Chapter 1

Introductory and Background Material

Without continued genetic enhancement using diverse germplasm from both wild and modified sources, the gains in crop yields obtained over the past seven decades are not sustainable, and yields might eventually grow more slowly or even decline. Agricultural production increasingly relies on 'temporal diversity,' changing varieties more frequently to maintain resistance to pests and diseases (Rubenstein et al, 2005).

Introduction: Crop wild relatives (CWR)

Crop wild relatives (CWR) collectively constitute an enormous reservoir of genetic variation that can be used in plant breeding and are a vital resource in meeting the challenge of providing food security, enhancing agricultural production and sustaining productivity in the context of a rapidly growing world population and accelerated climate change. They occur in a wide range of habitats but as numerous assessments testify, habitats continue to be lost or degraded across the world, putting many of these species at risk. It is therefore essential that urgent steps are taken to conserve them both in the wild (*in situ*) and in genebanks (*ex situ*) while the genetic diversity they contain is still available.

What are genetic resources?

Genetic resources were traditionally defined as genetic material (alleles) of known value used in plant or animal improvement, but the meaning has been widened by the Convention on Biological Diversity (CBD) to mean *any material of plant, animal, microbial or other origin containing functional units of heredity, of actual or potential value*. It thus covers both living (e.g. seeds) and preserved material (e.g. herbarium or museum specimens). The International Treaty on Plant Genetic

Resources for Food and Agriculture (ITPGRFA) adopts a similar definition. Crop Wild Relatives are a key component of plant genetic resources for food and agriculture.[1]

What is a crop wild relative?

In general terms, a crop wild relative (CWR) may be defined as a wild plant species that is more or less closely related to a particular crop and to which it may contribute genetic material, but unlike the crop species has not been domesticated (Heywood et al, 2007). It is difficult to give a more precise definition, yet we need one if we are to be able to assess how many CWR exist both nationally and globally. Being a CWR is a matter of degree – some are more closely related than others to the crop. Two ways of describing this relationship have been employed – genecological – based on the extent to which they can exchange genes with the crop – and taxonomic – based on their taxonomic relationship with the crop (see Table 1.1). The genecological approach often uses the Harlan and de Wet (1971) gene pool concept to define the degree of relatedness, based on the relative ease with which genes can be transferred from them to the crop. In the complete or partial absence of genetic data or information on crossability, use of the taxon group concept has been proposed by Maxted et al (2008), which relies on the likelihood of the existing taxonomic classification reflecting a degree of genetic relationship or crossability.

For the purposes of the United Nations Environment Programme (UNEP)/Global Environment Facility (GEF) CWR Project described in this manual (see p19), a CWR was defined as any species belonging to the same genus as the crop, based on the argument that species judged to be sufficiently

Table 1.1 *Taxonomic and genecological definitions of CWR*

Gene pool concept of CWR

Primary gene pool (GP1)

Contains close relatives that readily intercross with the crop

Secondary gene pool (GP2)

Contains all the biological species that can be crossed with the crop but where hybrids are usually sterile

Tertiary gene pool (GP3)

Comprises those species that can be crossed with the crop only with difficulty and where gene transfer is usually only possible with radical techniques

Taxon group concept of CWR

Taxon Group 1a – crop
Taxon Group 1b – same species as crop
Taxon Group 2 – same series or section as crop
Taxon Group 3 – same subgenus as crop
Taxon Group 4 – same genus as crop
Taxon Group 5 – different genus to the crop

similar to belong to the same genus are likely to be related genetically. A similar approach has been proposed by Meilleur and Hodgkin (2004) who suggest as a definition 'CWRs should include the wild congeners or closely related species of a domesticated crop or plant species, including relatives of species cultivated for medicinal, forestry, forage, or ornamental reasons'. A number of other recent major CWR projects follow this approach. Such a broad definition leads to large numbers of species being considered CWR. For example, Kell et al (2008) found that around 83 per cent of the Euro-Mediterranean flora comprises crop and CWR species. Faced with handling such large numbers of CWR, a priority determining mechanism needs to be used to select which species will be the subject of particular conservation actions (see Chapter 7). CWR are a very diverse group of plants and occur in a wide variety of habitats. They range from forest trees and shrubs to climbers, perennials, biennials and annuals. Some of them are widespread and may even occur as weeds while others have scattered or restricted distributions and some of them are rare and endangered.

Landmark events – a bit of history

Although genes from CWR have almost certainly been used in the development of crops from early times, recorded use of CWR in commercial plant breeding dates back to the end of the 19th century (Hodgkin and Hajjar, 2008) and the potential significance of CWR in plant breeding and crop improvement was recognized by Vavilov and other pioneers[2] of the genetic resources movement. Wider recognition of the value of genes from CWR in conferring desirable characteristics in crop cultivars developed in the 1940s and 1950s (see Hajjar and Hodgkin, 2007, for a summary of the early uses of CWR). It was not, however, until the 1960s that active steps were made to undertake coordinated conservation of the genetic diversity represented by landraces, local ecotypes and wild relatives of crops. The recommendations made by the Food and Agriculture Organization of the United Nations (FAO) Technical Meeting in Rome in 1961 represented a key development (Bennett, 1965). It recognized 'the great importance to this and future generations of preserving the gene pool of genetic variability which now occurs in the major gene-centres of the world, but which is threatened with destruction'. The FAO recommended the establishment of International Crop Centres within the gene-centres to be charged with the task of fully exploring the genetic potential of their respective regions on the basis of detailed local knowledge, of assessing and maintaining basic collections of crops and local races and of wild forms, and of setting up areas in genetic conservation to be managed in such a way as to preserve the evolutionary potential of local population–environment complexes (Bennett, 1965). The International Institute in Izmir (the Izmir Centre), Turkey, was established in 1964 with such terms of reference (Sencer, 1975).

In the 1970s and 1980s, there was increasing recognition of CWR as a significant component of plant genetic resources. In tune with the times, the main focus was on the collection and *ex situ* conservation of samples of genetic diversity, activities which accelerated in the mid-1980s, probably as a consequence of the introduction of ecogeographic surveying. It was only in the 1980s that a small number of agricultural and forestry scientists began to actively target CWR for *in situ* conservation, probably due to a growing awareness of habitat and species decline, followed by calls for the conservation of CWR by prominent international and conservation organizations. Although some time and resources began to be allocated to studying the possibilities of *in situ* CWR conservation, the necessary cross-sectoral approach was often lacking. A number of scientific meetings and publications followed, dealing with various aspects of *in situ* CWR conservation during the 1980s.

The entry into force of the Convention on Biological Diversity (CBD) in 1993, the endorsement of the Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (GPA) in 1996 and the International Treaty on Plant Genetic Resources (ITPGRFA) in 2001, whereby signatory countries adopted *in situ* CWR conservation as a national priority, and a series of books on *in situ* CWR conservation theory and methods, as well as some on-the-ground field projects, provided added impetus to our appreciation and understanding of the importance of CWR (Meilleur and Hodgkin, 2004).

Landmark publications on CWR

One of the first publications to draw attention to the importance of conserving CWR was the booklet *Conserving the Wild Relatives of Crops* by Erich Hoyt, published by the International Union for Conservation of Nature (IUCN), IBPGR [later to become IPGRI and today Bioversity International] and the World Wide Fund for Nature (WWF) in 1988.[3] Much of what it says is still valid and Hoyt's statement, 'The conservation of crop genetic resources – the plants that feed us and their wild relatives – is one of the most important issues for humankind today', remains true to this day. A major review of the use of CWR was published by Prescott-Allen and Prescott-Allen (1988).

A significant, although frequently overlooked, publication is the booklet *Plant Genetic Resources: Their Conservation* in situ *for Human Use* (FAO, 1989), which arose out of a decision taken during the first meeting of the ad hoc working group on *in situ* conservation of the Ecosystems Conservation Group in 1986, including members from FAO, the United Nations Educational, Scientific and Cultural Organization (UNESCO), UNEP, the IUCN and the International Board for Plant Genetic Resources (IBPGR). This included a series of cases studies from around the world, illustrating action planned or underway in *in situ* conservation of plant genetic resources.

Other important resources are the proceedings of the workshops initiated by the Council of Europe on 'Conservation of the Wild Relatives of European Cultivated Plants' (Valdés et al, 1997), which were held in Faro (Portugal), Neuchâtel (Switzerland) and Gibilmanna-Palermo (Sicily, Italy), and addressed a wide range of issues concerning the genetics, demography, ecology, conservation, management and protection of genetic variability through a series of case studies.

A further valuable resource is the global survey of *in situ* conservation of wild plant species (Heywood and Dulloo, 2005) that arose out of another UNEP/GEF-supported project 'Design, Testing and Evaluation of Best Practices for *In Situ* Conservation of Economically Important Wild Species'.

An additional landmark publication is *Crop Wild Relative Conservation and Use* (Maxted et al, 2008) which arose out of the first international conference on CWR, organized within the framework of the European Commission (EC)-funded Plant Genetic Resources (PGR) Forum project and held in Agrigento, Sicily, Italy in September 2005.[4]

The second report on the *State of the World's Plant Genetic Resources for Food and Agriculture*[5] was endorsed at the 12th Session of the Commission on Genetic Resources for Food and Agriculture (Rome, 18–23 October 2009). It updates the first report with the best data and information available, through a participatory process, and with a focus on changes that have occurred since 1996; the report provides a concise assessment of the status and trends of plant genetic resources for food and agriculture (PGRFA) and identifies the most significant gaps and needs in order to provide a basis to update the rolling Global Plan of Action. It contains several references to CWR, especially Section 1.2.3: Changes in the status of crop wild relatives; Section 2.2.1: Inventory and state of knowledge; and 2.2.2: *In situ* conservation of crop wild relatives in protected areas. Salient points are:

- while many new priority sites for conserving CWR have been identified around the world during the last decade, largely as a result of ecogeographic surveying, many species remain under threat as a result of land degradation, changes in land-use practices and other factors;
- since the publication of the first State of the World Report, most countries have carried out specific surveys and inventories of PGRFA, but the majority have been confined to single crops, small groups of species or limited areas;
- very little survey or inventory has been done on PGRFA in protected areas as compared with other components of biodiversity in these areas and *in situ* conservation of wild species continues to be an unplanned result of efforts to protect particular habitats or charismatic species; and
- relatively few countries have been active in conserving wild PGRFA in protected areas although some progress has been made.

The creation in 2003 of the Crop Wild Relative Specialist Group (CWR SG)[6] within the IUCN Species Survival Commission provided a network for those interested in the conservation and sustainable use of CWR. It publishes a regular newsletter, *Crop Wild Relative*.[7]

The value and use of CWR

The value of CWR is evident from the use that has been made of them in crop improvement, especially in the last few decades. In a recent review of their use, Maxted and Kell (2009) cited 91 articles that reported the identification and transfer of useful traits from 185 CWR taxa into 29 crop species (see Figure 1.1). They found that the degree to which breeders had used CWR diversity varied markedly between crops, both in terms of CWR taxa usage and number of citations of CWR usage reported. The use of CWR has been particularly notable in barley, cassava, potato, rice, tomato and wheat. The crops in which CWR have been most widely used are rice and wheat, both in terms of the number of CWR taxa and number of successful attempts to introgress traits from the CWR to the crop.

The key to successful crop improvement is a continued supply of genetic variability and beneficial traits contained in this diversity (Dwivedi et al, 2008), and wild relatives of modern crops are the source of much of this novel diversity. It is not widely realized how high the turnover rate of cultivars is in many crops as a consequence of losing, for example, resistance or tolerance or because of the need for continual innovation. For example, in tomato (*Lycopersicum esculentum*) the average turnover time of commercial cultivars is approximately five years, largely because seed companies must continuously develop new cultivars with added value and hence commercial tomato breeding is very innovative (Bai and Lindhout, 2007).

The deployment of innovative biotechnology tools provides new opportunities to make greater and more effective use of wild species in crop improvement (Tanksley and McCouch, 1997; Dwivedi et al, 2007). The latter argue that, 'the tools of genome research may finally unleash the genetic potential of our wild and cultivated germplasm resources for the benefit of society.' Genes from wild plants have so far provided cultivars with resistance against pests (e.g. Malik et al, 2003) and diseases (e.g. Brar, 2005), improved tolerance to abiotic stresses (e.g. Farooq and Azam, 2001), tolerance of extreme temperatures and salinity; and resistance to drought and enhanced nutritional quality (e.g. Kovacs et al, 1998; Dillon et al, 2007). Indeed, modern cultivars of most crops now contain some genes that are derived from a wild relative. For example, genes from several wild species of *Aegilops*, which is closely related to *Triticum*, have been transferred to cultivated wheat, including those that confer resistance to leaf rust, stem rust, powdery mildew and nematodes (Schneider et al, 2008); many other valuable genetic resources in *Aegilops* species remain untapped. Likewise, wild rice species have proven to be important gene reservoirs that can be used to increase domesticated rice yield, quality and resistance to diseases and insects. They have furnished genes for the hybrid rice revolution, exhibit yield-enhancing traits and have shown tolerance to biotic and abiotic stress (Brar and Khush, 1997; Xiao et al, 1998). In Sri Lanka, wild *Oryza nivara* is being used to breed resistance to the pest brown plant hopper into cultivated rice varieties (see Box 1.2). In cotton (*Gossypium*), the narrow genetic base of the primary cotton breeding gene pool is one of the major constraints in cotton breeding programmes worldwide. This underlies the necessity to enrich the gene pool with genetic diversity from landraces and CWR (Abdurakhmonov et al, 2007). The use of CWR in breeding stress- and disease-resistant cotton in Uzbekistan is summarized in Box 1.4.

Box 1.1 Examples of the use of CWR

In tomato, extensive use has been made of the genetic variation present in wild species (Rick and Chetelat, 1995; Bai and Lindhout, 2007; Robertson and Labate, 2007) in developing today's commercial varieties. Over 130 genes associated with drought responsiveness have been identified at AVRDC (The World Vegetable Center) and those from its wild relatives in the Chilean deserts are being introgressed into commercial lines. However, compared with the rich reservoir in wild species, the cultivated tomato is genetically poor and it is estimated that the genomes of tomato cultivars contain only 5 per cent of the genetic variation of their wild relatives (Miller and Tanksley, 1990). It is expected that the potential of tomato breeding using only cultivated germplasm will reach a ceiling, necessitating that future plant breeding initiatives explore the diversity available in related wild species (see review by Bai and Lindhout, 2007). With techniques like EcoTILLING,[8] allele mining will greatly facilitate the identification of useful genes in wild tomato germplasm (Comai et al, 2004).

It is clear that CWR represent a vast unexplored potential for future crop improvement. For example, in wild emmer wheat (*Triticum turgidum* subsp. *dicoccoides*) accessions, Chatzav et al (2010) found wide genetic diversity for all grain nutrients, with the concentrations of grain zinc, iron and protein being twice as much in wild accessions as in domesticated genotypes. They consider that wild

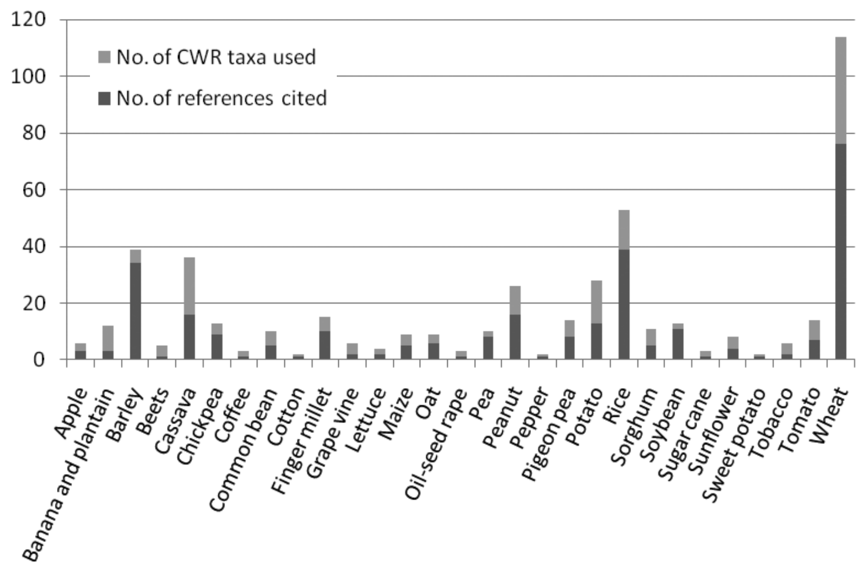

Figure 1.1 *The number of references reporting the identification and transfer of useful traits from 185 CWR taxa to 29 crop species, showing the number of CWR taxa used in each crop*

Source: Maxted and Kell, 2009

Figure 1.2 *Crossing cultivated rice with wild* Oryza nivara *at the Rice Research and Development Institute, Batalagoda, Sri Lanka*

emmer germplasm offers unique opportunities to exploit favourable alleles for grain nutrient properties excluded from the domesticated wheat gene pool. In maize (*Zea mays*), Ortiz et al (2009) found that only a small portion of the wide array of genetic diversity found in wild relatives of the crop is represented in current elite breeding pools. Given that growing demands for food production, feed and bio-energy are estimated to require a 2 per cent annual increase in global maize production, it can be expected that the diversity found in CWR will be tapped by breeders to meet these needs. On the other hand, as Hajjar and Hodgkin (2007) point out, CWR have contributed less than might be expected to the development of new cultivars, despite improved procedures for intercrossing species from different gene pools, advances in molecular methods for managing backcrossing programmes, increased numbers of wild species accessions in genebanks and the substantial literature available on beneficial traits associated with wild relatives. Heywood et al (2007) suggest the main reasons for the neglect of CWR conservation have to do with practicality, priorities and economics. There is, in fact, widespread uncertainty as to the benefits to be obtained from CWR *ex situ* and, especially, *in situ* conservation.

It is exceedingly difficult to quantify the monetary or commercial benefits to be obtained from the conservation and use of plant genetic resources and of CWR in particular (see NRC, 1991a, 1993; Rubenstein et al, 2005). It has been suggested that, on average, genetic contributions from wild species increase crop productivity by about 1 per cent each year, and this increase in productivity has

Box 1.2 Rice breeding programme with wild Oryza nivara in Sri Lanka

Brown plant hopper (BPH) is one of the major pests of rice in Sri Lanka. Annually, it affects an average of 5–10 per cent of the extent of total paddy cultivation. Presently, BPH resistance is incorporated into all new rice varieties; the source of the resistance was found decades ago in rice variety PTB 33. Due to continued use of the single resistance source, new biotypes of BPH have developed and the crop's resistance has been compromised. Rice breeders in Sri Lanka have been looking for a new source of resistance and have investigated wild rice as a possible genetic resource. There are five wild *Oryza* species in Sri Lanka, namely *O. nivara*, *O. rufipogon*, *O. eichingeri*, *O. rhizomatis* and *O. granulata*. Of these five species, *O. nivara* and *O. rufipogon* are in the same genome group as cultivated rice, *Oryza sativa*. Hence, both species are relatively easy to hybridize with cultivated rice.

With assistance from the UNEP/GEF Crop Wild Relatives project, plant breeders at the Central Rice Research and Development Institute in Sri Lanka collected 40 different accessions of *O. nivara* during 2006–2008. These accessions were tested for BPH resistance using standard screening procedures, and it was found that 3 accessions were highly resistant to BPH while 15 accessions were within the moderately resistant category. It was found that these three accessions survived even after the death of the resistant variety PTB 33 from the intensity of BPH attack, indicating the resistance in the three *O. nivara* accessions was different from that of PTB 33. Ten crosses were made between *O. nivara* and cultivated rice and eight were successful. Forty-two F_1 seeds were obtained from the successful crosses. All F_1 seeds were germinated and produced seeds, but only 10 per cent of the seeds were filled. Screening of the F_2 generation for resistance showed 30 per cent of the seedlings were resistant to BPH. F_3 seed formation from resistant lines resulted in 60 per cent filled seeds and F_3 screening results revealed that 50 per cent of seedlings were resistant to BPH. In the F_4 generation, empty seeds were reduced to 10 per cent and 92 per cent of seedlings were resistant to BPH. Currently, seeds of the F_6 generation have been harvested and are being used as parental material in the National Rice Breeding Programme. Yield observations of the new lines are expected to be conducted shortly. Rice Breeder: P.V. Hemachandra.

been valued at US$1 billion (NRC, 1991b). Some idea of the scale of benefits may, however, be obtained from published estimates referring to a selected number of crops. For example, the desirable traits of wild sunflowers (*Helianthus* spp.) are worth an estimated US$267 to US$384 million annually to the sunflower industry in the United States; one wild tomato variety has contributed to a 2.4 per cent increase in solids content worth US$250 million; and three wild peanuts have provided resistance to the root knot nematode, which costs peanut growers around the world US$100 million each year. Of course, the commercial contribution of the majority of CWR is likely to be on a much smaller scale.

Examples of CWR from the UNEP/GEF project countries and their desirable traits are given in Table 1.2.

Table 1.2 *Wild species being evaluated for their potential to improve the tolerance of their crop relatives to biotic and abiotic stresses as part of the UNEP/GEF project*

Country	*Wild relative of*	*Desirable traits*
Armenia	Wheat, pear	Resistance to adverse environmental conditions
Bolivia	Potato, quinoa, cañahua (*Chenopodium pallidicaule*)	Pest and diseases resistance of selected species from three genera Nutritious properties of quinoa and cañahua
Madagascar	Coffee, rice, yam	No or low caffeine, high content of chlorogenic acid Resistance to rice yellow mottle virus (RYMV) Potential for domestication
Sri Lanka	Rice	Resistance to biotic and abiotic stresses
Uzbekistan	Apple, pistachio	Resistance to adverse environmental conditions

Source: http://www.underutilized-species.org/Documents/PUBLICATIONS/sbstta_cwr_final.pdf

Box 1.3 Breeding potential of CWR in Madagascar

Rice breeders from the Centre National de la Recherche Appliquée au Développement Rural (FOFIFA) managed to obtain approximately 100 lines derived from inter-specific crosses with the wild species *Oryza longistaminata* and the cultivated species *Oryza sativa*, as well as multiple back crosses from the hybrid plant. They are different phenotypes, consistent and stable, and are believed to possess the genes of *Oryza longistaminata* in their gene pool. These lines are selected primarily for their trait of resistance to the rice yellow mottle virus (RYMV), which makes the panicles sterile, causing a drop in grain yield. It is transmitted mechanically by contact and by insects, mainly *Trichispa sericea* or *Hispa gestroy*. The disease occurs in the rice producing regions of the north Andapa Basin, northwest and west of the island. It has not been identified in the highlands, but it may be occasionally observed in the region of Lake Alaotra, especially during high rainfall periods, and more rarely in the southwest. It was observed that the wild species *Oryza longistaminata* is never attacked by the disease. However, many defects are observed, since it has rhizomes like a weed. Its seeds have a very low percentage of fertility and shatter easily, even when immature. In addition, its panicles are very loose, and the stigma is extruded. Recently, the prospect of improvement through inter-specific crossing between the wild species and the cultivated species *Oryza sativa* has become feasible. The goal is to introgress resistance to RYMV from the wild relative to the cultivated lines, while avoiding the inclusion of disadvantageous traits. Several attempts with 100 different crosses with cultivated lines have already been made, but they were not successful as there was no fertilization, the embryo being aborted before maturity. Although hybridization between the two species was a very laborious process, it was possible to fertilize a spikelet using a cultivated line 'Miandry Bararata' as a female parent and the wild species as pollinator. The resulting embryo was immature and needed a suitable culture medium to result in an adult plant with intermediate phenotype. The F_1 plant obtained possessed rhizomes and further backcrossing followed using multiple crosses with other lines to eliminate or reduce this disadvantageous feature.

Source: Rakotonjanahay Xavier pers.comm. to J. Ramelison (April 2008)

Box 1.4 Use and potential of cotton CWR in Uzbekistan

The Institute of Genetics and Experimental Plant Biology in Uzbekistan holds a collection of 45 wild cotton species and forms of *Gossypium*. The genetic potential of wild cotton relatives was used in inter-species hybridization whereby valuable features of wild species were successfully transmitted into cultivated species. Complex synthetic hybrids were created on the basis of trigenetic hybrids of *G. hirsutum* × (*G. harknessii* × *G. thurberi*) and prospective hybrid lines were obtained as the result of *G. hirsutum* × (*G. thurberi* × *G. raimondii*) crosses. These hybrids possess valuable features such as high fertility and fibre quality. Wild relatives of cultivated cotton species represent very valuable material with potential for adaptation, through resistance to environmental stress factors and agricultural pests. Wilt-resistant forms of *G. hirsutum* subsp. *mexicanum* and ruderal forms of *G. hirsutum* 'El Salvador' were used in breeding programmes as the basis for the creation of a series of new forms. Wild accessions of *G. herbaceum* L. and *G. arboreum* L. are characterized by hygroscopic fibres of high quality. They were used as donors in genetic breeding programmes to create intra- and inter-specific forms. *G. hirsutum* L. was used in obtaining wilt-, heat- and drought-resistant varieties (subsp. *mexicanum* var. *nervosum*, subsp. *punctatum*) and *G. barbadense* L. was used as the basis for the salt-resistant variety *G. barbadense* subsp. *darwinii*. Wild cotton relatives which were used to produce synthetic hybrids with valuable features are shown in Figure 1.3.

Source: Sativaldi Djataev

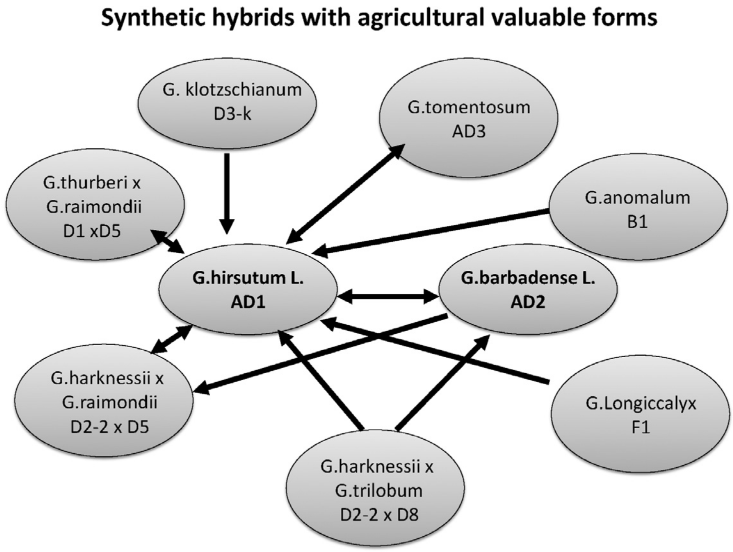

Figure 1.3 *Relationships of synthetic hybrids of cotton produced in Uzbekistan*

Source: Sativaldi Djataev

Why is *in situ* conservation of CWR important?

Despite the fact that the importance of *in situ* conservation for CWR has been widely recognized, until recently the main conservation strategy of the plant genetic resource sector has been to collect material of cultivars, landraces and, to a lesser extent, CWR and to store these material *ex situ* in genebanks for use or potential use in plant breeding (see Chapter 12). Little attention was paid to *in situ* approaches. Although a handful of reserves for the *in situ* conservation of CWR were established in the 1980s – the Sierra de Manantlán Biosphere Reserve for the maize wild relative, *Zea diploperennis*, in Mexico; the Erebuni Reserve in Armenia and the Ammiad Project Reserve in Israel for wheat wild relatives; and the National Citrus Gene Sanctuary-cum-Biosphere Reserve in the West Garo Hills, India, for citrus wild relatives – only in the last 10–15 years have serious efforts been made to conserve CWR in their natural wild habitats (*in situ*). In a major GEF/World Bank project on conservation of genetic diversity in Turkey (Tan and Tan, 2002), a wide range of crop wild relatives (*Triticum*, *Lens*, *Pisum*, *Castanea*, *Abies* and *Pinus*) were selected as target species for *in situ* conservation in 'gene management zones' (GMZs) – natural and semi-natural areas set aside for maintaining genetic diversity in a natural setting for the species of interest.

Practical experience is therefore very limited and there are no generally agreed procedures to follow. The reason the genetic resources sector is now paying attention to the conservation of CWR *in situ* is due to the recognition that such initiatives allow CWR to remain in their natural surroundings with associated species where populations can not only be maintained as a source of potentially useful variation for crop improvement, but also to continue to evolve and generate new variation, some of which might be valuable for use in future breeding efforts. There may also be additional economic benefits of *in situ* conservation, as will be discussed later (see Chapter 3). The importance of conserving CWR and other wild plants *in situ* was specifically identified in the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (1996) under the Plan's Priority Activity Area 4, while the Convention on Biological Diversity specifically mentions 'wild relatives of domesticated or cultivated species' in the indicative list of categories of the components of biological diversity to be identified and monitored given in its Annex 1.

> In situ *conservation is the only practical method presently available to conserve a great variety of ecosystems, species and genes which are today vulnerable, threatened or endangered. In addition to allowing conservation of a range of different species and co-evolution of biological systems,* in situ *conservation of genetic resources can be compatible with their management for the sustained production of goods to meet day-to-day requirements of local populations, such as food, fodder and medicines; and for the harvesting of timber, wood and fuel.*
>
> *Source:* FAO, 1989

Populations of many CWR species occur in existing protected areas, although the absence of proper inventories means detailed information on such species is not available. It may be assumed that because they are found in protected areas, CWR may be afforded some degree of protection, provided the area is well managed. However, as will be elaborated later, this alone does not, in many cases, represent effective *in situ* conservation as some degree of management or intervention targeted at CWR populations is necessary, particularly if the species is threatened. Moreover, reliance on the continued existence of protected areas in their current location is a risky strategy in the face of global change, especially climate change (see Chapter 14). What is more, the majority of CWR occur outside protected areas and there has been little experience thus far of how to safeguard CWR in such a context. It should also be emphasized that *in situ* conservation is not a short-term approach: on the contrary the timescale of concern is effectively open-ended. This presents major logistical, scientific, technical, economic, political and financial challenges for long-term sustainability.

Threats to the maintenance of CWR

As discussed in detail in Chapter 10, like many other wild species, CWR are increasingly threatened, primarily from habitat loss, fragmentation and degradation, changes in disturbance regimes and invasive alien species. An additional threat that must be addressed is the impact of accelerated global change. The loss of genetic material from CWR has profound implications for agriculture. It reduces the potential for continuous improvement in crop productivity and quality and in the ability of crops to adapt to changing environmental conditions. These assets are critical to reduce hunger and poverty across the developing world. Such loss in diversity could be especially serious in areas containing a wide range of wild progenitors and related wild species and may be exacerbated in some regions by the effects of global change such as demographic growth, population movements, changes in disturbance regimes and climate change.

Few studies have yet been made focusing on the impacts of climate change on the survival rates of CWR, but the evidence published to date, based on the use of bioclimatic modelling, suggests many will be at risk (see Box 1.5). There is an urgent need, therefore, to identify priority species and areas for conservation and, as elaborated in Chapter 12, to develop integrated *in situ* and *ex situ* conservation strategies to ensure that the rich genetic diversity of CWR is protected for the benefit of future generations.

The adaptation of crops to gradual change in climatic conditions will require screening of existing cultivars and breeding of new ones for adaptation to drought, temperature stresses, sustained productivity, disease resistance and other factors, highlighting the importance of maintaining the pools of genetic variation in CWR.

Box 1.5 Evaluating the impact of climate change on CWR

The survival of crop wild relatives is now threatened by the impacts of climate change. An evaluation was conducted by Andy Jarvis and colleagues at the International Centre for Tropical Agriculture (CIAT), the Global Biodiversity Information Facility (GBIF) and Bioversity International, using data accessible through the GBIF, of the possible threats posed by climate change on 11 wild gene pools of major crops worldwide, comprising a total of some 343 species.

For each species, data from both herbarium specimens and germplasm accessions were used to determine the potential distribution of each species and, based on 18 global climate models for the year 2050 under gas emissions scenario A2a[9] and assuming unlimited migration, their future geographical distribution was also mapped.

A map was then generated to illustrate the current richness of crop wild relatives, future predicted richness and the predicted change in richness. The map reveals the hotspots of change where significant loss of diversity is expected to occur. These sites, mostly in sub-Saharan Africa, eastern Turkey, the Mediterranean region and parts of Mexico, are priority areas for collection and conservation of genetic resources.

Another study by Lira and colleagues in Mexico used bioclimatic modelling and two possible scenarios of climatic change to analyse the distribution patterns of eight wild cucurbits closely related to cultivated species. The results showed that all eight taxa displayed a marked contraction in area under both climate scenarios and, that under a drastic climatic change scenario, the eight taxa would only be maintained in 29 of the 69 protected areas in which they currently occur.

Source: Jarvis et al, 2008 and Lira et al, 2009

The challenge of *in situ* conservation of CWR

As is evident in later chapters of this manual, the *in situ* conservation of crop wild relatives is a complex and multidisciplinary process and one that creates many challenges and difficulties. Not only are there complex issues to be addressed, such as the location and selection of populations for conservation, demography and size of populations, the nature of threats to both habitats and the CWR populations and how to manage them, the design of genetic reserves and the need for detailed management protocols, but the multiplicity and complexities of national political and administrative structures also render it extremely difficult to implement a common strategy or framework, assuming one could be agreed.

The limited practical experience in conserving CWR *in situ* to date means that there are no generally agreed protocols or recommendations, and good practice is limited by the shortage of successful examples for reference. On the other hand, there is much to be learned from the experience of *in situ* conservation of endangered wild species through recovery programmes in many European countries, the US, Australia and South Africa, supported by extensive conservation biology literature. Also, the forestry sector has been engaged in *in situ* conservation of forest

Box 1.6 Sierra de Manantlán and maize and its wild relatives

The discovery in the mid-1970s of the wild maize – the endemic perennial *Zea diploperennis* – in its natural habitat in Jalisco in western Mexico, led to the establishment of the Sierra de Manantlán Biosphere Reserve in 1987. Populations of the wild annual relative, *Z. mays* subsp. *parviglumis*, and the Tabloncilo and Reventador races of maize traditional in this area, are further targets for conservation. Although limits on external inputs (such as exotic improved germplasm and chemicals) may need to be set so as not to endanger the wild relative, plant geneticists are optimistic that *Z. diploperennis* and the three other taxa can be conserved *in situ*, as long as ways to provide opportunities for the cultivators involved in managing the system continue to be identified. Indeed, research has shown that populations of *Z. diploperennis* virtually require cultivation and grazing in adjacent fields to prosper.

Source: http://www.unesco.org/mab/sustainable/chap2/2sites.htm

genetic resources for several decades with support from FAO, which has reviewed this topic on a regular basis. Unfortunately, there are practically no examples of *in situ* conservation of CWR in the tropics, apart from the establishment of some genetic reserves for various species of fruit trees such as the Gene Sanctuary-cum-Biosphere for citrus in the Garo Hills of Meghalaya in northeast India. This reserve is located within the Nokrek National Park and was created in 1981; it is the first reserve specifically established for the conservation *in situ* of a tropical shrub (Singh, 1981; Smith et al, 1992). Further, in Mexico an *in situ* reserve was created in 1987 within the Biosphere Reserve of the Sierra de Manantlán for *Zea diploperennis*, a wild relative of maize (*Zea mays*) (Box 1.6).

Given the heterogeneity of species, environments, threats and needs, there is certainly no blueprint or 'one size fits all' approach to *in situ* conservation of CWR. While many of the challenges are of a technical nature, there are an equal number of political, institutional, cultural, legal and social issues that must be addressed and resolved. The sectors that must work together, i.e. the agricultural, forestry and environmental agencies, often have no linkages or tradition of collaboration. Frequently, there is no collaborative framework to guide the activities required to support conservation decision-making. The current disconnect existing among such agencies presents considerable challenges for partnership and coordination, as well as for establishing a suitable policy/legal enabling environment for CWR conservation. In addition, there may well be other complex political and social issues related to land ownership/tenure, access to resources and benefit-sharing. Such complexity usually guarantees that obstacles will need to be addressed to integrate CWR conservation into national programmes.

The situation is made more difficult by the fact that CWR are not usually considered to be flagship or iconic species; therefore, attracting interest and resources is a further challenge. As a result, there is often a lack of funding for

CWR research and conservation, as well as for capacity building and training. This, combined with a general lack of information about CWR, results in a limited understanding and awareness of the importance of CWR and the threats posed to their very existence by global change. The term *crop wild relative* is not readily comprehensible to most people and it might be preferable to replace it with another term such as 'gene donor species for crops'.

The way in which CWR are defined and the application of priority-determining mechanisms to focus resources are important issues that have a bearing on the number of candidate species a programme will need to consider, as well as financial and resource implications. The prioritization or selection of areas for CWR conservation also presents its own challenges.

A major limitation most countries and agencies will face when implementing a CWR conservation programme is the capacity and tools to bring together and use existing information. A substantial amount of relevant and useful information is often available within different institutions at both the national and international levels; however, it is typically highly dispersed and difficult to compile. Such information can include: data on species distribution and biology, held in national herbaria and botanic gardens, and in key international collections in other countries (such as the Royal Botanic Gardens, Kew, UK; Missouri Botanical Garden, USA; and Muséum National d'Histoire Naturelle, Paris, France); information on distribution and scope of existing protected areas held nationally and by organizations such as United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC); and information on species status and existing *ex situ* collections, conserved in genebanks. Mapped national survey data from different sources (geography, town planning, soil survey, etc.) provide further information to aid in the conservation planning process through the increasing power of GIS analysis. It should be noted that GBIF is a major repository of georeferenced data used in bioclimatic modelling.

Further, conservation activities often are sponsored by grants from agencies or fall within traditional project implementation and funding cycles, which adds to existing challenges. By their nature, grants and projects are time-bound, presenting obstacles for long-term conservation planning. Project-driven conservation also faces important issues in relation to sustainability and institutionalization of processes and activities, which means when the project finishes so do the activities. This problem may be mitigated to some extent if projects are more locally driven, with close involvement of the stakeholders most directly concerned, so that long-term conservation actions are not mainly dependent on externally funded sources. Some of these issues are dealt with in more detail in Chapters 4 and 5.

Many of the above issues have been addressed in a European context by the EC-funded project 'European Crop Wild Relative Diversity Assessment and Conservation Forum (PGR Forum)' for the assessment of taxonomic and genetic diversity of European CWR and the development of appropriate conservation methodologies (http://www.pgrforum.org/Publications.htm) and by the GEF/World Bank project on conservation of genetic diversity in Turkey (Tan and Tan, 2002).

Box 1.7 Goals of the UNEP/GEF CWR Project

1. To develop international and national information systems on CWR that include data on species biology, ecology, conservation status, distribution, actual and potential uses, conservation actions and information sources.
2. To build the capacity of national partners to use this information for developing and implementing rational and cost-effective approaches to conserving CWR *in situ*.
3. To raise awareness among policy-makers, conservation managers, plant breeders, educators and local users of the potential of CWR for improving agricultural sustainability.

The UNEP/GEF Crop Wild Relatives Project

The Global Environment Facility (GEF) is the financial mechanism for the Convention on Biological Diversity (CBD) and helps countries fulfil their obligations under the CBD. Biodiversity conservation constitutes one of the GEF's major priorities; since 1991, the GEF has invested nearly US$4.2 billion in grants and co-financing for biodiversity conservation in developing countries. Over the last ten years the GEF has supported a number of projects at the national, regional and global levels that seek to enhance the conservation and use of CWR, in line with its goal and objectives (see Box 1.8). Many developing countries, located within centres of plant diversity and centres of crop diversity, contain large numbers of important crop relatives. Although most of these countries have listed the conservation of CWR within their national biodiversity strategies and their agricultural development strategies, they generally possess such limited resources that they have not yet been able to invest in programmes to support the effective conservation and optimum use of CWR. The UNEP/GEF-supported project, '*In situ* conservation of crop wild relatives through enhanced information management and field application' (CWR Project) was specifically designed to address these issues and aims to seek ways of satisfying national and global needs to improve global food security through effective conservation and use of CWR (see Box 1.7). Five countries are involved in the project though their national governments – Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan. Each country has significant numbers of CWR, many of which are at risk and in need of conservation. Details of the institutions involved in the partner countries are provided in the acknowledgements section at the beginning of the manual.

To bring the necessary expertise and multidisciplinary skills to bear on a project of this complexity, international partners were identified and invited to collaborate and provide resources and technical support. The international partners are Botanic Gardens Conservation International (BGCI), the FAO, the IUCN and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). The executing agency of the project is Bioversity International (formerly IPGRI).

Box 1.8 Major GEF projects in support of CWR conservation

Kibale Forest Wild Coffee Project (Uganda) – This project assisted Uganda's implementation of its national biodiversity strategy and action plan by helping maintain biodiversity in the landscape mosaics beyond the boundaries of protected areas of global importance.

http://www.gefonline.org/projectDetailsSQL.cfm?projID=490

***In Situ*/On-Farm Conservation and Use of Agricultural Biodiversity (Horticultural Crops and Wild Fruit Species) in Central Asia** (multi-country) – The project provides farmers, institutes and local communities with knowledge, methodology and policies to conserve globally significant *in situ*/on-farm horticultural crops and wild fruit species in Central Asia.

http://www.gefonline.org/projectDetailsSQL.cfm?projID=1025

***In-Situ* Conservation of Andean Crops and their Wild Relatives in the Humahuaca Valley, the Southernmost Extension of the Central Andes** (Argentina) – The project aimed at ensuring that indigenous farmers in the Humahuaca Valley of Argentina adopted improved on-farm conservation and management practices, based on traditional production practices that contribute to *in situ* conservation of selected globally significant Andean crop varieties and their wild relatives

http://www.gefonline.org/projectDetailsSQL.cfm?projID=1732

Conservation and Sustainable Utilization of Wild Relatives of Crops (China) – The project aims at supporting plans to establish protected areas with an integrated and landscape approach and with participation from local communities, so as to secure the wild relatives of soybean, wheat and rice, including their natural habitats.

http://www.gefonline.org/projectDetailsSQL.cfm?projID=1319

***In Situ* Conservation of Native Cultivars and Their Wild Relatives** (Peru) – The project aimed at conserving the agrobiodiversity in one of the world's most important centres of origin of crop and plant genetic diversity. This project targeted 11 important crop species, including several local varieties and wild relatives, for conservation of their genetic diversity within functioning agroecosystems.

http://www.gefonline.org/projectDetailsSQL.cfm?projID=500

***In situ* Conservation of Native Landraces and their Wild Relatives** (Vietnam) – The project targeted the conservation of six important crop groups (rice, taro, tea, litchi-longan, citrus and rice bean) including native landraces and wild relatives in three local ecogeographical areas rich in biodiversity of native landraces and their wild relatives.

http://www.gefonline.org/projectDetailsSQL.cfm?projID=1307

Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity (Asia) – The aim of the project is to improve the conservation and use of tropical fruit genetic diversity by strengthening the capacity of farmers, local communities and institutions to sustainably manage and utilize tropical fruit trees.

http://www.gefonline.org/projectDetailsSQL.cfm?projID=2430

Box 1.9 National Information System of Crop Wild Relatives of Bolivia

The Bolivian National Information System of Crop Wild Relatives was designed and developed in the framework of the UNEP/GEF project: '*In situ* conservation of crop wild relatives through enhanced information management and field application'. Now operative, the system comprises eight institutional databases, each located at one of the national institutions that participated in the project: three herbaria, three genebanks, one agricultural research institution, and one Organization of the Indigenous Peoples of Bolivia. In addition, the National Portal and GisWeb are part of the system. The databases can be visited online through the National Portal website: http://www.cwrbolivia.gob.bo. The Google Maps application has been customized to function as an integrated GisWeb and is integrated into the National Portal.

The information system contains data on species from 15 genera (*Anacardium*, *Ananas*, *Annona*, *Arachis*, *Bactris*, *Capsicum*, *Chenopodium*, *Cyphomandra*, *Ipomoea*, *Manihot*, *Phaseolus*, *Rubus*, *Solanum*, *Theobroma*, *Vasconcellea*), regarding taxonomy, accessions, population and ecology. The database of the system has approximately 3223 records of 190 species, of which 33 species are endemic to Bolivia. It also incorporates a map gallery containing roughly 150 different types of maps, e.g. maps of current and potential distribution of CWR species, collection and other sites, and an image gallery with approximately 152 photos of different CWR species. The National Portal also contains an Atlas of Bolivian CWR.

The information contained in the database is released through the national and international portals, based on a data-sharing agreement between Bioversity International and the government of Bolivia. The system has tools for the identification and prioritization of species, implementation and monitoring of conservation actions and use of CWR. It is also a support tool for decision-makers regarding strategies and policies on CWR in the context of genetic resource management in Bolivia. This information is important to support the improvement of food security in Bolivia and the world.

The immediate objective of the UNEP/GEF CWR Project was to enhance conservation of CWR in each of the project countries. It aimed to achieve this through a series of coordinated components, including the development of a national information system in each country (see Box 1.9 for a description of the Bolivian system), a global information system, enhanced national capacity and conservation actions and public awareness. A major focus of the project was the systematic compilation, enhanced access to and use of information related to CWR. Analysis of this information is a first step towards developing and implementing national-level *in situ* conservation and monitoring strategies. The recently launched Crop Wild Relatives Global Portal (www.cropwildrelatives.org) (see Box 1.10) serves as a gateway through which CWR information can be made widely available. Users can search through databases maintained by national and international partners to obtain information for better decision-making, which leads to more effective conservation and sustainable use of crop wild relatives.

Box 1.10 Information included in the CWR Global Portal

The global UNEP/GEF CWR Project includes a component on information management, an important aspect for enhanced decision-making and conservation. Earlier studies, as well as baseline studies for the project showed that, although information on CWR was available, it was often scattered and hard to access, since it was not in digital format. The five partner countries – Armenia, Bolivia, Sri Lanka, Madagascar and Uzbekistan – set up national inventory databases on CWR, storing previously existing data from various sources, which in most cases were digitized during the life of the project, as well as many additional records gathered during field surveys. Given the different national and institutional contexts and varying levels of expertise and use of software programs, all five national inventories were designed according to appropriate national preferences and settings. Armenia developed a web-based system with PHP and MySQL, which is used in the institutions that have CWR data. Data is sent through modem connection from the institutions to the central database, which now contains more than 30,000 records for 104 species. The Uzbek national database was developed in Access, while in Madagascar and Sri Lanka the newly digitized data was first entered into Excel worksheets. Bolivia compiled at least 3010 records for over 160 CWR species. The development of the national systems allowed countries to map distribution of wild relatives in their countries, identify areas for CWR conservation and prioritize protected areas where CWR should be included in the protected areas management plans. In addition to the national information systems, a global portal was developed to provide access to CWR information at the global level. The national CWR inventories are all searchable through the global portal and are linked to it using TapirLink as the providing software. Further information and resources on CWR provided by the portal include publications, projects and experts, news and images. The choice of freely available and easy-to-use tools, as well as approved and widely used standards, make it easy to link additional national CWR inventories to the portal in the future and to provide a CWR-viewpoint on plant genetic resources data and distribution. Ideally, the global portal will be further developed by Bioversity International to link to all relevant information sources on CWR so as to provide a convenient information gateway.

The portal provides information on the following:

- species-level data on CWR;
- *ex situ* conservation;
- taxonomy;
- conservation status;
- distribution;
- the presence of CWR in protected areas;
- relevant contacts, literature sources, latest news and photos.

Information sources include: country partners (Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan); international partners (BGCI, FAO, IUCN and UNEP-WCMC); other countries' data accessible via the Global Biodiversity Information Facility (GBIF).

Source: www.cropwildrelatives.org

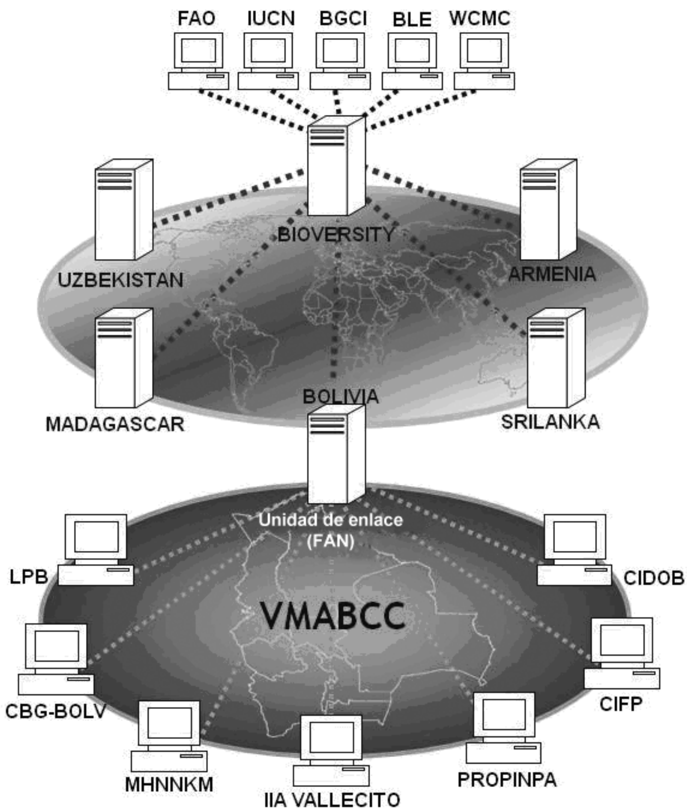

Figure 1.4 *Bolivian National Information System linked to the CWR International Portal*

In addition to addressing *in situ* conservation needs of target species, the project was also concerned with use of selected taxa for crop improvement. Hence, economic value for breeding, actual and potential, has been an important consideration in selecting target species for conservation action. They may possess characteristics, for example, which could provide resistance against disease or pests or difficult growing conditions such as a shortage or an excess of water, extreme heat or cold, or soil salinity.

About this manual

As already noted, *in situ* conservation of CWR has gained a certain momentum in the past 5–10 years but is still a poorly understood process and only a limited amount of practical experience can be drawn upon. The aim of this manual, therefore, is to share the experience obtained during this UNEP/GEF CWR Project of planning and implementing the *in situ* conservation and sustainable use of CWR, both on the part of the individual partner countries and institutional partners, and by the consortium as a whole. These include the difficulties faced, lessons learned and solutions proposed. Focusing primarily on the *in situ* conservation aspects of the project, it covers:

- national action plans for CWR conservation and use;
- identification of important areas of CWR conservation;
- assessment of threat status using IUCN Red List criteria;
- maps of geographic distribution of CWR species;
- adapting protected area management plans for CWR conservation;
- development of management plans for target CWR;
- guidelines for CWR conservation outside protected areas;
- monitoring plans for crop wild relative species.

The various steps involved in achieving these outputs are summarized in an overall scheme, 'The process of *in situ* conservation of CWR', presented in Table 1.3. The manual is intended to provide practical guidance on all the operations involved, such as information gathering, field assessment, taxon and area selection, and on the development, organization, implementation and monitoring of management plans and interventions to conserve CWR *in situ*. The manual will thus provide national and international conservation practitioners (including agrobiodiversity and conservation researchers, educators and students, NGO staff, genetic resource institutions, funding agencies, protected area managers, policy-makers and project managers) with practical information as well as tried and tested tools needed to plan and implement effective *in situ* conservation actions targeting the conservation of CWR. In this way, it goes well beyond the titles and literature already available.

Case studies from the five project countries are used to illustrate practical applications and real outcomes. While the valuable and complementary role of *ex situ* conservation is acknowledged, its detailed coverage is beyond the scope of both the project and this manual. The reader is referred to a number of key references on *ex situ* conservation listed in the references section.

This manual deals with the essential steps needed to achieve effective *in situ* conservation of CWR. After an introduction, it summarizes the importance of CWR in the five project partner countries, followed by an introduction to *in situ* conservation, looks at the planning issues involved and then details the major areas of work involved in CWR conservation, with illustrations and examples from the five countries.

It should also be pointed out that the materials in this manual are complemented by information and resources available through the CWR Global Portal described in Box 1.10. A page on the CWR Global Portal is, in fact, dedicated to the *In Situ* Manual at: http://www.cropwildrelatives.org/training/in_situ_conservation_manual.html. Chapter summaries, as well as other resources, including a glossary, additional annexes, examples of national action plans and management plans, and PowerPoint presentations are available for download at: http://www.cropwildrelatives.org/capacity_building/elearning/elearning.html. As

Table 1.3 *The process of* in situ *conservation of CWR*

The conservation of CWR *in situ* involves a series of procedures and actions which ideally should be undertaken in a logical sequence, for example:

1 Selection of priority/target species
2 Verification of taxonomic identity
3 Assessment of their geographical distribution, ecology, soil preferences
4 Assessment of their demography and population structure
5 Assessment of their phenology, reproductive biology and breeding systems
6 Assessment of their conservation status; and threat analysis
7 Assessment of their genetic variation and distribution of key alleles
8 Selection of the target populations to be conserved
9 Selection of the area(s) in which the target species are to be conserved: existing protected natural or semi-natural areas; or non-protected natural or semi-natural areas
10 Determination of the spatial scale of conservation needed – location, number and size of populations to be conserved; decision on whether to adopt a single-species or multi-species approach
11 Identification of aims of conservation and the appropriate conservation measures
12 Preparation of a conservation management plan for the target populations, if threatened, or monitoring plan if not currently threatened
13 Organization and planning of specific conservation activities
14 Identification and involvement of stakeholders
15 If the target area is already protected, assessment of the management status of the protected areas in which the target populations occur; and proposals for modification of management guidelines as appropriate
16 Consultation with protected area managers, local communities and other stakeholders
17 If the area or reserve/genetic reserve/gene management zone has to be created *de novo*, design of the reserve including boundaries, zoning and protection, and development of a management plan and guidelines
18 Determine statutory and legal requirements involved and arrange for necessary legislative approval (e.g. publication of management plan, gazetting new protected area/reserve) or legislative changes (e.g. modification of management plan of protected area) to be submitted to competent authorities
19 Development of a monitoring strategy for the area(s)
20 Development of a monitoring plan for assessing the effectiveness of the management interventions on the target populations and their conditions, genetic variability and needs
21 Development of a monitoring plan for assessing the impacts of human activities
22 Consideration of the possibilities of developing conservation strategies for species/populations occurring off-reserve/outside protected areas, such as easements, covenants, trusts, partnerships
23 Submit the management and monitoring plans and the whole conservation strategy to review
24 Prepare outreach and publicity materials
25 Preparation of a budget
26 Development of a timeline
27 Build a project team
28 Field implementation

In practice, as the circumstances and context of each *in situ* conservation project are unique, the actual sequence and emphasis given to each component will vary considerably.

additional relevant information and resources become available, they will be added to the online version of the *In Situ* Manual.

Further sources of information

A selection of useful sources of further information on CWR:

Bennett, A. (1965) 'Plant introduction and genetic conservation: genecological aspects of an urgent world problem', *Scottish Plant Breeding Station Record,* pp17–113.

Hamilton, A. and Hamilton, P. (2006) *Plant Conservation: An Ecosystems Approach*, Earthscan, London.

Heywood, V.H. and Dulloo, M.E. (2005) In Situ *Conservation of Wild Plant Species – A Critical Global Review of Good Practices*, IPGRI Technical Bulletin, no 11, FAO and IPGRI, IPGRI, Rome, Italy.

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A selection of important websites follows:

FAO home page; www.fao.org/

CGIAR home page; www.cgiar.org/

CWR Global Portal; www.cropwildrelatives.org/

Bioversity International home page; www.bioversityinternational.org/

IUCN Species Survival Commission Crop Wild Relative Specialist Group (CWRSG); www.cwrsg.org/

European Crop Wild Relative Diversity Assessment and Conservation Forum (PGR-Forum); www.pgrforum.org/

UNEP/GEF CWR project website http://www.bioversityinternational.org/research/conservation/crop_wild_relatives.html (accessed 23 November 2010)

Notes

1. As explained later, CWR also include those of fibre, oil, ornamental and medicinal species, not just agricultural (food) crops.
2. Although not specifically aimed at CWR, proposals for genetic resource centres were made as far back as 1890 by Emmanuel Ritter von Proskowetz and Frans Schindler at the International Agricultural and Forestry Congress, Vienna, and in 1914 Bauer warned of the dangers of the loss of local landraces through replacement by uniform bred varieties that could lead to a serious reduction in the genetic resource base, i.e. genetic erosion (see Flitner, 1995), both long before Vavilov.
3. French and Spanish versions were also published.
4. http://www.pgrforum.org/Conference.htm
5. http://typo3.fao.org/fileadmin/templates/agphome/documents/PGR/SoW2/Second_Report_SOWPGR-2.pdf (last accessed 27 October 2010)
6. CWR SG http://www.cwrsg.org/index.asp
7. http://www.cwrsg.org/Publications/Newsletters/crop%20wild%20relative%20Issue%207.pdf
8. EcoTILLING is a variation of TILLING (Targeting Induced Local Lesions IN Genomes) – a technique that can identify polymorphisms in a target gene by heteroduplex analysis – that aims to determine the extent of natural variation in selected genes in crops.
9. One of the emission scenarios reported in the Special Report on Emissions Scenarios (SRES) by the Intergovernmental Panel on Climate Change, IPCC (http://www.grida.no/climate/ipcc/emission/).

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