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.

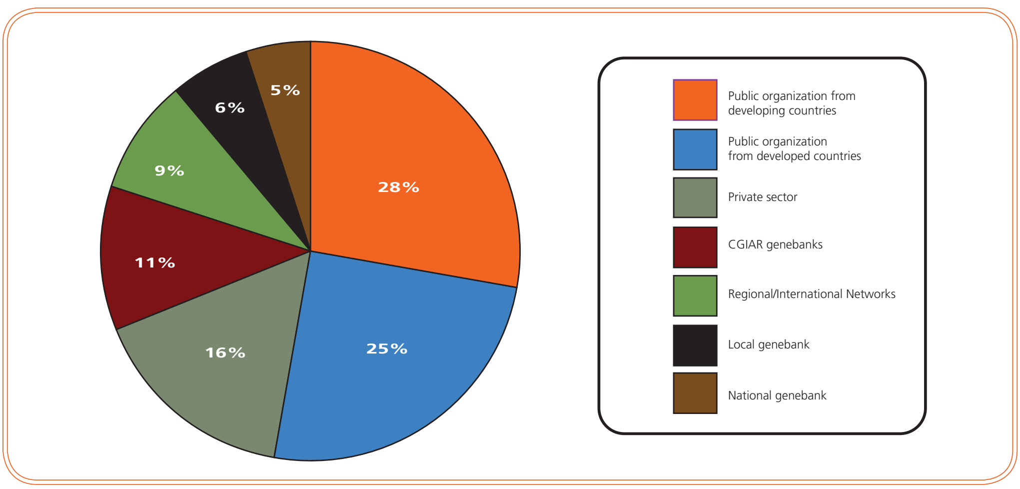
Although a wide range of genetic resources is available nationally and internationally, breeders often select the majority of their parental materials from their own working collections and from nurseries supplied by the CGIAR centres. This is largely because of the difficulty of transferring genes from 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.

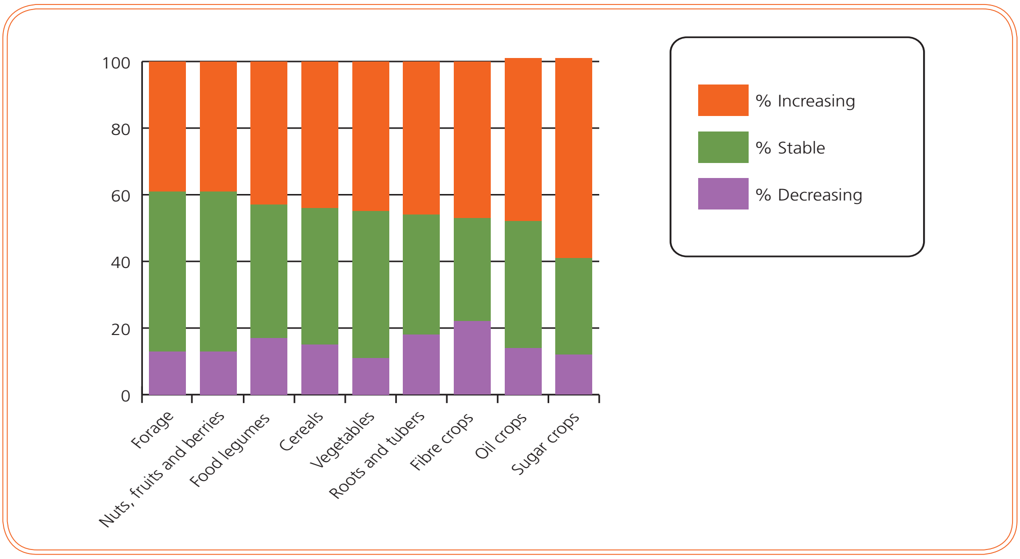
plant breeders[8] but there has been a decline in others, e.g. in Eastern Europe and Central Asia. Within the rest of Asia there have been decreases in Bangladesh and the Philippines while numbers have risen in Thailand.[9]

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]

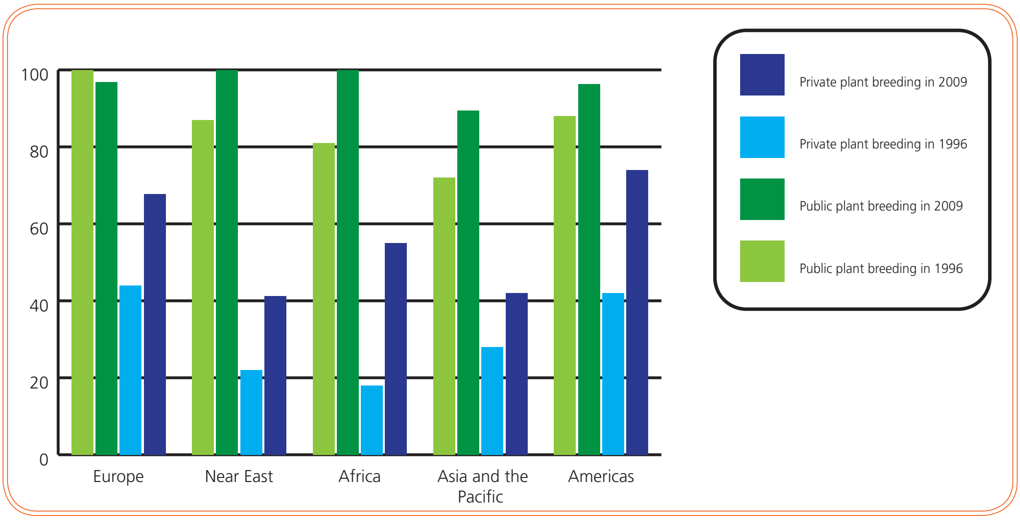
FIGURE 4.2

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/).

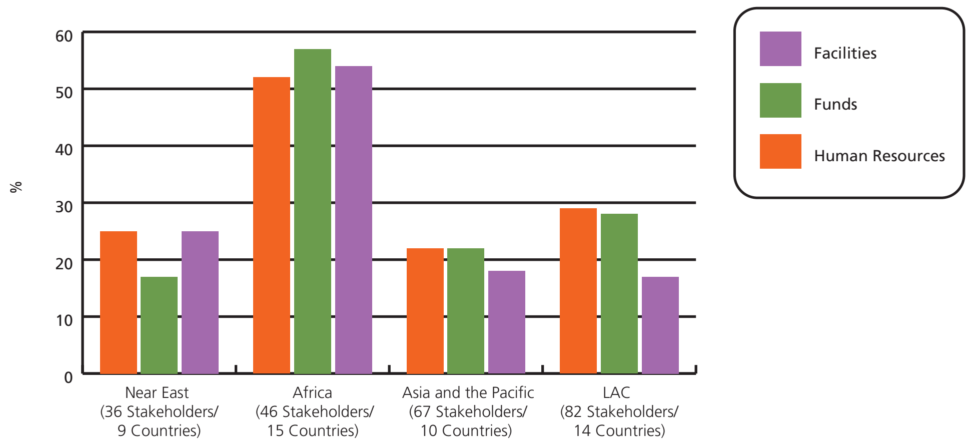
In the United States of America, it has been reported that "the decline in classical plant breeding [over recent years] is likely underestimated because marker development and other breeding related molecular genetics are included in plant breeding data".[12]

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-carotene, 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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