	VIR	2 375	4		70	<1	4	26
Lentil	*Lens*	CHL004	INIA CARI	1 345	2					100
Lentil	*Lens*	CAN004	PGRC	1 171	2	1	7	<1	3	88
Lentil	*Lens*	HUN003	RCA	1 074	2		3	1		96
Lentil	*Lens*	TUR001	AARI	1 073	2	1	98		1	
Lentil	*Lens*	ARM006	SCAPP	1 001	2			99	1	
Lentil	*Lens*		Others (94)	18 377	31	2	38	4	4	52
Lentil	***Lens***		**Total**	**58 405**	**100**	**3**	**36**	**4**	**3**	**55**
Faba bean	*Vicia*	SYR002	ICARDA	9 186	21		26		<1	74
Faba bean	*Vicia*	CHN001	ICGR-CAAS	4 207	10					100
Faba bean	*Vicia*	AUS039	ATFCC	2 565	6	<1	46	30	<1	24
Faba bean	*Vicia*	DEU146	IPK	1 921	4	<1	68	13	17	1
Faba bean	*Vicia*	FRA010	INRA-RENNES	1 700	4		59		41	
Faba bean	*Vicia*	ECU003	UC-ICN	1 650	4					100
Faba bean	*Vicia*	ITA004	IGV	1 420	3					100
Faba bean	*Vicia*	RUS001	VIR	1 259	3		2	3		95
Faba bean	*Vicia*	ESP004	INIACRF	1 252	3		91	2	5	2
Faba bean	*Vicia*	ETH085	IBC	1 143	3		100			
Faba bean	*Vicia*		Others (122)	17 392	40	2	34	15	11	38
Faba bean	***Vicia***		**Total**	**43 695**	**100**	**1**	**32**	**9**	**7**	**52**

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Food Legumes										
Pigeon pea	*Cajanus*	IND002	ICRISAT	13 289	33	2	62	36	1	<1
Pigeon pea	*Cajanus*	IND001	NBPGR	12 859	32	4	30	2	4	60
Pigeon pea	*Cajanus*	KEN015	KARI-NGBK	1 288	3	<1	73	4	2	21
Pigeon pea	*Cajanus*	PHL130	IPB-UPLB	629	2		100			
Pigeon pea	*Cajanus*	AUS048	ATCFC	406	1	50	12	23	1	13
Pigeon pea	*Cajanus*		Others (85)	12 349	30	3	50	2	1	45
Pigeon pea	***Cajanus***		**Total**	**40 820**	**100**	**3**	**49**	**13**	**2**	**33**
Lupin	*Lupinus*	AUS002	WADA	3 880	10	52	19	21	8	<1
Lupin	*Lupinus*	DEU146	IPK	2 464	6	17	47	9	15	11
Lupin	*Lupinus*	RUS001	VIR	2 411	6		24	39	19	19
Lupin	*Lupinus*	FRA001	INRA-POITOU	2 046	5	13		85		2
Lupin	*Lupinus*	PER003	UNSAAC	1 940	5	7	93			
Lupin	*Lupinus*	ESP010	SIAEX	1 519	4	46	47	1	4	2
Lupin	*Lupinus*	GBR045	RNG	1 300	3					100
Lupin	*Lupinus*	USA022	W6	1 294	3	46	38	1	9	6
Lupin	*Lupinus*	CHL004	INIA CARI	1 259	3		100			
Lupin	*Lupinus*	POL033	SHRWIAT	1 049	3	48		17		35
Lupin	*Lupinus*		Others (98)	18 888	50	12	19	4	6	60
Lupin	***Lupinus***		**Total**	**38 050**	**100**	**18**	**27**	**12**	**6**	**36**
Bambara groundnut	*Vigna*	NGA039	IITA	2 031	33	<1	100			
Bambara groundnut	*Vigna*	FRA202	ORSTOM-MONTP	1 416	23		100			
Bambara groundnut	*Vigna*	BWA002	DAR	338	6		2			98
Bambara groundnut	*Vigna*	GHA091	PGRRI	296	5					100
Bambara groundnut	*Vigna*	TZA016	NPGRC	283	5	<1	81			18
Bambara groundnut	*Vigna*	ZMB030	SPGRC	232	4		100			

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Food Legumes										
Bambara groundnut	*Vigna*		Others (26)	1 549	25	1	59	9	1	29
Bambara groundnut	***Vigna***		**Total**	**6 145**	**100**	**<1**	**79**	**2**	**<1**	**18**
Bean	*Psophocarpus*	PNG005	DOA	455	11		45			55
Bean	*Psophocarpus*	MYS009	DGCB-UM	435	10					100
Bean	*Psophocarpus*	CZE075	TROPIC	413	10	<1		22	<1	77
Bean	*Psophocarpus*	LKA005	IDI	400	9	<1	100			
Bean	*Psophocarpus*	IDN002	LBN	380	9					100
Bean	*Psophocarpus*		Others (35)	2 134	51	3	41	1	12	43
Bean	***Psophocarpus***		**Total**	**4 217**	**100**	**2**	**35**	**3**	**6**	**55**
Roots and Tubers										
Potato	*Solanum*	FRA179	INRA-RENNES	10 461	11	6	2	84	8	
Potato	*Solanum*	RUS001	VIR	8 889	9		46	3	26	25
Potato	*Solanum*	PER001	CIP	7 450	8	2	69	2	<1	27
Potato	*Solanum*	DEU159	IPK	5 392	5	18	37	7	32	6
Potato	*Solanum*	USA004	NR6	5 277	5	65	21	9	5	<1
Potato	*Solanum*	JPN003	NIAS	3 408	3	3	1	31		65
Potato	*Solanum*	COL029	CORPOICA	3 043	3					100
Potato	*Solanum*	IND029	CPRI	2 710	3	15		85		
Potato	*Solanum*	BOL064	BNGTRA-PROINPA	2 393	2	26	74			
Potato	Solanum	CZE027	HBROD	2 207	2	5	1	29	52	13
Potato	*Solanum*	ARG1347	BAL	1 739	2	85	15			
Potato	*Solanum*	BRA012	CNPH	1 735	2					100
Potato	*Solanum*	GBR165	SASA	1 671	2					100
Potato	*Solanum*	NLD028	ROPTA	1 610	2	3	1		1	95
Potato	*Solanum*	MEX116	PNP-INIFAP	1 500	2					100
Potato	*Solanum*	TWN006	TARI	1 282	1					100
Potato	*Solanum*	UZB033	SamAI	1 223	1					100
Potato	*Solanum*	POL002	IPRBON	1 182	1			8	92	

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Roots and Tubers										
Potato	*Solanum*	KAZ004	RIPV	1 117	1	26	2	15	57	
Potato	*Solanum*	SVK006	SVKLOMNICA	1 080	1	1	2	47	41	9
Potato	*Solanum*		Others (154)	32 916	33	19	15	3	16	46
Potato	***Solanum***		**Total**	**98 285**	**100**	**15**	**20**	**16**	**14**	**35**
Sweet potato	*Ipomoea*	PER001	CIP	6 417	18	23	77		<1	
Sweet potato	*Ipomoea*	JPN003	NIAS	5 736	16	1	2	4		93
Sweet potato	*Ipomoea*	USA016	S9	1 208	3	16	13	9	32	31
Sweet potato	*Ipomoea*	PNG039	MHRP	1 161	3					100
Sweet potato	*Ipomoea*	BRA012	CNPH	1 043	3					100
Sweet potato	*Ipomoea*	CHN146	BAAFS	800	2					100
Sweet potato	*Ipomoea*	TWN006	TARI	757	2					100
Sweet potato	*Ipomoea*	PER055	FF.CC.AA.	750	2	100				
Sweet potato	*Ipomoea*	ARG1342	BBC-INTA	567	2	36	56	1	6	
Sweet potato	*Ipomoea*	VNM049	PRC	532	1		100			
Sweet potato	*Ipomoea*	MYS003	MARDI	528	1		100			
Sweet potato	*Ipomoea*		Others (146)	15 979	45	5	24	21	11	39
Sweet potato	***Ipomoea***		**Total**	**35 478**	**100**	**10**	**30**	**10**	**6**	**44**
Cassava	*Manihot*	COL003	CIAT	5 436	17	1	87	11		<1
Cassava	*Manihot*	BRA004	CNPMF	2 889	9					100
Cassava	*Manihot*	NGA039	IITA	2 756	8		28	47		25
Cassava	*Manihot*	IND007	ICAR	1 327	4					100
Cassava	*Manihot*	NGA002	NRCRI	1 174	4					100
Cassava	*Manihot*	UGA001	SAARI	1 136	4	<1	4	90	7	
Cassava	*Manihot*	MWI001	MARS	978	3		22	72	6	
Cassava	*Manihot*	IDN182	ICRR	954	3				100	
Cassava	*Manihot*	THA005	FCRI-DA/TH	609	2			100		
Cassava	*Manihot*	BEN018	FAST	600	2		100			
Cassava	*Manihot*	TGO035	ITRA	435	1		100			
Cassava	*Manihot*		Others (133)	14 148	44	6	26	3	14	51
Cassava	***Manihot***		**Total**	**32 442**	**100**	**3**	**32**	**15**	**9**	**41**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Roots and Tubers										
Yam	*Dioscorea*	NGA039	IITA	3 319	21	1	68	20		12
Yam	*Dioscorea*	CIV006	UNCI	1 538	10	25	75			
Yam	*Dioscorea*	BEN030	UAC	1 100	7	55	45			
Yam	*Dioscorea*	GHA091	PGRRI	756	5		65			35
Yam	*Dioscorea*	SLB001	DCRS	480	3		97	3	<1	
Yam	*Dioscorea*	LKA002	PU	474	3	1	99			
Yam	*Dioscorea*		Others (93)	8 236	52	8	48	1	8	35
Yam	***Dioscorea***		**Total**	**15 903**	**100**	**10**	**59**	**5**	**4**	**22**
Taro	*Colocasia*	PNG006	WLMP	859	12					100
Taro	*Colocasia*	FJI049	RGC	850	12					100
Taro	*Colocasia*	MYS003	MARDI	622	9		100			
Taro	*Colocasia*	IND024	NBPGR	469	6		100			
Taro	*Colocasia*	THA056	HRI-DA/THA	453	6			100		
Taro	Colocasia	VNM049	PRC	393	5		100			
Taro	*Colocasia*	IDN002	LBN	350	5					100
Taro	*Colocasia*	USA037	UH	308	4					100
Taro	*Colocasia*	SLB001	DCRS	268	4	<1				100
Taro	*Colocasia*	JPN003	NIAS	250	3	<1	5			95
Taro	*Colocasia*	GHA091	PGRRI	215	3		73			27
Taro	*Colocasia*	AUS019	RSPAS	193	3	15			73	12
Taro	*Colocasia*		Others (59)	2 072	28	5	55	<1	17	23
Taro	***Colocasia***		**Total**	**7 302**	**100**	**2**	**38**	**6**	**7**	**47**
Vegetables										
Tomato	*Lycopersicon*	TWN001	AVRDC	7 548	9		1	3	1	96
Tomato	*Lycopersicon*	USA003	NE9	6 283	8	4	8	3	9	75
Tomato	*Lycopersicon*	PHL130	IPB-UPLB	4 751	6	9	86			5
Tomato	*Lycopersicon*	DEU146	IPK	4 062	5	3	40	22	33	1
Tomato	*Lycopersicon*	RUS001	VIR	2 540	3		19	1	79	1
Tomato	*Lycopersicon*	JPN003	NIAS	2 428	3	<1	1	5		93
Tomato	*Lycopersicon*	CAN004	PGRC	2 137	3	1	1	27	69	1

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Vegetables										
Tomato	*Lycopersicon*	COL004	ICA/REGION 5	2 018	2					100
Tomato	*Lycopersicon*	ESP026	BGUPV	1 927	2	9	69	<1	1	20
Tomato	*Lycopersicon*	IND001	NBPGR	1 796	2	4	10	22	8	56
Tomato	*Lycopersicon*	HUN003	RCA	1 749	2	1	16	<1	2	82
Tomato	*Lycopersicon*	BRA006	IAC	1 688	2					100
Tomato	*Lycopersicon*	KAZ004	RIPV	1 500	2	2	11	36	51	
Tomato	Lycopersicon	NLD037	CGN	1 306	2	8	7	13	55	17
Tomato	*Lycopersicon*	FRA215	GEVES	1 254	1				100	
Tomato	*Lycopersicon*	BGD186	EWS R&D	1 235	1					100
Tomato	*Lycopersicon*	CZE061	RICP	1 232	1	3	8	3	84	2
Tomato	*Lycopersicon*	BGR001	IPGR	1 128	1		10	11	3	76
Tomato	*Lycopersicon*	AUS048	ATCFC	1 074	1	9		6	74	12
Tomato	*Lycopersicon*	SRB002	IFVCNS	1 030	1				100	
Tomato	Lycopersicon	VNM006	FCRI	1 000	1		100			
Tomato	*Lycopersicon*		Others (143)	34 034	41	5	12	33	14	35
Tomato	***Lycopersicon***		**Total**	**83 720**	**100**	**4**	**17**	**18**	**19**	**42**
Capsicum	*Capsicum*	TWN001	AVRDC	7 860	11		3		3	94
Capsicum	*Capsicum*	USA016	S9	4 698	6	1	9	<1	16	74
Capsicum	*Capsicum*	MEX008	INIFAP	4 661	6				2	98
Capsicum	*Capsicum*	IND001	NBPGR	3 835	5	13	15	1	9	62
Capsicum	*Capsicum*	BRA006	IAC	2 321	3					100
Capsicum	*Capsicum*	JPN003	NIAS	2 271	3	1	2	2		95
Capsicum	*Capsicum*	PHL130	IPB-UPLB	1 880	3		84			16
Capsicum	*Capsicum*	TWN005	TSS-PDAF	1 800	2				100	
Capsicum	*Capsicum*	DEU146	IPK	1 526	2	1	66	4	28	2
Capsicum	*Capsicum*	CHN004	BVRC	1 394	2					100
Capsicum	*Capsicum*	FRA011	INRA-UGAFL	1 371	2	1			88	11
Capsicum	*Capsicum*	TUR001	AARI	1 334	2		99		1	
Capsicum	*Capsicum*	RUS001	VIR	1 273	2		6		53	41
Capsicum	*Capsicum*	CRI001	CATIE	1 163	2					100
Capsicum	*Capsicum*	PER002	UNALM	1 157	2		54			46

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Vegetables										
Capsicum	*Capsicum*	ESP026	BGUPV	1 074	1	1	88	<1	2	10
Capsicum	*Capsicum*	HUN001	VEGTBUD	1 069	1					100
Capsicum	*Capsicum*	SRB002	IFVCNS	1 055	1				100	
Capsicum	*Capsicum*	NLD037	CGN	1 009	1	5	22	2	50	21
Capsicum	*Capsicum*		Others (167)	30 767	42	3	22	4	13	58
Capsicum	***Capsicum***		**Total**	**73 518**	**100**	**2**	**19**	**2**	**15**	**62**
Cantaloupe	*Cucumis*	USA020	NC7	4 878	11	6	24	5	7	59
Cantaloupe	*Cucumis*	JPN003	NIAS	4 242	10	1	3	4		92
Cantaloupe	*Cucumis*	RUS001	VIR	2 998	7	1	3	33	4	59
Cantaloupe	*Cucumis*	CHN001	ICGR-CAAS	2 892	7					100
Cantaloupe	*Cucumis*	BRA012	CNPH	2 400	5					100
Cantaloupe	*Cucumis*	KAZ004	RIPV	2 377	5		1	95	3	
Cantaloupe	*Cucumis*	FRA215	GEVES	1 399	3				100	
Cantaloupe	*Cucumis*	DEU146	IPK	1 154	3	<1	38	3	53	6
Cantaloupe	*Cucumis*	IND001	NBPGR	1 070	2	29	44	1	17	8
Cantaloupe	*Cucumis*	IRN029	NPGBI-SPII	1 046	2		18			82
Cantaloupe	*Cucumis*	BGR001	IPGR	1 006	2		5	1	<1	94
Cantaloupe	*Cucumis*		Others (127)	18 836	43	2	28	12	9	49
Cantaloupe	***Cucumis***		**Total**	**44 298**	**100**	**3**	**18**	**13**	**10**	**56**
Cucurbita	*Cucurbita*	RUS001	VIR	5 771	15		53	25	12	10
Cucurbita	*Cucurbita*	CRI001	CATIE	2 612	7					100
Cucurbita	*Cucurbita*	BRA003	CENARGEN	1 897	5					100
Cucurbita	*Cucurbita*	CHN001	ICGR-CAAS	1 767	4					100
Cucurbita	*Cucurbita*	MEX008	INIFAP	1 580	4					100
Cucurbita	*Cucurbita*	JPN003	NIAS	1 295	3		2	1		96
Cucurbita	*Cucurbita*	USA016	S9	1 276	3	10	44	<1	3	42
Cucurbita	*Cucurbita*	DEU146	IPK	1 042	3		52	3	32	14
Cucurbita	*Cucurbita*		Others (144)	22 343	56	3	38	1	7	52
Cucurbita	***Cucurbita***		**Total**	**39 583**	**100**	**2**	**32**	**4**	**6**	**56**

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Vegetables										
Allium	*Allium*	IND1457	NRCOG	2 050	7		100			
Allium	*Allium*	RUS001	VIR	1 888	6		34		61	5
Allium	*Allium*	JPN003	NIAS	1 352	5	<1	2	5		94
Allium	*Allium*	USA003	NE9	1 304	4	<1	20	3	10	68
Allium	*Allium*	DEU146	IPK	1 264	4	8	58	8	22	4
Allium	*Allium*	GBR004	RBG	1 100	4	11			89	
Allium	*Allium*	TWN001	AVRDC	1 082	4		<1		7	93
Allium	*Allium*		Others (168)	19 858	66	6	25	6	16	48
Allium	***Allium***		**Total**	**29 898**	**100**	**5**	**29**	**4**	**19**	**43**
Rape	*Brassica*	CHN001	ICGR-CAAS	4 090	16					100
Rape	*Brassica*	IND001	NBPGR	2 585	10	<1	33		3	64
Rape	*Brassica*	BGD028	BINA	2 100	8					100
Rape	*Brassica*	JPN003	NIAS	1 579	6	<1	6	4		90
Rape	*Brassica*	AUS039	ATFCC	1 184	5	<1	6	1	3	90
Rape	*Brassica*	TWN001	AVRDC	1 091	4		10		69	21
Rape	*Brassica*	PAK001	PGRI	682	3		100			
Rape	*Brassica*	USA020	NC7	645	3	<1	6	2	1	90
Rape	*Brassica*	GBR006	HRIGRU	581	2	1	30		69	
Rape	*Brassica*	DEU146	IPK	493	2	<1	27	3	51	18
Rape	*Brassica*		Others (80)	10 536	41	1	31	1	7	59
Rape	***Brassica***		**Total**	**25 566**	**100**	**1**	**21**	**1**	**9**	**68**
Okra	*Abelmoschus*	CIV005	IDESSA	4 185	19					100
Okra	*Abelmoschus*	USA016	S9	2 969	13	<1	10		<1	89
Okra	*Abelmoschus*	IND001	NBPGR	2 651	12	16	30	<1	3	51
Okra	*Abelmoschus*	PHL130	IPB-UPLB	968	4	4	96			
Okra	*Abelmoschus*	FRA202	ORSTOM-MONTP	965	4	9			91	
Okra	*Abelmoschus*	GHA091	PGRRI	595	3					100
Okra	*Abelmoschus*	TUR001	AARI	563	3		98		2	
Okra	*Abelmoschus*		Others (88)	9 532	43	3	55	1	4	38
Okra	***Abelmoschus***		**Total**	**22 428**	**100**	**4**	**35**	**<1**	**6**	**55**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Vegetables										
Eggplant	*Solanum*	IND001	NBPGR	3 060	15	11	23	<1	5	61
Eggplant	*Solanum*	TWN001	AVRDC	3 003	14		17	<1	2	80
Eggplant	*Solanum*	JPN003	NIAS	1 223	6	<1	7	4		89
Eggplant	*Solanum*	USA016	S9	887	4	1	2		2	94
Eggplant	*Solanum*	BGD186	EWS R&D	826	4					100
Eggplant	*Solanum*	PHL130	IPB-UPLB	661	3	2	98			
Eggplant	*Solanum*	NLD037	CGN	659	3	27	47	2	14	10
Eggplant	*Solanum*		Others (124)	10 776	51	17	33	8	7	36
Eggplant	***Solanum***		**Total**	**21 095**	**100**	**11**	**28**	**4**	**5**	**52**
Oleracea	*Brassica*	GBR165	SASA	2 367	12		1			99
Oleracea	*Brassica*	USA003	NE9	1 625	8		6	1	5	88
Oleracea	*Brassica*	CHN004	BVRC	1 235	6					100
Oleracea	*Brassica*	DEU146	IPK	1 215	6	2	32	3	60	3
Oleracea	*Brassica*	FRA215	GEVES	1 200	6				100	
Oleracea	*Brassica*	RUS001	VIR	980	5		26		74	<1
Oleracea	*Brassica*	JPN003	NIAS	672	3		1	7		91
Oleracea	*Brassica*	NLD037	CGN	631	3	<1	12	2	75	11
Oleracea	*Brassica*		Others (98)	10 257	51	3	24	5	34	35
Oleracea	***Brassica***		**Total**	**20 182**	**100**	**1**	**16**	**3**	**33**	**46**
Melon	*Citrullus*	RUS001	VIR	2 412	16	1	40	54	2	3
Melon	*Citrullus*	USA016	S9	1 841	12	5	26	<1	5	64
Melon	*Citrullus*	CHN001	ICGR-CAAS	1 197	8					100
Melon	*Citrullus*	ISR002	IGB	840	6					100
Melon	*Citrullus*	UZB006	UzRIPI	805	5					100
Melon	*Citrullus*	BRA017	CPATSA	753	5					100
Melon	*Citrullus*	JPN003	NIAS	594	4	1	2	4		94
Melon	*Citrullus*	IRN029	NPGBI-SPII	570	4		65			35
Melon	*Citrullus*	KAZ004	RIPV	450	3		5	93	2	
Melon	*Citrullus*		Others (81)	5 681	38	9	37	3	13	39
Melon	***Citrullus***		**Total**	**15 143**	**100**	**4**	**26**	**13**	**6**	**51**

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Vegetables										
Carrot	*Daucus*	USA020	NC7	1 126	14	28	13	1	8	50
Carrot	*Daucus*	GBR006	HRIGRU	1 094	13	10	20	3	67	
Carrot	*Daucus*	RUS001	VIR	1 001	12	2	17			82
Carrot	*Daucus*	POL030	SKV	541	7	45	25	8	12	10
Carrot	*Daucus*	DEU146	IPK	488	6	35	16	1	48	1
Carrot	*Daucus*	CHN004	BVRC	407	5					100
Carrot	*Daucus*	FRA215	GEVES	384	5				100	
Carrot	*Daucus*	CZE061	RICP	366	4	6	1	1	89	4
Carrot	*Daucus*	JPN003	NIAS	342	4			4		96
Carrot	*Daucus*	UKR021	IOB	320	4		14	37	26	24
Carrot	*Daucus*		Others (67)	2 243	27	14	23	4	20	39
Carrot	***Daucus***		**Total**	**8 312**	**100**	**14**	**16**	**4**	**28**	**38**
Radish	*Raphanus*	JPN003	NIAS	877	11	<1	7	8		85
Radish	*Raphanus*	DEU146	IPK	741	9	23	35	1	38	3
Radish	*Raphanus*	USA003	NE9	696	9	1	4		16	80
Radish	*Raphanus*	RUS001	VIR	626	8		8	92	<1	
Radish	*Raphanus*	IND001	NBPGR	458	6	4	7	2	15	72
Radish	*Raphanus*	GBR165	SASA	453	6					100
Radish	*Raphanus*	NLD037	CGN	307	4		4	16	56	24
Radish	*Raphanus*		Others (85)	3 848	48	4	31	1	29	35
Radish	***Raphanus***		**Total**	**8 006**	**100**	**5**	**20**	**9**	**22**	**44**
Nuts, Fruits and Berries										
Prunus	*Prunus*	RUS001	VIR	6 579	9	18	13	2	24	44
Prunus	*Prunus*	USA276	UNMIHT	6 100	9			98		2
Prunus	*Prunus*	ITA378	CRA-FRU	2 421	3	<1	18	6	51	25
Prunus	*Prunus*	HUN021	EFOPP	2 259	3				5	95
Prunus	*Prunus*	TUR001	AARI	1 874	3	<1	81		19	
Prunus	*Prunus*	UKR046	KPS	1 458	2	1	11	1	41	46
Prunus	*Prunus*	CHE065	FRUCTUS	1 450	2		39			61

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Nuts, Fruits and Berries										
Prunus	*Prunus*	JPN003	NIAS	1 423	2	1	13	29		57
Prunus	*Prunus*	FRA057	INRA-BORDEAU	1 220	2	<1	<1		19	81
Prunus	*Prunus*	MEX008	INIFAP	1 116	2	3			97	<1
Prunus	*Prunus*	ROM009	ICPP Pitesti	1 093	2	2	30	37	29	1
Prunus	*Prunus*	IRN029	NPGBI-SPII	1 006	1					100
Prunus	*Prunus*	BRA020	CPACT/EMBRAP	1 006	1					100
Prunus	*Prunus*		Others (211)	40 492	58	4	10	10	38	38
Prunus	***Prunus***		**Total**	**69 497**	**100**	**4**	**12**	**16**	**30**	**38**
Apple	*Malus*	USA167	GEN	6 980	12	64	<1	9	1	26
Apple	*Malus*	RUS001	VIR	3 743	6	3	17	23	5	52
Apple	*Malus*	JPN003	NIAS	2 671	4	7	2	6		85
Apple	*Malus*	GBR030	NFC	2 223	4					100
Apple	*Malus*	CHE063	PSR	1 935	3					100
Apple	*Malus*	AUT024	KLOST	1 904	3					100
Apple	*Malus*	FRA028	INRA-ANGERS	1 895	3	10			90	
Apple	*Malus*	KAZ027	PG	1 719	3	3	<1		97	
Apple	*Malus*	BRA044	IAPAR	1 464	2					100
Apple	*Malus*	BEL019	CRAGXPP	1 175	2					100
Apple	*Malus*	CZE031	HOLOVOU	1 094	2	2	13	37	43	5
Apple	*Malus*	POL029	SKF	1 069	2	2		5	93	
Apple	*Malus*		Others (157)	32 050	53	2	18	4	31	45
Apple	***Malus***		**Total**	**59 922**	**100**	**9**	**11**	**6**	**25**	**49**
Grape	*Vitis*	FRA139	INRA/ENSA-M	5 158	9					100
Grape	*Vitis*	DEU098	JKI	3 657	6	4	22	44	28	2
Grape	*Vitis*	CHE019	RAC	3 254	5					100
Grape	*Vitis*	USA028	DAV	3 038	5	<1	<1	9	1	89
Grape	*Vitis*	UKR050	IVM	2 201	4	<1	57	24	8	10
Grape	*Vitis*	ITA388	CRA-VIT	2 106	4		1	37	60	2
Grape	*Vitis*	SVK018	SVKBRAT	1 900	3		<1	83	15	2

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Nuts, Fruits and Berries										
Grape	*Vitis*	UZB006	UzRIPI	1 580	3					100
Grape	*Vitis*	TUR001	AARI	1 437	2		100			
Grape	*Vitis*	BRA141	CNPUV	1 345	2					100
Grape	*Vitis*	ESP080	IMIACM	1 224	2					100
Grape	*Vitis*	ROM017	ICVV Valea C	1 187	2	1		5	95	
Grape	*Vitis*	HUN047	UHFI-RIVE	1 135	2					100
Grape	*Vitis*		Others (125)	30 385	51	3	12	6	26	53
Grape	***Vitis***		**Total**	**59 607**	**100**	**2**	**12**	**11**	**20**	**55**
Lemon	*Citrus*	BRA125	CCSM-IASP	2 134	7		5			95
Lemon	*Citrus*	JPN003	NIAS	2 118	7	<1	8	3		89
Lemon	*Citrus*	CHN020	CRI	1 880	6	1	31			68
Lemon	*Citrus*	USA129	NCGRCD	1 103	4	<1	1	1	71	27
Lemon	*Citrus*	FRA014	Cirad	1 100	4					100
Lemon	*Citrus*	ZAF004	CSFRI	1 005	3					100
Lemon	*Citrus*		Others (144)	20 350	69	1	13	13	25	48
Lemon	***Citrus***		**Total**	**29 690**	**100**	**1**	**12**	**9**	**20**	**59**
Mango	*Mangifera*	AUS088	Ayr DPI	18 606	73	<1		99	1	
Mango	*Mangifera*	IND045	CISH	726	3		100			
Mango	*Mangifera*	THA056	HRI-DA/THA	252	1			100		
Mango	*Mangifera*	USA047	MIA	240	1			1	48	51
Mango	*Mangifera*	IDN177	ILETRI	239	1				100	
Mango	*Mangifera*	SLE015	NUC	200	1				100	
Mango	*Mangifera*		Others (109)	5 396	21	<1	27	6	31	37
Mango	**Mangifera**		**Total**	**25 659**	**100**	**<1**	**8**	**74**	**10**	**8**
Pear	*Pyrus*	USA026	COR	2 232	9	11	5	34	48	2
Pear	*Pyrus*	RUS001	VIR	1 486	6		<1			100
Pear	*Pyrus*	CHE090	OSS Roggwil	1 240	5		1			99
Pear	*Pyrus*	FRA097	CBNA	914	4					100

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Nuts, Fruits and Berries										
Pear	*Pyrus*	BEL019	CRAGXPP	855	3					100
Pear	*Pyrus*	ITA378	CRA-FRU	761	3	2	29	12	30	27
Pear	*Pyrus*	JPN003	NIAS	744	3	14	11	7		68
Pear	*Pyrus*	UKR046	KPS	671	3	3	4	1	23	69
Pear	*Pyrus*	KAZ027	PG	607	2	100				
Pear	*Pyrus*	TUR001	AARI	553	2	<1	100			
Pear	*Pyrus*		Others (137)	14 679	59	2	20	4	28	45
Pear	***Pyrus***		**Total**	**24 742**	**100**	**5**	**16**	**6**	**23**	**50**
Banana	*Musa*	BEL084	INIBAP	1 198	9	14	73			13
Banana	*Musa*	FRA014	Cirad	520	4				4	96
Banana	*Musa*	HND003	DTRUFC	490	4	40		30	30	
Banana	*Musa*	AUS035	QDPI	400	3					100
Banana	*Musa*	BRA004	CNPMF	400	3					100
Banana	*Musa*	CMR052	CARBAP	385	3				100	
Banana	*Musa*	IND349	NRCB	364	3	2	95	3		
Banana	*Musa*	THA002	AD-KU	323	2	<1				100
Banana	*Musa*	COL029	CORPOICA	310	2					100
Banana	*Musa*	UGA003	RRS-AD	309	2	<1			100	
Banana	*Musa*	COD003	INERA	300	2					100
Banana	*Musa*	NGA039	IITA	283	2					100
Banana	*Musa*	JAM003	BB	257	2			9	53	38
Banana	*Musa*	PHL019	SEABGRC-BPI	245	2					100
Banana	*Musa*	CRI011	CORBANA	240	2	100				
Banana	*Musa*	PNG004	DLP Laloki	230	2					100
Banana	*Musa*	MYS142	HRC, MARDI	217	2		100			
Banana	*Musa*		Others (115)	7 015	52	5	21	3	23	47
Banana	***Musa***		**Total**	**13 486**	**100**	**7**	**21**	**3**	**19**	**49**
Strawberry	*Fragaria*	CAN004	PGRC	1 897	16	4			4	92
Strawberry	*Fragaria*	USA026	COR	1 822	15	34	3	35	28	<1

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Nuts, Fruits and Berries										
Strawberry	*Fragaria*	RUS001	VIR	940	8		7	2	69	23
Strawberry	*Fragaria*	JPN003	NIAS	912	8	2		10		88
Strawberry	*Fragaria*	DEU451	JKI	622	5					100
Strawberry	*Fragaria*	CHL008	INIA QUIL	500	4	100				
Strawberry	*Fragaria*	GBR012	GBREMR	329	3	10			85	5
Strawberry	*Fragaria*	ITA380	CRA-FRF	220	2		1	<1	99	
Strawberry	*Fragaria*	ROM009	ICPP Pitesti	201	2	5	<1	81	7	5
Strawberry	*Fragaria*		Others (68)	4 584	38	16	1	5	33	45
Strawberry	***Fragaria***		**Total**	**12 027**	**100**	**16**	**2**	**9**	**27**	**46**
Cashew	*Anacardium*	GHA005	CRIG	3 382	35			100		
Cashew	*Anacardium*	IND003	CPCRI	880	9					100
Cashew	*Anacardium*	THA022	PHES	744	8				100	
Cashew	*Anacardium*	BRA146	CNPAT	621	6					100
Cashew	*Anacardium*	NGA008	CRIN	574	6					100
Cashew	*Anacardium*	MOZ003	UDAC	530	5		100			
Cashew	*Anacardium*	COL029	CORPOICA	473	5					100
Cashew	*Anacardium*		Others (64)	2 546	26	<1	32	9	4	55
Cashew	***Anacardium***		**Total**	**9 750**	**100**	**<1**	**14**	**37**	**9**	**40**
Ribes	*Ribes*	USA026	COR	1 510	17	46	6	6	40	2
Ribes	*Ribes*	RUS001	VIR	888	10		1	4	63	32
Ribes	*Ribes*	GBR048	SCRI	860	10					100
Ribes	*Ribes*	NOR001	SFL	522	6	<1		96	4	
Ribes	*Ribes*	LTU010	BGVU	393	4	27		12	61	
Ribes	*Ribes*	FRA028	INRA-ANGERS	390	4					100
Ribes	*Ribes*	UKR029	LFS	356	4		9	1	70	20
Ribes	*Ribes*	CHE063	PSR	305	3					100
Ribes	*Ribes*		Others (50)	3 584	41	2	2	3	46	47
Ribes	***Ribes***		**Total**	**8 808**	**100**	**10**	**2**	**9**	**38**	**41**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Nuts, Fruits and Berries										
Rose	*Rosa*	FRA217	GEVES	1 200	32					100
Rose	*Rosa*	JPN003	NIAS	634	17					100
Rose	*Rosa*	AZE017	CBG	250	7	60			40	
Rose	*Rosa*		Others (44)	1 710	45	19	9	8	23	42
Rose	***Rosa***		**Total**	**3 794**	**100**	**12**	**4**	**3**	**13**	**67**
Hazel	*Corylus*	USA026	COR	837	28	13	13	25	48	1
Hazel	*Corylus*	TUR001	AARI	413	14		100			
Hazel	*Corylus*	UKR046	KPS	188	6				1	99
Hazel	*Corylus*	AZE009	HSCRI	169	6		32	22	46	
Hazel	*Corylus*	ESP014	IRTAMB	120	4		6			94
Hazel	*Corylus*	UZB031	UzRIHVWM	118	4					100
Hazel	*Corylus*		Others (53)	1 153	38	3	9	13	37	39
Hazel	***Corylus***		**Total**	**2 998**	**100**	**5**	**23**	**13**	**30**	**29**
Peach palm	*Bactris*	CRI016	UCR-BIO	800	31					100
Peach palm	*Bactris*	BRA006	IAC	332	13					100
Peach palm	*Bactris*	COL029	CORPOICA	254	10					100
Peach palm	*Bactris*	ECU022	EENP	145	6		100			
Peach palm	*Bactris*	PAN002	INRENARE	65	3				100	
Peach palm	*Bactris*		Others (23)	997	38	7	2	<1	1	90
Peach palm	***Bactris***		**Total**	**2 593**	**100**	**3**	**6**	**<1**	**3**	**88**
Pistachio	*Pistacia*	IRN029	NPGBI-SPII	340	29					100
Pistachio	*Pistacia*	USA028	DAV	304	26	4	<1			96
Pistachio	*Pistacia*	ESP014	IRTAMB	106	9					100
Pistachio	*Pistacia*	AZE015	GRI	60	5		3	88	8	
Pistachio	*Pistacia*		Others (28)	358	31	33	4	3	28	31
Pistachio	***Pistacia***		**Total**	**1 168**	**100**	**11**	**2**	**6**	**9**	**73**

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Nuts, Fruits and Berries										
Sorbus	*Sorbus*	USA026	COR	282	37	32	44	13	6	6
Sorbus	*Sorbus*	GBR004	RBG	110	14	100				
Sorbus	*Sorbus*	AUT024	KLOST	71	9					100
Sorbus	*Sorbus*	UKR030	DFS	59	8					100
Sorbus	*Sorbus*	NLD145	NAKB	46	6				100	
Sorbus	*Sorbus*		Others (30)	195	26	18	15	7	11	48
Sorbus	***Sorbus***		**Total**	**763**	**100**	**31**	**20**	**7**	**11**	**31**

Crop Grouping	Genus	Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Oil Crops										
Sesame	*Sesamum*	IND001	NBPGR	8 413	17	2	32	<1	26	39
Sesame	*Sesamum*	CHN001	ICGR-CAAS	4 726	9					100
Sesame	*Sesamum*	ISR001	REHOVOT	3 000	6					100
Sesame	*Sesamum*	KEN015	KARI-NGBK	2 477	5	1	3			96
Sesame	*Sesamum*	BRA003	CENARGEN	1 950	4					100
Sesame	*Sesamum*	JPN003	NIAS	1 789	4	<1	15	14		71
Sesame	*Sesamum*	MEX001	INIA-Iguala	1 600	3					100
Sesame	*Sesamum*	RUS001	VIR	1 504	3	<1	66	27	8	
Sesame	*Sesamum*	UZB006	UzRIPI	1 334	3					100
Sesame	*Sesamum*	USA016	S9	1 215	2	<1	14	1	12	72
Sesame	*Sesamum*	VEN132	INIA - CENIAP	1 024	2		100			
Sesame	*Sesamum*		Others (69)	21 432	42	1	55	5	1	38
Sesame	**Sesamum**		**Total**	**50 464**	**100**	**1**	**34**	**4**	**5**	**57**
Sunflower	*Helianthus*	SRB002	IFVCNS	5 330	14	6			94	
Sunflower	*Helianthus*	USA020	NC7	3 729	9	42	7	16	8	28
Sunflower	*Helianthus*	CHN001	ICGR-CAAS	2 646	7					100
Sunflower	*Helianthus*	FRA040	INRA-CLERMON	2 500	6		32	20	48	
Sunflower	*Helianthus*	BRA014	CNPSO	2 400	6					100
Sunflower	*Helianthus*	RUS001	VIR	1 701	4					100
Sunflower	*Helianthus*	AUS048	ATCFC	1 290	3	17	1	47	18	18
Sunflower	*Helianthus*	IND041	DOR	1 260	3		100			

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Oil Crops										
Sunflower	*Helianthus*	MAR088	INRA CRRAS	1 223	3					100
Sunflower	*Helianthus*	POL003	IHAR	1 105	3		<1			100
Sunflower	*Helianthus*	HUN003	RCA	1 032	3	<1	30	<1	61	9
Sunflower	*Helianthus*		Others (82)	15 164	39	8	15	12	8	58
Sunflower	***Helianthus***		**Total**	**39 380**	**100**	**8**	**12**	**9**	**22**	**49**
Safflower	*Carthamus*	IND041	DOR	6 863	24		100			
Safflower	*Carthamus*	CHN001	ICGR-CAAS	2 499	9					100
Safflower	*Carthamus*	USA022	W6	2 453	8	17	52	8	9	13
Safflower	*Carthamus*	MEX001	INIA-Iguala	1 550	5					100
Safflower	*Carthamus*	IRN029	NPGBI-SPII	816	3					100
Safflower	*Carthamus*	BRA007	CNPA	800	3					100
Safflower	*Carthamus*		Others (53)	14 214	49	2	22	3	3	70
Safflower	***Carthamus***		**Total**	**29 195**	**100**	**2**	**39**	**2**	**2**	**55**
Palm	*Elaeis*	COD003	INERA	17 631	84	1		99	<1	
Palm	*Elaeis*	MYS104	MPOB	1 467	7	100				
Palm	*Elaeis*	BRA027	CPAA	564	3					100
Palm	*Elaeis*	COL096	ICA/REGION 5	301	1				100	
Palm	*Elaeis*	IDN193	IOPRI	237	1		1	97		2
Palm	*Elaeis*	SLE015	NUC	200	1				100	
Palm	*Elaeis*	GHA019	OPRI	150	1		100			
Palm	*Elaeis*		Others (22)	553	3	1	17		41	41
Palm	***Elaeis***		**Total**	**21 103**	**100**	**8**	**1**	**84**	**4**	**4**
Castor seed	*Ricinus*	IND001	NBPGR	4 307	24	3	15	<1	<1	81
Castor seed	*Ricinus*	CHN001	ICGR-CAAS	2 111	12					100
Castor seed	*Ricinus*	BRA007	CNPA	1 000	6					100
Castor seed	*Ricinus*	RUS001	VIR	696	4	<1	5			95
Castor seed	*Ricinus*	USA995	NCGRP	669	4			<1	<1	100
Castor seed	*Ricinus*	ETH085	IBC	510	3	88	2			10

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Oil Crops										
Castor seed	*Ricinus*		Others (52)	8 699	48	37	17	3	1	42
Castor seed	***Ricinus***		**Total**	**17 992**	**100**	**21**	**12**	**1**	**<1**	**65**
Physic nut	*Jatropha*	MEX006	UACH	1 444	44	4	96			
Physic nut	*Jatropha*	IND001	NBPGR	1 260	39	68	17		1	14
Physic nut	*Jatropha*	BRA007	CNPA	143	4					100
Physic nut	*Jatropha*		Others (20)	417	13	64	3	<1		32
Physic nut	***Jatropha***		**Total**	**3 264**	**100**	**36**	**49**	**<1**	**<1**	**14**
Olive	*Olea*	ITA401	CRA-OLI	443	17		33		67	
Olive	*Olea*	ESP046	CIFACOR	309	12		63			37
Olive	*Olea*	IRN029	NPGBI-SPII	247	9		15			85
Olive	*Olea*	USA028	DAV	142	5					100
Olive	*Olea*	AZE009	HSCRI	136	5			81	19	
Olive	*Olea*	TUR001	AARI	130	5		100			
Olive	*Olea*		Others (46)	1 222	46	2	15	5	45	34
Olive	***Olea***		**Total**	**2 629**	**100**	**1**	**26**	**6**	**33**	**34**
Forage Crops										
Legumes	Various	IND001	NBPGR	19 579	11	6	20	<1	13	61
Legumes	Various	COL003	CIAT	13 690	7	99	<1			1
Legumes	Various	CHN001	ICGR-CAAS	11 201	6					100
Legumes	Various	TWN001	AVRDC	10 207	6		2		<1	98
Legumes	Various	AUS048	ATCFC	8 951	5	29	6	9	2	54
Legumes	Various	USA016	S9	7 474	4	7	3	7	<1	82
Legumes	Various	PHL130	IPB-UPLB	7 445	4	<1	100			<1
Legumes	Various	ETH013	ILRI-Ethiopia	7 310	4	99			1	
Legumes	Various	JPN003	NIAS	6 040	3	6	18	1		75
Legumes	Various	KEN015	KARI-NGBK	4 473	2	8	19	3		71
Legumes	Various	SYR002	ICARDA	3 435	2	98	2			<1
Legumes	Various	NZL001	AGRESEARCH	3 104	2					100
Legumes	Various	GBR004	RBG	2 809	2	100				

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Forage Crops										
Legumes	Various	MEX001	INIA-Iguala	2 300	1					100
Legumes	Various	THA005	FCRI-DA/TH	2 250	1			100		
Legumes	Various		Others (301)	72 810	40	28	28	2	3	39
Legumes	**Various**		**Total**	**183 078**	**100**	**29**	**19**	**3**	**3**	**47**
Medicago	*Medicago*	AUS006	AMGRC	27 827	30	78	1	16	3	3
Medicago	*Medicago*	UZB036	UzRICBSP	10 043	11					100
Medicago	*Medicago*	SYR002	ICARDA	9 164	10	90	4			6
Medicago	*Medicago*	USA022	W6	7 845	9	54	18	4	11	13
Medicago	*Medicago*	MAR088	INRA CRRAS	3 373	4	18	<1			82
Medicago	*Medicago*	RUS001	VIR	2 909	3	13	33			53
Medicago	*Medicago*	FRA041	INRA-MONTPEL	2 479	3	7	8			85
Medicago	*Medicago*	IRN029	NPGBI-SPII	2 415	3		15			85
Medicago	*Medicago*	LBY001	ARC	1 927	2	100				<1
Medicago	*Medicago*	JPN003	NIAS	1 486	2		1	3		96
Medicago	*Medicago*	ITA363	PERUG	1 338	1	16	7	50	5	23
Medicago	*Medicago*	TUR001	AARI	1 006	1	100			<1	
Medicago	*Medicago*		Others (130)	20 110	22	22	11	7	18	42
Medicago	***Medicago***		**Total**	**91 922**	**100**	**47**	**6**	**7**	**6**	**34**
Clover	*Trifolium*	AUS137	WADA	11 326	15	99		<1	1	
Clover	*Trifolium*	NZL001	AGRESEARCH	6 607	9					100
Clover	*Trifolium*	SYR002	ICARDA	4 522	6	82	4			14
Clover	*Trifolium*	GBR016	IBERS-GRU	4 362	6	32	1	17	15	35
Clover	*Trifolium*	ESP010	SIAEX	4 031	5	88		1	1	10
Clover	*Trifolium*	USA022	W6	3 476	5	46	9	5	17	23
Clover	*Trifolium*	RUS001	VIR	2 965	4	33	28	4		35
Clover	*Trifolium*	ITA394	CRA-FLC	1 878	3	94	1	1	4	
Clover	*Trifolium*	IRN029	NPGBI-SPII	1 626	2		14			86
Clover	*Trifolium*	ETH013	ILRI-Ethiopia	1 529	2	95			5	
Clover	*Trifolium*	JPN003	NIAS	1 441	2	2	1	4		93
Clover	*Trifolium*	TUR001	AARI	1 055	1	100				

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Forage										
Clover	*Trifolium*	DEU146	IPK	1 052	1	62	<1	1	18	19
Clover	*Trifolium*		Others (124)	28 288	38	43	7	4	9	37
Clover	***Trifolium***		**Total**	**74 158**	**100**	**53**	**5**	**3**	**6**	**33**
Grasses	Various	JPN055	KNAES	5 614	10					100
Grasses	Various	NZL001	AGRESEARCH	5 063	9					100
Grasses	Various	USA022	W6	4 502	8	67	4	1	5	23
Grasses	Various	KEN015	KARI-NGBK	4 491	8	4	10	<1		86
Grasses	Various	ETH013	ILRI-Ethiopia	2 016	4	96			4	
Grasses	Various	AUS048	ATCFC	1 528	3	40	<1	<1	1	59
Grasses	Various	MEX008	INIFAP	1 509	3	2				98
Grasses	Various	GBR004	RBG	1 337	2	100				
Grasses	Various		Others (210)	28 895	53	34	3	5	3	55
Grasses	**Various**		**Total**	**54 955**	**100**	**31**	**3**	**3**	**2**	**61**
Vicia	*Vicia*	SYR002	ICARDA	6 108	16	52	11			38
Vicia	*Vicia*	RUS001	VIR	5 751	15		27	1		72
Vicia	*Vicia*	DEU146	IPK	3 254	8	4	39	25	11	21
Vicia	*Vicia*	AUS039	ATFCC	2 749	7	6	<1	<1	<1	94
Vicia	*Vicia*	ITA004	IGV	2 210	6					100
Vicia	*Vicia*	TUR001	AARI	1 985	5	41	58		<1	
Vicia	*Vicia*	USA022	W6	1 841	5	46	14	<1	5	35
Vicia	*Vicia*	GBR001	SOUTA	1 781	5	100				
Vicia	*Vicia*	ESP004	INIACRF	1 516	4	15	83		<1	2
Vicia	*Vicia*	BGR001	IPGR	1 399	4	17			<1	83
Vicia	*Vicia*		Others (101)	9 866	26	23	26	4	5	41
Vicia	***Vicia***		**Total**	**38 460**	**100**	**25**	**23**	**3**	**3**	**46**
Fescue	*Festuca*	POL003	IHAR	4 777	14		<1			100
Fescue	*Festuca*	JPN003	NIAS	4 258	13		4	3		93
Fescue	*Festuca*	USA022	W6	2 452	7	63	6	1	14	16
Fescue	*Festuca*	DEU271	IPK	2 180	7	62	<1	4	25	9

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Forage										
Fescue	*Festuca*	GBR016	IBERS-GRU	1 498	5	65	5	6	6	19
Fescue	*Festuca*		Others (99)	17 843	54	22	24	1	7	46
Fescue	***Festuca***		**Total**	**33 008**	**100**	**24**	**14**	**2**	**7**	**54**
Grasses	*Dactylis*	POL022	BYDG	6 010	19		97		1	2
Grasses	*Dactylis*	JPN019	NGRI	2 684	9					100
Grasses	*Dactylis*	DEU271	IPK	1 929	6	79	<1	4	14	2
Grasses	*Dactylis*	USA022	W6	1 588	5	58	8	4	8	22
Grasses	*Dactylis*	GBR016	IBERS-GRU	1 094	3	66	2	16	9	7
Grasses	*Dactylis*		Others (93)	18 089	58	50	4	1	4	41
Grasses	***Dactylis***		**Total**	**31 394**	**100**	**39**	**21**	**2**	**4**	**34**
Pea	*Lathyrus*	FRA092	LEM/IBEAS	3 627	14	9				91
Pea	*Lathyrus*	SYR002	ICARDA	3 225	12	45	12			43
Pea	*Lathyrus*	IND001	NBPGR	2 797	11	<1	2	<1	3	94
Pea	*Lathyrus*	BGD164	BARI	1 845	7		100			
Pea	*Lathyrus*	CHL004	INIA CARI	1 424	5	100				
Pea	*Lathyrus*	AUS039	ATFCC	1 366	5					100
Pea	*Lathyrus*	GBR001	SOUTA	1 185	5	100				
Pea	*Lathyrus*		Others (88)	10 597	41	20	29	1	1	49
Pea	***Lathyrus***		**Total**	**26 066**	**100**	**25**	**21**	**<1**	**1**	**53**
Grasses	*Lolium*	DEU271	IPK	3 408	13	61	<1	3	27	9
Grasses	*Lolium*	GBR016	IBERS-GRU	3 194	12	58	1	10	20	11
Grasses	*Lolium*	POL022	BYDG	2 152	8		96		2	3
Grasses	*Lolium*	JPN003	NIAS	1 896	7	3	1	13		84
Grasses	*Lolium*	NZL001	AGRESEARCH	1 841	7					100
Grasses	*Lolium*	USA022	W6	1 364	5	45	6	<1	26	23
Grasses	*Lolium*	FRA040	INRA-CLERMON	1 000	4	70				30
Grasses	*Lolium*		Others (93)	10 732	42	25	8	2	17	48
Grasses	***Lolium***		**Total**	**25 587**	**100**	**31**	**12**	**3**	**15**	**39**

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Forage										
Millet	*Panicum*	JPN003	NIAS	5 758	33	2	<1	1		97
Millet	*Panicum*	KEN015	KARI-NGBK	2 328	13	1	<1			98
Millet	*Panicum*	USA016	S9	784	4	2	<1	2	2	93
Millet	*Panicum*	CIV010	CN	570	3					100
Millet	*Panicum*	COL003	CIAT	563	3	98				2
Millet	*Panicum*		Others (86)	7 630	43	16	2	7	1	74
Millet	***Panicum***		**Total**	**17 633**	**100**	**11**	**1**	**3**	**1**	**84**
Pencilflower	*Stylosanthes*	COL003	CIAT	4 276	40	99	<1			<1
Pencilflower	*Stylosanthes*	AUS048	ATCFC	1 849	17	7		1	<1	92
Pencilflower	*Stylosanthes*	BRA010	CNPGC	1 062	10					100
Pencilflower	*Stylosanthes*	KEN015	KARI-NGBK	1 056	10	3	90			8
Pencilflower	*Stylosanthes*	ETH013	ILRI-Ethiopia	994	9	98			2	
Pencilflower	*Stylosanthes*	USA016	S9	111	1			1	1	98
Pencilflower	*Stylosanthes*		Others (39)	1 385	13	7	6	2	1	84
Pencilflower	***Stylosanthes***		**Total**	**10 733**	**100**	**51**	**10**	**<1**	**<1**	**38**
Grasses	*Poa*	POL022	BYDG	2 329	23		96		3	1
Grasses	*Poa*	USA022	W6	1 716	17	82	2	1	10	5
Grasses	*Poa*	DEU271	IPK	1 122	11	60	<1	4	26	10
Grasses	*Poa*	SWE054	NORDGEN	594	6	81	4	2	10	2
Grasses	*Poa*	NZL001	AGRESEARCH	321	3					100
Grasses	*Poa*	JPN003	NIAS	271	3	17	2	44		37
Grasses	*Poa*		Others (64)	3 897	38	29	1	2	12	56
Grasses	***Poa***		**Total**	**10 250**	**100**	**36**	**23**	**3**	**10**	**28**
Grasses	*Phleum*	POL003	IHAR	2 549	27		<1			100
Grasses	*Phleum*	DEU271	IPK	1 093	12	73	2	2	18	6
Grasses	*Phleum*	SWE054	NORDGEN	767	8	65	21	1	7	5
Grasses	*Phleum*	USA022	W6	692	7	37	10	<1	16	36
Grasses	*Phleum*	JPN003	NIAS	222	2		12	7		81

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Forage										
Grasses	*Phleum*		Others (56)	4 011	43	15	62	2	9	12
Grasses	***Phleum***		**Total**	**9 334**	**100**	**23**	**30**	**1**	**8**	**38**
Trefoil	*Lotus*	AUS006	AMGRC	1 934	24	92	<1	4	5	<1
Trefoil	*Lotus*	NZL001	AGRESEARCH	1 157	14					100
Trefoil	*Lotus*	USA022	W6	929	11	56	3	4	12	24
Trefoil	*Lotus*	GBR016	IBERS-GRU	492	6	20	1	30	16	34
Trefoil	*Lotus*	POL003	IHAR	269	3		4			96
Trefoil	*Lotus*	CHL004	INIA CARI	260	3	100				
Trefoil	*Lotus*	ITA363	PERUG	246	3	63		7	12	17
Trefoil	*Lotus*		Others (82)	2 895	35	51	15	2	5	28
Trefoil	***Lotus***		**Total**	**8 182**	**100**	**52**	**6**	**4**	**5**	**32**
Grasses	*Bromus*	USA022	W6	1 203	15	68	5	1	9	17
Grasses	*Bromus*	NZL001	AGRESEARCH	840	11					100
Grasses	*Bromus*	CHL028	INIA INTIH	595	8	100				
Grasses	*Bromus*	ARG1227	EEA INTA Anguil	490	6	100				
Grasses	*Bromus*	KAZ019	SPCGF	364	5	21		79		
Grasses	*Bromus*	URY002	FAGRO	320	4	100				
Grasses	*Bromus*	DEU146	IPK	317	4	11	<1		2	87
Grasses	*Bromus*	CAN004	PGRC	293	4	77	10	2	10	2
Grasses	*Bromus*	AUS006	AMGRC	229	3	93		<1	4	3
Grasses	*Bromus*		Others (82)	3 157	40	50	1	2	3	44
Grasses	***Bromus***		**Total**	**7 808**	**100**	**55**	**2**	**5**	**3**	**35**
Rye	*Elymus*	USA022	W6	3 310	67	92	3	<1	1	3
Rye	*Elymus*	SWE054	NORDGEN	305	6	100				
Rye	*Elymus*	AUS006	AMGRC	179	4	92			6	2
Rye	*Elymus*	DEU146	IPK	125	3	6	1		2	90
Rye	*Elymus*	CHN001	ICGR-CAAS	117	2					100
Rye	*Elymus*	CZE122	RICP	110	2	98			2	

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Forage										
Rye	*Elymus*		Others (40)	770	16	68	<1	1	3	28
Rye	***Elymus***		**Total**	**4 916**	**100**	**85**	**2**	**<1**	**2**	**11**
Grasses	*Cenchrus*	KEN015	KARI-NGBK	1 138	30	1	2			96
Grasses	*Cenchrus*	GBR016	IBERS-GRU	469	12	74		1	3	23
Grasses	*Cenchrus*	AUS048	ATCFC	395	11	10			<1	90
Grasses	*Cenchrus*	ETH013	ILRI-Ethiopia	293	8	95			5	
Grasses	*Cenchrus*	BRA017	CPATSA	237	6					100
Grasses	*Cenchrus*	JPN003	NIAS	195	5	5	1			94
Grasses	*Cenchrus*		Others (45)	1 031	27	22	5	8	<1	66
Grasses	***Cenchrus***		**Total**	**3 758**	**100**	**24**	**2**	**2**	**1**	**71**
Grasses	*Andropogon*	USA995	NCGRP	1 071	61	1			1	99
Grasses	*Andropogon*	KEN015	KARI-NGBK	116	7	1				99
Grasses	*Andropogon*	ETH013	ILRI-Ethiopia	104	6	98			2	
Grasses	*Andropogon*	COL003	CIAT	93	5	100				
Grasses	*Andropogon*	CAN041	LRS	55	3	100				
Grasses	*Andropogon*	ARG1133	IBONE	50	3					100
Grasses	*Andropogon*		Others (42)	277	16	28	5	4	5	58
Grasses	***Andropogon***		**Total**	**1 766**	**100**	**19**	**1**	**1**	**1**	**78**
Sugar Crops										
Sugar cane	*Saccharum*	BRA189	CTC	5 000	12					100
Sugar cane	*Saccharum*	CUB041	INICA	3 619	9	2			98	
Sugar cane	*Saccharum*	BRB001	WICSBS	3 493	8					100
Sugar cane	*Saccharum*	JPN003	NIAS	2 916	7	8	1	27		64
Sugar cane	*Saccharum*	USA047	MIA	2 426	6	10	3	2	7	77
Sugar cane	*Saccharum*	GUY016	GSC	2 223	5				100	
Sugar cane	*Saccharum*	DOM010	CRC	1 965	5					100
Sugar cane	*Saccharum*	BGD015	BSRI	1 364	3	3	27	31		40
Sugar cane	*Saccharum*	PAK130	SRI	1 200	3			100		
Sugar cane	*Saccharum*	PHL251	SRA-LGAREC	1 161	3		1	22	77	

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Sugar Crops										
Sugar cane	*Saccharum*	THA005	FCRI-DA/TH	1 093	3	59		41		
Sugar cane	*Saccharum*		Others (49)	14 668	36	1	10	4	27	58
Sugar cane	***Saccharum***		**Total**	**41 128**	**100**	**3**	**5**	**9**	**26**	**56**
Beet	*Beta*	USA022	W6	2 510	11	26	34	19	15	5
Beet	*Beta*	DEU146	IPK	2 209	10	48	17	8	24	3
Beet	*Beta*	SRB002	IFVCNS	2 140	10				100	
Beet	*Beta*	FRA043	INRA-DIJON	1 630	7	11	31	28	31	
Beet	*Beta*	CHN001	ICGR-CAAS	1 388	6					100
Beet	*Beta*	RUS001	VIR	1 354	6		1	50	46	3
Beet	*Beta*	JPN003	NIAS	1 339	6	2		21		77
Beet	*Beta*		Others (95)	9 776	44	12	7	10	10	61
Beet	***Beta***		**Total**	**22 346**	**100**	**14**	**11**	**14**	**23**	**39**
Fibre Crops										
Cotton	*Gossypium*	UZB036	UzRICBSP	12 048	11					100
Cotton	*Gossypium*	USA049	COT	9 387	9	21	2	8	4	64
Cotton	*Gossypium*	IND512	CICR	9 000	9		100			
Cotton	*Gossypium*	CHN001	ICGR-CAAS	7 226	7	7				93
Cotton	*Gossypium*	RUS001	VIR	6 205	6		23	16	58	3
Cotton	*Gossypium*	FRA002	IRCT-Cirad	4 116	4	12	38			50
Cotton	*Gossypium*	BRA003	CENARGEN	3 179	3					100
Cotton	*Gossypium*	PAK009	CCRI	1 830	2	2		98		
Cotton	*Gossypium*	VNM013	INCORD	1 400	1			100		
Cotton	*Gossypium*	AZE015	GRI	1 370	1			<1	100	
Cotton	*Gossypium*		Others (98)	49 019	47	5	6	7	5	78
Cotton	***Gossypium***		**Total**	**104 780**	**100**	**5**	**15**	**8**	**7**	**65**
Flax	*Linum*	RUS001	VIR	5 282	12		10	39	<1	50
Flax	*Linum*	ETH085	IBC	3 433	8		100			
Flax	*Linum*	CAN004	PGRC	3 418	8	2	6	12	11	69
Flax	*Linum*	CHN001	ICGR-CAAS	3 003	7					100

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TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Fibre Crops										
Flax	*Linum*	USA020	NC7	2 994	7	3	1	<1	5	90
Flax	*Linum*	ROM002	ICCPT Fundul	2 880	7	3	2	44	51	
Flax	*Linum*	IND849	Linseed	2 730	6		100			
Flax	*Linum*	DEU146	IPK	2 323	5	2	39	15	40	3
Flax	*Linum*	ARG1342	BBC-INTA	2 226	5				100	
Flax	*Linum*	CZE090	SUMPERK	2 054	5		25	24	50	1
Flax	*Linum*	BGR001	IPGR	1 437	3	<1	3		<1	96
Flax	*Linum*	UKR015	ILK	1 063	2		14	3	74	10
Flax	*Linum*		Others (69)	10 158	24	1	25	19	23	32
Flax	***Linum***		**Total**	**43 001**	**100**	**1**	**26**	**15**	**22**	**36**
Jute	*Corchorus*	IND001	NBPGR	5 408	46	5	37	3	2	54
Jute	*Corchorus*	BGD001	BJRI	4 110	35	7				93
Jute	*Corchorus*	KEN015	KARI-NGBK	203	2	22	66			12
Jute	*Corchorus*	THA005	FCRI-DA/TH	160	1			100		
Jute	*Corchorus*	RUS001	VIR	150	1		1			99
Jute	*Corchorus*	TWN001	AVRDC	143	1		26		1	73
Jute	*Corchorus*		Others (35)	1 515	13	29	38	11	1	22
Jute	***Corchorus***		**Total**	**11 689**	**100**	**9**	**24**	**4**	**1**	**63**
Medicinal, Aromatic Plants, Spices and Stimulants Crops										
Coffee	*Coffea*	CIV011	IRCC/Cirad	6 560	22	87			2	11
Coffee	*Coffea*	BRA006	IAC	4 152	14					100
Coffee	*Coffea*	FRA014	Cirad	3 800	13				55	45
Coffee	*Coffea*	CRI134	CATIE	1 835	6					100
Coffee	*Coffea*	CUB035	ECICC	1 597	5	10	64	10	16	
Coffee	*Coffea*	ETH075	JARC	1 284	4				7	93
Coffee	*Coffea*	COL014	CENICAFE	1 119	4	4				96
Coffee	*Coffea*		Others (57)	9 960	33	6	18	9	10	57
Coffee	***Coffea***		**Total**	**30 307**	**100**	**21**	**9**	**3**	**12**	**54**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Medicinal, Aromatic Plants, Spices and Stimulants Crops										
Mustard	*Sinapis*	IND001	NBPGR	5 509	21	1	23	<1	2	75
Mustard	*Sinapis*	CHN001	ICGR-CAAS	3 073	12					100
Mustard	*Sinapis*	AUS039	ATFCC	1 547	6	2	11	19	17	51
Mustard	*Sinapis*	RUS001	VIR	1 372	5		4	17	79	
Mustard	*Sinapis*	VNM006	FCRI	1 300	5		100			
Mustard	*Sinapis*		Others (79)	13 610	52	3	57	2	5	32
Mustard	***Sinapis***		**Total**	**26 411**	**100**	**2**	**40**	**3**	**8**	**47**
Tobacco	*Nicotiana*	CHN001	ICGR-CAAS	3 407	16					100
Tobacco	*Nicotiana*	IND115	CTRI	2 550	12	6				94
Tobacco	*Nicotiana*	USA074	TOB	2 108	10	6	6	6	26	55
Tobacco	*Nicotiana*	ITA403	CRA-CAT	1 711	8	84			16	
Tobacco	*Nicotiana*	AUS048	ATCFC	948	4	42	3	43	10	1
Tobacco	*Nicotiana*	POL057	PULT	908	4					100
Tobacco	*Nicotiana*	CUB029	IIT	780	4	4	7	88	1	
Tobacco	*Nicotiana*	TUR001	AARI	638	3		94		6	
Tobacco	*Nicotiana*	UKR079	KST	612	3		13		9	77
Tobacco	*Nicotiana*		Others (60)	8 053	37	4	11	15	22	49
Tobacco	***Nicotiana***		**Total**	**21 715**	**100**	**11**	**8**	**11**	**13**	**57**
Cocoa	*Theobroma*	TTO005	CRU	2 325	19	44	1		55	
Cocoa	*Theobroma*	GHA005	CRIG	1 000	8			100		
Cocoa	*Theobroma*	BRA074	CEPEC	754	6					100
Cocoa	*Theobroma*	COL029	CORPOICA	746	6					100
Cocoa	*Theobroma*	CRI134	CATIE	710	6					100
Cocoa	*Theobroma*	CIV059	IDEFOR-DCC	700	6					100
Cocoa	*Theobroma*	FRA014	Cirad	700	6				29	71
Cocoa	*Theobroma*	ECU021	EETP	645	5					100
Cocoa	*Theobroma*	SLE015	NUC	200	2				100	
Cocoa	*Theobroma*		Others (51)	4 593	37	<1	22	8	6	64
Cocoa	***Theobroma***		**Total**	**12 373**	**100**	**8**	**8**	**11**	**16**	**56**

APPENDIX 2

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Medicinal, Aromatic Plants, Spices and Stimulants Crops										
Tea	*Camellia*	JPN003	NIAS	7 312	62	<1	<1	2		98
Tea	*Camellia*	VNM025	VINATRI	2 500	21		100			
Tea	*Camellia*	IND368	UPASI-TRI	567	5		100			
Tea	*Camellia*	LKA123	TRI	560	5			100		
Tea	*Camellia*	BGD012	BTRI	474	4	<1	76		<1	24
Tea	*Camellia*	ARG1222	EEA INTA Cerro Azul	189	2			100		
Tea	*Camellia*	AZE009	HSCRI	81	1			86	14	
Tea	*Camellia*		Others (10)	156	1	3	13	40		45
Tea	***Camellia***		**Total**	**11 839**	**100**	**<1**	**29**	**9**	**<1**	**62**
Opium	*Papaver*	TUR001	AARI	3 559	35	1	99			
Opium	*Papaver*	DEU146	IPK	1 154	11	4	59	3	21	14
Opium	*Papaver*	UKR008	UDS	1 081	11		3	28	1	68
Opium	*Papaver*	HUN003	RCA	967	10	<1	66		13	21
Opium	*Papaver*	IND001	NBPGR	823	8	1	<1	17	<1	81
Opium	*Papaver*	USA022	W6	338	3	79	4		1	16
Opium	*Papaver*	RUS001	VIR	267	3		61	1	32	5
Opium	*Papaver*	SVK001	SVKPIEST	262	3		49	28	23	1
Opium	*Papaver*	BGR001	IPGR	244	2		2		<1	98
Opium	*Papaver*		Others (38)	1 377	14	15	20	5	16	45
Opium	***Papaver***		**Total**	**10 072**	**100**	**6**	**54**	**6**	**7**	**27**
Industrial and Ornamental Crops										
Para rubber	*Hevea*	MYS111	MRB	60 000	81	100				
Para rubber	*Hevea*	IND031	RRII	4 772	6	95			5	
Para rubber	*Hevea*	CIV061	IDEFOR-DPL	2 330	3					100
Para rubber	*Hevea*	LBR004	FPC	1 215	2			99	1	
Para rubber	*Hevea*	BRA006	IAC	1 000	1					100
Para rubber	*Hevea*	VNM009	RRI	960	1					100
Para rubber	*Hevea*		Others (16)	3 379	5	3	<1		6	91
Para rubber	***Hevea***		**Total**	**73 656**	**100**	**88**	**<1**	**2**	**1**	**10**

TABLE A2
Germplasm collections by crop

Crop Grouping	Genus	Genebank		Accessions		Type of accession (%)				
		Instcode	Acronym	No.	%	WS	LR	BL	AC	OT
Industrial and Ornamental Crops										
Wood crops	*Various*	FRA219	INRA-BORDEAU	24 275	40					100
Wood crops	*Various*	NLD039	IBN-DLO	10 795	18	2	2		1	96
Wood crops	*Various*	BRA190	CNPF	4 000	7					100
Wood crops	*Various*	GBR004	RBG	1 080	2	100				
Wood crops	*Various*	COL102	CC	791	1					100
Wood crops	*Various*	ARG1342	BBC-INTA	777	1	21	21		12	46
Wood crops	*Various*	IRL007	COILLTE	612	1	37		63		
Wood crops	*Various*	USA131	NA	529	1	60	13		1	26
Wood crops	*Various*	HND030	CONSEFORH	485	1	68	<1		32	
Wood crops	*Various*	POL001	PAN	450	1					100
Wood crops	*Various*	LTU001	LIA	302	<1		3	35		63
Wood crops	*Various*	ESP022	INIAFOR	240	<1				83	17
Wood crops	*Various*	HUN044	UHFI-DFD	239	<1	10			57	32
Wood crops	*Various*		Others (94)	15 986	26	7	3	1	3	86
Wood crops	***Various***		**Total**	**60 561**	**100**	**6**	**1**	**1**	**2**	**90**
Ornamentals	*Various*	JPN003	NIAS	3 807	22		<1	1		99
Ornamentals	*Various*	FRA179	INRA-RENNES	1 650	9		3		97	
Ornamentals	*Various*	POL001	PAN	1 540	9					100
Ornamentals	*Various*	CZE079	PRUHON	1 288	7	1	1	<1	93	5
Ornamentals	*Various*	BRA203	IBOT	1 272	7					100
Ornamentals	*Various*		Others (75)	8 112	46	17	3	19	20	41
Ornamentals	***Various***		**Total**	**17 669**	**100**	**8**	**2**	**9**	**25**	**56**

Appendix 3

The state-of-the-art: methodologies and technologies for the identification, conservation and use of plant genetic resources for food and agriculture

A3.1 Introduction

The magnitude and structure of the genetic diversity of a population determine the ability of that population to adapt to its environment through natural selection. This is because when genetic diversity is low, the possible combinations of genes that can confer fitness, and hence, adaptation to variations in environmental conditions are reduced, decreasing the probability of successful individuals arising in the population. Thus, a population in nature (or managed in a protected area) needs to have adequate genetic diversity to sustain its continued existence in the face of the continually changing biotic and abiotic components of its ecosystem.

A parallel scenario depicting natural populations takes place in crop improvement programmes with regard to available heritable variation within the germplasm. Breeders seek and recombine genetic variability in their breeding populations and screen for desired traits or characteristics that enable the crop to be successful in target environments or against targeted pests or pathogens. Breeders therefore need access to adequate genetic diversity for success in breeding programmes.

Underlying these scenarios (variations in nature and in germplasm collections for breeding), superficially conceptualized as 'diversity is good' in nature and in crop improvement programmes, there are many complicated issues. A fundamental imperative is the need to distinguish phenotypic diversity (net result of the interaction between both heritable and non-heritable components of variation) from genetic (heritable) diversity. Other issues relate to strategies for finding genetic diversity, maintaining, measuring and monitoring it, as well as devising mechanisms for exploiting it most efficiently. The processes of both scenarios can be further complicated by the biology of the species which encompass its breeding system, whether it is annual or perennial, the ploidy levels, and its ecological tolerances. The extent to which these factors are understood therefore has an impact on the ability of researchers to develop breeding or conservation strategies for the species in question.

There are also non-biological issues that can complicate management practices for both natural populations and breeding materials; these include organizational, policy, legal and economic issues. There are also issues of scale - ranging from national through regional to global - with respect to collaboration, incentives and efficiencies that facilitate conservation and use of genetic resources.

The objective of this Appendix is to summarize primarily the status of scientific knowledge, practices and technologies pertaining to genetic diversity that have arisen since the first SoW report published in 1998 which had a similar summary presented in Annex 1. The status of the social enabling environment also will be addresses as its components impact directly on national capacities for the conservation and use of genetic resources.

Annex 1 to the first SoW report clearly set out the importance of genetic diversity in the context of both the conservation and use of plant germplasm; the contrasts between qualitative and quantitative genetic variation and the different emphasis placed on these by curators and users of genetic resources; the means and techniques for conservation; the various breeding strategies and their roles and challenges with respect to breeding goals and finally, the legal and economic issues that can promote or deter conservation and use of genetic resources. This Appendix will not repeat that information but will focus on new developments since the publication of first SoW report.

A3.2 Advances in knowledge of genetics relevant to PGRFA conservation and use

The principal advances in the understanding and application of heredity in the management of PGRFA in the past 12 years emanate from the immense strides that have been made in molecular biology during the period especially with regard to genomics, the study of the totality of an individual's genetic makeup (genome). With the ability to sequence whole genomes in a timely and cost-efficient manner, the period has been characterized by an ever increasing volume of publicly accessible DNA, gene and protein sequence information. This has been complemented by the incredible advancements in the scopes for both the generation and analysis of data to degrees that were unfathomable a couple of decades ago. This paradigm contrasts sharply with the significantly narrower scope of the understanding of heredity that had hitherto been possible using classical genetics in isolation.

Genomics and the related fields of proteomics (the study of proteins), metabolomics (the study of metabolites) and the more recent phenomics (study of phenotypes in relation to genomics) have developed from the confluence of classical genetics, automated laboratory tools for generating molecular data, and methods of information management, especially bioinformatics. Advances in taxonomy and systematics, largely attributable to refined information arising from the use of molecular biology approaches in genome characterizations, have led to better understanding of the structure of genepools, relationships within and between taxonomic groupings and, in some cases, to the reversal of hitherto assigned taxonomic classifications. These novel fields of the biological sciences have direct implications for germplasm management (e.g. in the designation of core collections) and in determining the needs for further collections of genetic resources. Furthermore, molecular data, being environment-neutral, are particularly useful in devising crop improvement strategies including pre-breeding activities as they are particularly suited for trawling through the genepool for new sources of gene alleles.

The contributions of genomics and the other – omics to basic biology have been equally profound as their judicious applications continue to lead to better understanding of metabolic processes, their key components and pathways. This allows researchers to ultimately achieve greater precision in the identification of genes and their alleles for use in crop improvement. Quite importantly also, molecular biology techniques are permitting better and more precise understanding of adaptation and evolution making it possible therefore to delineate reliably neutral genetic diversity from adaptive genetic diversity, and the role different markers can play in identifying and using genetic diversity.

With the current pervasive ability to use appropriate molecular approaches to identify genome segments that discriminate between individuals (known as molecular markers) and apply statistical algorithms to identify precisely the genome locations of these "landmarks", molecular markers are now the tools of choice for both tracing the inheritance of target regions of genomes in plant breeding programmes (marker assisted selection) and for characterizing germplasm collections. The routine use of molecular tools in analysing germplasm collections in PGRFA management, will lead to enhanced efficiencies in the management of collections. Advantages would include greater ease in the identification and elimination of duplicates (or other levels of redundancies) in germplasm collections and at the same facilitate the creation of core collections.

Another area of PGRFA management that has been profoundly impacted by the applications of molecular biology techniques is population genetics. This is on account of the widespread use of molecular data in the study of populations (diversity and structure). The heavy reliance on molecular data in population genetics has spawned the neologism, population genomics. It is becoming commonplace, for instance, to identify specific loci under natural selection and thus of adaptive importance merely by sampling at a population level . It has also become quite routine to track gene expression (based on transcript profiling; or transcriptomics), even at tissue levels, under different environmental influences (biotic and abiotic) and under a time series regimen. Such a strategy, in addition to permitting the identification of genes that modulate particular phenotypic expression, also leads to the elucidation of the functions of genes and their interactions with other genes. The refined understanding of genes and their functions and the tools being generated in this manner will prove invaluable as efforts are invested in crop improvement programmes to develop varieties that will thrive in spite of the extreme climatic conditions expected as consequences of global climate change and variations.

One specific example of the striking contrast between what was considered possible in 1995 and what is possible now comes from Annex 1 of the first SoW report, where it was stated that the direct application of DNA sequencing was more useful in the identification of a gene or genes than for analysing a complete genotype. The conclusion at the time was that there was only "a very limited possibility to sample many variants for PGRFA characterization". Today, with improvements in technology, especially with regard to high throughput platforms for DNA extraction, amplifying and visualizing DNA (and RNA) fragments, with sequencing DNA fragments (and whole genomes), significantly enhanced computing capacity (data storage and analysis) and the suite of custom analytical software, it has become routine to characterize large numbers of accessions for polymorphisms (differences in sequences) at thousands of DNA loci across the genome.[1]

Another area of great progress since 1995 is the identification of conserved linear order of genes on chromosomes, a phenomenon known as synteny. This has been established not only between closely related species but also with more distant taxons and even between species that differ by large differences in genome sizes. Synteny has now been documented for many taxons in such families as the *Fabaceae*, *Poaceae*, *Solanaceae* and *Brassicaceae*. These findings have provided the impetus for the investment of a significant amount of effort in comparative genomics with the goal of leveraging gene sequence information from model species for the identification of genes in taxons other than the model species. Microsynteny (similarity between taxons in the ordering of nucleotide sequences along the same chromosome) has only become measurable with the availability of copious amounts of genome sequence data that are now available in the public domain. The demonstrated instances of macrosynteny (similarity between taxons in the ordering of large numbers of genes along the same chromosome) suggest therefore that there are ancestral genomic segments conserved across many taxons. The implication is that molecular markers identified in those segments could be used in genone characterizations even across the different taxons. Of course, the utility of synteny will always be subject to the influences of chromosome rearrangements.[2]

In general, the increased understanding of, and the enhanced ability to study, genetic diversity within species, populations and genepools with respect to distribution and structure have been key developments since the first SoW report. It is now established that nucleotide sequence polymorphism provide valuable information for understanding and deploying genetic diversity for crop improvement. The utility of these polymorphisms, as molecular markers, is even enhanced when the polymorphism occurs within a target gene (yielding functional markers). Representative examples are presented below.

A3.3 Advances in biotechnology relevant to PGRFA conservation and use

The initial applications of molecular biology in the characterization of plant genomes included single gene sequencing, the development and use of restriction fragment length polymorphism (RFLP) markers and low-density dotblot types of DNA arrays (or northern blots). The state of knowledge initially also favoured the one-gene, one-phenotype paradigm. All of these were in place at the time of the first SoW report but were quickly supplanted by whole-genome sequencing, widespread use of molecular genetic markers based on PCR, the single nucleotide polymorphism (SNP) markers, and medium-density arrays (for gene discovery and function elucidation). Currently, comparative whole genome sequencing (using multiple related species), extremely high-density genotyping (involving re-sequencing of individuals) and whole-genome arrays for monitoring genome-wide transcription, alternative (or differential) splicing, are but a few of the examples of new molecular biology tools that are revolutionizing the depth and breadth of genome analysis of crop germplasm. Also, the one-gene, one-phenotype paradigm is giving way to a new philosophy of a dynamic genome responding globally to developmental pathways and environmental signals.[3]

Speed, scale and size are the parameters that are most impacted upward by technological advances. Speed or throughput has increased significantly in many diverse activities ranging from DNA extraction, through polymerase chain reactions to microarray transcriptome profiling. Scale of approach has also increased significantly as exemplified by the numbers of molecular markers that can be used to assay individual DNA samples simultaneously; the numbers

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of progeny from mutation events or recombination events that can be screened for low probability responses; or the numbers of samples that can be handled simultaneously with robotics. In general, the manageable sizes and scopes of many activities and assays have increased significantly; the number of nucleotide base pairs that can be amplified or sequenced, the extent of coverage of genome in any assay, the density of molecular markers (number of markers per centiMorgan) on a molecular genetic linkage map, the lengths of fragments inserted into bacterial artificial chromosome (BAC) libraries, and lengths of contigs that can be assembled while comparing sequence data are a few examples of such increases.

Interestingly, increases in scope and scale have progressed in tandem with concomitant enhancements in efficiency levels as costs and time per unit data point have been reduced significantly; equipment and supplies have become cheaper and therefore lent themselves to wider access to research facilities of varying levels of budget, infrastructure and human resource capacities. However, it is also noteworthy that the net result of the increases in speed, scale and size and decreases in cost and time itself is a new kind of bottleneck - massive amounts of data that must be stored, processed, analysed, interpreted and displayed. Developments in computing hardware and software are addressing this bottleneck very satisfactorily as researchers usually have a wide array of choices in information technology paraphernalia for managing molecular data.

Genome sequencing has also continued apace with the aforementioned advances in the science of molecular biology and innovations in the ancillary technology platforms. The first fully sequenced plant genome was *Arabidopsis thaliana* in 2000.[4] This species has a small genome and has become a model plant species for research in biology and genetics. The second plant species sequenced was a crop species, rice - the sequences of two different genotypes of rice were published in 2002 (*Oryza sativa* indica[5] and *O. sativa* japonica[6]). Also, the first tree genome sequenced was a species of poplar (*Populus trichocarpa*) in 2006.[7] Also in 2006, the draft sequence of the genome of *Medicago truncatula* was published.[8] This species provides a genome model for legumes. The other crop genomes that have been sequenced were those of sorghum (*Sorghum bicolor*), grape (*Vitis vinifera*) and papaya (*Carica papaya*); all three sequences were published in 2007.[9] In 2008, draft sequences for soybean (*Glycine max*)[10] and *Arabidopsis lyrata*[11] were published. *Arabidopsis lyrata* is a close relative of *A. thaliana*, but with a larger genome. Most recently (2009), the sequences for *Brachypodium distachyon*[12] (a new model species for temperate grasses and herbaceous energy crops) and for maize (*Zea mays*)[13] were published. Box A3.1 identifies several other higher plant species for which genome sequencing projects are underway (as of early 2010).[14] In addition to full genome sequencing, large amounts of sequence data are available for many plant species; these result from the sequencing of sizeable fragments of their genomes (e.g. the sequencing of BAC libraries or whole chromosomes). Examples of crop species (or species closely related to crops) with substantial deposits of DNA sequences in publicly accessible databases are *Brassica rapa*, *Carica papaya*,

Box A3.1
List of plant species with ongoing genome sequencing projects in 2010[15]

Amaranthus tuberculatus, Aquilegia coerulea, A. formosa, Arabadopsis arenosa, Arundo donax, Beta vulgaris, Brassica napus, B. oleracea, B. rapa, Capsella rubella, Chlorophytum borivilianum, Citrus sinensis, C. trifoliata, Cucumis sativus, Dioscorea alata, Eucalyptus grandis, Gossypium hirsutum, Glycyrrhiza uralensis, Hordeum vulgare, Jatropha curcas, J. tanjorensis, Lotus japonicus, Madhuca indica, Malus x domestica, Manihot esculenta, Millettia pinnata, Mimulus guttatus, Miscanthus sinensis, Musa acuminata, Nicotiana benthamiana, N. tabacum, Oryza barthii, Panicum virgatum, Phoenix dactylifera, Pinus taeda, Ricinus communis, Solanum demissum, S. lycopersicum, S. phureja, S. pimpinellifolium, S. tuberosum, Theobroma cacao, Triphysaria versicolor, Triticum aestivum, Vigna radiata and *Zostera marina.*

Gossypium hirsutum, Glycine max, Hordeum vulgare, Lotus japonicus, Medicago truncatula, Sorghum bicolor, Solanum lycopersicum, Triticum aestivum, Vitis vinifera and *Zea mays*.[16] Another source of sequence information is the collections of expressed sequence tags (ESTs, produced by the sequencing of complimentary DNA or cDNA libraries) that are being generated for many crops. Maize, wheat, rice, barley, soybean and *Arabidopsis* have the largest collections of EST sequences for plants; over one million ESTs have been published for each of these plant species.[17]

The development of new DNA sequencing technology[18] has been driven by both publicly and privately funded research and development activities in human genomics. Lagging behind, but benefiting greatly nonetheless from progress being made in human genomics, is the application of these technologies to plant research in general, and more specifically, to research relevant to crop improvement, plant evolution and PGR conservation. Steady advances are being made in both the hardware and software for genome sequencing[19] and it is envisaged that in the near future, whole genome sequencing will become so widely affordable as to be the genome characterization strategy of choice. To buttress this prognosis, the so-called next generation sequencing platforms (i.e. the newer methods that are not based on the Sanger method of 1997, namely, Roche's 454 sequencer and Illumina's SOLEXA sequencer, but are rather based on the more cost-effective and faster pyrosequencing technology), are continually gaining acceptance and hence larger shares of the sequencing market.

A3.4 Assessing and analysing genetic diversity

There are currently many strategies for assessing genetic diversity and structure of plant populations. Many were in use at the time when the first SoW report was published and are still valuable; these include pedigree analysis and replicated field experiments (to quantify heritable variations and their components). The molecular tools used for germplasm characterization and diversity studies in 1995 included, isozyme, RFLPs, Random Amplified Polymorphic DNA (RAPD), Simple Sequence Repeat (SSR) and Amplified Fragment Length Polymorphism (AFLP) markers. With more widespread genome sequencing and generation of ESTs, SSR markers have become easier to generate and thus more widely used. Developments in high throughput marker screening systems, especially platforms that are amenable to automation and varying degrees of multiplexing, have also led to greater ease and increased efficiencies for using PCR-based markers including AFLPs. Quite importantly, the ability to discover SNPs, a marker type that is fast becoming the preferred option in high throughput systems, with ease in all parts of genomes is a direct result of significantly enhanced sequencing capacity. SSRs and the more recent SNPs are suitable for genotype fingerprinting.[20] SNPs offer the promise of higher map resolution, higher throughput, lower cost and a lower error rate compared with SSR markers.[21]

An additional feature of markers such as SNPs and SSRs is the possibility to transfer them from the genotypes in which they are identified to related materials for which sequence information is not available, without the need to re-sequence[22]. Fingerprinting individuals for SNPs dispersed throughout a genome or a particular section of interest has become a very powerful way to characterize collections such as breeding materials (including segregating populations) and genebank accessions.[23]

The utility of SNP-based genome characterization for crop improvement and genebank (*in situ* and *ex situ* materials) may be compromised in situations where sequence information is not available. In such cases, SNPs would not be an option; a high throughput microarray assay procedure, Diversity Array Technology (DArT), may be a suitable alternative. DArT technology discriminates between individuals based on polymorphisms from their simultaneous comparisons to a defined common genomic representation. It is a low-cost high-throughput system that requires minimal DNA per individual and at the same time provides comprehensive genome coverage even in organisms without any DNA sequence information.[24] Since the proof of concept with Rice in 2001, DArT has been employed for high throughput analyses in many genera including barley, *Musa* and Eucalyptus.

For instance, DArT markers were as useful at revealing genetic relationships among 48 *Musa* accessions (derived from two wild species with different genome compositions) as other markers were, but with a lower cost and greater resolution and speed.[25]

Qualitative traits (such as many disease resistances and stress tolerances) and quantitative traits (such as indices of yield and productivity) are typically the targets for improvement in plant breeding programmes and for characterization of genebank collections. Obtaining this information for collections of individuals is laborious and costly, involving screening in the presence of pathogens and stresses in replicated field experiments with adequate sample sizes. The utility of molecular markers that could serve as proxies for this type of laborious and expensive studies is obvious.

Both natural and artificial selections are directed at genes. Though selection is a locus-specific force, it creates a pattern of variation involving few loci in specific regions of the genome. Variation in the traits governed by genes should therefore be a measure of the adaptive genetic diversity or adaptive potential of a population or breeding genepool. A majority of molecular markers only measure neutral genetic variation, i.e. variations in sections of the genome not involved with coding for genes or in the regulation of genes and hence, assumed not to be under natural selection pressure. These patterns of genetic variation are genome wide. Due to the fact that molecular methods are fast and relatively cheap, surveys of molecular marker variations are becoming widespread and attractive as means for evaluating genetic diversity across populations or genepools. There are even greater benefits when gene-based markers are used for analysis. A relevant advance in the past decade is that the relationships between adaptive genetic diversity and neutral genetic diversity are becoming much clearer.[26]

Unfortunately, many neutral molecular markers are not usually indicative of the adaptive potential of populations or accessions they are used to characterize (for example, RFLPs, RAPDs, AFLPs and SSRs).[27] In some cases, they have been used inappropriately for this purpose with the assumption that neutral markers and quantitative adaptive variation are positively correlated. There are uses of neutral molecular markers that are appropriately of value for conservation and use of genetic resources. When the patterns of genetic variation at many neutral molecular markers randomly scattered throughout a genome can be measured, they can be very useful for providing a measure of processes within ecosystems such as gene flow, genetic drift and migration or dispersal, which act on the entire genome; these are important for population biology, for monitoring progress in maintaining species in protected areas, or for testing the success of spatial connections between reserves.[28]

With the many recent, reasoned enunciations of the distinctions between types of molecular markers and the appropriateness of their respective usages for conservation and utilization of genetic resources, it is expected that any report on the deployment of molecular markers should provide a rationale for the type of marker used with respect to the objective of the work.[29] An example of investigating the utility of specific marker types for specific uses was an analysis in barley of three types of markers (EST-derived SSRs, EST-derived SNPs and AFLPs) for use in diversity analyses in breeding, natural populations and genebank materials. No one marker type was best for all studied uses.[30]

Given the ability to work with raw genomic sequence, the comprehensive pattern of DNA polymorphisms within a species can now be appreciated. *Arabidopsis thaliana* is the most thoroughly studied plant at this level since its genome was sequenced. There is an abundant natural variation for both neutral DNA markers and also for those loci that cause phenotypic changes.[31] Building on this model will be increasingly possible for crop species themselves as the genomic sequences become readily accessible. SNPs derived from ESTs were used successfully for cultivar identification in melon; this provides an example of the deployment of DNA-level polymorphism for genome characterization where few genomic tools exist other than ESTs and genetic maps based on early molecular markers.[32]

As researchers take advantage of these innovations, it needs to be emphasized that strategies adopted for estimates of genetic diversity have to be suitable to the objectives for the conservation and use of the genetic resources. To illustrate, if the aim for assaying a number of populations of a species for diversity - as measured by a neutral molecular marker - is to accord higher priority for conservation to the most diverse populations with the assumption that this will also conserve the greatest adaptive genetic diversity, the researcher may decide that relatively few populations might be needed to capture the greatest amount of the neutral genetic diversity. A possible pitfall in this scenario is that if, for instance, the other populations were abandoned to the exclusion of the few diverse populations, significant amounts of adaptive genetic diversity, which is not distributed uniformly among all populations, would thus be lost. This would then be contrary to the originally stated objective for the assessment of genetic diversity.[33]

Molecular markers are also increasingly been used in more downstream applications. For instance, in addition to serving as tools for conserving and using genetic resources, markers have been used successfully to investigate the genetic impacts of traditional farmer practices which are often poorly documented. A case study involving yams in Benin showed that the traditional practice by farmers of selecting spontaneous wild yams from areas surrounding farms and cultivating them resulted in the creation of new varieties with new genetic combinations. These new variants arose as a direct result of sexual reproduction between wild and cultivated yams as the alleles could be traced to the progenitors. The markers used in this study were SSRs. It was therefore deduced that the mix of a cycle of sexual reproduction followed by the traditional vegetative propagation (using tubers) leads to the large-scale cultivation of the best genotypes while facilitating the introgression of potential diversity that could be useful for future adaptation.[34]

A3.5 Conservation technologies and strategies

An aspect of the use and conservation of PGRFA that has remained largely without significant advances since the first SoW Report is the orthodox seed storage conditions. Current recommendations for temperature and humidity are still the same as those developed before the first SoW report. Since then, however, the country reports that are part of this SoWPGR-2 and the crop-specific conservation strategy developed by the GCDT, call attention to the concerns for backlogs in accession testing and regeneration. For instance, it has been reported that viability testing results have indicated the need for regeneration after shorter periods of storage than were currently the norm. It is possible that, as one researcher has shown, humidity is the more critical of the two storage factors, and that seeds are exposed to higher humidity levels in the seed packaging materials than are optimal with resulting losses of viability.[35] Given the room for potential enhancements in efficiencies in seed storage, it is probably time to apply the innovative tools of biology to decipher the seemingly complex interactions in the seed storage container types, temperature and humidity regimen matrices.[36]

In the past 12 years, there have been progressively increasing reports of the assessments of the utility of molecular markers as reliable tools for managing conserved diversity in genebanks. One example of this kind of study was the use of AFLP markers to assess the extent of within-accession genetic diversity for the self-fertilizing species, lettuce, at the Centre for Genetic Resources (CGN), in the Netherlands. Two plants each with a total of 1390 accessions, (comprising six cultivar types) were screened by the array of available markers. Overall, there was a very low average probability (about one percent) that the two plants of an accession would differ. However, this probability differed among the cultivar types. The types composed of accessions that are primarily modern cultivars had probabilities of difference between the two plants of about 0.5 percent, while the two types composed of accessions which are mainly landraces had probabilities greater than one. This information would be useful in determining whether and how the observed level of diversity for each accession should be maintained in future generations of the accession.[37]

The utility of molecular markers in contributing to decisions in strategies for managing conserved diversity has also been demonstrated amply with field collections. Fingerprinting techniques have been used to determine identity and redundancy in large field collections. For example, at the ICGT in

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Trinidad and Tobago, over 2 000 crop accessions are maintained as a field collection, with each accession being represented by as many as 16 individual trees, with an overall average of six trees per accession. Multi-locus SSR fingerprinting was successfully used to resolve ambiguities arising from mislabelling of plants, a critical problem in such extensive operations.[38]

An emerging trend, for the past 12 years has been the maintenance of DNA banks of PGRFA. There have been reported cases of DNA libraries of germplasm accessions, mapping populations, breeding materials, etc. that are retrieved at will for use in subjecting the materials to molecular assays. This practice is bound to become more pervasive as the costs for molecular assays and the requisite facilities become cheaper in turn rendering this technology option more accessible to practitioners in this field. It is indicative of this trend that more formal repositories for plant DNA have been established under the auspices of botanic gardens (with examples including the RGB Kew DNA Bank or the DNA bank at the Berlin Botanic Garden and Botanical Museum) or as stand-alone entities (e.g. the Australian Plant DNA Bank and the National Institute of Agrobiological Sciences [NIAS] DNA Bank, Japan). In addition to the usual data management platforms for classical germplasm accessions, an associated bioinformatics facility is required for a DNA bank in order to accommodate the management of molecular data such as sequence and marker information for each accession. DNA banks could also serve as sources of genetic information from endangered taxa without the need for additional germplasm prospection.[39]

A3.6 Breeding methodologies

Upfront, it is worthy to emphasize that the use of genomic tools in the different facets of PGRFA management has not reduced the importance of phenotypic characterization of breeding materials, mapping populations and natural populations, or genebank accessions. On the contrary, thorough and accurate phenotyping remains as important as it has ever been and is key to the utility of molecular data as markers have value only as long as they are accurately linked to phenotypes.

Early efforts to develop large numbers of molecular markers, high-density genetic maps and appropriately structured mapping populations have now begun to enhance the efficiency of the genetic improvement of many crop species. The results from numerous mapping studies provide greatly improved estimates for the number of loci, allelic effects and gene action controlling traits of interest.[40] There have been several major advances in the incorporation of molecular techniques in crop breeding strategies since the publication of the first SoW report. These advances have led to the paradigm of molecular breeding, the collective term that encompasses marker assisted selection and recombinant DNA technologies as crop improvement strategies.

MAS

This refers to the novel crop improvement strategy of using molecular markers (genome landmarks) to aid decision making in the screening of breeding materials. This paradigm shift has been greatly facilitated by high-throughput methods for identifying and using molecular markers on a large scale, including information technology infrastructure, and by inter-disciplinary approaches that make phenotyping and trait characterizations possible across several environments. Firm verifications of the co-segregation of the trait of interest with one of the many possible types of DNA markers precede the use of the marker to select for the trait in breeding materials. MAS is becoming a valuable tool for many different crops with its utility expected to greatly increase as molecular biology assays become more cost efficient.[41] Marker development has been greatly facilitated by improvements in the genome locations of gene alleles that control traits. The advances in the construction of molecular genetic linkage maps, in building physical maps and more recently, association mapping, contribute to continually populate the repertoire of useful molecular markers for crop improvement.

Association mapping, also known as linkage disequilibrium (LD) mapping or association analysis and the most novel of the mapping methods, is a population-based survey used to link sequence polymorphisms (usually SNPs) to phenotypic variations based on linkage disequilibrium (non-random association between alleles at linked loci) without the necessity for creating structured segregating mapping populations. By mapping nearby SNPs it is therefore possible to ascertain the genome locations of genes associated with a trait without cloning the genes. Causal SNPs identified through high density association maps are usually subsequently confirmed through functional assays. There are three main advantages of association mapping over linkage analysis: increased mapping resolution, reduced research time and greater allele number.[42]

The deployment of these strategies has been restricted primarily to crop improvement institutions which have also developed the capacity to produce sequence information for their target crops. National PGR conservation and utilization programmes are increasingly enhancing expertise and general capacity in plant biotechnology as documented in the country reports published as part of this SoWPGR-2.[43] International and other national efforts at capacity and infrastructure building have contributed to this emerging trend. However, full deployment of advanced breeding strategies, bioinformatics and genomics capabilities has not taken place in developing countries and even in many developed countries, they are only possible through collaboration with other national or international genomics projects.

The challenge within a breeding programme would be the devising of appropriate strategies for the many different scenarios that call for the integration of molecular biology techniques in PGRFA[44]. For instance while, marker-assisted backcrossing might require a few markers for genotyping hundreds of samples (backcross progenies) for a particular simply inherited trait as would the screening for introgressed elements or GMO constructs, genetic characterization or fingerprinting on the other hand would require hundreds to thousands of markers in order to be effective. In general, a genomics research service centre would be required for programmes characterized by extensive marker diversity, high throughput and large sample sizes. This requirement for high start-up investment costs probably explains the preponderance of MAS applications in large multinational breeding companies to the exclusion of the publicly funded entities.

Genetic transformation

Methods based on recombinant DNA, i.e. molecules containing DNA sequences, derived from more than one source, are used to create novel genetic variations. In crop improvement, this has involved the incorporation of exogenous DNA or RNA sequences, using either biolistics or vectors, into the genome of the recipient organism which as a result expresses novel and agronomically useful traits. The new variants are referred to as genetically modified organisms or GMOs. Transgenic crops were first grown on a commercial scale in the mid-1990s about the time of the publication of the first SoW report. Since then, the commercially grown GMOs have been four commodity crops, namely, maize, soybean, canola and cotton). By 2008, these collectively accounted for over 99.5 percent of transgenic crop production (James, 2008[45]). Interestingly also, only two transformation events, i.e. herbicide tolerance and insect resistance or their combinations were expressed in these crops. This implies therefore that more than 25 years after the first successful production of transgenic plants, the scope of the utility of genetic transformation as a routine crop improvement strategy remains limited in spite of the obvious potentials of this technology. The drawbacks include the lack of efficient genotype-independent regeneration systems for most crops and probably most limiting of all factors is the associated IPR restrictions. When GMOs have remained the exclusive preserve of private sector breeding enterprises in developed countries it has restricted (with patents) several components of the research and development efforts in the lead up to production of the transgenic crops. The interesting emerging trends - that could ultimately precipitate the review of the place of IPR protections in PGRFA - are that GMO crops are currently grown in developing countries as exemplified in the cultivation of transgenic soybean in South America and the cultivation of transgenic cotton in both India and China (James, 2008; Glover 2007,[46] 2008[47]).

As more developing countries acquire the requisite capacity for dealing with the statutory regulations governing the cultivation of GMOs, especially in line with biosafety regulations as enunciated in the

Cartagena Protocol on Biosafety, concerted efforts will need to be targeted at building capacity to navigate the IPR restrictions that effectively impeded the exploration of the full potentials of transgenesis in PGRFA. Moving forward, it is surmised that research efforts on the other hand will target the refining of plant regeneration systems and, quite importantly, expanding the scope of agronomic traits that can be improved using genetic transformation. So far, the stacking of several transformation events and getting them to express phenotypes in one recipient organism has remained impractical. Removing the technological barriers will be key to taking advantage of genetic transformation to address polygenic traits, especially those related to climate change and variations such as drought and salinity. Removing this bottleneck will also be important for gene pyramiding.

A3.7 Bioinformatics

One consequence of the relative ease for generating molecular genetic data has been the need for ever increasing capacity for electronic data storage, analysis and retrieval systems. Currently, the data storage requirements are estimated in petabytes, about three orders of magnitude greater than what was commonly in use in 1995. A trend in cost reductions for bioinformatics facilities is that costly mainframe computer installations for bioinformatics work have been mainly replaced at genomics centres by computer server farms comprised of off-the-shelf, ordinary PCs or servers harnessed together to provide equal or greater computing capacity at lower cost and with built-in Central Processing Unit (CPU) redundancy. These units are conditioned to ensure greater reliability even with individual unit failures. Access to such storage and analysis systems is increasingly made available by the incorporation of internet servers within the system.

It is the combination of creative software engineering, open-source operating systems and database software, the advent of the ubiquitous access to, and use of, the Internet and both private and public investment that have led to the availability of reliable tools to manage genomics laboratories and hence the capacity to store, analyse, distribute and interpret the massive datasets generated from sequencing projects and molecular biology based activities.

New algorithms and statistics are continually necessary to study relationships among data sets. Maps are the most common formats for presenting genetic information and developing software for producing and displaying maps has remained one of the most active fields of research and development in molecular biology. Advances in bioinformatics will continue to be necessary to facilitate the analysis of genomic data and the integration of genomics information with data from the related fields of transcriptomics, proteomics, metabolomics and phenomics.

Collaborative genome projects have led to the creation of databases that store data centrally but are accessible globally. Integral to such efforts are collections of genomic resources whose inventories and access are components of the genome database. Funding for such projects has been largely within the public sector (nationally and internationally).

A3.8 Policy, organizational and legal considerations

The major international instrument impacting PGR conservation and use since 1995 was the ITPGRFA which was adopted in 2001 and came into force in 2004.[48] This agreement, aimed at improving upon the Convention on Biological Diversity, obligates parties to the Treaty to develop legislation and regulations to fulfill its mandates to facilitate conservation, exchange and use of the genetic resources covered by the ITPGRFA. The development of a specialized funding mechanism for the ITPGRFA subsequently took place and the GCDT was created in 2004. Currently, the GCDT is raising an endowment and additional funding for upgrading national germplasm collection facilities, building capacity and strengthening information systems. Special focus has been on the collaborative development of regional and global crop conservation strategies.[49] A major development in the exchange of PGRFA since the first SoW report has been the SMTA that provides the Contracting Parties with a multilateral system for executing the exchange of crop germplasm.

National and international research funding bodies, in recognizing the need for collaboration for successful genomics projects have tailored some of their funding programmes to specifically underwrite collaborative efforts. The results have been public investments in sequencing centres, databases of genomic data, tools for analyses and public access, typically via the internet. The ability to sustain or increase such investments will depend on the status of the global and national economies. While there was a fall in world gross product in 2009, the first since World War II, prospects seem to be improving for a recovery in 2010.[50]

The technical advancements in DNA fingerprinting may have relevance for intellectual property protection to the extent that it is possible to unambiguously identify cultivars. SNP fingerprinting will be precise and applicable in a high-throughput process; however, widespread application is still limited to crops with SNP databases. More widely used to date are fingerprinting platforms based on SSR markers or even AFLP and RAPD markers.[51]

Concerns for the protection of inventors' IPR in endeavors relating to PGRFA were initially restricted to the safeguarding of PBR. At the national levels, this safeguard was provided through different forms of legislations that vested IPR over new crop varieties with the developer, namely, the plant breeder. Efforts at harmonizing these national laws resulted in the 1961 International Convention and Union for the Protection of New Varieties of Plants (UPOV) and its revised Acts of 1972, 1978 and 1991. This was followed by the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) which was signed in 1994. TRIPS had specific provisions for IPR protection relating to innovations in agricultural produce (crops and animals). Efforts at engendering IPR at both the national and international levels always had the stated aim of facilitating access to inventions in a fair and equitable manner. It is axiomatic that the net results of such well intentioned interventions have been further restrictions to access.

Inventions in biotechnology, including those relating to PGRFA, have spawned such an unprecedented rash of patents as to amount to a virtual gridlock in efforts to access biotechnological innovations. Since the first SoW report, the profile of biotechnology in food and agriculture has continued to rise especially with the near ubiquity of GMO crops either in commercial production or in trial stages in many parts of the world. The patent protections for the crops and even the materials used in developing them, such as the sequences of the gene constructs, have been notoriously restrictive. For instance, it is such IPR issues that have impeded the widespread use of the genetically engineered high beta-carotene rice, the golden rice, as public good. Considering the moral imperatives of safeguarding food security, it is surprising that a lot more efforts have not been invested in breaking these gridlocks.

The options for accessing proprietary biotechnologies by national research organizations are severely limited as the costs are usually prohibitive. The alternatives, normally requiring accessing the technologies without permission, would involve the exploitation of loopholes in patent and protected variety jurisdictions. International public research entities, notably the centers of the Consultative Group for International Agricultural Research, have also been successful with negotiating royalty-free access. A pioneering regional effort, the African Agricultural Technology Foundation, has also been able to broker access to IPR protected biotechnologies that impact on the ability of national programmes to harness the full potentials of their PGRFA. In general, the current efforts at accessing such technologies under IPR regimens have been piecemeal, expensive and clearly call for concerted international collaborations. The starting point will be education and capacity building in order to deal with the very complex issues involved.

A3.9 Future perspectives

The future will present multiple challenges to crop performance that can be met effectively by a combination of the development of resilient and hardy crop varieties (modifying crop genomes through plant breeding, preferably facilitated by efficient molecular approaches) and the introduction of suites of mitigating factors into agronomic management practices. In order to increase the reliability of predictions of crop performance based on molecular genetic information, new tools that enhance the ability for more precise linkage of molecular profiles (genotypes) to performance (phenotypes) will have to be readily accessible to the researcher.

Gaps in knowledge abound that must also be addressed. For instance, the subtleties of phenotypic plasticity in the face of a changing environment and the layers of genetic redundancy that characterize biological systems remain largely uncharted. The concerted application of the myriad tools and procedures that are both available now and are under development holds great promise for deciphering these processes and thereby enhance the ability to more efficiently manage PGRFA in the face of the daunting challenges of an increasingly variable climate, increasing world populations and competing demands for diverting foodstuffs to non-traditional uses in fuel, animal feeds and fibre industries.

The cumulative progress achieved to date in genomics and its ancillary scientific and technological endeavors has only provided the very beginning of understanding for the way in which a genotype confers a particular set of attributes to a living organism. Today, it is possible to dissect a complex phenotype and to determine where individual genes or, more correctly, QTL are physically located along the chromosomes. Information about DNA markers linked to QTL represents a powerful diagnostic tool that enables a breeder to select for specific introgressions of interest. As more genes of interest are cloned, identified or mapped and their contributions to complex biological systems are better understood, there will be many opportunities for creative "synthesis" of new varieties. It is possible that some of the opportunities will involve genetic engineering approaches, where new information about genes, gene regulation and plant responses to the environment may be used in innovative ways to fine-tune existing plant varieties so that they utilize resources more efficiently, provide greater nutritional value, or simply taste better.

A continuing need will be that of extending molecular crop improvement strategies and capacities to under-studied and under-funded crops (the so called orphan crops) but which ironically remain the bulwarks for the food security of a huge percentage of humankind. Achieving a widespread and routine application of novel biotechnologies to orphan crops, with the attendant potential for extensive positive impacts on human welfare, therefore represents an irresistible opportunity not only to those dedicated to public goods but to humanity in general. The current unacceptably high level of food insecurity need not remain so, nor get worse; the judicious management of PGRFA – while taking advantage of the novel tools and advancements - holds the key to reversing the trend.

The immediate steps will involve the investment of resources in empirical studies with the aim of attaining an understanding of the biological processes that underpin the phenotypes of the crops themselves.[52] To date, the species sequenced or for which sequencing is underway, represent only about 13 plant families. There is a compelling need to make inroads into the balance of over 600 plant families for which genome sequences have not commenced as the benefits of whole genome sequence data are proving incalculable. Precisely, many orphan crop species and others need to become candidates for sequencing.

None of these advances in technological innovations lessens the need for collections of PGR. In fact, to make the best use of the new tools, new strategies may be necessary to capture even greater genetic diversity and for maintaining that diversity during conservation and regeneration of samples. Genebanks remain vital and are in need of increased support.[53]

Also, parallel progress in genome analysis of plant pests and pathogens should lead to greater insights into mechanisms of disease and pest resistance. Global climate change and variations will present some predictable challenges to agricultural production systems (for example, higher temperatures, drought, flood, stronger winds and increased and new pests and pathogens). To address those challenges, research should make full use of available molecular tools and strategies not only to improve productivity but also to reduce impact on the environment, increase carbon sequestration and substitute for fossil fuels.[54]

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Appendix 4

State of diversity of major and minor crops

A4.1 Introduction

In Annex 2 of the first SoW report, a number of crops of major and minor importance for food security in one or more global subregions were surveyed for the state of their diversity. Similarly in this Appendix, major crops (wheat, rice, maize, sorghum, cassava, potato, sweet potato, beans (*Phaseolus*), soybean, sugar crops, and banana/plantain) and a number of globally minor, but subregionally or nationally major, crops (millets, roots and tubers other than the ones listed above, pulse crops other than species of *Phaseolus*, grapes, tree nuts, and vegetables and melons) are surveyed. While this range of crops is not a definitive list of staple or important food and oil crops, it does include examples of different crop groups (cereals, food legumes, roots and tubers, tree crops), species with different breeding systems (cross-pollinating, self-pollinating, clonally propagated), and crops of temperate and tropical origins. It also includes crops for which there has been great investment in conservation and improvement, notably wheat, rice and maize, as well as crops for which there has been relatively less investment, such as cassava, sweet potato, and plantain. This list of major and minor crops also provides a good sampling of the crops listed in Annex 1 of the ITPGRFA,[1] although not all crops surveyed here are in Annex 1 (e.g. soybean, groundnut, sugar cane, grape and some millets).

The purpose of this Appendix is not simply to repeat information presented in Chapters 1, 2, and 3 of the main report, but to highlight some of that information in a crop-oriented context. General information is provided here on the major patterns of production and on the area harvested of the major and minor crops over the years 1995 through 2008;[2] the composition of their genepools; the state of *in situ* diversity for crop species, if wild forms exist, and of CWR and *in situ* conservation programmes (more details are given in Chapter 2); specific reports of genetic erosion; summaries of the status of major *ex situ* collections (more details are given in Chapter 3 and Appendix 2); the status of safety duplication of *ex situ* collections, gaps, opportunities and priorities in the extent of coverage of the genepool diversity in *ex situ* collections; the extent of documentation, characterization and evaluation of collections; issues related to utilization of collections; the impact of climate change on priorities and concerns for both *in situ* and *ex situ* conservation; and the role of specific crops for sustainable production systems, organic production systems, and farmer opportunities. In the individual crop sections that follow, specific concerns are highlighted.[3]

Diversity status

Since 1995, more than 1 million germplasm samples have been added to *ex situ* collections and at least a quarter of these accessions are the result of new collecting missions (from fields, markets, and nature).[4] The remainder are probably a result of increased exchange of accessions among collections. The number of accessions is not a direct measure of diversity. There are many germplasm descriptors from which the diversity status of a collection can be inferred (for example, passport information, phenotype information for many characters, genotype information from many possible markers and assays, and basic taxon biology). The assessment of diversity thus depends upon the uniform availability of such information for the collections to be studied. As pointed out by many sources, uneven documentation of crop germplasm is a major shortcoming for most collections.

Even less is known about the state of diversity represented in genebank accessions of wild species related to crops or about the status of diversity in taxa growing in any sort of natural reserve or other *in situ* conservation areas. As pointed out in Chapter 2, very few (<50) CWR have been assessed for their diversity status compared to the hundreds of known CWR. Many country reports have stressed concern for the lack of attention paid to both *in situ* and *ex situ* conservation of CWR. Chapter 2 also reports on the CGRFA-commissioned study to identify conservation priorities and specific locations for critical *in situ* conservation of CWRs of the major food crops in almost all continents.[5]

The negative impact on biological diversity and efforts at germplasm conservation and utilization caused by armed conflicts and outright war was noted in Chapter 2, but was also strongly emphasized by some country reports.[6] Political instability, changes in political systems, economic disparities and uneven development across national landscapes have also negative repercussions on biological diversity and both precede and follow outright conflicts. Specific impacts include destruction of habitat, basic infrastructure and the collections themselves.[7]

Even as studies and reports have been identifying gaps and deficiencies and raising alarms, there has been progress in diversity assessments since the first SoW report, motivated by many factors, actors, and initiatives:

- increasing country compliance with mandates of the 1992 CBD (*in situ* and *ex situ* conservation and access and sustainable use of biodiversity) as well as national biodiversity strategies and action plans for carrying them out;
- the coming into force of the ITPGRFA and steps taken by countries for its implementation;
- the FAO Commission on Genetic Resources for Food and Agriculture, the first SoW report, and the subsequent GPA;
- the international research organization IPBGR/IPGRI/Bioversity International and its efforts at research, documentation, and training dedicated to conservation of agrobiodiversity;
- the efforts of the international centres of the CGIAR with their various mandated crops;
- national and regional efforts (for example, the United States Department of Agriculture [USDA], the United States Agency for International Development [USAID], the Swedish International Development Cooperation Agency [Sida], the European Commissions) at training and capacity building for conservation and utilization in countries with priority crops;
- the establishment of the GCDT and its efforts to motivate assessments and conservation strategies and to provide funding to carry out the priorities thus established.

As reported in Chapter 2, since 1995 many countries have carried out specific surveys and inventories at least at the level of species, either as part of their National Biodiversity Strategy and Action Plans or within the framework of individual projects. Most have been limited to single crops, small groups of species, or limited areas within the national territory. ICARDA has assisted countries in North Africa, the Near East and Central Asia in surveys to assess density, frequency, and threats to CWR. Academic research undertakings have surveyed active farms in several countries to assess the extent of traditional varieties still grown in spite of the availability of modern, high-yielding varieties of many crops and report that a significant amount of crop genetic diversity in the form of traditional varieties continues to be maintained on-farm (Chapter 2 and country reports from Bosnia Herzegovina, Iceland, the Niger, Poland, Switzerland and the Former Yugoslav Republic of Macedonia, which affirm that crop diversity is still high and that special efforts are made to keep it that way). For example, in the Niger, no genetic erosion was observed during recent collecting missions and many traditional cultivars still prevailed in farmers' fields. No losses of millets and sorghum varieties could be detected in comparing collecting missions in 1973 and 2003, however, improved varieties of millet had increased.[8]

On the other hand, there continue to be recurring reports and alerts about the dwindling diversity of landraces and traditional varieties in production and in conservation.[9] Among the country reports, the majority pointed to decreases in cultivation of traditional varieties and landraces due to replacement by modern varieties.[10] Along with this conclusion, however, most of these country reports also stated that the detailed surveys and inventories that could document these decreases have not been done. The strongest conclusion that can be made from these country reports is that the extent of diversity maintained in crop production systems or in the wild either is not known or varies greatly with crop or ecosystem and country.

Among the strategies countries have reported for preventing genetic erosion caused by pressures for variety replacement are:

- on-going collection of wild and on-farm germplasm and diversification of production with traditional cultivars to allow farmers to produce for local markets and traditional use;[11]
- adequate conservation of landraces and traditional grass varieties by the Nordic Gene Bank;[12]
- collection, identification and *ex situ* conservation of crop landraces by public and private institutions;[13]

- absence of intensification of agriculture in many areas so that there is a continuing high number of varieties and species in cultivation;[14]
- since the late 1990s measures have been in place to protect habitat, promote continued landrace cultivation through farmer-participation projects, reintroduce landraces and old cultivars for organic production, and on-going collection missions;[15] and
- on-going collection missions and promotion of on-farm conservation of heritage pasture, vegetable and fruit tree varieties.[16]

Many country reports have indicated that "informal" seed systems remain a key element in the maintenance of crop diversity on farms (Chapter 4). It was noted in the United Republic of Tanzania that such an informal system accounts for up to 90 percent of seed movement.[17] The country reports of both Finland and Germany called attention to EU Council Regulation No. 1698/2005, which came into force in 2006 on the national and state levels. Under these regulations, payments can be made (premiums per hectare) for the cultivation of crop varieties threatened by genetic erosion, as well as for specific actions supporting the conservation and sustainable use of these varieties.

Following the adoption of the ITPGRFA, the GCDT was established in 2004. Among its goals is the identification and addressing of the highest priority diversity conservation issues which involve *ex situ* conservation of the ITPGRFA mandate crops (listed in Annex 1 of the Treaty).[18] The Svalbard Global Seed Vault opened in 2008 and provides the ultimate global security backup collection of crop diversity held in genebanks around the world, for insurance against both incremental and catastrophic loss. Since its opening, there has been a concerted effort at depositing duplicate accessions from the CGIAR global collections and many national and regional collections.

In 2006, the GCDT initiated the development of crop-based conservation and utilization strategies, convening teams of curators, breeders, and crop experts. The priorities that have emerged from this process were the next targets for the Trust, which now offers a grant process to fund work to address the priorities. The Trust's achievements in 2008 included signing over 50 grant agreements with partner organizations around the world to rescue, regenerate, characterize, evaluate, and ensure that the existing diversity, once better conserved and better understood, is quickly and easily available to plant breeders.[19]

In situ conservation status

The wild forms of many crops (especially cereals and legumes), and most of the species in their primary and secondary genepools, are usually annual species and thus populations are dynamic, and possibly transient, from year to year making it difficult for natural areas to be defined based specifically on the conservation of CWR. Most protected natural areas in the world are defined on the basis of geographic and ecological features and the presence of some dominant perennial plant taxa. Therefore the success of protected areas in maintaining annual CWR taxa is haphazard at best. An effort to support CWR conservation has been led by Bioversity International and partners with projects in five countries (see Box 2.1 in Chapter 2).[20]

On-farm conservation of old and heirloom varieties and landraces has been given impetus by many crop or food specific projects led by NGOs, public advocacy groups, and academic institutions. Several country reports have documented on-farm and participatory conservation efforts in those countries.[21] A major advance since the first SoW report was published has been increasing numbers of national surveys and inventories supported by a wide range of organizations (see Chapter 2) that have documented the status of conservation efforts and priorities for further action.

Gaps

There are still gaps in the coverage of cultivars, traditional varieties, landraces, and CWR in the *ex situ* collections of many major crops.[22] Similar, and in some cases even more extensive gaps, are found for collections of minor crops. There is a better understanding of the extent and nature of gaps in *ex situ* collections today than was the case at the time of the first SoW report. Some gaps arise by loss of once collected material. Others are due to lack of collection. Perennial taxa present special problems in regeneration, leading to loss and the need to recollect. *In situ* maintenance is often the better conservation option for perennial taxa from a genetic diversity standpoint.

The identification of gaps and recommendations for addressing them is a key component of the GCDT crop strategies. The CGIAR centres pursue these issues for their mandated crops. National PGRFA conservation programs in their country reports have documented needs in addressing gaps as well. Almost uniformly, the country reports cite needs for increased monitoring and establishment of early warning systems as a means to identify gaps in coverage and status of conservation.

Documentation, characterization and evaluation

Information systems vary greatly in type and sophistication from one collection to another. GIS and molecular data are used in the most sophisticated collections. Standardization and training are needed.[23] More detailed discussion of the trends in documentation and characterization of PGRFA and the priorities for the near future are reported in Chapter 3.

Utilization

Constraints to utilization of germplasm accessions include lack of accession data, especially evaluation data, unavailability of useful material, and concern over IPR. Priorities to increase utilization include wider use of diverse mapping populations, enhanced use of mutant and genetic stocks and wild relatives, and deployment of newer technologies such as increasingly cost effective high-throughput marker detection and DNA sequencing technology.[24]

Participatory breeding approaches have increasingly emerged as a means to target production of cultivars tailored more specifically to farmers' needs, as noted by many country reports and summarized in Chapter 4. More specific discussion of the trends in utilization of PGRFA and the priorities for the near future is also included in Chapter 4. Examples of priority needs include capacity building in both the crop improvement areas and the germplasm conservation areas and strengthened cooperation among those involved in the conservation and sustainable use of PGRFA at all stages of the seed and food chains.

Climate change

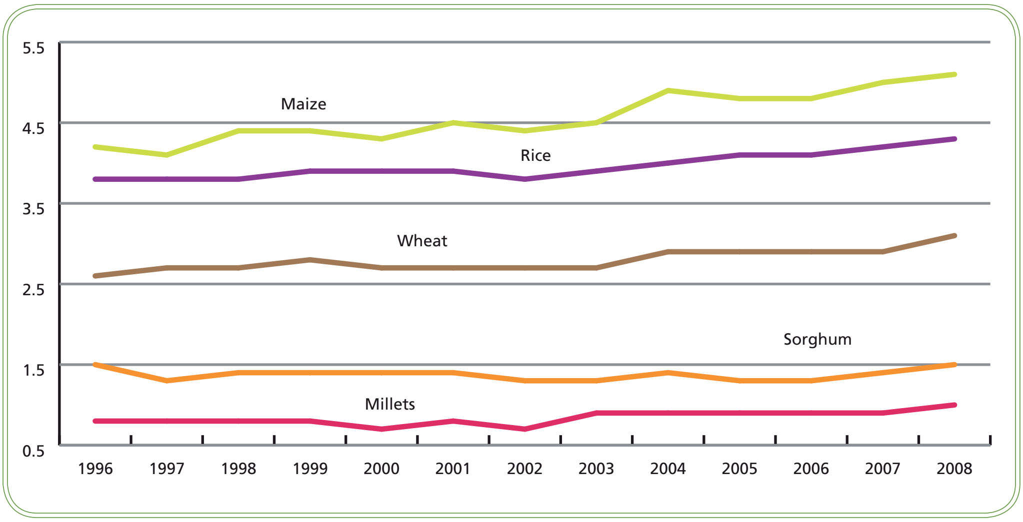
Many country reports document loss of diversity over the past decade from collections and farms due to the impacts of pest and disease outbreaks or to absence of tolerance to abiotic stresses, such as heat, drought or frost, leading to loss of accessions during regeneration and in field collections, as well as to loss of cultivars and landraces during crop production. These kinds of diversity losses are expected to grow with increasing manifestations of global climate change. Many country reports point to the threats of climate change for genetic resources. All the scenarios predicted by the IPCC[25] will have major consequences for the adaptation and geographic distribution of crops, specific varieties, and CWR. In China, for example, projections indicate shortages of water supplies for agriculture in the coming decades.[26] Systems of protected areas and reserves will be impacted in ways that will require changes in scale, size, and management plans.[27] Regeneration and grow-out issues for *ex situ* collections will be even more critical to resolve because demand for accessions will increase if breeders are to be successful in finding and incorporating new sources of disease and pest resistance and stress tolerance into cultivars to facilitate crop adaptation to impacts of increasing climate diversity. However, as the country reports document and Chapter 4 summarizes, overall, plant breeding capacity has not changed significantly since the first SoW report was first published. There is thus an urgent need to increase this capacity worldwide to address the climate change crisis.

A4.2 State of diversity of major crops

A4.2.1 State of wheat genetic resources

The yield of wheat has increased from 2.6 t/ha in 1996 to 3.1 t/ha in 2008 (Figure A4.1). Wheat continued to be the most widely cultivated crop, harvested from 224 million hectares in 2008,[28] down from the 227 million hectares in 1996. Total world production in 2008 was 690 million tonnes,[29] up from the 585 million tonnes

FIGURE A4.1
Global yields of selected cereal crops (tonnes per hectare)



Source: FAOSTAT 1996/2008

reported for 1996. The five largest producers in 2008 were still China (16 percent of global production), India (11 percent), the United States of America (10 percent), the Russian Federation (9 percent), and France (6 percent).

World wheat production is based almost entirely on two species: common or bread wheat (*Triticum aestivum*, almost 95 percent of production) and *durum* or macaroni wheat (*T. turgidum* subsp. *durum*, about 5 percent of production).[30] The former is a hexaploid species ($2n=2x=42$) and the latter tetraploid ($2n=2x=28$). Very minor, extremely local production may still be found with diploid wheats and tetraploid subsp. besides durum.

The genepool for wheats consists of modern and obsolete cultivars and breeding lines, landraces, related species (both wild and domesticated) in the *Triticeae* tribe, and genetic and cytogenetic stocks. Details of the genepool composition are described in the GCDT strategy plan:[31] The primary pool consists of the biological species, including cultivated, wild, and weedy forms of the crop species which can be easily hybridized. In the secondary genepool are species from which gene transfer is possible but with greater difficulty, typically species of *Triticum* and *Aegilops*. The tertiary genepool is composed of other species of the tribe (primarily annual species) from which gene transfer is possible only with great difficulty. 'Ease' of gene transfer is a technology-dependent concept and subject to change as are the taxonomic delimitations within the tribe. Wild relatives of wheat have proven to be highly useful sources of resistance to biotic and abiotic stresses in wheat breeding over the last two decades and this trend is expected to accelerate in the future. Similarly, genetic stocks are finding increasing use as tools in the sophisticated application of modern biotechnologies in wheat improvement.[32]

In situ conservation status

One of the few global examples of a protected area created specifically for conservation of annual cereal CWR is the "Erebuni" State Reserve in Armenia, an 89 hectare region in the transition area between semi-desert and mountain-steppe zones. Three out of the four known species of wild-growing wheat occur here

APPENDIX 4

(wild one-grain wheat, *T. boeticum*, wild two-grain Ararat wheat, *T. araraticum*, and wild urartu wheat, *T. urartu*) along with several species of *Aegilops*, in addition to a number of CWR of other cereal species (barley and rye).[33] Succession with other indigenous species and invasive species (both plants and animals) are threats to the integrity of the CWR species in this reserve as well as in any other in which cereal CWR may be found. In general, any protected areas in countries with Mediterranean climates are likely to include some wheat CWR taxa. Whether the genetic integrity of such populations are being maintained in these reserves is the key question.

Ex situ conservation status

Altogether, over 235 000 accessions are maintained in more than 200 *ex situ* collections.[34] Landraces, modern and obsolete improved cultivars are generally well conserved in wheat germplasm collections, while wild relatives of wheats are poorly represented.[35] Because of the specialized needs and conditions for developing and reliably maintaining genetic and cytogenetic stocks, these are not well represented in germplasm collections (probably in fewer than 90 collections) and are most likely to be found in research institutions. Regeneration progress is lacking in many country collections and is probably the single greatest threat to the safety of wheat accessions held in globally important genebanks. Lack of funding is the principle limitation.[36]

Genetic erosion and vulnerability

The instances of absence of genetic erosion or lack of vulnerability are rare. Chapter 1 highlights the increase in genetic diversity and allelic richness in varieties released from the CIMMYT spring bread wheat improvement program. Many CWR have a weedy habit and thrive in disturbed areas or areas of cultivation and thus are often widespread, but there is little known in general about the genetic diversity itself in these adventitious populations.

Regeneration progress is lacking in many country wheat genetic resources collections (about 10 percent of collection, globally) and it is probably the single greatest threat to the safety of wheat accessions held in globally important genebanks. Lack of funding is the principle limitation.[37]

Examples of concerns from country reports are: there is a gradual disappearance of landraces of wheat;[38] all primitive wheat cultivars are lost;[39] and old varieties of wheat are replaced by modern cultivars in main production areas.[40]

Gaps and priorities

As summarized in Chapter 3, according to the opinion of collection managers, the major gaps in collections relate to landraces and cultivars. Key users of wheat genetic resources, however, indicated the need for more mapping populations, mutants, genetic stocks and a wider range of wild relatives. This divergence of perceptions of the major function of collections between genebank managers and germplasm users complicates evaluation of the status of diversity.[41] CWR are relatively poorly represented in collections and more collecting is needed.[42, 43] The level of genetic diversity and breadth of provenance of wild related species maintained in existing collections is small.

One of the scenarios of climate change is increased regional temperatures. This could be beneficial for the wheat crop in some regions, but it could reduce productivity in regions where temperatures are optimal for wheat. New wheat cultivars will be needed to adapt the crop to changing environments and still meet the nutritional needs of people. Identification and deployment of heat-tolerant germplasm is a high priority.[44]

Safety duplication

Safety duplication is lacking for most country collections of wheat. Less than 10 percent of the globally important wheat collections have their entire collection duplicated elsewhere for safety, while a majority have only partial or no safety duplication in place.[45]

Utilization

There are large differences in productivity between countries, even when similar agronomic practices are applied. Thus, there is an opportunity to increase productivity in many countries and genetic resource collections will be important for this. Genetic and molecular stock collections are increasing in size and sophistication in concert with advances in biotechnological tools for genome analysis. These will increasingly be deployed (for example with MAS) to enable effective utilization of the genetic variation available in traditional germplasm collections.[46]

Role of crop in sustainable production systems

Wheat is produced for a wide range of end-users and it is a critical staple food for a large proportion of the world's poor farmers and consumers. It provides 16 percent of total dietary calories for humans in developing countries and is the single largest import food commodity into developing countries as well as a major component of food aid from developed countries. The lower food prices for wheat in developing countries, due to increased global production, has contributed to a reduction of the proportion of poor people in developing countries.[47]

A4.2.2 State of rice genetic resources

During the period 1996-2008, the yield of rice (*Oryza sativa*) increased by about 14 percent worlwide (Figure A4.1). In 2008, world rice production accounted for 685 million tonnes harvested from an area of 159 million hectares.[48] The highest producers of rice were China (28 percent of global production), India (22 percent), Indonesia (9 percent), Bangladesh (7 percent), and Viet Nam (6 percent).

The primary genepool has been a source of useful genes for breeding and research. It consists of the other domesticated species *O. glaberrima* and *O. rufipogan* and several other wild species, all with a common genome (A), that can hybridize naturally with *O. sativa*.[49] The secondary and tertiary genepools, *Oryza* species with genome constitutions other than A, have potential as gene sources, but introgression of genes into rice is proving difficult.[50] However anther culture and embryo rescue techniques can be used effectively to overcome hybrid sterility. At CIAT, advanced breeding lines from crosses between *O. sativa* and *O. latifolia* (CCDD genomes) have been generated and distributed to NARs in Latin America.[51]

In situ conservation status

Potential genetic reserve locations in Asia and the Pacific have been identified for *O. longiglumis*, *O. minuta*, *O. rhizomatis* and *O. schlechteri* which are high priority CWR for *in situ* conservation. Efforts for the conservation of landraces and CWR outside protected areas aimed to preserve globally significant agrobiodiversity of rice have been reported in Viet Nam.[52]

Ex situ conservation status

Overall, about 775 000 accessions are maintained in more than 175 *ex situ* collections; however, about 44 percent of these total holdings is conserved in five genebanks located in Asia.[53] Landraces, obsolete and modern improved cultivars, as well as genetic and cytogenetic stocks are generally well represented in rice germplasm collections. In general, CWR are poorly represented in the *ex situ* collections with the exception of those held at IRRI and at the National Institute of Agricultural Biotechnology in the Republic of Korea.

Genetic erosion and vulnerability

A sampling of the concerns raised by country reports include: the assessment that rice varieties have become more uniform and thus more genetically vulnerable,[54] the fact that specific rice varieties and landraces have disappeared,[55] and wild species in the primary genepool are becoming extinct.[56] Causes noted are increasingly unfavorable climate conditions, such as drought, replacement by introduced high-yielding, early-maturing varieties, and loss of habitat. In some countries, government policies do not facilitate germplasm collecting and therefore, the characterization and utilization of wild relatives of rice.

Gaps and priorities

Further collecting for better wild species representation in genebanks from all levels of genepools, as well as regeneration of existing wild accessions and networks for sharing conservation responsibility for wild species among the several genebanks and research centres that maintain them are needed.[57]

Safety duplication

Seed multiplication and safety duplication is inadequate in most rice collections.[58]

Utilization

Improved conservation protocols and facilities, as well as more systematic germplasm characterization would enhance utilization of accessions (e.g. glutinous rice accessions) that do not store well under the moisture and temperature regimes of conventional storage conditions.[59]

A4.2.3 State of maize genetic resources

During the period 1996-2008, the yield of maize (*Zea mays*) increased by 21 percent (Figure A4.1). In 2008, maize was grown in over 161 million hectares with a global production of 823 million tonnes, having overtaken rice and wheat in production since 1995.[60] The five highest producers of maize in 2008 were the United States of America (37 percent of global production), China (20 percent), Brazil (7 percent), Mexico (3 percent), and Argentina (3 percent).[61]

The primary genepool includes the maize species (*Zea mays*) and teosinte, with which maize hybridizes readily with production of fertile progeny. The secondary genepool includes *Tripsacum* species (~16 species), some of which are endangered. The variability among maize landraces (some 300 have been identified) exceeds that for any other crop.[62] Great variation exists for plant height, days to maturity, ears per plant, kernels per ear, yield per hectare and latitudinal and elevational ranges of cultivation.[63] Teosinte is represented by annual and perennial diploid species ($2n = 2x = 20$) and by a tetraploid species ($2n = 4x = 40$). They are found within the tropical and subtropical areas of Mexico, Guatemala, Honduras, and Nicaragua as isolated populations of variable population sizes, occupying from less than one hectare to several hundreds of square kilometres. The distribution of teosinte extends from the southern part of the cultural region known as Arid America, in the Western Sierra Madre of Chihuahua and the Guadiana Valley in Durango in Mexico, to the western part of Nicaragua, including practically the entire western part of Mesoamerica.[64]

In situ conservation status

It is extremely important to act now to complete ecogeographic sampling for New World maize, since economic and demographic changes are eroding the genetic diversity of maize in many areas that were once untouched by modern agricultural, horticultural, forestry, and industrial practices.[65]

Ex situ conservation status

While there are relatively few areas where no comprehensive collection has already been made, maize from portions of the Amazon basin and parts of Central America and waxy maize in Southeast Asia have never been adequately collected. Public or private tropical inbred lines are not well represented in collections, nor are important hybrids (or their bulk increases).[66] Wild *Zea* and *Tripsacum* species are potentially important sources of genetic variation for maize, but they are not well represented in collections and existing accessions are in small quantities. The Maize Genetic Cooperation Stock Center at the University of Illinois is the primary genebank holding maize mutants, genetic stocks, and chromosomal stocks.[67] Teosinte representation is uneven and incomplete in major genebanks.[68] The major teosinte collections are those of the INIFAP, the University of Guadelajara and CIMMYT in Mexico and in the USDA-ARS collections in the United States of America.[69]

Genetic erosion and vulnerability

As with wheat, a rare instance of improved genetic variability is the increase in genetic diversity and allelic richness in varieties released from CIMMYT's maize improvement program (Chapter 1). More typical is the report by individual countries of a loss of older varieties and landraces.[70] The predominant cause reported is replacement of traditional varieties by modern cultivars. All populations of teosinte are threatened.[71]

Gaps and priorities

National and international reserves need to be established to protect the remaining fragments of the Balsas, Guatemala, Huehuetenango, and Nicaraguan races of teosinte. CIMMYT's current *ex situ Tripsacum* garden at Tlaltizapan, Morelos, should continue to be maintained, with a duplicate garden established in Veracruz (or some equivalent lowland, tropical environment). Another *Tripsacum* garden could be established near IITA headquarters in Africa. *In situ* monitoring of *Tripsacum* populations should be conducted in Mexico and Guatemala, the center of diversity for the genus, and in other countries in Central and South America, where both widespread and endemic species are found. *Ex situ Tripsacum* gardens at CIMMYT and USDA in Florida should be enriched with the diversity found from the wild, and more collaboration should occur between these two unique sites.[72]

As summarized in Chapter 3, major gaps identified in existing *ex situ* maize collections include hybrids and tropical inbred lines, in addition to the gaps resulting from the loss of accessions from collections; for example, the entire collection of Dominica has been lost as has much of the material collected by IBPGR in the 1970s. The GCDT maize strategy emphasized specifically that hybrids and private inbred lines (not those now with plant variety protection [PVP] or with recently expired PVP) are missing from genebanks.[73]

There is a need to identify core subsets of the maize races, but it depends on expertise not only in statistical procedures, but more critically, in racial and accession classification and the availability of the type of data needed to develop reasonable classification decisions.[74]

While coverage of New World maize is good in genebanks,[75] about 10 percent of those New World holdings are in need of regeneration.[76] In some cases, recollection of adequate samples makes more sense than regeneration, particularly for high-elevation landraces growing in areas unaffected by improvement programs (much of Oaxaca and Chiapas in Mexico, many Central American highlands, much of Andean Argentina, Bolivia [Plurinational State of], Chile, Ecuador, Colombia, and Peru). Collection of indigenous knowledge must be a priority for all recollecting.[77]

Further collecting of wild species is needed, along with *in situ* conservation efforts. As with some landraces, recollecting of wild species is often more efficient than regeneration.[78]

Safety duplication

A network of safety duplicates for most accessions of major New World genebanks is in place. However, few of the accessions housed in the national collections of the Old World are backed up at the international centres; many are essentially unavailable to non-national (and sometimes even to national) users; and assurance of periodic regeneration is often uncertain.[79]

Safety backup for about 85 percent of the genetic stock collections is in place at the USDA NCGRCP, Ft. Collins, Colorado, the United States of America.[80]

Because the genetic diversity of teosinte and *Tripsacum* is relevant to maize research and breeding efforts for maize productivity, nutritional quality, bio-energy production, and other uses, *ex situ* backup of these materials is critical.[81]

Documentation, characterization and evaluation

Documentation of the materials held in national collections is inconsistent and sometimes poor, and is held in multiple databases that are not necessarily well maintained or easily accessible. Standardization across databases is lacking. The most pressing problem is to resolve the various acronyms and numbering systems used for the same accession. Only the US-GRIN system is internet accessible.[82] Implementation of a global information system for maize is anticipated and would serve especially to improve the regeneration progress. A separate database may be useful for teosinte.[83]

An operational comprehensive maize metadatabase would make more efficient safety duplication for all accessions possible.[84]

Utilization

Distribution of germplasm accessions is an indirect measure of the use of genetic resources for crop improvement. The CIMMYT maize collection is one of the world's largest (second only to the Mexican national collection) and had its peak distribution year in 1989 followed by a net drop through 1995. However, there has been a net increase in distribution from 1996 through 2004 suggesting a renewed interest in germplasm utilization.[85] Increased use of germplasm may come about through improved technology for distribution of DNA itself.[86]

Constraints noted for greater utilization include ownership issues and inadequate personnel. Distribution of accessions is hampered by IPR concerns.[87] There is a serious need to train a new generation of maize germplasm specialists in conservation and use.[88]

Role of crop in sustainable production systems

Strategic evaluation of maize germplasm accessions combined with genetic enhancement will be important to achieve increased food security and reduced poverty and to protect the environment, particularly in Sub-Saharan Africa and in Indigenous areas of the Americas.[89]

A4.2.4 State of sorghum genetic resources

Over the period 1996-2008, the yield of sorghum (*Sorghum bicolor*) did not changed significantly (see Fig. A4.1). In 2008, sorghum was cultivated over a harvested area of 45 million hectares with a global production of 66 million tonnes.[90] Sorghum is mainly used for human consumption in Africa and India and for animal feed in China and the United States of America. The five highest producers of sorghum in 2007 were the United States of America (18 percent of global production), Nigeria (14 percent), India (12 percent), Mexico (10 percent), and the Sudan (6 percent).

The primary genepool consists of *S. bicolor* and its many races and several other species, the number of which depends on the taxonomic treatments.[91]

Ex situ conservation status

The major sorghum collections are at ICRISAT and at the USDA Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, followed by those at the Institute of Crop Germplasm Resources (ICGR) in China and at the National Bureau of Plant Genetic Resources (NBPGR) in India. In addition, there are about 30 other institutions holding *ex situ* sorghum collections (primarily national collections). Altogether, over 235,000 accessions are maintained, of which 4,700 accessions are wild materials.[92] A high degree of duplication of accessions among collections is suspected, except for the Chinese collection which consists primarily of Chinese landraces.[93]

Genetic erosion and vulnerability

In Mali, 60 percent of local varieties of sorghum have disappeared in one region over the last 20 years due to the expansion of cotton production, introduction of maize cultivation, and the saturation of the available cropping area. In one village, diffusion of an improved variety displaced three local varieties of sorghum.[94] Several other African countries also indicated in their reports that improved varieties had displaced local varieties.[95] In Niger, however, no losses of varieties and landraces from farmers' fields had been detected in collecting missions.[96] In Japan, sorghum is no longer cultivated at all, but the farmers' varieties were collected for the national gene bank.[97]

Gaps and priorities

A massive number (28 000) of accessions urgently need regeneration, bottlenecks include quarantines and day length issues, labour costs and capacities.[98]

Ecosampling of the wild progenitors and landraces of *S. bicolor* in each of its primary, secondary, and tertiary centres of diversity is needed.[99] Further collection and conservation of wild close relatives is needed.[100] Gaps in geographic coverage were noted for West Africa, Central America, Central Asia and the Caucasus, and Sudan in Darfur and the south.[101]

Safety duplication

The status of safety duplication varies greatly from collection to collection. Only nine of the collections are stored under long-term storage conditions (or close to it) and only eight are backed up under secure conditions.[102] ICRISAT has proposed to duplicate its entire sorghum collection of about 38 000 accessions for deposit at the SGSV and so far has sent 13 000 accessions.[103]

Documentation, characterization and evaluation

While passport data are available for most accessions, the nomenclature used varies greatly among institutions making it difficult to target duplicates. Characterization data are documented electronically at a reasonable level, but evaluation data are lacking.[104] Most data are not accessible through the internet.[105]

Utilization

Germplasm exchange and thus utilization is limited. Additional constraints on utilization are lack of useful trait information about accessions, decline in breeding programs, insufficient seed availability, and poor communication between breeders and conservers.[106]

Core and mini-core collections based on sampling the available genetic diversity have been developed and used to identify trait-specific accessions resistant to biotic stresses.[107]

The two primary collections have distributed most. The main recipients from the USDA have been public sector breeders, while from ICRISAT, recipients have been in-house research scientists (focus on crop improvement).[108]

Role of crop in sustainable production systems

As demand increases for more reliable food and feed sources from environments challenged by water shortage and high temperatures, sorghum will play a more prominent role due to its wide adaptation and diverse uses.[109]

A4.2.5 State of cassava genetic resources

From 1996 to 2008, the yield of cassava showed a net increase of 2.7 tonnes/ha (Figure A4.2). In 2008, cassava (*Manihot esculenta*) was grown over a harvested area of 19 million hectares with a global production of 233 million tonnes.[110] Cassava is essential to food security in most regions of Africa. In 2008, almost 51 percent of global production was from Africa and the five highest producers of cassava were Nigeria (19 percent of global production), Thailand (12 percent), Brazil (11 percent), Indonesia (9 percent), and the Democratic Republic of Congo (6 percent).

The genepool consists of the cultivated *M. esculenta* and 70 to 100 wild *Manihot* species, depending on the taxonomic classification. Landraces, however, have been and will continue to be the primary sources of genes and gene combinations for new varieties. The wild species offer interesting traits (i.e. tolerance to post-harvest physiological deterioration, high protein content in the roots, resistance to pests and diseases), but are challenging to use and conserve.[111] The genus *Manihot* is native to the Americas, and most of the genetic diversification occurred there. Both Asia and Africa are important secondary centres of genetic diversity.[112]

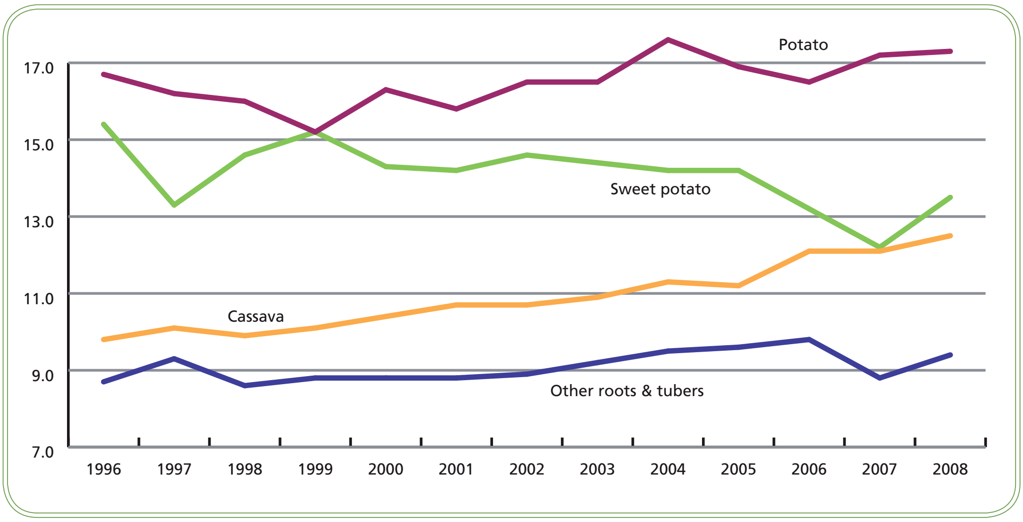
The primary genepool consists of the cultivars themselves and species known to cross readily with cassava and yield fertile offspring: *M. flabellifolia* and *M. peruviana*, native to South America.[113] Taxa crossing with difficulty with cassava but giving some positive results make up the secondary genepool, including *M. glaziovii*, *M. dichotoma*, *M. pringlei*, *M. aesculifolia* and *M. pilosa*.[114]

In situ conservation status

Despite long-standing proposals to create *in situ* reserves for wild *Manihot* species, this has not been realized.[115]

APPENDIX 4

FIGURE A4.2
Global yields of root and tuber crops (tonnes per hectare)



Source: FAOSTAT 1996/2008

Ex situ conservation status

The primary conservation strategy is field collections, *in vitro* collections are employed to a lesser extent, followed by cryopreservation.[116] Seed storage as a method for germplasm conservation has received limited attention, but shows promise as a means of preserving genes and especially for many wild species which are difficult to maintain by the alternative methods and are seed propagated in the wild. Cassava seeds are apparently orthodox in behavior and therefore can be stored under conventional conditions of low humidity and low temperatures.[117] CIAT has recently initiated a process to generate botanical seed through self-pollination of accessions in the cassava collection. The genotype of the accession is lost but its genes are preserved in the seeds produced.[118]

Most cassava-growing countries have established a genebank of local landraces. Nearly all rely primarily on field-grown plants, but may have part of their collection under *in vitro* propagation as well. Two international centres, CIAT and IITA, maintain regional collections for the Americas and Asia (CIAT) and for Africa (IITA). Overall, there are more than 32 000 accessions of cassava stored *ex situ*. Of these, 32 percent are estimated to be landraces.[119] According to a GCDT study, in order to represent the complete genetic diversity of the species, additional collecting should be carried out; priority countries for collecting the additional landraces are the Plurinational State of Bolivia, Brazil, Colombia, the Democratic Republic of the Congo, Haiti, Mozambique, Nicaragua, Peru, Uganda, the United Republic of Tanzania and the Bolivarian Republic of Venezuela.[120]

Gaps and priorities

Field collections are not in good shape and there are backlogs within *in vitro* collections due to funding shortages. High maintenance of conservation and relatively short regeneration intervals are key bottlenecks.[121]

Wild *Manihot* species are poorly represented in *ex situ* collections, both by species (only about one-third of the species in the genus) and by populations. Funding is a constraint. Further collecting is needed, some species are at risk from expanding agriculture and habitat loss.[122] Only EMBRAPA, Universidade de Brasilia (Nagib Nassar) and CIAT have a serious program for long-term conservation of wild *Manihot*.[123] The habitats of many populations are threatened by urbanization and expanding agriculture, especially in central Brazil. Effective collection and conservation are also compromised by the deficiencies in knowledge of taxonomy and phylogeny. Their *ex situ* conservation is difficult and needs intensive research to establish efficient and secure genebanks.[124]

Safety duplication

Safe duplication is not complete.[125]

Documentation, characterization and evaluation

Little documentation is available in national collections. A global database is an urgent priority.[126]

Utilization

Few countries engage in international exchange of cassava germplasm on a regular basis.[127] Major constraints to utilization is lack of accession information and difficulty of exchange.[128]

Efforts needed to enhance utilization include disease indexing of accessions, development of better protocols for seed and *in vitro* conservation and cryoconservation, viability testing for pollen conservation, and improved seed germination protocols.[129] CIAT, jointly with IITA, has initiated a process to generate partially inbred genetic stocks as a source of desirable traits for facilitated exchange of germplasm.[130]

Indexing methods for viruses that are exclusive to each continent are available and these need to be refined and made broadly available to genebank managers and quarantine agencies.[131]

Role of crop in sustainable production systems

Cassava is one of the most efficient crops in biomass production. In comparison with many other crops, it excels, under sub-optimal conditions, and can withstand drought conditions.

Most cassava production is still based on landrace varieties, although this is changing quickly, especially in the past decade, and in selected countries like Brazil, Colombia, Nigeria, Thailand and Vietnam. Landraces are still used extensively in breeding programs as parents in crossing nurseries.[132]

A4.2.6 State of potato genetic resources

Since 1995, the yield of potato has been erratic from year to year, though showing an overall slight increase (see Fig. A4.2). Potato was cultivated in 2008 over a harvested area of 18 million hectares with a global production of 314 million tonnes.[133] The five highest producers in 2008 were China (18 percent of the global production), India (11 percent), the Russian Federation (9 percent), Ukraine and the United States of America (6 percent).[134] Potato is important to food security and income generation in the developing world. In 2005, global potato production originating in developing countries surpassed production levels in the developed world.[135]

The genepool can be divided into four types of germplasm: [136]

1. modern cultivars (and old varieties) of the common potato (*Solanum tuberosum* subsp. *tuberosum*), the most cultivated potato subspecies in the world;
2. native cultivars, including local potato cultivars occurring in the center of diversity (seven to 12 species depending on taxonomic treatment);
3. wild relatives, consisting of wild tuber-bearing species and a few nontuber-producing species, occurring in the center of diversity (180 to 200 species depending on taxonomic treatment);
4. other germplasm or research material; all types of genetic stocks e.g., interspecific hybrids, breeding clones, genetically enhanced stocks, etc.

In situ conservation status

Farmers in the crop's centre of origin and diversity, particularly in the Plurinational State of Bolivia and Peru, still maintain hundreds of native cultivars and thereby actively contribute to the ongoing *in situ* conservation and evolution of the cultivated potato.[137, 138, 139] A better understanding of effective strategies to support these farmers is urgently needed. Little is known about the *in situ* conservation status of wild potato species and efforts towards the conservation of important habitats of endemic species are, as yet, non-existent.

Ex situ conservation status

Globally, about 98,000 accessions can be found *ex situ*, 80 percent of which are maintained in 30 key collections.[140] Accessions are conserved as botanical seeds or vegetatively as tubers and *in vitro* plantlets. Latin American collections contain many native cultivars and wild relatives and the collections in Europe and North America contain modern cultivars and breeding materials, as well as wild relatives.[141]

Genetic erosion and vulnerability

One example of erosion: before modernization of agriculture, peasant farmers on the Island of Chiloé cultivated 800 to 1,000 varieties of potato, now one finds only about 270 varieties.[142] The cultivated Andean diploid species *Solanum phureja* is also reported to be vulnerable.[143, 144] A recent study on the effect of climate change predicts that 7 to 13 out of 108 wild potato species studied may become extinct.[145]

Gaps and priorities

In Chapter 3, it was summarized that the most useful genetic material has already been collected and there are currently few significant gaps. However, several Latin American collections are threatened by lack of funding and, if any of those were lost, it would result in important gaps in the overall coverage of the genepool in collections.

The limited regeneration capacity is a constraint in all collections, especially for wild accessions and native cultivars. Genetic drift is becoming an issue in wild species collections where individual species are represented by too few accessions.[146]

Critical functions for optimal conservation such as regeneration, documentation, storage, health control, and safety duplication are not adequately performed in a number of genebanks. Several genebanks in Latin America and Russia do not have (access to) sufficient experience or facilities to keep the potato germplasm healthy.[147]

The extent of new collecting of wild material and monitoring of the conservation status of localized vulnerable populations in the centre of diversity has been very limited in the past 10 years. Approximately 30 wild species are not yet represented in collections and may still need to be collected. In addition, for another 25 wild species, fewer than three accessions are present in the collections. In the Andean context, because on-farm conserved potato cultivars are vital for regional food security, confronting climate change and long-term conservation, there is a need to strengthen understanding of the dynamic *in situ* and *ex situ* conservation systems that support farmers' livelihoods.[148]

Safety duplication

There is not in sufficient detail on how many accessions of potato are currently safety duplicated.[149]

Documentation, characterization and evaluation

National collection databases are incomplete and not accessible. Efforts to document and characterize *in situ* collections of wild and cultivated species and their inherent infraspecific diversity are needed as a baseline for future research on genetic erosion, species loss, genetic drift and integrity.[150]

Utilization

Breeders prefer to use well-adapted germplasm of *Solanum tuberosum* subsp. *tuberosum*, the most common potato, or research material with interesting properties.[151] Exotic germplasm has been used to great advantage, though relatively little has been used in comparison with the great breadth of materials available.

The substantial amount of potato germplasm distributed to users indicates that germplasm is extensively used. There are, however, large differences in distribution between genebanks, ranging from 23 to 7 630 accessions per year.[152] Unfortunately, recipients or users do not consistently return information from their evaluation of the requested germplasm to the providing genebank.[153] The most serious constraint to utilization of collections is lack of information about accessions, especially characterization and evaluation data.[154] Increased attention is needed to ensure the return and collation of such data for the benefit of the providing genebanks and ultimately for the benefit of all users.[155]

The domestic public sector makes use of germplasm most frequently, but some genebanks provide large numbers of accessions to the private sector (breeding companies). In South America and Canada, farmers and NGOs intensively use the germplasm of the national genebanks. However, some genebanks distribute a substantial number of accessions to users abroad. NGOs and farmers use native cultivars and old varieties, often for crop production on-farm, and contribute to *in situ* conservation (regeneration, evaluation, and storage) of germplasm with this activity.[156]

A technological tool to enhance germplasm utilization would be test kits for protection against viruses to be made widely available.[157]

A4.2.7 State of sweet potato genetic resources

Since 1996, the yield of sweet potato has been very erratic from year to year, with an overall decreasing trend (see Fig. A4.2). In 2008, sweet potato (*Ipomoea batatas*) was cultivated over a harvested area of 8 million hectares with a global production of 110 million tonnes.[158] The highest producers of sweet potato in 2007 were China (77 percent of global production), Nigeria (3 percent), Uganda (2 percent), Indonesia (2 percent), and Viet Nam (1 percent).

The genus includes 600 to 700 species of which sweet potato is the only one cultivated. More than 50 percent are in the Americas. Sweet potato and 13 wild *Ipomoea* species closely related to sweet potato belong to the section *Batatas*; all of these, except *I. littoralis* are endemic to the Americas.[159]

Ex situ conservation status

Globally, 35 500 accessions of sweet potato genetic resources are conserved, 80 percent of which are in less than 30 collections.[160] These accessions include landraces, improved material, and wild *Ipomoea* species. The global collection maintained in CIP, Peru, includes accessions from 57 countries, with Peru and other South American and Caribbean countries (primary centres of sweet potato diversity) as the most important contributors.[161] However, collection activities in the last 10 years produced only 1 041 accessions; most were improved material, followed by landraces.[162]

Some 162 CWR species are conserved in five collections, as seed. Thirteen of these species are especially closely related and are the focus of conservation efforts.[163]

Gaps and priorities

Chapter 3 notes that for sweet potato, the important geographic as well as trait gaps in collections have already been identified.

There are regeneration backlogs for most collections with 50 to 100 percent of accessions in some collections needing urgent regeneration. For collections holding wild accessions, 20 to 100 percent of the taxa need urgent seed regeneration. Many collections lack the capacity for *in vitro* regeneration or greenhouse conditions.[164] Most collections showed drawbacks and constraints in functions like plant health, documentation, regeneration, and safety duplication.[165]

Documentation, characterization and evaluation

Half of the collections have computerized databases and only a few are internet accessible. Standardization is needed.[166]

Utilization

Optimization of conservation protocols would enhance utilization.[167]

APPENDIX 4

Role of crop in sustainable production systems

Sweet potato is a tropical perennial, cultivated as an annual in temperate climates; grown in more than 100 countries.[168]

A4.2.8 State of common bean genetic resources

Since 1996, the yield of common bean (*Phaseolus vulgaris*) has been essentially flat (Figure A4.3). Dry beans were grown over a harvested area of 28 million hectares with a global production of 20 million tonnes in 2008 (excluding production from intercropped fields).[169] The six highest producers are India (19 percent of global production), Brazil (17 percent), Myanmar (12 percent), the United States of America and Mexico (6 percent), and China (5 percent).

The common bean primary genepool consists of the cultivars and wild forms of *P. vulgaris*. The primary genepool has two distinct geographic components: the Andean zone and the MesoAmerican zone with domestication presumed to have occurred independently in each zone. The secondary genepool consists of *P. costaricensis*, *P. coccineus*, and *P. polyanthus*, crosses of each with common bean result in hybrid progeny without any special rescue efforts, but the progeny can be partially sterile and difficult from which to retrieve stable common bean phenotypes. The tertiary genepool consists of *P. acutifolius* and *P. parvifolius*, crosses of either with common bean need embryo rescue to produce progeny.[170, 171]

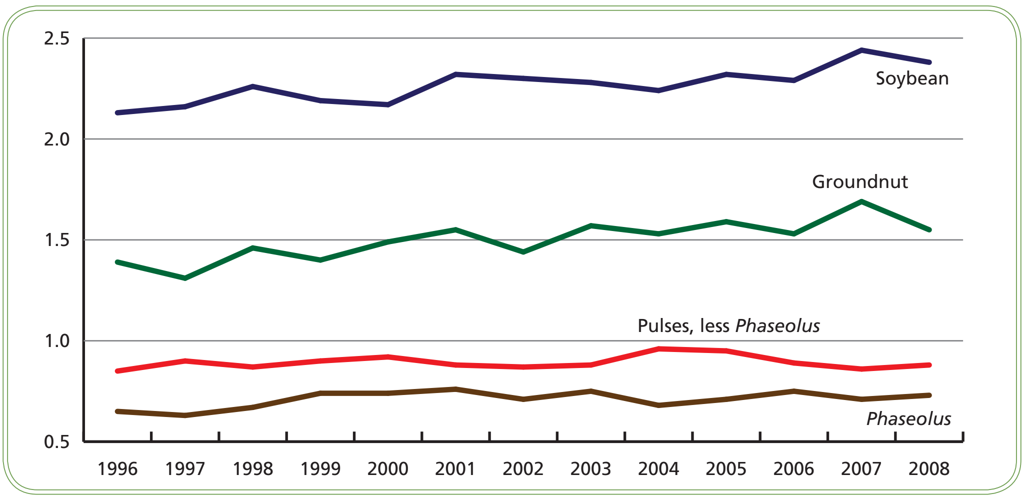
Ex situ conservation status

CIAT in Colombia is the primary global collection with some 14 percent of the world's approximately 262,000 genebank accessions of common bean.[172]

Genetic erosion and vulnerability

Genetic erosion is reported by several country reports for common bean and related taxa overall,[173] and, more specifically, cultivars have disappeared due to pathogen outbreaks,[174] eight years of recurring droughts,[175] and replacement by introduced varieties.[176]

FIGURE A4.3
Global yields of selected legume crops (tonnes per hectare)



Source: FAOSTAT 1996/2008

A4.2.9 State of soybean genetic resources

Since 1996, the yield of soybean (*Glycine max* (L.) Merrill) has varied up and down from year to year, but with an overall increase (Figure A4.3). Soybean was grown in 2008 over a harvested area of 97 million hectares with global production of 231 million tonnes.[177] The five largest producers of soybean in 2008 were the United States of America (35 percent of global production), Brazil (26 percent), Argentina (20 percent), China (7 percent), and India (4 percent).

The genus *Glycine* includes about 20 annual and perennial species distributed primarily in Australia and Asia. The primary genepool consists of the cultivated forms of *G. max*, the annual wild soybean, *G. soja* (considered the immediate ancestor of the cultivated soybean), and a weedy species *G. gracilis*, with its diversification centre in China, Korea, Japan, and the Far East region of the Russian Federation. The secondary genepool consists of the other wild species of *Glycine*, and the tertiary genepool is considered to be species in the legume tribe *Phaseoleae*.[178]

Ex situ conservation status

The ICGR-CAAS maintains the primary global collection with some 14 percent of the world's approximately 230,000 genebank accessions of soybean.[179] Soybean is not one of the crops covered under the ITPGRFA.[180]

Genetic erosion and vulnerability

The genetic base of soybean production has been shown to be narrow for regions such as the southern United States of America[181] and Brazil.[182] In China, many traditionally grown local landraces can only be found in genebanks today.[183]

Utilization

In 2005, the need for information about the extent and distribution of diversity within the Chinese landraces was stressed in the context of an effort to estimate the genetic variation within and among four Chinese provinces for which accessions were available in the USNPGR. RAPD markers were used with ten landraces from each of the four geographically divergent provinces. It was suggested that these markers could be useful in generating a core collection, but the uneven representation of some provinces in the United States of America genebank would mean under-representation of some geographic areas in any core collection assembled in the United States of America.[184]

The distribution of landraces in China itself and the substantial representation of them in the Chinese genebank presented an opportunity for assessment of population genetic structure in the primary genepool of soybean. An analysis for genetic diversity and genetic differentiation was carried out based on 59 SSR loci with 1 863 of the Chinese landraces. The goal was to derive information useful for effective management of the material in the genebank and to facilitate effective utilization of the landraces for soybean improvement. The SSR loci generated 1 160 alleles and identified seven clusters among the landraces. This high level of genetic diversity suggests the landraces will be important sources for soybean cultivar improvement. The rare alleles found were at loci that had high polymorphism and have potential for use in categorization of germplasm collections and as unique markers. Rareness in alleles at multiple loci in landraces of a given cluster suggests isolation of those from other landraces and further suggests they may harbour rare alleles for functional traits as well.[185]

A core collection has been assembled in China and used as a foundation for marker-assisted soybean breeding.[186]

A4.2.10 State of groundnut genetic resources

Since 1996, the yield of groundnut (*Arachis hypogaea*) has varied up and down from year to year, but with an overall increase (Figure A4.3). Groundnut was grown in 2008 over a harvested area of 25 million hectares with global production of 38 million tonnes.[187] The five largest producers of groundnut in 2008 were China (38 percent of global production), India (19 percent), Nigeria (10 percent), the United States of America (6 percent), and Myanmar (3 percent). Groundnut (also known as peanut) provides high quality edible oil (36 to 54 percent) and easily digestible protein (12 to 36 percent). It is an important crop, cultivated either as a grain legume or an oilseed in 113 countries.[188] Groundnut is an allotetraploid species ($2n = 4x = 40$) thought to have originated in the region of South America encompassing the southern regions of the Plurinational State of Bolivia and northwestern Argentina.[189] The genus *Arachis* comprises 80 species placed in nine sections. The section *Arachis* contains cultivated groundnut. Wild diploid *Arachis* species in South America are promising pest and disease resistance gene sources for groundnut breeding programmes.[190, 191]

In situ conservation status

Regeneration of groundnut wild relatives is problematic. Ideally conservation strategies for *in situ* conservation should be developed for wild taxa of groundnut.[192]

Ex situ conservation status

The largest groundnut collection is that at ICRISAT consisting of 15 419 accessions (12 percent of the world's 128 461 accessions). Other organizations holding considerable numbers of accessions include the USDA-ARS in the United States of America, the NBPGR in India, INTA in Argentina and the ICGR-CAAS in China.[193]

Genetic erosion and vulnerability

With the introduction of improved varieties, urbanization and natural calamities, many landraces and wild species are being eroded in different countries.[194] More specifically, geographic- and habitat-focused collecting and conservation strategies are needed for the A and B-genome diploid wild *Arachis* species in South America, where many are at risk of extinction and are not well represented in existing collections.[195]

Safety duplication

ICRISAT has proposed to duplicate its groundnut collection for deposit at the SGSV and so far has sent 4 550 accessions.[196]

Documentation, characterization and evaluation

Passport, characterization, inventory and distribution databases are being maintained for the largest groundnut collection.[197] About 97 percent of the cultivated accessions have been characterized for 50 morpho-agronomic characteristics.[198]

Utilization

Both core (10 percent of the entire collection) and mini-core (10 percent of core collection, 1 percent of entire collection) collections have been established at ICRISAT. The mini-core, comprising 184 accessions, serves as a gateway to the utilization of groundnut genetic resources in crop improvement programmes. Using the mini-core collection, trait-specific germplasm for resistance to drought, salinity and low temperature and for agronomic and seed quality traits has been identified.[199]

Role of crop in sustainable production systems

Over two-thirds of groundnut global production occurs in seasonally rainfed regions. Groundnut is suitable for different cropping patterns. Strategic evaluation of groundnut germplasm accessions combined with genetic enhancement will be important to increase food security, reduce poverty and protect the environment.[200]

A4.2.11 State of major sugar crop genetic resources

Sugarcane (*Saccharum officinarum*) and sugarbeet (*Beta vulgaris*) are the two primary species used for sugar production. The global yield of sugarcane, accounting for about 70 percent of produced sugar, has varied greatly since 1996 with a period of low yields in 2000 through 2003, but ending with a net increase (Figure A4.4). Sugarcane was cultivated in 2008 over a harvested area of 24 million hectares with a total global production of 1 743 million tonnes.[201] The six largest producers of sugarcane in 2008 were Brazil (37 percent of global production), India (20 percent), China (7 percent), Thailand (4 percent), and Pakistan and Mexico (3 percent each).

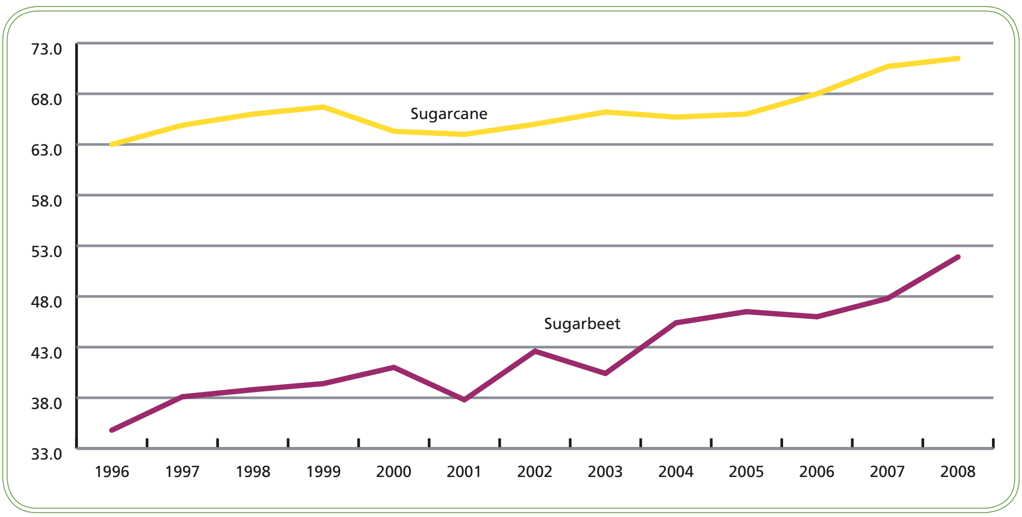
The cytotaxonomy and species relationships generating what today is the sugarcane crop plant are complex. The crop is of hybrid origin, the taxonomic status of the genus is not settled, and there may have been multiple domestication events.[202] Therefore the genepool definitions are also complicated. One presentation is that there are four species in genus *Saccharum*: *S. officinarum*, the 'type' cane of the genus, not known in the wild; *S. robustum*, the wild ancestor of *S. officinarum, S. spontaneum*, a more primitive wild ancestor than *S. robustum*; and *S. barberi*, with an unclear origin, one possibility is that it is of hybrid origin. Two separate origins for the domesticates are postulated: India and Papua New Guinea.[203] These four species would comprise the primary genepool of sugarcane and cultivars today are predominantly of hybrid origin from crosses between *S. officinarum* and one of the other species. In general, hybrid seedlings are more resistant to diseases and more adaptable to climate variables than is *S. officinarum*.[204]

A broader genepool is accessible, termed the *Saccharum* complex, and includes other genera now thought to be involved in the origin of sugarcane: *Erianthus*, *Ripidium*, *Sclerostachya*, *Narenga*, and possibly *Miscanthus*.[205] The wild species of *Saccharum* and the related genera *Erianthus* and *Miscanthus* have played important roles in the production of improved varieties of sugar cane. Their role in sugar-cane improvement will increase as breeders look into the production of high energy canes.

Sugarbeet production was not analyzed in the first SoW report, but the global yield of sugarbeet has also varied since 1995, with the perturbations coming in 2000 through 2003. There was a net increase in production by 2006 (Figure A4.4). Sugarbeet was cultivated in 2008 in a harvested area of 4.4 million hectares with a total global production of 227 million tonnes.[206] The five largest producers of sugarbeet in 2008 were France and the Russian Federation (each with 13 percent of global production), the United States of America (12 percent), Germany (10 percent), and Turkey (7 percent).

The genetic base of the sugarbeet crop (open pollinated) is considered narrow. The immediate

FIGURE A4.4
Global yields of sugar crops (tonnes per hectare)



Source: FAOSTAT 1996/2008

progenitor is the wild sea beet, a conspecific subspecies to the crop.[207] The primary genepool is the species in section *Beta* of genus *Beta*, in which the crop is also classified; two other of the four sections of the genus comprise the secondary genepool (*Corollinae* and *Nanae*), and the fourth section *Procumbentes* comprises the tertiary genepool.[208]

Ex situ conservation status

The Centro de Tecnologia Canavieira collection of sugarcane germplasm in Brazil is the largest global collection with 12 percent of the world's approximately 41 000 accessions; the Instituto Nacional de Investigación de la Caña de Azúcar in Cuba is second with 9 percent.[209]

The USDA collection of sugarbeet germplasm in the United States of America is the largest global collection with 11 percent of the world's approximately 22 500 accessions; the Genebank of the Leibniz Institute of Plant Genetics and Crop Plant Research in Germany and Institute for Field and Vegetable Crops in Serbia are close seconds with 10 percent each.[210]

Genetic erosion and vulnerability

In Belgium there has been a reduction in sugarbeet varieties cultivated.[211]

A4.2.12 State of banana/plantain genetic resources

Since 1996, the yields of banana and plantain (species in genus *Musa*) have varied slightly, ending with net increases (Figure A4.5). Bananas and plantains were each grown in 2008 over harvested areas of 5 million hectares each, 10.2 million hectares in total, with a global production of 125 million tonnes (90 and 34 million tonnes, respectively).[212] The six largest producers of banana in 2008 were India (26 percent of global production), the Philippines (10 percent), China (9 percent), Brazil (8 percent), and Ecuador (7 percent). For plantain, the largest producers were Uganda (27 percent of global production), Colombia (10 percent), Ghana, Rwanda and Nigeria (8 percent each).

The genus *Musa* represents a group of approximately 25 forest-dwelling species, divided into four sections, distributed between India and the Pacific, as far north as Nepal and extending to the northern tip of Australia. The genus belongs to the family *Musaceae*, which also comprises some seven species of *Ensete* and possibly a third, monospecific, genus *Musella*, which is closely related to *Musa*. *Musa acuminata* subsp. *banksii* is believed to be the ancestral parent of the majority of edible banana cultivars, contributing what is called the 'A' genome while *Musa balbisiana* contributed the 'B' genome to several banana cultivar groups and all plantains. The largest portion of the genepool is in the form of 12 cultivar types or genome groups.[213]

A secondary region of diversity is in Africa where the crops were introduced some 3 000 years ago and radiated into more than 60 cooking types in the highlands of East Africa and 120 plantain types in West and Central Africa.[214] An additional group of edible bananas, known as Fe'I bananas, are confined to the Pacific. Their genetic origin is obscure, but taxonomic studies suggest ancestral links either with the wild species *Musa maclayi* or *M. lododensis*.[215]

Ex situ conservation status

About 13 000 accessions of *Musa* are reportedly conserved *ex situ*. Thirty-nine collections world-wide conserve more than 100 accessions each. Altogether they account for 77 percent of the total number of *Musa* accessions conserved *ex situ*.[216]

Wild species offer potential for genetic diversity for such traits as resistance to abiotic stresses and tolerance to cold, water logging, and drought.[217] CWR currently account for 7 percent of the global collection.[218]

The vast majority of the 60 or so *Musa*-dedicated national collections manage the majority of their accessions as full-sized plants in field collections. As part of a GCDT study, twenty-five field collections were surveyed and reported to hold slightly more than 6000 accessions in total. Of these institutions, 15 hosted *in vitro* collections containing slightly more than 2 000 accessions. In addition, the INIBAP Transit Center (ITC) holds an additional 1 176 accessions *in vitro*. The *in vitro* collections are used for safety duplication of the field collections and for rapid multiplication and dissemination of disease-free planting material. About 13 national collections also have international recognition and several contribute to the long-term conservation goals of the ITC global collection.[219]

Two cryopreservation protocols are available for a range of banana cultivar groups and the ITC is implementing a program for cryopreserving its entire collection as a more cost-effective alternative for backup.[220]

Genetic erosion and vulnerability

A large proportion of national collections of banana is deteriorating due to management limitations.[221] Hurricane impacts in Grenada have resulted in severe losses to banana production, which is one of the top three major traditional crops.

Gaps and priorities

It is reported in Chapter 3 that one of the best estimates of genepool coverage is available for banana and plantain. About 300 to 400 key cultivars are known to be missing from the ITC including 20 plantains from Africa, 50 *Callimusa* from Borneo, 20 to 30 *M. balbisiana* and 20 other types from India and China, 10 accessions from Myanmar, 40 wild types from Thailand and Indonesia, and up to 100 wild types from the Pacific.

Wild species account for about 7 percent of the collections and improved varieties amount to about 19 percent.[222] New wild species and varieties continue to be described and are inadequately represented in collections. Threats posed by habitat destruction and the replacement or loss of traditional cultivars intensify the urgency for collection and conservation efforts. There is a need for larger quantities of virus-indexed material within regions.[223]

Safety duplication

Field collections are safety duplicated with *in vitro* collections.[224]

Utilization

Better descriptor and characterization information is a priority to facilitate use of banana germplasm. In addition, development and implementation of cryopreservation of protocols for banana accessions would make them more available for use.[225] While diversity is demanded by researchers and growers, many national collections and large parts of major collections are underutilized. For example, 70 percent of the ITC collection have not been requested and remain unused. A partial reason is inadequate documentation of holdings.[226]

Most national collections regularly or occasionally exchange germplasm with the ITC and since its establishment the ITC has distributed more than 60 000 germplasm samples of 450 accessions to 88 countries. Accessions are supplied without fee, but a maximum of only five plants is made available per accession. Some national and regional collections also distribute to international users. Most national collections are directly associated with breeding initiatives and many provide material directly to farmers.[227]

A4.3 State of diversity of minor crops

A4.3.1 State of millet genetic resources

Since 1996, the yield of millets has increased only slightly (Figure A4.1). Millets were grown over a harvested area of 35 million hectares with a global production of 33 million tonnes (2008).[228] They are often dual-purpose crops (human consumption and animal feed) and are important staple foods in Africa and India. The highest producers in 2008 were India (32 percent of global production), Nigeria (25 percent), Niger (11 percent), China (5 percent), Burkina Faso (4 percent), and Mali (3 percent).[229] Millets include the major millet, pearl millet (*Pennisetum* spp.), and minor millets such as finger millet (*Eleusine coracana*), Japanese barnyard millet (*Echinochloa frumentacea*), common or proso millet (*Panicum miliaceum*), and foxtail millet (*Setaria italica*).

APPENDIX 4

Ex situ conservation status

The primary global collection of pearl millet is at ICRISAT with 33 percent of the world's approximately 65 400 genebank accessions.[230] The ICGR-CAAS in China maintains 56 percent of the world's approximately 46 600 accessions of *Setaria*. The Indian National Bureau for Plant Genetic Resources maintains the largest *Eleusine* collection with 27 percent of the world's approximately 35,400 accessions. The National Institute of Agrobiological Sciences in Japan maintains the largest *Panicum* collection with 33 percent of the world's approximately 17 600 genebank accessions. ICRISAT conserves 10 193 accessions of the six small millet species.[231]

Genetic erosion and vulnerability

A number of studies and reports call attention to reduction in diversity of farmers' varieties and landraces in cultivation: traditional pearl millet varieties in Niger decreased as improved varieties were adopted by farmers;[232] absence of an early warning system threatens the diversity of indigenous cultivation of millets;[233] comparison of the number of landraces of finger millet found now in cultivation compared with that from 10 years ago showed serious genetic erosion had occurred;[234] there has been a gradual disappearance of landraces of native cultivated millets such as *Paspalum scrobiculatum*, *Setaria italica*, and *Panicum miliare*;[235] rice is replacing millet;[236] and high-yielding modern varieties of several millet species are replacing tradition varieties of those millets.[237]

Gaps and priorities

Identification of gaps in the germplasm collections is necessary to achieve completeness of the collections and direct exploration for additional accessions. For pearl millet, geographical assessment shows gaps in Burkina Faso, Chad, Ghana, Mali, Mauritania and Nigeria.

Safety duplication

A total of 8 050 pearl millet accessions were conserved as a safety backup in the SGSV, Norway and the remaining accessions will be transferred in the near future. ICRISAT has proposed to deposit the entire collection of small millet at the SGSV and to date has sent 6 400 accessions.[238]

Documentation, characterization and evaluation

Passport, characterization, inventory and distribution databases are being maintained for the pearl millet and small millets collections at ICRISAT.[239]

Utilization

In order to enhance the utilization of pearl millet germplasm, core[240] and mini-core collections have been developed. Due to the reduced size, the core and the mini-core sets have been evaluated and characterized precisely and useful trait-specific accessions have been identified for use in breeding programmes to develop cultivars with a broad genetic base. The core and mini-core collections of finger millet and foxtail millet[241] have been constituted at ICRISAT and trait-specific germplasm identified for early maturity, high yield, Fe (iron), Zn (zinc), Ca (calcium) and protein contents and for tolerance to drought and salinity.

A4.3.2 State of root and tuber crop genetic resources, other than cassava, potato and sweet potato

Since 1996, the yield of roots and tubers other than the aforementioned, treated separately, appeared to have increased through 2006; a drop in yield in 2007 was partially recovered the following year (Figure A4.2). Roots and tubers, other than cassava, potato, and sweet potato,[242] were grown in 2008 over a harvested area of 8 million hectares with global production of 72 million tonnes.[243] The seven largest producers in 2008 were Nigeria (with 56 percent of global production), Côte d'Ivoire (10 percent), Ghana and Ethiopia (each with 7 percent), and Benin, China and Cameroon (with 2 percent each).

Taro (*Colocasia esculenta*) and yam (species of *Dioscorea*) account for the bulk of this miscellany of roots and tubers. Others are ulluco (*Ullucus tuberosus*), yautia or new cocoyam (*Xanthosoma sagittifolium*), and giant swamp taro (*Cyrtosperma paeonifolius*) with regional importance in the Andes, West Africa, and Melanesia, respectively. Individually, these are all minor crops when considered on a global scale. Accordingly, research on diversity, basic biology, and species relationships has been minimal. Most is known for taro. There are two major genepools for taro: Southeast Asia and Southwest Pacific regions.[244]

Ex situ conservation status

Seed collections are not part of any aroid conservation strategies.[245] For **taro**, most collections are entirely field collections, with little use of *in vitro* conservation, and these suffer from losses, especially due to diseases. Many have been lost over the years. The primary risk is the high cost of maintenance and various biotic and abiotic stresses.[246]

Taro collections have been assembled in many countries in the Pacific and Southeast Asia as part of the TaroGen and Taro Network for Southeast Asia and Oceania (TANSAO) projects, respectively. From the 2 300 TANSAO accessions (complete with passport and characterization data), a core collection of 168 was selected based on morphological and DNA data as representative of the diversity found in the region.[247] TaroGen has done similar work in the Pacific and the regional core collection is conserved *in vitro* at the Centre for Pacific Crops and Trees at the Secretariat of the Pacific Community, Fiji.

There are also taro collections in China and India and they are characterized morphologically but no molecular information is available and no core collections from them have been established.[248]

Worldwide taro *ex situ* holdings reportedly account for a total of about 7 300 accessions.[249]

Genetic erosion and vulnerability

Both the number of farmers' varieties and wild species of taro have decreased globally in the last ten years and disease threats and replacement in production by sweet potato (in the Pacific) are among the causes in reduction in diversity of global taro cultivation.[250] Similarly at national levels, other reductions in diversity are reported: Wild yam species are considered likely to disappear soon.[251] Erosion of yam diversity is occurring both from traditional areas of cultivation and from the wild.[252] The indigenous diversity of cocoyam is under threat, in the absence of an early warning system to assess genetic erosion.[253] The market chain for some crops (e.g., species of *Colocasia* and *Xanthosoma*) is still poorly developed, and undervaluing of local crop varieties has partly contributed to the loss in diversity in such crops.[254] A study in several regions of Peru indicates that genetic erosion is ongoing in the crop species oca, ulluco, and mashua, as well as in some related wild species.[255] There is genetic erosion in yam species other than *Dioscorea alata* and cassava, attributed to acculturation, industrialization, and deforestation.[256] In its country report, Papua New Guinea claims that all root crops are threatened by replacement by rice cultivation and loss of traditional beliefs. Specifically, taro is threatened by the taro beetle, yam by labour shortages and replacement by introduced African yam, and taro kongkong by root rot disease.[257] Weather catastrophes can play a role in cultivar loss. Prior to Hurricane Ivan in 2004, the island of Grenada was self sufficient in root and tuber crop production, which has severely decreased since then.[258]

Gaps and priorities

Further collection of CWR is needed. There are gaps in collections for taro wild species representation, especially for wild taro and giant swamp taro.[259]

Many sources point out the need for funding and organization of networks for the many root and tuber crops to ensure cost effective and efficient study and conservation of these diverse taxa, especially as some (e.g. taro) are not covered by any CGIAR centre.

Safety duplication

There is a core collection of taro, that is well duplicated. The only collection of giant swamp taro is a field collection and needs duplication (preferably *in vitro*).[260]

Documentation, characterization and evaluation

Major international germplasm databases do not include edible aroids and where there is existing information it is often out of date.[261]

Utilization

The low use of taro and other aroid collections has led to vulnerability of those collections. Better coordination between improvement programmes and collections is needed. Cryopreservation protocols for taro would enhance germplasm availability.[262] The taro collections of most countries are not being used in improvement programs, adding to their vulnerability due to the high costs involved in their upkeep. Only in India, Papua New Guinea, and Vanuatu are taro collections part of crop improvement programmes.[263]

There is considerable research interest in CWR of several root and tuber crops due to their high allelic diversity. Markers to allow MAS are priorities.[264]

All the countries with major collections distribute taro germplasm within the country, albeit a modest amount, but none outside, except for Vanuatu and the Secretariat of the CePaCT in Fiji. Researchers, including breeders, are the most common recipients, rather than farmers and extension personnel. There is an indication from most countries that the amount of germplasm distributed is on the increase.[265] More attention to seed would facilitate use of collections, including directly by farmers.

Role of crop in sustainable production systems

In all countries where it is grown, **taro** plays an important role in food and nutritional security. It has a value for sustainable agriculture in midland and upland areas of the Philippines and Viet Nam. In addition to being an important food crop with high cultural value, taro is also a cash crop.[266]

Giant swamp taro plays an important role in food and nutritional security in Melanesia and the Federated States of Micronesia.[267]

For some crops (e.g., *Colocasia* spp. and *Xanthosoma* spp.) niche markets exist that can be strengthened, providing a source of income for vulnerable groups such as women.[268]

A4.3.3 State of pulse crop genetic resources, other than *Phaseolus*

Since 1996, the yield of pulses other than *Phaseolus* species was rather stable over the years (Figure A4.3). Pulses,[269] not counting *Phaseolus* species, were grown in 2008 over a harvested area of 46 million hectares with global production of 41 million tonnes.[270] The ten largest producers in 2008 were India (with 28 percent of global production), Canada (12 percent), Nigeria (7 percent), China (6 percent), the Russian Federation, Ethiopia and Australia (4 percent each), and, Niger, Turkey, and Myanmar (with 3 percent each).

Lentil (*Lens culinaris*), is one of the founding crops of agriculture, domesticated at about the same time as wheat and barley in the Fertile Crescent, from today's Jordan northward to Turkey and southeast to the Islamic Republic of Iran. A substantial portion of global lentil production is still concentrated in this area. However, the largest producers of lentils are India and Canada. The progenitor of lentil is identified as the wild subspecies *L. culinaris* subsp. *orientalis*, which looks like a miniature cultivated lentil and bears pods that burst open immediately after maturation. Selection by early farmers around 7000 BC led to the cultivated species with nondehiscent pods and nondormant seeds, more erect habit, and a considerable increase in seed size and variety in color. The crop has developed into a range of varieties adapted to diverse growing areas and cultural preferences, and containing unique nutritional compositions, colors, shapes, and tastes.[271]

Taxa contained within *L. culinaris* comprise the primary genepool for lentil. The three other species in the genus constitute the secondary-tertiary genepool. All four species are diploid (2n=14), annual, and self pollinating with a low outcrossing frequency.[272]

The genus *Cicer* comprises 42 wild species and one cultivated species, chickpea or garbanzo (*Cicer arietinum*). Chickpea is a crop of relatively minor importance on the world market, but is extremely important to local trade in numerous regions within the tropics and subtropics. Populations of what were botanically classified as a species distinct from *C. arietinum* were found by botanists in southeast Turkey and named *C. reticulatum*. However, they are cross fertile with and morphologically similar to domesticated chickpea and possibly represent wild forms of the crop species. This would suggest that chickpea was domesticated in present-day Turkey or in the northern parts of Iraq or the Syrian Arab Republic.[273]

The primary genepool for chickpea consists of varieties, landraces, *C. reticulatum*, and *C. chinospermum*. One of the species in the secondary genepool is *C. bijugum* and it is considered a priority for collection.[274]

Vicia is a large genus of 140 to 190 species, chiefly located in Europe, Asia, and North America, extending to temperate South America and tropical East Africa. Primary diversity for the genus is centered in the Near East and Middle East, with a large percentage of the species occurring in the Irano-Tauranian floristic region. Approximately 34 of the species have been utilized by humans. *V. faba* (faba bean) is cultivated primarily for its edible seeds, while a number of other species (*V. sativa*, *V. ervilia*, *V. articulata*, *V. narbonensis*, *V. villosa*, *V. benghalensis*, and *V. pannonica*.) are cultivated as a forage or grain legume for livestock, or for soil improvement.[275]

The wild progenitor and the exact origin of faba bean are unknown. In practice, a continuous variation in *V. faba* for most morphological and chemical traits has been observed, making discrete differentiation of varieties challenging.[276]

The grasspea genus *Lathyrus* comprises approximately 160 species, primarily native to temperate regions of the world, with approximately 52 species originating in Europe, 30 in North America, 78 in Asia, 24 in tropical East Africa, and 24 in temperate South America. Five *Lathyrus* species are grown as a pulse - i.e. that are harvested as a dry seed for human consumption: *L. sativus*, *L. cicera*, *L. ochrus* and, to a lesser extent, *L. clymenum*. Another species that is occasionally grown for human consumption, but for its edible tubers rather than its seed, is *L. tuberosus*, known as the tuberous pea or earthnut pea.[277]

Pigeonpea (*Cajanus cajan*), originated in India and is a major grain legume crop of the tropics and subtropics grown in about 87 countries lying between 30°N and 30°S latitudes accounting for 4.89 million harvested hectares in 2008.[278] It has wide adaptability to diverse climates and is mainly grown for its multiple uses. India is the largest producer (75 percent of total production in 2008).[279] Pigeonpea is the only cultivated species in the genus *Cajanus* and the other 31 species are wild. *Cajanus cajanifolius* is considered the progenitor of the cultivated pigeonpea species.

In situ conservation status

While perennial *Cicer* species should be collected before they are extirpated, their regeneration is problematic. Ideally conservation strategies for *in situ* conservation should be developed for these taxa.[280]

As reported in the GCDT's *Vicia faba* conservation strategy the creation of *in situ* conservation measures have been recommended for members of *Vicia* subgenus *Vicia* in the Eastern Mediterranean region, specifically, Lebanon, the Islamic Republic of Iran, Iraq, Israel, the Syrian Arab Republic, Turkey and the Caucasian Republics, with targeted sites encompassing the distinct ecogeographic preferences of individual taxa. The species within the subgenus most seriously threatened by extinction were shown to be restricted to Israel, Lebanon, the Syrian Arab Republic and Turkey; the highest concentration of potentially threatened taxa are located in the Syrian Arab Republic.[281]

Ex situ conservation status

The lentil collection at ICARDA is the single international collection and it is also the largest lentil germplasm collection holding 19 percent of the total world collections (58 405 accessions).[282] There are 43 other national collections conserving more than 100 accessions each.[283] The bulk of the accessions of most of these collections are landraces which were collected in more than 70 countries.[284]

Similarly, the faba bean collection at ICARDA is the single international collection and it is also the largest faba bean germplasm collection holding 21 percent of the total world collections (43 695 accessions).[285] There are 53 other national collections, each maintaining more than 100 accessions.[286] The bulk of the accessions of most of these collections are landraces originating from more than 80 countries.[287]

APPENDIX 4

The two global chickpea collections (ICRISAT and ICARDA) hold about 33 percent of the total world collections (98 313 accessions). There are 48 other national collections with more than 100 accessions each. The bulk of the accessions of most of these collections are landraces from more than 75 countries.[288] Although the holdings of the wild species of *Cicer* are small compared to the cultivated species *C. arietinum*,[289] they are potentially very important for research and crop improvement

The grasspea collection at ICARDA is the single international collection and the second largest grasspea germplasm collection holding 12 percent of the total world collections (26 066 accessions) which are comprised of few large collections and several small but key collections, having a high proportion of indigenous accessions.[290] The collection maintained in France is the largest. There are about 62 other national collections whose number of accessions is greater than 50; landraces and wild materials comprise the bulk of the accessions which originate from about 90 countries.[291]

The majority of chickpea, grasspea, faba bean, and lentil collections reported that they have long-term storage conditions available, however, there is no guarantee that uniform criteria were used or understood to define 'long-term' by each reporting collection. Similarly the assessments of needs for regeneration are not necessarily reported by each collection using standard protocols and seed viability measures. It is probable that for many collections, long-term storage security, regeneration, and multiplication represent major constraints for security of accessions, especially for perennial, wild, and out-crossing accessions.[292, 293, 294, 295]

Genetic erosion and vulnerability

Country reports documented a wide variety of concerns and measures of loss or reduction in genotypes of many pulse crops:

- there is genetic erosion for *Hedysarum humile*, chickpea, pea, lupin, and lentil; for wild, endemic taxa attention is not paid to diverse biotypes;[296]
- the indigenous diversity of bambara groundnut is under threat in the absence of an early warning system to assess genetic erosion;[297]
- comprehensive studies on cowpea were conducted to quantify the level of genetic erosion. As judged by the number of landraces found in cultivation today compared with that found 10 years ago, serious genetic erosion has occurred; [298]
- food legumes are at risk because of drought, increased use of new commercial varieties, and some crop-specific pests and pathogens;[299]
- in Zimbabwe, recurrent droughts, most notably the 2002 cropping season, and flooding induced by cyclones have resulted in substantial loss of *in situ* plant diversity. Disaster recovery programmes led by the Government, have, in most cases, focused on providing chiefly hybrid seed of cowpea, beans, and groundnuts, and fertilizers. There are no records of attempts to restore the landraces and other plant genetic diversity of the affected areas, which suggests that lost material was not recovered;[300]
- In Nepal, there is gradual disappearance of landraces of cowpea and of native cultivated species such as *Vigna angularis* and *Lathyrus sativus*;[301]
- various local races/cultivars of chickpea, lentil, mung, and mash were observed to be lost in recent years from farmer's fields;[302]
- there is genetic erosion in mungbean, yardlong bean, and cowpea.[303]

Gaps and priorities

For **lentil**, landraces from Morocco and China and wild species, particularly from southwest Turkey, are not well represented in collections. There are gaps in **chickpea** collections from Central Asia and Ethiopia and there are relatively few accessions of wild relatives, particularly from the secondary genepool. For **faba bean** various geographic gaps have been identified including local varieties and landraces from North Africa, the Egyptian oases, South America and China. The small-seeded subspecies, *V. faba* subsp. *paucijuga*, is also under-represented in collections and there are trait gaps, especially for heat tolerance. Geographic gaps for **grasspea** include the Russian Black Sea coast and Volga-Kama region, the Kurdish area of Iraq, Northeast and Eastern India, high altitude areas of Ethiopia, Northeast and Central Afghanistan, and the Andalucia and Murcia regions of Spain. An important consideration for many legume collections is the need to collect and maintain samples of rhizobia. This is especially the case for wild legume species, but such rhizobia collections are rare (see also Chapter 3).[304, 305, 306, 307]

There are regeneration needs for chickpea, grasspea, lentil, and wild species of pigeonpea.[308]

Landraces of lentil in Morocco and in China are potentially undersampled and hence under-represented in germplasm collections.[309]

Landraces of chickpea from the Hindu-Khush Himalayan region, west and northern China, Ethiopia, Uzbekistan, Armenia, and Georgia are under-represented in collections. The world collection covers very little of the wild distribution for the *Cicer* genus, thus the accessions in *ex situ* collections represent only a fraction of the potential diversity available in wild populations.[310]

Species related to chickpea and lentil are greatly undersampled geographically in collections. Species related to grasspea are poorly known and both grasspea and pigeonpea CWR are not well collected.[311]

Research into regeneration and conservation protocols for wild chickpea and lentil species is a high priority.[312, 313]

Safety duplication

It is apparent that many important lentil, faba bean, chickpea, grasspea collections are inadequately duplicated and are thus at risk. Safety duplication requires a formal arrangement. The fact that an accession is present in another collection does not immediately signify that the accession is safety duplicated in long-term conservation conditions. At a minimum all unique materials should be duplicated for safety reasons, preferably in a second country. Depositions of safety backup samples with the SGSV is underway, especially by the global collections (e.g., those at ICARDA and ICRISAT).[314, 315, 316, 317] For example, ICRISAT has already deposited 5 000 of its 13 289 pigeonpea accessions with the SGSV.[318]

Documentation, characterization and evaluation

Some chickpea and lentil databases are not yet internet accessible, a global registry for each and documentation training are needed. Only a minority of grasspea databases are internet accessible, but there is a *Lathyrus* global information system managed by Bioversity and ICARDA which is available.[319]

Many chickpea and lentil accessions are not yet characterized or evaluated and little of the data that are available is electronically accessible.[320, 321]

Information currently held on *Vicia faba* accessions in collections is often fragmented and not easily accessible outside the institution. Genebank information systems generally need strengthening. Technical advice for information systems is needed.[322]

Utilization

Chickpea CWR have been sources of resistance used in breeding programs. Lentil CWR have been used in breeding programs to broaden the genetic base and provide genes for tolerance and resistance. Pigeonpea CWR are sources of resistance and protein.[323]

Lentil, faba bean, and chickpea genetic resources are underutilized due to deficiencies in accession level data; suboptimal availability and accessibility of that data; lack of pre-breeding, core-collection creation, and other 'value-adding' work in genebanks; and few collaborative relationships with user communities.[324, 325, 326] However, a core collection (10 percent of the entire ICRISAT collection) and a mini-core collection (10 percent of the core collection) for chickpea[327] and a core collection and a mini-core collection for pigeonpea[328] have been established.

Almost all national collections of faba beans appear to be distributing almost entirely to domestic users.[329]

Higher and more stable yields are key breeding objectives for chickpea. Some of the wild relatives have been utilized in breeding programs and resistance to abiotic and biotic stresses have been incorporated into the crop from *Cicer reticulatum* and *C. echinospermum*, chickpea's closest relatives.[330]

Constraints in chickpea and lentil germplasm utilization are deficient data (and data access) about accessions, lack of pre-breeding, and collaborative relationships. Similarly, lack of accession information is a constraint for grasspea germplasm. For pigeonpea germplasm, constraints include inadequate accession data, difficulty in use of CWR, genetic contamination in collections, absence of pest and disease resistance traits, and poor interaction between breeders and collections' curators.[331]

There are relatively few efforts throughout the world to genetically improve grasspea. There are some important programs that aim to improve its yield, resistance to biotic and abiotic stresses and, most importantly, to reduce the percentage, or ideally eliminate, the neurotoxin from the seed. However, local landraces and cultivars are being lost as farmers switch to alternative crops, potentially limiting the progress that can be made through genetic enhancement.[332]

Role of crop in sustainable and organic production systems

Chickpea is grown and consumed in large quantities from South East Asia across the Indian sub-continent, and throughout the Middle East and Mediterranean countries, playing an important cultural as well as nutritional role. Over 95 percent of production and consumption of chickpea takes place in developing countries. The crop meets up to 80 percent of its nitrogen requirement from symbiotic nitrogen fixation and can fix up to 140 kg nitrogen per hectare per season from the air.[333]

Lentil plants provide a number of functions aside from being sources of human food. Lentil straw is an important fodder for small ruminants in the Middle East and North Africa, and through nitrogen sequestration, the plant improves soil fertility and therefore increases sustainability of agricultural production systems.[334]

Pigeonpea has wide adaptability to diverse climates and soils. About 92 percent of pigeonpea cultivation is in developing countries. Due to its multiple uses as food, fodder, fuelwood, hedges, windbreaks, soil binder and soil enricher. It is also used as green manure and for roof thatching and rearing lac insects in Malawi, the United Republic of Tanzania and Zambia in Africa. As it is also used in many cropping systems, it therefore plays an important role in sustainable production systems.[335]

Because of the extreme tolerance of grasspea to difficult environmental conditions, including both drought and water-logging, it often survives when other crops are decimated. However, in years when conditions are particularly harsh, human consumption of this survival food may increase, due to the lack of any suitable alternative, especially among the poorest rural people, to a level at which there is a severe risk of the consumer succumbing to a neurological disorder, lathyrism, caused by the presence of a neurotoxin in the seed. The toxicity results in irreversible paralysis, characterized by lack of strength in, or inability to move the lower limbs. It is particularly prevalent in some areas of Bangladesh, Ethiopia, India, and Nepal, and affects more men than women.[336]

Grasspea is important locally for the poorest of the poor in many of the harshest agro-environments, especially in South Asia and Ethiopia.[337]

A4.3.4 State of grape genetic resources

During 1996-2004 the yield of grapes (*Vitis*) increased, since then it has remained constant (Figure A4.5). Grapes were grown in 2008 over a harvested area of 7 million hectares with global production of 68 million tonnes.[338] The five largest producers of grapes in 2008 were Italy (12 percent of global production), China (11 percent), the United States of America and Spain (9 percent each) and France (8 percent).

In situ conservation status

Little information was available from the country reports on actual numbers of traditional varieties maintained in farmers' fields. Some 525 indigenous grape varieties are still being grown in the mountainous countryside and isolated villages in Georgia,[339] while in the Western Carpathians of Romania, more than 200 local landraces of crops have been identified.[340]

Ex situ conservation status

Approximately 59 600 accessions of *Vitis* are held in the world's genebanks. The six largest hold between nine and four percent of the total accessions each.[341] The project "Management and Conservation of Grapevine Genetic Resources", funded under the European Union Council Regulation (EC) No 870/2004", lasting four years (2007-2010), has the goal of promoting an optimized scheme for the safe conservation of *Vitis* germplasm, including *V. sylvestris* presently threatened with local extinction and involving several conservation means (*ex situ* collections, cryopreservation, on-farm conservation) so that the resources are conserved, made accessible and field-tested in a pertinent agricultural context.[342]

Field collections have been established for the 70 most important autochthonous grapevine cultivars in Portugal.[343] Field collections of local cultivars can also be found in Albania, Armenia, Azerbaijan, Bulgaria, Croatia, France, Georgia, Germany, Italy, Montenegro, Republic of Moldova, the Russian Federation, Serbia, The former Yugoslav Republic of Macedonia and Ukraine.[344] Conservation of grapevine genetic resources in the Caucasus and North Black Sea area has been promoted since 2003 under the coordination of IPGRI (now Bioversity International). New collections of local varieties have been established in Armenia, Azerbaijan, Georgia and the Russian Federation.[345]

Genetic erosion and vulnerability

Traditional grapevine varieties are still used. However the number of varieties used at a large scale has been substantially reduced.[346] The traditional grapevine crop is threatened by genetic erosion in Portugal.[347] The ECPGR Working Group on Vitis expressed serious concern for genetic erosion of the grapevine variability and clonal diversity. The causes of this erosion were listed as follows:[348]

- increased international trade;
- predominance of a small number of varieties in several countries;
- predominance of a few clones of each single variety;
- a decrease in the area of land devoted to viticulture, especially in those sites particularly rich in biodiversity;
- restrictive laws not allowing the use of traditional varieties for planting and marketing.

Recommendations were also expressed that each country should maintain its own traditional varieties in national or regional ampelographic collections and should also protect *V. sylvestris in situ*, as well as strive to preserve clonal variability as far as possible.

Documentation, characterization and evaluation

The European Vitis Database has been maintained since 2007 by the JKI and the Institute for Grapevine Breeding Geilweilerhof, Siebeldingen, Germany. The aim of the database is to enhance the utilization of relevant and highly valuable germplasm in breeding. The database contains passport data of more than 31 000 accessions representing 31 *Vitis* collections from 21 European countries. Characterization and evaluation data on phenology, yield, quality and biotic stresses are also available for about 1 500 accessions.[349]

Utilization

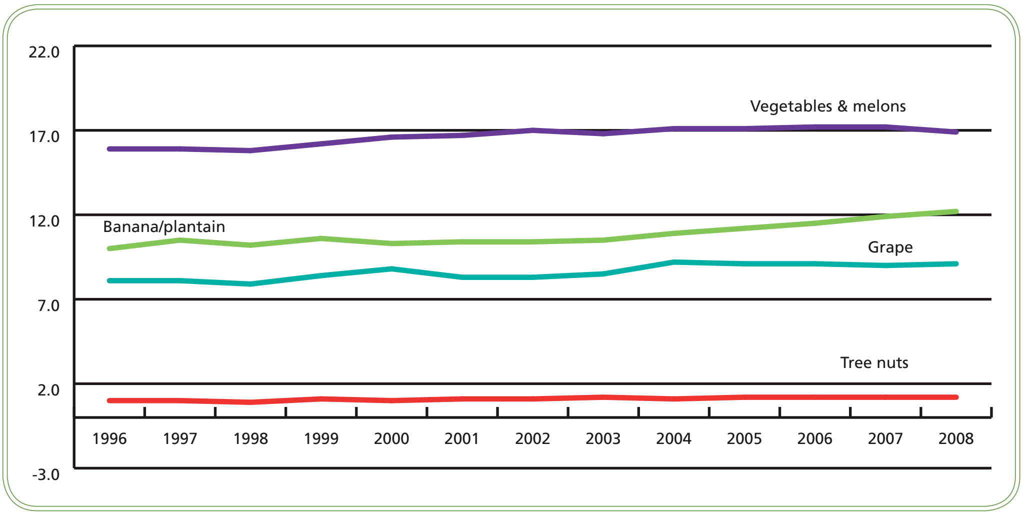
Efforts to enhance access to diversified grape genetic resources and to promote the improvement of varieties, tastes, products and brands also by limiting the impact of grape cultivation on the environment through a reduced use of pesticides, are being supported by the European Union-funded project GrapeGen06 (2007-2010). The project is being accomplished in collaboration with wine growers and professional organizations. It also supports characterization of grape genetic resources, some of which are today either forgotten, endangered or underexploited.[350]

A4.3.5 State of tree nut genetic resources

Since 1996, the yield of tree nuts has moderately grown (Figure A4.5).[351] Tree nuts were grown in 2008 over a harvested area of nine million hectares with global production of eleven million tonnes.[352] The six largest producers in 2008 were the United States of America (with 15 percent of global production), China (14 percent), Turkey and Viet Nam (11 percent), and India and Nigeria (6 percent each). China produced the most diverse assemblage of this large group of tree nuts with 6 out of 8 of them, the United States of America, Italy, and Turkey each produced 5, and the Islamic Republic of Iran and Pakistan each produced 4.

APPENDIX 4

FIGURE A4.5
Global yields of miscellaneous crops (tonnes per hectare)



Source: FAOSTAT 1996/2007

Ex situ conservation status

- Cashew nut (*Anacardium occidentale*): about 9 800 accessions are conserved in world genebanks, with 35 percent of the accessions maintained in Ghana, 9 percent in India, 8 percent in Thailand and about 6 percent in both Brazil and Nigeria;[353]
- Almond (under synonyms *Prunus amygdalus*, *P. dulcis* and *Amygdalus communis*): about 3 000 accessions are conserved in the world with the main collections in Italy, the Islamic Republic of Iran and Turkey;[354]
- Hazelnut (species of *Corylus*): about 3 000 accessions are conserved worldwide, 28 percent of which are held in the United States of America and 14 percent in Turkey;[355]
- Pistachio (*Pistacia vera*): about 1 200 accessions are in world collections, with 29 percent in the Islamic Republic of Iran and 26 percent in the United States of America;[356]
- Chestnut (*Castanea sativa*): about 1 600 accessions are conserved worldwide, 75 percent of which are in France, Japan, Italy and Spain;[357]
- Brazil nut (*Bertholletia excelsa*): only about 50 accessions are held in world genebanks, mostly in Brazil.[358]

Documentation, characterization and evaluation

The European Union-funded project GEN RES 68 for the Safeguard of hazelnut and almond genetic resources (SAFENUT) (2007–2010) ensures data acquisition of the genetic diversity present in the European Mediterranean Basin, *ex situ* and *in situ* collections of *Corylus avellana* and *Prunus dulci*, as well as characterization of interesting genotypes, with particular attention to the nutritional and nutriceutical aspects of nuts.[359] Documentation of European almond accessions was part of the European Union-funded project GEN RES 61 on *Prunus* (International Network on *Prunus* genetic resources [1996–1999]). A European *Prunus* Database (EPDB) was prepared including passport, characterization and evaluation data.[360]

Genetic erosion and vulnerability

Wild almond trees in Georgia are under threat due to the replacement by new varieties.[361]

In the Beka'a Valley in Lebanon, all commercial almond orchards consist of one or two early-blooming varieties, thus susceptible to spring frost, explaining the observed decrease in national almond production in certain years.[362]

A4.3.6 State of vegetable and melon genetic resources

The yield of vegetables and melons increased slightly during 1996-2002, since then it has remained relatively constant (Figure A4.5).[363] Vegetables and melons were grown in 2008 over a harvested area of 54 million hectares with a global production of 916 million tonnes.[364] The six largest producers in 2008 were China (50 percent of global production), India (9 percent), the United States of America (4 percent), Turkey (3 percent), and the Russian Federation and the Islamic Republic of Iran (2 percent each). China produced the most diverse assemblage of this large group of vegetables and melons with 24 out of 25 of them, the United States of America produced 23, Turkey, Spain, and Mexico produced 20 each, Japan produced 19, and Italy produced 18. The eight most produced vegetables in 2008 were tomatoes (under synonyms *Lycopersicon esculentum*, *Solanum lycopersicum*, etc.) accounting for 14 percent of total production within the vegetables and melons group, followed by watermelons (*Citrullus lanatus*) with 11 percent, cabbages and other brassicas (*Brassica* spp.) 8 percent, dry onions (*Allium* cepa) 7 percent, cucumbers and gherkins (*Cucumis sativus*) 5 percent, eggplants (*Solanum melongena*) 4 percent, and other melons including cantaloupes (*Cucumis* spp.) and peppers (*Capsicum* spp.) 3 percent each.

Ex situ conservation status

Approximately half a million accessions of vegetable crops are conserved *ex situ* worldwide.[365] Landraces and traditional and advanced cultivars represent about 36 percent of these total holdings, wild materials about 5 percent and genetic stocks 8 percent. AVRDC holds about 57 000 accessions of vegetable germplasm including some of the largest world vegetable collections. About 35 percent of total vegetable accessions are conserved in the national genebanks of nine countries.[366]

- Tomato: almost 84 000 accessions are conserved in genebanks worldwide, 19 percent of these are advanced cultivars, 17 percent old cultivars and landraces, 18 percent genetic stocks and research materials, and 4 percent CWR. The two largest tomato collections are at AVRDC (about 9 percent of the total world collections) and USDA Northeast Regional Plant Introduction Station (8 percent);[367]
- Pepper (*Capsicum* spp.): the global holdings of peppers account for about 73 500 accessions from more than 30 *Capsicum* species. The six largest *Capsicum* collections are at AVRDC (about 11 percent of the total world collections), the USDA Southern Regional Plant Introduction Station and INIFAP in Mexico (6 percent each), NBPGR in India (5 percent), the Instituto Agronómico de Campinas in Brazil and the National Institute of Agrobiological Sciences (NIAS) in Japan (3 percent each);[368]
- Cantaloupe (*Cucumis* spp.): about 44 300 accessions are conserved worldwide, 3 percent of these are wild relatives. *C. melo* is represented by 52 percent of the total accessions and *C. sativum* by 38 percent. The six largest collections are held in the United States of America, Japan, the Russian Federation, China, Brazil and Kazakhstan;[369]
- *Cucurbita* spp.: total accessions for this genus amount to 39 583, of these 9 867 accessions are *C. moschata*, 8 153 accessions are *C. pepo* and 5 761 accessions are *C. maxima*. The largest collections of this genus are found at VIR in the Russian Federation (15 percent of the total world collection), CATIE (7 percent) and CENARGEN in Brazil (5 percent). CWR are relatively poorly represented accounting for only 2 percent of the total *ex situ* germplasm of *Cucurbita*;[370]
- *Allium* spp.: about 30 000 accessions are conserved *ex situ*. Onions (*A. cepa*) are represented by 15 326 accessions and garlic (*A. sativum*) by 5 043 accessions. More than 200 additional *Allium* species

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are also conserved. CWR are well represented in the collections of the Leibniz Institute of Plant Genetics and Crop Plant Research in Germany and of the Millennium Seed Bank Project, Royal Botanic Gardens in the United Kingdom;[371]

- Eggplant (*Solanum melongena*): total world collections amount to about 21 000 accessions. The three largest collections with more than 1 000 accessions each, are at NBPGR in India, AVRDC and NIAS in Japan; altogether they account for 35 percent of the total *ex situ* holdings. CWR represent 11 percent of the total accessions;[372]
- Watermelon (*Citrullus lanatus*): more than 15 000 accessions constitute the world collection, 42 percent of which is conserved in the Russian Federation, China, Israel and the United States of America;[373]
- Carrot (*Daucus carota*): about 8 300 accessions from 19 *Daucus* species are conserved worldwide. The three largest collections with more than 1 000 accessions each, are at the USDA North Central Regional Plant Introduction Station in the United States of America (14 percent of the total accessions), the Horticultural Research International, University of Warwick in the United Kingdom (13 percent), and at VIR in the Russian Federation (12 percent). CWR represent 14 percent of the total accessions.[374]

Genetic erosion and vulnerability

A diversity of countries reported instances of concern for diversity of several different vegetables:

- in Madagascar several vegetable crops (carrot, turnip, eggplant, onion, and cauliflower) are at risk from new commercial varieties (Madagascar Country Report);[375]
- in Trinidad and Tobago there is loss of diversity in vegetables crops;[376]
- in Nepal there is gradual disappearance of cabbage and cauliflower landraces;[377]
- in Pakistan, due to market demand and unavailability of local seeds, the rate of genetic erosion has been very high in major vegetables like tomatoes, onions, peas, okra, brinjal (eggplant), cauliflower, carrots, radish, and turnips. Indigenous diversity is still found in cucurbits, bitter gourd, spinach, luffa, and species of *Brassica*. The genetic resources of indigenous underutilized minor-crop species face rapid destruction owing to the erosion of traditional farming culture, change of traditional food habits, and the introduction of high yielding crops;[378]
- in the Philippines, there is genetic erosion in eggplant, bitter gourd, sponge gourd, bottle gourd, and tomato;[379]
- in Tajikistan, due to importing new varieties and hybrids and lack of seeds of local varieties, the rate of genetic erosion has been very high in major vegetables like cucumbers, tomatoes, onions, cabbage, carrots, radish, black radish, turnips, etc.;[380]
- in Greece genetic erosion in vegetable crops, due to the replacement of local germplasm by modern varieties, has been 15 to 20 years behind the rate in cereals, however, in recent years, local landraces are being rapidly displaced even from backyard gardens;[381]
- in Ireland, commercial horticultural production is dominated by imported modern high-yielding varieties, few or no landraces or farmers' varieties are grown. In contrast, great diversity in horticulture crops is found in the various private gardens around the nation in the form of home-saved seed.[382]

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[270] Op cit. Endnote 28.

[271] **GCDT.** 2008. Global strategy for the *ex situ* conservation of lentil (*Lens* Miller). Global Crop Diversity Trust. Rome, Italy. http://www.croptrust.org/documents/web/LensStrategy_FINAL_3Dec08.pdf

[272] Op cit. Endnote 251.

[273] **GCDT.** 2008. Global strategy for the *ex situ* conservation of chickpea (*Cicer* L.). Global Crop Diversity Trust. Rome, Italy. http://www.croptrust.org/documents/web/CicerStrategy_FINAL_2Dec08.pdf

[274] Ibid.

[275] **GCDT.** 2009. Global strategy for the *ex situ* conservation of faba bean (*Vicia faba* L.). Global Crop Diversity Trust. Rome, Italy. http://www.croptrust.org/documents/web/Faba_Strategy_FINAL_21April09.pdf

[276] Ibid.

[277] **GCDT.** 2007. Strategy for the *ex situ* conservation of *Lathyrus* (grass pea), with special reference to *Lathyrus sativus, L. cicera, L. ochrus.* Global Crop Diversity Trust. Rome, Italy. http://www.croptrust.org/documents/web/Lathyrus-Strategy-FINAL-31Oct07.pdf

[278] Op cit. Endnote 34.

[279] Op cit. Endnote 34.

[280] Op cit. Endnote 275.

[281] Op cit. Endnote 275.

[282] Op cit. Endnote 34.

[283] Op cit. Endnote 34.

[284] Op cit. Endnote 34.

[285] Op cit. Endnote 34.

[286] Op cit. Endnote 34.

[287] Op cit. Endnote 34.

[288] Op cit. Endnote 34.

[289] Op cit. Endnote 34.

[290] Op cit. Endnote 34.

APPENDIX 4

[291] Op cit. Endnote 34.

[292] Op cit. Endnote 271.

[293] Op cit. Endnote 273.

[294] Op cit. Endnote 275.

[295] Op cit. Endnote 277.

[296] Country report: Algeria.

[297] Country report: Ghana.

[298] Country report: Malawi.

[299] Country report: Morocco.

[300] Country report: Zimbabwe.

[301] Country report: Nepal.

[302] Country report: Pakisan.

[303] Country report: Philippines.

[304] Op cit. Endnote 271.

[305] Op cit. Endnote 273.

[306] Op cit. Endnote 275.

[307] Op cit. Endnote 277.

[308] Op cit. Endnote 23.

[309] Op cit. Endnote 271.

[310] Op cit. Endnote 273.

[311] Op cit. Endnote 23.

[312] Op cit. Endnote 273.

[313] Op cit. Endnote 271.

[314] Op cit. Endnote 271.

[315] Op cit. Endnote 273.

[316] Op cit. Endnote 275.

[317] Op cit. Endnote 277.

[318] Op cit. Endnote 196.

[319] Op cit. Endnote 23.

[320] Op cit. Endnote 273.

[321] Op cit. Endnote 271.

[322] Op cit. Endnote 275.

[323] Op cit. Endnote 23.

[324] Op cit. Endnote 271.

[225] Op cit. Endnote 275.

[326] Op cit. Endnote 273.

[327] **Upadhyaya, H.D. & Ortiz, R.** 2001. A mini-core subset for capturing diversity and promoting utilization of chickpea genetic resources in crop improvement. *Theor. Appl. Genet.,* 102:1292-1298.

[328] **Upadhyaya, H.D., Reddy, L.J., Gowda, C.L.L., Reddy, K.N. & Singh, S.** 2006. Development of mini-core subset for enhanced and diversified utilization of pigeonpea germplasm resources. *Crop Science,* 46:2127-2132.

[329] Op cit. Endnote 275.

[330] Op cit. Endnote 273.

[331] Op cit. Endnote 23.

[332] Op cit. Endnote 277.

333 Op cit. Endnote 273.

334 Op cit. Endnote 271.

335 Op cit. Endnote 196.

336 Op cit. Endnote 277.

3372 Op cit. Endnote 277.

338 Op cit. Endnote 28.

339 Country report: Georgia.

340 Country report: Romania.

341 Op cit. Endnote 34.

342 **GrapeGen06**; http://www1.montpellier.inra.fr/grapegen06/accueil.php

343 Country report: Portugal.

344 **Maul, E., Eiras Dias, J.E., Kaserer, H., Lacombe, T., Ortiz, J.M., Schneider, A., Maggioni, L. & Lipman, E.** (compilers) 2008. ECPGR Report of a Working Group on *Vitis*. First Meeting, 12–14 June 2003, Palić, Serbia and Montenegro. Bioversity International, Rome, Italy.

345 **Maghradze, D., Failla, O., Turok, J., Amanov, M., Avidzba, A., Chkhartishvili, N., Costantini, L., Cornea, V., Hausman, J-F., Gasparian, S., Gogishvili, K., Gorislavets, S., Maul, E., Melyan, G., Pollulyakh, A., Risovanava, V., Savin, G., Scienza, A., Smurigin, A., Troshin, L., Tsertsvadze, N. & Volynkin, V.** 2006. Conservation and sustainable use of grapevine genetic resources in the Caucasus and Northern Black Sea region. Poster presented at the Ninth International Conference on Grape Genetics and Breeding, Udine, Italy, 2-6 July 2006. http://www.vitis.ru/pdf/magh2.pdf

346 Country report: Greece.

347 Country report: Portugal.

348 Op cit. Endnote 344.

349 The European *Vitis* Database, http://www.eu-vitis.de/index.php

350 Ibid. **GrapeGen06**.

351 Almond, Brazil nut, cashew, chestnut, hazelnut, pistachio, walnut, and nuts not elsewhere counted.

352 Op cit. Endnote 28.

353 Op cit. Endnote 34.

354 World Information and Early Warning System on PGRFA (WIEWS), http://apps3.fao.org/wiews/wiews.jsp?i_l=EN

355 Op cit. Endnote 34.

356 Op cit. Endnote 34.

357 Op cit. Endnote 354.

358 Op cit. Endnote 354.

359 SAFENUT, http://safenut.casaccia.enea.it/

360 Genetic Resources in Agriculture: A Summary of the Projects Co-Financed Under Council Regulation (EC) No 1467/94, Community Programme 1994-99, http://ec.europa.eu/agriculture/publi/genres/prog94_99_en.pdf

361 Country report: Georgia.

362 Country report: Lebanon.

363 Artichokes, asparagus, beans (green), cabbages, carrots and turnips, cauliflower and broccolis, chillies and peppers (green), cucumbers and gherkins, eggplants, garlic, leguminous vegetables not counted elsewhere, lettuce and chicory, maize (green), mushrooms, okra, onions (green), onions (dry), cantaloupes and other melons, peas (green), pumpkins and squash, spinach, beans (string), tomatoes, fresh vegetables not counted elsewhere and watermelons.

364 Op cit Endnote 28.

APPENDIX 4

366 Ibid. Endnote 354.

366 Brazil, China, France, Germany, India, Japan, the Philippines, the Russian Federation and the United States of America.

367 Op cit. Endnote 34.

368 Op cit. Endnote 34.

369 Op cit. Endnote 34.

370 Op cit. Endnote 34.

371 Op cit. Endnote 34.

372 Op cit. Endnote 34.

373 Op cit. Endnote 34.

374 Op cit. Endnote 34.

375 Country report: Madagascar.

376 Country report: Trinidad and Tobago.

377 Country report: Nepal.

378 Country report: Pakistan.

379 Country report: Philippines

380 Country report: Tajikistan.

381 Country report: Greece

382 Country report: Ireland

Abbreviations and acronyms

AARI	Aegean Agricultural Research Institute of Turkey
AARINENA	Association of Agricultural Research Institutions in the Near East and North Africa
ABI	Institute for Agrobotany (Hungary)
ABS	Access and benefit-sharing
Acc.	Accessions
ACCI	African Centre for Crop Improvement
ACIAR	Australian Centre for International Agricultural Research
ACSAD	Arab Centre for the Study of Arid Zones and Dry Lands
AD-KU	Department of Agronomy, Faculty of Agriculture, University of Kasetsart (Thailand)
ADMARC	Agricultural Development and Marketing Corporation
AEGIS	A European Genebank Integrated System
AFLP	Amplified Fragment-Length Polymorphism
AGRESEARCH	Margot Forde Forage Germplasm Centre, Agriculture Research Institute Ltd (New Zealand)
AICRP-Soybean	All India Coordinated Research Project on Soybean (India)
AMFO	G.I.E. Amelioration Fourragère (France)
AMGRC	Australian Medicago Genetic Resource Centre, South Australian Research and Development Institute
ANGOC	Asian NGO Coalition for Agrarian Reform and Rural Development
AOAD	Arab Organization for Agricultural Development
APAARI	Asia-Pacific Association of Agricultural Research Institutions
ARC (LBY001)	Agricultural Research Centre (Libyan Arab Jamahiriya)
ARC (SDN001)	Plant Breeding Section, Agricultural Research Corporation (Sudan)
AREO	Agricultural Research and Education Organization, Iran (Islamic Republic of)
ARI (CYP004)	National (CYPARI) Genebank, Agricultural Research Institute, Ministry of Agriculture, Natural Resources and Environment (Cyprus)
ARI (ALB002)	Agricultural Research Institute (Albania)
ARIPO	African Regional Industrial Property Organization
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASEAN	Association of Southeast Asian Nations
ASN	Africa Seed Network
ASPNET	Asia-Pacific Network
ATCFC	Australian Tropical Crops & Forages Genetic Resources Centre
ATFCC	Australian Temperate Field Crops Collection
AusPGRIS	Australian Plant Genetic Resource Information Service
AVRDC	World Vegetable Centre (former Asian Vegetable Research and Development Centre)
AWCC	Australian Winter Cereals Collection
AYR-DPI	Mango Collection, Ayr, Department of Primary Industries (Australia)

BAAFS	Beijing Academy of Agriculture and Forestry Sciences (China)
BAL	Banco Activo de Germoplasma de Papa, Forrajeras y Girasol Silvestre (Argentina)
BAP	Banco Activo de Germoplasma de Pergamino (Argentina)
BAPNET	Banana Asia Pacific Network
BARI	Plant Genetic Resources Centre (Bangladesh)
BARNESA	Banana Research Network for Eastern and Southern Africa
BAZ	Federal Centre of Breeding Research on Cultivated Plants (Braunschweig, Germany)
BB	Banana Board (Jamaica)
BBC-INTA	Banco Base de Germoplasma, Instituto de Recursos Biológicos, Instituto Nacional de Tecnología Agropecuaria (Argentina)
BCA	Bunda College of Agriculture (Malawi)
BCCCA	Biscuit, Cake, Chocolate and Confectionery Association
BECA	Biosciences Eastern and Central Africa
BGCI	Botanic Garden Conservation International
BGRI	Borlaug Global Rust Initiative
BGUPV	Generalidad Valenciana, Universidad Politécnica de Valencia. Escuela Técnica Superior de Ingenieros Agrónomos, Banco de Germoplasma (Spain)
BG-VU	Botanical Garden, Vilnius University (Lithuania)
BINA	Bangladesh Institute of Nuclear Agriculture
BJRI	Bangladesh Jute Research Institute
BNGGA-PROINPA	Fundación para la Promoción e Investigación de Productos Andinos, Regional Altiplano (Bolivia, Plurinational State of)
BNGTRA-PROINPA	Banco Nacional de Germoplasma de Tubérculos y Raíces Andinas, Fundación para la Promoción e Investigación de Productos Andinos (Bolivia, Plurinational State of)
BPGV-DRAEDM	Portuguese Bank of Plant Germplasm
BRDO	Biotechnology Research and Development Office (Thailand)
BRGV Suceava	Suceava Genebank (Romania)
BRRI	Bangladesh Rice Research Institute
BSRI	Bangladesh Sugarcane Research Institute
BTRI	Bangladesh Tea Research Institute
BVRC	Beijing Vegetable Research Centre (China)
BYDG	Botanical Garden of Plant Breeding and Acclimatization Institute (Poland)
CAAS	Chinese Academy of Agricultural Sciences
CABMV	Cowpea Aphid-Borne Mosaic Virus
CACAARI	Central Asia and the Caucasus Association of Agricultural Research Institutions
CacaoNet	Global Cacao Genetic Resources Network
CACN-PGR	Central Asian and Caucasian Network on Plant Genetic Resources
CAPGERNET	Caribbean Plant Genetic Resources Network
CARBAP	Centre Africain de Recherches sur Bananiers et Plantains

CARDI	Caribbean Agricultural Research and Development Institute
CAS-IP	Central Advisory Service on Intellectual Property
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
CBD	Convention on Biological Diversity
CBDC	Community Biodiversity Development Conservation
CBG	Central Botanical Garden (Azerbaijan)
CBICAU	Crop Breeding Institute (Zimbabwe)
CBNA	Conservatoire Botanique National Alpin de Gap-Charance (France)
CC	Cartón de Colombia S.A.
CCSM-IASP	Centro de Citricultura «Sylvio Moreira», Instituto Agronomico de São Paulo (Brazil)
CCRI	Central Cotton Research Institute, Multan (Pakistan)
CEARD	Centre of Excellence for Agrobiodiversity Resources and Development of China
CENARGEN	Embrapa Recursos Genéticos e Biotecnologia (Brazil)
CENICAFE	Centro Nacional de Investigaciones de Café "Pedro Uribe Mejia", Federación Nacional de Cafeteros de Colombia
CePaCT	Centre for Pacific Crops and Trees
CEPEC	Centro de Pesquisa do Cacao (Brazil)
CERI	Cereal Institute, National Agricultural Research Foundation (Greece)
CGIAR	Consultative Group on International Agricultural Research
CGN	Centre for Genetic Resources
CGRFA	Commission on Genetic Resources for Food and Agriculture
CIAT	Centro Internacional de Agricultura Tropical
CICR	Central Institute for Cotton Research (India)
CIFACOR	Junta de Andalucía, Instituto Andaluz de Investigación Agroalimentaria y Pesquera, Centro de Investigación y Formación Agroalimentaria Córdoba (Spain)
CIFAP-CAL	Centro de Investigaciones Forestales y Agropecuarias, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (Mexico)
CIFP	Centro de Investigaciones Fitoecogenéticas de Pairumani (Bolivia, Plurinational State of)
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CIP	Centro Internacional de la Papa
Cirad	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
CIS	Commonwealth of Independent States
CISH	Central Institute for Subtropical Horticulture (India)
CITH	Central Institute of Temperate Horticulture (India)
CLAN	Cereal and Legume Asia Network
Clayuca	Consorcio Latinoamericano y del Caribe de Apoyo a la Investigación y al Desarrollo de la Yuca

CN	Centre Néerlandais (Côte d'Ivoire)
CNPA	Embrapa Algodão (Brazil)
CNPAF	Embrapa Arroz e Feijão (Brazil)
CNPAT	Embrapa Agroindústria Tropical (Brazil)
CNPF	Embrapa Florestas (Brazil)
CNPGC	Embrapa Gado de Corte (Brazil)
CNPH	Embrapa Hortaliças (Brazil)
CNPMF	Embrapa Mandioca e Fruticultura Tropical (Brazil)
CNPMS	Embrapa Milho e Sorgo (Brazil)
CNPq	Conselho Nacional de Desenvolvimento Científico e Tecnológico
CNPSO	Embrapa Soja (Brazil)
CNPT	Embrapa Trigo (Brazil)
CNPUV	Embrapa Uva e Vinho (Brazil)
CNRRI	China National Rice Research Institute
COILLTE	Coillte Teoranta, The Irish Forestry Board (Ireland)
CONSEFORH	Proyecto de Conservación y Silvicultura de Especies Forestales de Honduras
COP	Conference of the Parties to the Convention on Biological Diversity
COPAL	Cocoa Producers Alliance
COR	National Clonal Germplasm Repository, United States Department of Agriculture, Agricultural Research Services
CORBANA	Corporación Bananera Nacional S.A. (Costa Rica)
CORPOICA	Centro de Investigación La Selva, Corporación Colombiana de Investigación Agropecuaria (Colombia)
CORRA	Council for Partnerships on Rice Research in Asia
COT	Crop Germplasm Research Unit, United States Department of Agriculture, Agricultural Research Services
CPAA	Embrapa Amazônia Ocidental (Brazil)
CPACT/Embrapa	Embrapa Clima Temperado (Brazil)
CPATSA	Embrapa Semi-Árido (Brazil)
CPBBD	Central Plant Breeding and Biotechnology Division, Nepal Agricultural Research Council
CPRI	Central Potato Research Institute (India)
CPU	Central Processing Unit
CRA-CAT	Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Unità di Ricerca per le Colture alternative al Tabacco (Italy)
CRA-FLC	Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Centro di Ricerca per le Produzioni Foraggere e Lattiero-Casearie (Italy)
CRA-FRF	Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Unitá di Ricerca per la Frutticoltura (Italy)
CRA-FRU	Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Centro di Ricerca per la Frutticoltura (Italy)

CRAGXPP	Département de Lutte Biologique et Ressources Phytogénétiques, Centre de Recherches Agronomiques de Gembloux, Ministere des Classes Moyennes et de l'Agriculture (Belgium)
CRA-OLI	Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Centro di Ricerca per l'Olivicoltura e l'Industria Olearia (Italy)
CRA-VIT	Consiglio per la Ricerca e la Sperimentazione in Agricoltura - Centro di Ricerca per la Viticoltura (Italy)
CRC	Central Romana Corporation (Dominican Republic)
CRI	Citrus Research Institute, Chinese Academy of Agricultural Sciences
CRIA	Central Research Institute for Agriculture (Indonesia)
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Niger
CRU	Cocoa Research Unit, University of the West Indies (Trinidad and Tobago)
CSFRI	Citrus and Subtropical Fruit Research Institute (South Africa)
CSIRO	Commonwealth Scientific & Industrial Research Organization, Division of Horticultural Research
CTA	Technical Centre for Agricultural and Rural Cooperation
CTC	Centro de Tecnologia Canavieira (Brazil)
CTRI	Central Tobacco Research Institute (India)
CWR	Crop wild relatives
DANAC	Fundación para la Investigación Agrícola DANAC (Venezuela, Bolivarian Republic of)
DAR	Department of Agricultural Research, Ministry of Agriculture (Botswana)
DAV	National Germplasm Repository, United States Department of Agriculture, Agricultural Research Services, University of California
DB NRRC	Dale Bumpers National Rice Research Centre, United States Department of Agriculture, Agricultural Research Services
DCRS	Dodo Creek Research Station, Ministry of Home Affairs and Natural Development (Solomon Islands)
DENAREF	Departamento Nacional de Recursos Fitogenéticos y Biotecnología (Ecuador)
DFS	Artemivs'k Experimental Station (Ukraine)
DGCB-UM	Department of Genetics and Cellular Biology, University Malaya (Malaysia)
DLP Laloki	Dry-lowlands Research Programme, Laloki (NARI) (Papua New Guinea)
DNA	Deoxyribonucleic acid
DOA	Department of Agriculture, Papua New Guinea University of Technology
DOR	Directorate of Oilseeds Research (India)

DTRUFC	División of Tropical Research, United Fruit Company (Honduras)
EA-PGR	Regional Network for Conservation and Use of Plant Genetic Resources in East Asia
EAPGREN	East African Plant Genetic Resources Network
EAPZ	Escuela Agrícola Panamericana El Zamorano (Honduras)
EARTH	Escuela de Agricultura de la Region Tropical Humeda (Costa Rica)
ECICC	Estación Central de Investigaciones de Café y Cacao (Cuba)
ECOWAS	Economic Community of West African States
ECPGR	European Cooperative Programme for Genetic Resources
EEA INTA Anguil	Estación Experimental Agropecuaria "Ing. Agr. Guillermos Covas" (Argentina)
EEA INTA Bordenave	Estación Experimental Agropecuaria Bordenave (Argentina)
EEA INTA Cerro Azul	Estación Experimental Agropecuaria Cerro Azul (Argentina)
EENP	Estación Experimental Napo-Payamino (Ecuador)
EETP	Estación Experimental Pichilingue (Ecuador)
EFOPP	Enterprise for Extension and Research in Fruit Growing and Ornamentals (Hungary)
Embrapa	Empresa Brasileira de Pesquisa Agropecuaria
ENSCONET	European Native Seed Conservation Network
ePIC	Electronic Plant Information Centre (United Kingdom)
ESA	Environmentally Sensitive Areas
ESCORENA	European System of Cooperative Research Networks on Agriculture
ETC Group	Action Group on Erosion, Technology and Concentration
EUFORGEN	European Forest Genetic Resources Network
EURISCO	European Internet Search Catalogue
EWS R&D	East West Seed Research and Development Division (Bangladesh)
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Database
FARA	Forum for Agricultural Research in Africa
FAST	Faculté des Sciences et Techniques (Benin)
FCRI	Food Crops Research Institute (Viet Nam)
FCRI-DA	Field Crops Research Institute – Department of Agriculture (Thailand)
FF.CC.AA.	Facultad de Ciencias Agrarias (Peru)
FHIA	Fundación Hondureña de Investigación Agrícola
FIGS	Focused Identification of Germplasm Strategy
FONTAGRO	Fondo Regional de Tecnología Agropecuaria
FORAGRO	Foro de las Américas para la Investigación y Desarrollo Tecnológico Agropecuario
FPC	Firestone Plantations Company (Liberia)
FRIM	Forest Research Institute of Malaysia

FRUCTUS	Association Suisse pour la Sauvegarde du Patrimoine Fruitier (Switzerland)
GBREMR	East Malling Research (United Kingdom)
GBWS	Germplasm Bank of Wild Species (China)
GCDT	Global Crop Diversity Trust
GCP	Generation Challenge Programme
GEF	Global Environment Facility
GEN	Plant Genetic Resources Unit, Cornell University, New York State Agricultural Experiment Station, United States Department of Agriculture, Agricultural Research Services
GEVES	Unité Expérimentale de Sophia-Antipolis, Groupe d'Étude et de Sophia-Antiopolis contrôle des Variétés et des Semences (France)
GFAR	Global Forum on Agricultural Research
GIPB	Global Partnership Initiative for Plant Breeding Capacity Building
GIS	Geographic Information System
GM	Genetically modified
GMO	Genetically modified organisms
GMZ	Gene Management Zones
GPA	Global Plan of Action for the Conservation and Utilization of Plant Genetic Resources for Food and Agriculture
GPRI	Genetic Resources Policy Initiative of Biodiversity International
GPS	Global Positioning Systems
GRENEWECA	Genetic Resources Network for West and Central Africa
GRI	Genetic Resources Institute (Azerbaijan)
GRIN	Germplasm Resources Information Network
GSC	Guyana Sugar Corporation, Breeding and Selection Department
GSLY	C.M. Rick Tomato Genetics Resource Centre (United States)
GSPC	Global Strategy for Plant Conservation
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
HBROD	Potato Research Institute Havlickuv Brod Ltd. (Czech Republic)
HIV/AIDS	Human immunodeficiency virus/ Acquired Immune Deficiency Syndrome
HOLOVOU	Research and Breeding Institute of Pomology, Holovousy Ltd. (Czech Republic)
HRC, MARDI	Horticulture Research Centre, Malaysian Agricultural Research and Development Institute
HRI-DA/THA	Horticultural Research Institute, Department of Agriculture (Thailand)

HRIGRU	Horticultural Research International, University of Warwick, Genetic Resources Unit (United Kingdom)
HSCRI	Horticulture and Subtropical Crops Research Institute (Azerbaijan)
IAC	Instituto Agronómico de Campinas (Brazil)
IAO	Istituto Agronomico per l'Oltremare (Italy)
IAPAR	Instituto Agronomico do Paraná (Brazil)
IARC	International Agricultural Research Centre
IARI	Indian Agricultural Research Institute
IBC	Institute of Biodiversity Conservation (Ethiopia)
IBERS-GRU	Institute of Biological, Environmental & Rural Sciences, Genetic Resources Unit, Aberystwyth University (United Kingdom)
IBN-DLO	Institute for Forestry and Nature Research (Netherlands)
IBONE	Instituto de Botánica del Nordeste, Universidad Nacional de Nordeste, Consejo Nacional de Investigaciones Científicas y Técnicas (Argentina)
IBOT	Jardim Botânico de São Paulo (Brazil)
IBPGR	International Board for Plant Genetic Resources
ICA/REGION 1	Corporación Colombiana de Investigación Agropecuaria Tibaitata (Colombia)
ICA/REGION 5	Centro de Investigación El Mira, Instituto Colombiano Agropecuario El Mira (Colombia)
ICA/REGION 5	Centro de Investigaciones de Palmira, Instituto Colombiano Agropecuario Palmira (Colombia)
ICABIOGRAD	Indonesian Centre for Agricultural Biotechnology and Genetic Resources Research and Development
ICAR	Indian Council of Agricultural Research
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICBA	International Centre for Biosaline Agriculture
ICCI-TELAVUN	Lieberman Germplasm Bank, Institute for Cereal Crops Improvement, Tel-Aviv University (Israel)
ICCO	International Cocoa Organization
ICCPT Fundul	Research Institute for Cereals and Technical Plants Fundulea (Romania)
ICG	Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore
ICGN	International Coffee Genome Network
ICGR-CAAS	Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences
ICGT	International Cocoa Genebank (Trinidad and Tobago)
ICPP Pitesti	Fruit Growing Research Institute Maracineni-Arges (Romania)
ICRAF	International Centre for Research in Agroforestry (now the World Agroforestry Centre)

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICRR	Indonesian Centre for Rice Research
ICVV Valea C	Wine Growing Research Institute Valea Calugareasca-Prahova (Romania)
IDB	Inter-American Development Bank
IDEFOR	Institut pour le Développement des Forêts (Côte d'Ivoire)
IDEFOR-DCC	Département du Café et du Cacao, Institut pour le Développement des Forêts (Côte d'Ivoire)
IDEFOR-DPL	Département des Plantes à Latex, Institut pour le Développement des Forêts (Côte d'Ivoire)
IDESSA	Institut des Savanes (Côte d'Ivoire)
IDI	International Dambala (Winged Bean) Institute (Sri Lanka)
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFAP	International Federation of Agricultural Producers
IFS	International Foundation for Science
IFVCNS	Institute for Field and Vegetable Crops (Serbia)
IGB	Israel Gene Bank for Agricultural Crops, Agricultural Research Organization, Volcani Centre
IGC	The WIPO Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore
IGFRI	Indian Grassland and Fodder Research Institute
IGV	Istituto di Genetica Vegetale, Consiglio Nazionale delle Richerche (Italy)
IHAR	Plant Breeding and Acclimatization Institute (Poland)
IICA	Instituto Interamericano de Cooperación para la Agricultura
IIT	Instituto de Investigaciones del Tabaco (Cuba)
IITA	International Institute of Tropical Agriculture
ILETRI	Indonesian Legume and Tuber Crops Research Institute
ILK	Institute of Bast Crops (Ukraine)
ILRI	International Livestock Research Institute
IMIACM	Comunidad de Madrid, Dirección General de Agricultura y Desarrollo Rural, Instituto Madrileño de Investigación Agraria y Alimentaria (Spain)
INBAR	International Network for Bamboo and Rattan
INCANA	Inter-regional Network on Cotton in Asia and North Africa
INCORD	Cotton Institute for Research and Development (Viet Nam)
INERA	Institut National pour l'Etude et la Recherche Agronomique (Congo)
INGENIC	International Group for the Genetic Improvement of Cocoa
INGER	International Network for the Genetic Evaluation of Rice
INIA-CENIAP	Centro Nacional de Investigaciones Agropecuarias, Instituto Nacional de Investigaciones Agrícolas, Venezuela (Bolivarian Republic of)

INIA CARI	Centro Regional de Investigación, Instituto Nacional de Investigaciones Agrícolas, Carillanca (Chile)
INIA INTIH	Banco Base, Instituto de Investigaciones Agropecuarias, Intihuasi (Chile)
INIA QUIL	Centro Regional de Investigación, Instituto de Investigaciones Agropecuarias, Quilamapu (Chile)
INIACRF	Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria,Centro de Recursos Fitogenéticos (Spain)
INIA-EEA.ILL	Estación Experimental Agraria, Illpa (Peru)
INIA-EEA.POV	Estación Experimental Agraria, El Porvenir (Peru)
INIAFOR	Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, Centro de Investigaciones Forestales (Spain)
INIA-Iguala	Estación de Iguala, Instituto Nacional de Investigaciones Agrícolas (Mexico)
INIAP	Instituto Nacional de Tecnología Agropecuaria (Ecuador)
INIBAP	International Network for the Improvement of Banana and Plantain
INICA	Instituto Nacional de Investigación de la Caña de Azúcar (Cuba)
INIFAP	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (Mexico)
INRA	Institut national de la recherche agronomique (France)
INRA/CRRAS	Institut national de la recherche agronomique/Centre Régional de la Recherche Agronomique de Settat (Morocco)
INRA/ENSA-M	Institut national de la recherche agronomique/Station de Recherches Viticoles (France)
INRA-ANGERS	Institut national de la recherche agronomique/Station d'Amélioration des Espèces Fruitières et Ornementales, (France)
INRA BORDEAUX (FRA057)	Unité de Recherches sur Espèces Fruitières et Vigne (France)
INRA BORDEAUX (FRA219)	Institut national de la recherche agronomique/Recherches Forestières (France)
INRA-CLERMONT	Institut national de la recherche agronomique/Station d'Amélioration des Plantes (France)
INRA-DIJON	Institut national de la recherche agronomique/Station de Génétique et d'Amélioration des Plantes (France)
INRA-MONTPELLIER	Institut national de la recherche agronomique/Genetics and Plant Breeding Station (France)
INRA-POITOU	Institut national de la recherche agronomique/Station d'Amélioration des Plantes Fourragères (France)
INRA-RENNES (FRA010)	Institut national de la recherche agronomique/Station d'Amélioration des Plantes (France)
INRA-RENNES (FRA179)	Institut national de la recherche agronomique/Station d'Amélioration Pomme de Terre et Plantes à Bulbes (France)
INRA-UGAFL	Institut national de la recherche agronomique/Unité de Génétique et Amélioration des Fruits et Légumes (France)

INRENARE	Instituto Nacional de Recursos Naturales Renovables (Panama)
IOB	Institute of Vegetable and Melon Growing (Ukraine)
IOPRI	Indonesian Palm Oil Research Institute
IP	Intellectual property
IPB-UPLB	Institute of Plant Breeding, College of Agriculture, University of the Philippines, Los Baños College (Philippines)
IPCC	Intergovernmental Panel on Climate Change
IPEN	International Plant Exchange Network
IPGR	Institute for Plant Genetic Resources «K.Malkov» (Bulgaria)
IPGRI	International Plant Genetic Resources Institute
IPK (DEU271)	External Branch North of the Department Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research, Oil Plants and Fodder Crops in Malchow (Germany)
IPK (DEU159)	External Branch North of the Department Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research, Potato Collection in Gross-Luesewitz (Germany)
IPK (DEU146)	Genebank, Leibniz Institute of Plant Genetics and Crop Plant Research (Germany)
IPPC	International Plant Protection Convention
IPR	Intellectual property rights
IPRBON	Institute for Potato Research, Bonin, Poland
IPSR	Department of Applied Genetics, John Innes Centre, Norwich Research Park (United Kingdom)
IR	Institute of Plant Production n.a. V.Y. Yurjev of UAAS (Ukraine)
IRCC/Cirad	Institut de Recherches du Café et du Cacao et autres Plantes Stimulantes/Centre de Coopération Internationale en Recherche Agronomique pour le Développement (Côte d'Ivoire)
IRCT/Cirad	Département des Cultures Annuelles/Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
IRRI	International Rice Research Institute
IRTAMB	Generalitat de Catalunya, Institut de Recerca i Tecnologia Agroalimentàries, Centre Mas Bové (Spain)
ISAR	Institut des Sciences Agronomiques du Rwanda
ISF	International Seed Federation
ISFP	Initiative on Soaring Food Prices
ISRA-URCI	Institut Sénégalais de Recherche Agricole-Unité de recherche commune en culture *in vitro*
IT	Information technology
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
ITRA	Institut Togolais de Recherche Agronomique
IUCN	International Union for Conservation of Nature

IVM	Institute of Grape and Wine «Maharach» (Ukraine)
JARC	Jimma Agricultural Research Centre (Ethiopia)
JICA	Japan International Cooperation Agency
JIRCAS	Japan International Research Centre for Agricultural Sciences
JKI	Julius Kühn Institute, Federal Research Centre for Cultivated Plants (Germany)
JKI (DEU098)	Julius Kühn Institute, Federal Research Centre for Cultivated Plants - Institute for Grapevine Breeding Geilweilerhof (Germany)
JKI (DEU451)	Julius Kühn Institute, Federal Research Centre for Cultivated Plants - Institute of Horticultural Crops and Fruit Breeding (Germany)
KARI	Kenya Agricultural Research Institute
KARI-NGBK	National Genebank of Kenya, Crop Plant Genetic Resources Centre, Muguga (Kenya)
KEFRI	Kenya Forest Research Institute
KLOST	Federal College and Research Institute for Viticulture and Fruit Growing (Austria)
KPS	Crimean Pomological Station (Ukraine)
KROME	Agricultural Research Institute Kromeriz, Ltd. (Czech Republic)
KST	Crimean Tobacco Experimental Station (Ukraine)
LACNET	Latin America and Caribbean Network
LAREC	Lam Dong Agricultural Research and Experiment Centre (Viet Nam)
LBN	National Biological Institute (Indonesia)
LD	Linkage Disequilibrium
LEM/IBEAS	IBEAS, Laboratoire d'Ecologie Moléculaire, Université de Pau (France)
LFS	L'viv Experimental Station of Horticulture (Ukraine)
LIA	Lithuanian Institute of Agriculture
LI-BIRD	Local Initiatives for Biodiversity, Research and Development (Nepal NGO)
Linseed	All India Coordinated Research Project on Linseed, CSA University of Agriculture & Technology, Kanpur, Uttar Pradesh (India)
LPGPB	Laboratory of Plants Gene Pool and Breeding (Armenia)
LRS	Lethbridge Research Station, Agriculture (Canada)
LUBLIN	Institute of Genetics and Plant Breeding, University of Agriculture (Poland)
MARDI	Malaysian Agricultural Research and Development Institute
MARS	Makoka Agricultural Research Station (Malawi)
MAS	Marker Assisted Selection
MDG	Millennium Development Goal
MEA	Millennium Ecosystem Assessment

MHRP	Main Highlands Research Programme, Aiyura (Papua New Guinea)
MIA	Subtropical Horticultural Research Unit, National Germplasm Repository- Miami, United States Department of Agriculture
MLS	Multilateral System
MPOB	Malaysia Palm Oil Board
MRB	Malaysian Rubber Board
MRIZP	Maize Research Institute «Zemun Polje» (Serbia)
MRS	Msekera Research Station (Zambia)
MSBP	Millennium Seed Bank Project
MUSACO	Réseau Musa pour l'Afrique Centrale et Occidentale
MUSALAC	Plantain and Banana Research and Development Network for Latin America and the Caribbean
NA	U.S. National Arboretum, United States Department of Agriculture, Agricultural Research Services, Woody Landscape Plant Germplasm Repository
NABNET	North Africa Biosciences Network
NAEP	National Agri-Environment Programme (Hungary)
NAKB	Inspection Service for Floriculture and Arboriculture (Netherlands)
NARC (LAO010)	Napok Agricultural Research Centre (Lao People's Democratic Republic)
NARC (NPL026)	Nepal Agricultural Research Council
NARS	National Agricultural Research System
NBPGR (IND001)	National Bureau of Plant Genetic Resources (India)
NBPGR (IND064)	Regional Station Jodhpur, National Bureau of Plant Genetic Resources (India)
NBPGR (IND024)	Regional Station Thrissur, National Bureau of Plant Genetic Resources (India)
NC7	North Central Regional Plant Introduction Station, United States Department of Agriculture, Agricultural Research Services
NCGRCD	National Clonal Germplasm Repository for Citrus & Dates, United States Department of Agriculture, Agricultural Research Services
NCGRP	National Centre for Genetic Resources Preservation (United States)
NE9	Northeast Regional Plant Introduction Station, Plant Genetic Resources Unit, United States Department of Agriculture, Agricultural Research Services, New York State Agricultural Experiment Station, Cornell University
NEPAD	The New Partnership for Africa's Development
NFC	National Fruit Collections, University of Reading (United Kingdom)
NGO	Non-governmental organization
NIAS	National Institute of Agrobiological Sciences (Japan)

NISM	National Information Sharing Mechanism on GPA implementation.
NMK	National Museums of Kenya
NordGen	Nordic Genetic Resources Centre
NORGEN	Plant Genetic Resources Network for North America
NPGRC	National Plant Genetic Resources Centre (United Republic of Tanzania)
NPGS	National Plant Germplasm System
NR6	Potato Germplasm Introduction Station, United States Department of Agriculture, Agricultural Research Services
NRCB	National Research Centre for Banana (India)
NRCOG	National Research Centre for Onion and Garlic (India)
NRCRI	National Root Crops Research Institute (Nigeria)
NSGC	National Small Grains Germplasm Research Facility, United States Department of Agriculture, Agricultural Research Services
NUC	Njala University College (Sierra Leone)
OAPI	African Intellectual Property Organization
OAU	Organization of African Unity
OECD	Organisation for Economic Co-operation and Development
OPRI	Oil Palm Research Institute (Ghana)
ORSTOM-MONTPELLIER	Laboratoire des Ressources Génétiques et Amélioration des Plantes Tropicales, ORSTOM (France)
OSS Roggwil	Verein Obstsortensammlung Roggwil (Switzerland)
PABRA	Pan-African Bean Research Alliance
PAN	Botanical Garden of the Polish Academy of Sciences (Poland)
PAPGREN	Pacific Agricultural Plant Genetic Resources Network
PBBC	Plant Breeding and Related Biotechnology Capacity assessment
PBR	Plant breeders' rights
PCA-ZRC	Philippine Coconut Authority-Zamboanga Research Centre
PCR	Polymerase Chain Reaction
PDO	Protected Designation of Origin
PERUG	Dipartimento di Biologia Applicata, Universitá degli Studi, Perugia (Italy)
PES	Payment for environmental services
PG	Pomological Garden (Kazakhstan)
PGR	Plant genetic resources
PGRC (CAN004)	Plant Gene Resources of Canada, Saskatoon Research Centre, Agriculture and Agri-Food Canada
PGRC	Plant Genetic Resources Centre (Sri Lanka)
PGRFA	Plant genetic resources for food and agriculture
PGRI	Plant Genetic Resources Institute (Pakistan)
PGR-IZs	Plant Genetic Resources Important Zones
PGRRI	Plant Genetic Resources Research Institute (Ghana)
PHES	Plew Horticultural Experimental Station (Thailand)

PhilRice	Philippine Rice Research Institute
PNP-INIFAP	Programa Nacional de la Papa, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (Mexico)
PotatoGene	Potato Gene Engineering Network
PPB	Paticipatory plant breeding
PRC	Plant Resources Centre (Viet Nam)
PRGA	Participatory Research and Gender Analysis
PROCIANDINO	Programa Cooperativo de Innovación Tecnológica Agropecuaria para la Región Andina
PROCICARIBE	Programa para la Cooperación de Institutos de Ciencia Agrícola y Tecnología en el Caribe
PROCINORTE	Programa cooperativo en investigación y tecnología para la Región Norte
PROCISUR	Programa Cooperativo para el Desarrollo Tecnológico Agropecuario del Cono Sur
PROCITROPICOS	Programa Cooperativo de Investigación y Transferencia de Tecnología para los Trópicos Suramericanos
PRUHON	Research Institute of Landscaping and Ornamental Gardening (Czech Republic)
PSR	Pro Specie Rara (Switzerland)
PU	Peradeniya University (Sri Lanka)
PULT	Department of Special Crops (Tobacco), Institute Soil Science and Plant Cultivation (Poland)
PVP	Plant variety protection
QDPI	Queensland Department of Primary Industries, Maroochy Research Station (Australia)
QPM	Quality protein maize
QTL	Quantitative trait locus
RAC (CHE019)	Domaine de Caudoz - Viticulture RAC Changins (Switzerland)
RAC (CHE001)	Station Fédérale de Recherches en Production Végétale de Changins (Switzerland)
RAPD	Random Amplification of Polymorphic DNA
RBG	Millennium Seed Bank Project, Seed Conservation Department, Royal Botanic Gardens, Kew, Wakehurst Place (United Kingdom)
RCA	Institute for Agrobotany (Hungary)
RDAGB-GRD	Genetic Resources Division, National Institute of Agricultural Biotechnology, Rural Development Administration (Republic of Korea)
RECSEA-PGR	Regional Cooperation in South East Asia for Plant Genetic Resources
REDARFIT	Andean Network on Plant Genetic Resources
REDBIO	Red de cooperación técnica en biotecnología vegetal
RedSICTA	The Agricultural Innovation Network Project
REGENSUR	Plant Genetic Resources Network for the Southern Cone

REHOVOT	Department of Field and Vegetable Crops, Hebrew University of Jerusalem (Israel)
REMERFI	Mesoamerican Network on Plant Genetic Resources
RFLP	Restriction fragment length polymorphisms
RGC	Regional Germplasm Centre (Secretariat of the Pacific Community)
RIA	Research Institute of Agriculture (Kazakhstan)
RICP (CZE061)	Genebank Department, Vegetable Section Olomuc, Research Institute of Crop Production (Czech Republic)
RICP (CZE122)	Genebank Department, Division of Genetics and Plant Breeding, Research Institute of Crop Production (Czech Republic)
RICP	Research Institute of Crop Production (Czech Republic)
RIGA	FAO Rural Income Generation Project
RIPV	Research Institute of Potato and Vegetables (Kazakhstan)
RNA	Ribonucleic acid
RNG	School of Plant Science, University of Reading (United Kingdom)
ROCARIZ	West and Central Africa Rice Research and Development Network
ROPTA	Plant Breeding Station Ropta (Netherlands)
RPPO	Regional Plant Protection Organization
RRI	Rubber Research Institute (Viet Nam)
RRII	Rubber Research Institute of India
RRS-AD	Banana National Programme (Uganda)
RSPAS	Research School of Pacific and Asian Studies (Australia)
S9	Plant Genetic Resources Conservation Unit, Southern Regional Plant Introduction Station, University of Georgia, United States Department of Agriculture, Agricultural Research Services
SAARI	Serere Agriculture and Animal Production Research Institute (Uganda)
SADC	Southern African Development Community
SADC-FANR	Southern African Development Community, Food, Agriculture and Natural Resources Directorate
SADC-PGRN	Southern African Development Community, Plant Genetic Resources Network
SamAI	Samarkand Agricultural Institute named F. Khodjaev (Uzbekistan)
SANBio	South African Network for Biosciences
SANPGR	South Asia Network on Plant Genetic Resources
SARD	Sustainable Agriculture and Rural Development
SAREC	Swedish Agency for Research Cooperation
SASA	Science and Advice for Scottish Agriculture, Scottish Government (United Kingdom)
SAVE Foundation	Safeguard for Agricultural Varieties in Europe (Foundation)

SCAPP	Scientific Centre of Agriculture and Plant Protection (Armenia)
SCRDC	Soil and Crops Research and Development Centre, Agriculture and Agri-Food Canada
SCRI	Scottish Crop Research Institute (United Kingdom)
SDC	Swiss Agency for Development and Cooperation
SDIS	Southern African Development Community Documentation and Information System
SEABGRC	South East Asian Banana Germplasm Resources Centre, Davao Experimental Station, Bureau of Plant Industry (Philippines)
SeedNet	South East European Development Network on Plant Genetic Resources
SFL	Holt Agricultural Research Station (Norway)
SGRP	System-wide Genetic Resources Programme
SGSV	Svalbard Global Seed Vault
SHRWIAT	Plant Breeding Station (Poland)
SIAEX	Junta de Extremadura. Servicio de Investigación y Desarrollo Tecnológico, Finca la Orden (Spain)
SIBRAGEN	Sistema brasileiro de informação de recursos genéticos
SICTA	Sistema de Integracion Centroamericana de Tecnologia Agricola
SINAC	National System of Conservation Areas (Costa Rica)
SINGER	System-wide Information Network for Genetic Resources
SKF	Research Institute of Pomology and Floriculture (Poland)
SKUAST	Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir (India)
SKV	Plant Genetic Resources Laboratory, Research Institute of Vegetable Crops (Poland)
SMTA	Standard Material Transfer Agreement
SOUTA	School of Biological Sciences, University of Southampton (United Kingdom)
SoW	State of the World
SOY	Soybean Germplasm Collection, United States Department of Agriculture, Agricultural Research Services
SPB-UWA	School of Plant Biology, Faculty of Natural and Agricultural Sciences, University of Western Australia
SPC	Secretariat of the Pacific Community
SPCGF	Scientific Production Centre of Grain Farming "A. I. Baraev" (Kazakhstan)
SPGRC	Southern African Development Community Plant Genetic Resources Centre
SPS	Sanitary and Phytosanitary Measures Agreement
SR, MARDI	Strategic Resource Research Centre MARDI (Malaysia)
SRA-LGAREC	La Granja Agricultural Research and Extension Centre (Philippines)

SRI	Sugar Crop Research Institute, Mardan (Pakistan)
SSC-IUCN	Species Survival Commission, International Union for Conservation of Nature
SSEEA	South, South East and East Asia
SSJC	Soutnern Seed Joint-Stock Company (Viet Nam)
SUMPERK	AGRITEC, Research, Breeding and Services Ltd. (Czech Republic)
SVKBRAT	Research Institute for Viticulture and Enology (Slovakia)
SVKLOMNICA	Potato Research and Breeding Institute (Slovakia)
SVKPIEST	Research Institute of Plant Production Piestany (Slovakia)
TAMAWC	Australian Winter Cereals Collection, Agricultural Research Centre
TANSAO	Taro Network for Southeast Asia and Oceania
TARI	Taiwan Agricultural Research Institute
TaroGen	Taro Genetic Resources Network
TOB	Oxford Tobacco Research Station, Crops Science Department, North Carolina State University
TRI	Tea Research Institute (Sri Lanka)
TRIPS	Trade-Related Aspects of Intellectual Property Rights
TROPIC	Institute of Tropical and Subtropical Agriculture, Czech University of Agriculture
TROPIGEN	Amazonian Network for Plant Genetic Resources
TSS-PDAF	Taiwan Seed Service, Provincial Department of Agriculture and Forestry
TWAS	Third World Academy of Science
U.NACIONAL	Facultad de Agronomía, Universidad Nacional de Colombia
UAC	Université d'Abomey Calavi (Benin)
UACH	Banco Nacional de Germoplasma Vegetal, Departamento de Fitotecnia, Universidad Autónoma de Chapingo (Mexico)
UBA-FA	Facultad de Agronomía, Universidad de Buenos Aires (Argentina)
UC-ICN	Instituto de Ciencias Naturales (Ecuador)
UCR-BIO	Banco de Germoplasma de Pejibaye UCR-MAG, Escuela de Biología, Escuela de Zootecnia, Universidad de Costa Rica
UDAC	Unidade de Direcção Agraria de Cajú (Mozambique)
UDS	Ustymivka Experimental Station of Plant Production (Ukraine)
UH	University of Hawaii at Manoa (United States of America)
UHFI-DFD	Department of Floriculture and Dendrology, University of Horticulture and Food Industry (Hungary)
UHFI-RIVE	Institute for Viticulture and Enology, University of Horticulture and Food Industry (Hungary)
UM	Universiti Malaya (Malaya University, Malaysia)
UN	United Nations
UNALM	Universidad Nacional Agraria La Molina (Peru)

UNCED	United Nations Conference on Environment and Development
UNCI	Université Nationale de Côte d'Ivoire
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNMIHT	Horticulture Department, Michigan State University (United States)
UNSAAC	Universidad Nacional San Antonio Abad del Cusco, Centro K'Ayra (Peru)
UNSAAC/CICA	Universidad Nacional San Antonio Abad del Cusco
UPASI-TRI	United Planters' Association of South India-Tea Research Institute (India)
UPLB	University of the Philippines, Los Baños
UPM	University Putra, Malaysia
UPOU	University of Philippines Open University
UPOV	International Union for the Protection of New Varieties of Plants
URG	Unité des Ressources Génétiques (Mali)
USDA	United States Department of Agriculture
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USP	University of South Pacific
UzRICBSP	Uzbek Research Institute of Cotton Breeding and Seed Production
UzRIHVWM	Uzbek Research Institute of Horticulture, Vine Growing and Wine Making named R.R. Shreder
UzRIPI	Uzbek Research Institute of Plant Industry
VEGTBUD	Station of Budapest, Vegetable Crops Research Institute (Hungary)
VINATRI	Tea Research Institute of Viet Nam
VIR	N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry (Russian Federation)
W6	Western Regional Plant Introduction Station, United States Department of Agriculture, Agricultural Research Services, Washington State University
WABNET	West Africa Biosciences Network
WACCI	West African Centre for Crop Improvement
WADA (AUS137)	Australian Trifolium Genetic Resource Centre, Western Australian Department of Agriculture
WADA (AUS002)	Western Australian Department of Agriculture (Australia)
WANA	West Asia and North Africa
WANANET	West Asia and North Africa Genetic Resources Network
WARDA	West African Rice Development Association
WASNET	West Africa Seed Network
WCF	World Cocoa Foundation

WCMC	World Conservation Monitoring Centre
WDPA	World Database on Protected Areas
WICSBS	West Indies Central Sugarcane Breeding Station
WIEWS	World Information and Early Warning System on PGRFA
WIPO	World Intellectual Property Organization
WLMP	Sir Alkan Tololo Research Centre, Bubia (Papua New Guinea)
WRS	Cereal Research Centre, Agriculture and Agri-Food Canada
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization

Plant genetic resources provide a basis for food security, livelihood support and economic development as a major component of biodiversity. The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture demonstrates the central role plant genetic diversity continues to play in shaping agriculture growth in the face of climate change and other environmental challenges. It is based on information gathered from Country Reports, regional syntheses, thematic studies and scientific literature, documenting the major achievements made in this sector during the past decade and identifying the critical gaps and needs that should urgently be addressed.

The Report provides the decision-makers with a technical basis for updating the *Global Plan of Action on Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture.* It also aims to attract the attention of the global community to set priorities for the effective management of plant genetic resources for the future.

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