What is Conservation and Sustainable Use?

LESSON 1

Learning objectives

At the end of this lesson, the reader will be able to:

- recognize the necessity to conserve crop diversity for the use of present and future generations;
- summarize different conservation techniques;
- recognize the need for a complementary approach to *in situ* and *ex situ* conservation;
- describe the concept of sustainable use of crop diversity;
- illustrate the strong linkage between conservation and sustainable use of crop diversity by means of some concrete real-world examples.

Target learner groups

Policy makers and their staff, civil servants, as well as other interested parties and institutions.

Solanum melongena, eggplant, by Elizabeth Blackwell (1739)

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1.1. Overview of the Lesson

Crop diversity is one of the most fundamental resources on earth, on which the food security and well-being of humankind depend. In recognition of the threats posed by global changes, the world community has taken measures with the aim to ensure that crop genetic diversity is properly conserved and used sustainably. Most notably, conservation and sustainable use of plant genetic resources for food and agriculture (PGRFA) are among the three main objectives of the International Treaty on Plant Genetic Resources for Food and Agriculture (hereafter "International Treaty"). The third objective is the fair and equitable sharing of benefits that arise from the use of PGRFA.[1] This lesson will examine the nexus between conservation and sustainable use and provide examples of how this linkage can be further strengthened.

The first section discusses the importance of crop diversity to food security and the threats it faces. Among them are the impacts of climate change on crop diversity and the genetic vulnerability of agricultural production systems resulting from the widespread adoption of the same improved varieties over millions of hectares. The two major methods for conservation of crop diversity will be described, and different techniques for conserving crop diversity *ex situ* (seed banks, field gene banks, *in vitro* storage, cryopreservation, DNA storage, botanical gardens) and *in situ* (conservation of crop wild relatives (CWR) in wild habitats and of traditional crop varieties on-farm) will be explained. The relative advantages and disadvantages, as well as the complementarities of *in situ* and *ex situ* conservation methods, will also be discussed.

In the last section, the concept of sustainability is explained as it relates to the use of crop genetic diversity. The extent of use of collections of PGRFA is discussed and reasons provided as to why PGRFA are often not optimally utilized. Some examples of how the crop diversity that is conserved both in gene banks and *in situ*/on-farm can be better used to cope with climate change are given as an illustration of how the linkage of conservation and sustainable use can and needs to be further strengthened.

Cross-references:

- For the **text of the International Treaty** see: ftp://ftp.fao.org/docrep/fao/011/i0510e/i0510e.pdf
- To learn more about the **objectives of the International Treaty** refer to sub-section 2.2.1. of lesson 2 of Module I (Objectives, Scope and Basic Concepts).
- For more detailed background information on the **global challenges of crop diversity, food security and climate change**, and the ways the International Treaty addresses these challenges, refer to section 1.2. of lesson 1 of Module I (A Global Treaty for Food Security in an Era of Climate Change).
- For working **definitions of terms and concepts** such as crop diversity, PGRFA, food security, etc, refer to section 2.3. of lesson 2 of Module I (Objectives, Scope and Basic Concepts).

[1] International Treaty on Plant Genetic Resources for Food and Agriculture (2001), Article 1.

1.2. Complementary Conservation Methods

1.2.1. Importance of Crop Diversity Conservation for Present and Future Food Security

Crop diversity is one of the most fundamental and essential resources to humankind, as we depend entirely on it for our food security and well-being. Since the beginning of agriculture about 10 000 years ago, plant diversity has been the raw material that enabled farming systems and agriculture to evolve. Food plants have been collected, domesticated, used and improved through traditional systems of selection over many generations. Today, however, 75 percent of the world's food is generated from just 12 plant and five animal species. Of the 4 percent of the 250 000 to 300 000 known plant species that are edible for humans, we only use 150 to 200 and only three - rice, maize and wheat - contribute nearly 60 percent of the calories and proteins we obtain from plants.[2]

The diversity of genetic resources resulting from the selection processes practiced by early farmers now forms the basis on which modern high-yielding and disease-resistant varieties are being produced.[3] Indeed, breeding and agronomic improvements have, on average, achieved a linear increase in food production globally, at an average rate of 32 million metric tons per year over the period 1961 to 2007.[4] About half of this increase is attributable to plant breeding.

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[2] FAO (2005), p. 3.
[3] Plucknett (1987).
[4] Tester and Langridge (2010), p. 819.

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The improvement of crop performance has also increasingly relied on the use of genes from wild relatives of domesticated crops.[5] Without the genes from CWR, many useful traits, such as pest and disease resistance, abiotic stress tolerance or quality improvements, would not exist in today's crops. For example, genes from *Oryza nivara*, a wild relative of rice, are providing strong and extensive resistance to grassy stunt virus on millions of hectares of rice fields in South and Southeast Asia.[6] A chickpea cultivar with wild genes conferring drought and heat tolerance yields about 40 percent more than competing cultivars.[7]

Crop diversity is of particular importance to food security as diversity within a field or within a production system is likely to enhance stability in overall food production. A diverse cropping system helps to buffer against the spread of pests and diseases and the vagaries of weather, which are more likely to occur in a monoculture of a uniform variety. In other words, crop diversity helps to reduce 'genetic vulnerability'. This is a term used to describe the condition that results when every individual of a widely planted crop is uniformly susceptible to a given pest, pathogen or environmental hazard. Genetic uniformity creates a potential for widespread crop losses.[8] In the global context, the phenomenon of genetic vulnerability represents a major risk with regards to the capacity of our agricultural system to ensure sustainable food security, as well as to the livelihoods of farmers.

Therefore, in its Article 6.2f), the International Treaty calls for the conservation and the wider use of crop diversity and the creation of strong links to plant breeding and agricultural development in order to reduce crop vulnerability and genetic erosion. Box 1.1 below provides an example of genetic vulnerability of taro in Samoa. Other examples where crop uniformity led to crop failures through pest and diseases include the cases of the destruction of maize crop in the United States by a race of maize leaf blight[9], susceptibility of Cadenvish banana by the

5 Hajjar and Hodgkin (2007), p. 1.
6 Barclay (2004), p.15.
7 Hajjar and Hodgkin, *Op. cit.*, p. 6.
8 NRC (1972), p. 6.
9 *Idem*, pp. 5-16.

Box 1.1: An Example of Genetic Vulnerability – the Case of Taro Leaf Blight in Samoa

Taro was a very important cash crop for Samoan farmers until the early 1990s. More than 90 percent of households grew taro, mostly of the Nuie variety, which was thus planted uniformly across very large areas. In June 1993 an outbreak of the taro leaf blight disease severely affected the crops, resulting in a loss in the export market of around US$ 4 million per year with a similar decline in domestic supplies. The blight destroyed the whole taro industry and Samoans abandoned taro cultivation and shifted to planting sweet potatoes.[10]

The impact of this blight led to the development of a project called 'Taro Genetic Resources: conservation and utilization' (hereafter "TaroGen"). TaroGen is a regional project working with national programmes to develop a regional strategy for taro genetic resources conservation and crop improvement, working on disease control and ways to prevent further loss of genetic resources and spread of the disease, through the development of improved lines and resistant varieties.

This example illustrates clearly the devastation that a disease can cause when diversity is not consciously integrated into production systems, and highlights the vulnerability of widely distributed uniform taro populations that were cultivated for decades in the absence of the disease.

fungal disease Black Sigatoka, and cotton crop by Cotton Leaf Curl Virus.[11]

The above examples serve to illustrate the vulnerability of uniform agricultural production systems. Thereby, they highlight the importance of conserving genetic diversity of crops, to stabilize crop production and reduce the risk of crop failures due to pests and diseases through plant breeding and crop diversification. Many agricultural communities consider local crop diversity a critical factor for the long-term productivity and viability of their agricultural systems.[12] For example, interweaving multiple varieties of rice in the same paddy has been shown to increase productivity by lowering the loss from pests and pathogens.

Maintaining crop diversity is also a key strategy for farmers around the world to guarantee their sustenance. Many studies have shown that crop genetic diversity in the form of traditional varieties continues to be maintained on-farm by poor, small-scale farmers who rely on traditional crop varieties to meet their livelihood needs.[13] Such diversity is vital to cope with the vagaries of climate for farmers who depend on rainfed agriculture. It is common to find poor farmers growing many varieties of the same crop to increase the likelihood of producing a crop to feed their families, regardless of the specific weather conditions in a given year. For example, a farmer in Papua New Guinea mentioned that he grows 50 different varieties of sweet potato on his farm.[14]

In addition, many plant species growing in wild ecosystems are valuable for food and agriculture and often play an important cultural role in local societies. They can provide a safety net when food is scarce and are increasingly marketed locally and internationally, providing an important contribution to household incomes.[15] Further, CWR provide genetic variability that can be crucial for overcoming outbreaks of pests and pathogens and new environmental stresses.[16]

[10] Chan *et al.* (1998).
[11] FAO (2010), p. 184.
[12] MEA (2005), p. 73.
[13] Bezançon *et al.* (2009); Kontoleon, Pascual and Smale (2009); Rana *et al.* (2007); Sadiki *et al.* (2007).
[14] Prem Mathur, personal communication.
[15] FAO *Op. cit.*, p. 31.
[16] Maxted *et al.* (2008).

Cross-references:

- For more detailed explanations of the **measures to promote conservation and sustainable use of PGRFA put forward in articles 5 and 6 of the International Treaty**, refer to lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).

The Need for Conservation of Crop Diversity

In a changing world where climate change, rising food prices and other drivers are affecting food security and the environment, the conservation and use of crop diversity for food and agriculture is becoming increasingly important. FAO estimates that food production will need to be increased by 70 percent in order to meet the food demands of the expected 9.2 billion people by 2050 and that much of this increase will have to come from the further use of crop diversity.[17]

Many threats or drivers of change in biodiversity have been recognized and found to have intensified in recent years.[18] With regard to agriculture, the most important ones include changes in land use, replacement of traditional varieties by modern cultivars, agricultural intensification, increased population, poverty, land degradation and environmental change (including climate change).[19]

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[17] FAO (2010), p. 183.
[18] MEA (2005), pp. 14-16.
[19] FAO, *Op. cit.*, pp. 43-44; Dulloo, Hunter and Borelli (2010), pp. 123-124; Van de Wouw *et al.* (2009).

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The introduction of improved varieties of crops (i.e. 'modern crops') is one of the major factors affecting crop diversity in agricultural production systems. FAO reports that this is a major issue in more than 40 countries. For example, Pakistan reported that the release of certain high yielding varieties of black grams, chickpea, lentils and mung beans has led to the loss of local varieties from farmers' fields.[20] The replacement of local varieties with modern varieties may also increase genetic vulnerability and thus the propensity for crop failures.

Appropriate breeding methods that allow to breed desirable resistance and adaptation traits into modern varieties are one way to reduce vulnerability. This will often include the use of a broad genetic base in the breeding process and the close participation of farmers in establishing selection criteria. Another strategy to reduce crop vulnerability, however, is to use a range of locally adapted varieties in the same field, especially for farmers in the developing world that live in marginal areas, as it presents a more easily applicable solution that does not require extensive technical knowledge.

It is predicted that climate change will have a significant impact on agriculture, with temperatures rising on average between 2 and 4 degrees Celsius over the next 50 years, causing significant changes in regional and seasonal patterns of precipitation.[21] Recent climate projections[22], and comparisons of current global suitability maps for cultivation of 43 crops with those projected for 2050, revealed that suitable areas for those crops may decline by more than 50 percent. Evidence based on bioclimatic modelling suggests that climate change could cause a marked contraction in the distribution ranges of CWR. In the case of wild populations of peanut, potato and cowpea, studies suggest that 16-22 percent of these species may become extinct by 2055, with most species possibly losing 50 percent of their range.[23]

[20] FAO (2010), p. 44. The reported high yielding varieties were *Vigna mungo (L.) Hepper, Cicer arietinum (L.), Lens culinaris Medikus and Vigna radiata (L.)* R. Wilczek, respectively.
[21] Burke, Lobell and Guarino (2009); IPCC (2007), p. 13.
[22] Lane and Jarvis (2007).
[23] Jarvis, Lane and Hijmans. (2008), p. 8. The wild species referred to belong to *Arachis spp.*, *Solanum spp.* and *Vigna spp.*, respectively.

These threats or drivers of change are likely to lead to loss of agricultural biodiversity and consequently its genetic variability.[24] Information regarding the threat from and rate of genetic erosion among various components of agricultural biodiversity is important, yet very little work has been carried out to quantify the magnitude of any trends.[25] The availability of large gene pools, including CWR, is becoming even more important as farmers will need to adapt to changing conditions that result from these pressures. It is likely that many of the genetic traits which will be necessary to adapt our crops to changing climate will be found in CWR.

Key points to remember:

- Food plants that have been domesticated and selected by farmers over the last 10 000 years are the raw material for today's modern plant breeding.
- Plant breeding has accounted for half of the steadily growing yield increases since the 1960s. The role of plant breeding for crop diversity will become even more important as food production needs to be increased by 70 percent by 2050.
- Crop diversity contributes to reducing genetic vulnerability, as diverse farming systems are more resistant to pests, diseases and environmental stresses.
- Many farmers, especially smallholders in developing countries, rely on crop diversification as a strategy to minimize the risk of crop failure.
- Wild edible plants contribute to household incomes and can provide safety nets when food is scarce.
- The continuing trend of replacing genetically diverse traditional varieties with improved uniform varieties in many countries, and the increasing impacts of climate change, are main drivers of genetic erosion.
- CWR provide genetic variability that can be crucial for overcoming outbreaks of pests and pathogens and new environmental stresses. It is likely that many of the traits necessary to adapt our crops to climate change will be found in CWR.
- The International Treaty calls for the conservation and wider use of crop diversity, and the creation of strong links to plant breeding and agricultural development, to reduce crop vulnerability and genetic erosion, for global food security.

Cross-references:

- For the **text of the International Treaty** see: ftp://ftp.fao.org/docrep/fao/011/i0510e/i0510e.pdf
- For a general overview of the **importance of the International Treaty** to cope with the triple challenge of countering the loss of crop diversity and using it more effectively to achieve and maintain food security under the growing pressures of climate change, refer to section 1.2. of lesson 1 of Module I (A Global Treaty for Food Security in an Era of Climate Change).

[24] MEA (2005), pp. 37, 41, 62. ; Van de Wouw *et al.* (2009).
[25] Dulloo, Hunter and Borelli (2010), p. 124; Frankham (2010).

1.2.2. Different Methods and Techniques of Conservation

There are two main methods of conservation of crop diversity: *ex situ* and *in situ* conservation. Different techniques for both methods of conservation are outlined below. In its Article 2, the International Treaty defines *ex situ* conservation as “the conservation of plant genetic resources for food and agriculture outside their natural habitats” and *in situ* conservation as “the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated plant species, in the surroundings where they have developed their distinctive properties”.

Ex Situ Conservation Techniques

Ex situ conservation is usually carried out in gene banks and botanical gardens. Different types of gene banks have been established for the storage of plant diversity, depending on the type of plant material conserved. These include seed banks (for seeds), field gene banks (for live plants), *in vitro* gene banks (for plant tissues and cells), pollen and Deoxyribonucleic acid (DNA) banks.[26] The form of *ex situ* conservation used is largely determined by the method of reproduction of the species being conserved and the purpose of the conservation and use of the plant material. Currently, there are about 7.4 million PGRFA accessions conserved in over 1750 gene banks. More than 2500 botanical gardens grow over 80 000 plant species.[27]

Seed Banks

Seeds are usually the most convenient and easiest material to collect and to maintain in a viable state (i.e. capable of germination) for long periods of time, and are therefore often the preferred option for conserving PGRFA.[28] Seeds are typically conserved at moisture content between 3-7 percent, and stored at 4 degrees Celsius for short-term conservation, and between -18 and -20 degrees Celsius for long-term conservation.[29] Seeds that can be conveniently stored under such conditions are known as ‘orthodox’ seeds.

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26 Engelmann and Engels (2002); Thormann and Dulloo (2006).
27 FAO (2010), pp 55, 85.
28 Roberts (1973).
29 FAO/IPGRI (1994), p. 4; Rao *et al.* (2006a, p. 1; 2006b).

However, not all seeds can be conserved under these conditions.[30] Many seeds of tropical origin are known to lose viability and die on drying or when exposed to cold. These are said to be 'recalcitrant', and are typically fleshy and large. Examples of such crops include cacao, coconut, mango, oil palm and rubber. In these cases, if conserved *ex situ*, the species need to be conserved as live plants in field gene banks or as plant material other than seeds, e.g. in tissue culture.

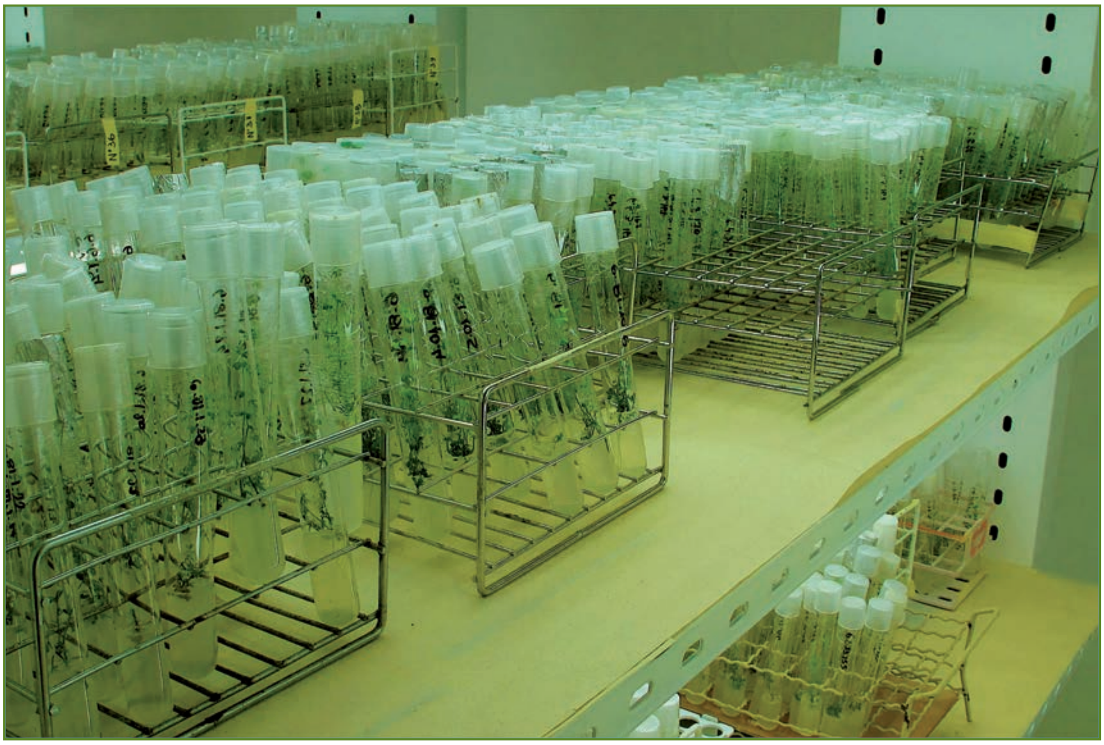
Field Gene Banks

A field gene bank is a collection of plants assembled and grown in a field or very often in pots in a screen house or green house. Field gene banks are the most common means of conserving diversity in crops which cannot be conserved as seeds, such as species having recalcitrant seeds or those which are not propagated by seeds, like roots and tubers, and other vegetatively propagated crops.[31] Vegetative propagation is the ability of plants to reproduce without sexual reproduction, by producing new plants from existing vegetative structures.

Field gene banks have the advantage that the material can be readily used for characterization and research in the field, compared to other forms of *ex situ* conservation, where the plant material must first be germinated/regenerated and grown before it can be used for those purposes. Characterization refers to the recording of highly heritable characters that can be easily seen and are expressed in all environments. However, although field gene banks do not need costly equipment and sophisticated technology, they are normally more expensive to maintain compared to any other form of *ex situ* conservation, such as seeds or cryopreservation (see Box 1.2).[32] The maintenance of living collections requires large inputs of labour and time, and vast areas of land to contain adequate samples of the genetic variability of the species. They are vulnerable to pests and diseases and bad weather conditions, and only limited genetic material can be conserved because of the space factor.[33]

Courtesy Flickr/Mavis'

30 Hong and Ellis (1996), pp. 10-20.
31 Reed *et al.* (2004), pp. 10-15.
32 Dulloo *et al.* (2009).
33 Dulloo *et al.* (2001).



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In Vitro Storage

In vitro storage is an alternative method which is complementary to field gene banks for the storage of vegetatively propagated species and has good potential for species with recalcitrant seeds. It involves the maintenance of cells or plant tissue transferred to a sterile, pathogen-free environment with a synthetic nutrient medium, usually in a test tube or glass jar.[34]

It is possible to establish a working tissue culture facility with minimal resources. The major pre-requisites for *in vitro* conservation are, however, the availability of skilled personnel and reasonably equipped laboratory facilities. *In vitro* stored material can be rapidly propagated and disseminated. However, the technique requires suitable crop-specific (sometimes species-specific) protocols to be developed. A protocol is a set

Box 1.2: Cost-effectiveness of Cryopreservation

The cost-effectiveness of cryopreservation as compared to field collections as a long-term conservation method has been demonstrated in a study on coffee genetic resources. This study compared the per unit costs of maintaining one of the world's largest coffee field collections at the Tropical Agricultural Research and Education Centre (CATIE) in Costa Rica, with those of establishing a coffee cryo-collection, also at CATIE. The results indicated that, although the per-accession establishment costs of a cryo-collection (US$ 95.00 per accession) were higher than those of establishing a field collection (US$ 69.62 per accession), the per-accession annual costs for maintenance of the cryo-collection of 300 accessions (US$ 8.00 per accession) were significantly less than those of the field collection of 1992 accessions (US$ 15.00 per year per accession). The cost forecast for conserving 2000 accessions (comparable to the current field collection) was even lower on a per unit basis (US$ 3.00 per year per accession).[35]

[34] Reed *et al.* (2004), pp. 10-15.
[35] Dulloo *et al.* (2009).

of guidelines, or rules, in this case step-wise guidelines on how to propagate a specific crop or species *in vitro*. One major drawback of *in vitro* conservation is the possibility of genetic instability in plant material, which can occur during the culture process.[36]

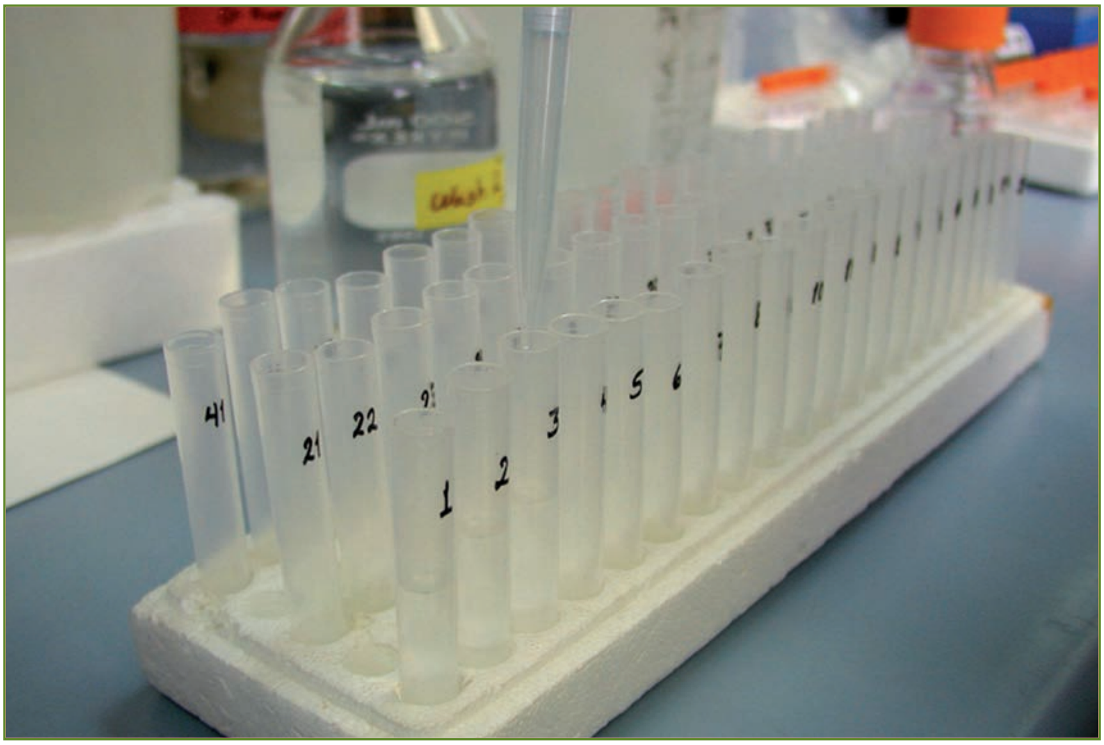
Cryopreservation

Cryopreservation is a form of *in vitro* storage that involves the storage of living tissue at extremely low temperatures, usually at -196 degrees Celsius in liquid nitrogen, at which cell metabolism is reduced by arresting cell division activities. This guarantees long-term preservation of germplasm in a genetically unaltered state. However, cryopreservation protocols, like *in vitro* culture techniques, are species-specific.

Significant progress has been made in cryopreservation research over the past 20 years and has enabled the development of a number of analytical tools, which allowed a more scientific and rational approach to the establishment of cryopreservation protocols. Such tools include thermal (Differential Scanning Calorimetry), biochemical (sugars, lipids, proteins) and histo-cytological analyses. These advances have led to the development of cryo-protocols for conserving more than 200 plant species.[37] It is now realized that cryopreservation methods can offer great security for long-term conservation of PGRFA, including orthodox seeds. One of the most important advantages of cryopreservation is that it occupies very little space. This makes it very cost-effective over the long term (see Box 1.2).[38]

DNA Storage

DNA storage is becoming an increasingly important method of conservation of genetic material, especially as a ‘back-up’ to traditional *ex situ* collections such as seed and tissue gene banks. This is due to the rapid development of technological and analytical tools, as well as to the demand for DNA material from molecular laboratories and breeders for use in molecular breeding.[39] DNA material can be maintained at very



Courtesy Flickr/CIMMYT

36 Reed *et al.*, pp. 35-65.
37 Dussert and Engelmann (2006); Engelmann (2004); Engelmann and Takagi (2000); Engelmann and Panis (2009); Panis, Piette and Svennen (2005).
38 Dulloo *et al.*, (2009).
39 De Vicente and Andersson (2006), pp. 12-16.

low temperature and its associated sequence information may be a cost effective form for conserving germplasm, depending on the objective of the conservation and the type of use to which it would be applied.

For example, the Royal Botanic Gardens Kew in the United Kingdom (hereafter "Kew Gardens") holds approximately 40 000 samples of plant genomic DNA (as at the beginning of 2010), all stored at -80 degrees Celsius. For many species that are difficult to conserve by conventional means (either by seeds, or vegetatively) or that are highly threatened in the wild, DNA storage may provide the ultimate way to conserve the genetic diversity of these species and populations in the short term.

Efforts made to establish plant DNA banks include Missouri Botanical Garden (United States), the Kew Gardens, Australian Plant DNA Bank and Trinity College Dublin (Ireland).[40] They can provide an efficient and simple method to conserve the genetic information that overcomes many physical limitations and constraints that characterize other forms of storage. However, there are still problems with subsequent gene isolation, cloning and transfer. The current technology also does not permit the regeneration of original live organisms from isolated DNA or electronic information.

Botanical Gardens

Botanical gardens, like field gene banks, maintain their plant material traditionally as living collections in the garden landscape. Botanical gardens have a strong focus on wild species, and CWR are well represented.[41] It is estimated that there are over 2500 botanical gardens known in the world, in 148 countries, conserving more than 6 million accessions in their living collections.[42] Botanical gardens have played a key role in the collection and exchange of seed and other propagules with other gardens.[43] Propagules can be defined as any structure with the capacity to give

Courtesy Flickr/IITA Image Library

[40] Hodkinson *et al.* (2007); Rice, Henry and Rossetto (2006).
[41] See notably table 3.8 on p. 86 in FAO (2010).
[42] *Idem*, p. 85.
[43] Heywood (2009).

rise to a new plant, whether through sexual or asexual (vegetative) reproduction. This includes seeds, spores, and any part of the vegetative body capable of independent growth if detached from the parent. Many botanical gardens maintain *ex situ* collections in the field or in green houses. Some have seed banks for medium- to long-term storage. Very few use *in vitro* or cryopreservation techniques for conservation. The role of the gardens in conserving diversity within species is, however, limited because most conserve only a few representatives of each species.

Regarding both botanical gardens as well as field gene banks it is important to note that although these techniques may conserve PGRFA in fields and/or garden landscapes, they are considered *ex situ* conservation techniques insofar as the PGRFA are conserved outside their natural habitat and not in the surroundings where they have developed their distinctive properties.

Key points to remember:

- There are two main methods of conservation of crop diversity: *ex situ* and *in situ*.
- *Ex situ* conservation is usually carried out in gene banks and botanical gardens, however different types of gene banks have been established depending on the type of crop genetic materials to be stored and the purpose of conservation.
- Seed banks are used to maintain orthodox seeds in dry conditions at temperatures below zero over long periods of time.
- Recalcitrant seeds are seeds that cannot be easily stored under such conditions.
- Species with recalcitrant seeds and crops that are vegetatively propagated (i.e. not by seeds) are most commonly conserved as live collections in field gene banks.
- Another means to conserve vegetatively propagated species and species with recalcitrant seeds *ex situ* is *in vitro* storage. It involves the maintenance of plant tissue in a sterile environment with a synthetic nutrient medium, usually in a test tube.
- Cryopreservation is a specific form of *in vitro* storage at extremely low temperatures, usually at -196 degrees Celsius in liquid nitrogen. This guarantees long-term preservation of germplasm in a genetically unaltered state.
- DNA storage is becoming increasingly important as a ‘back-up’ to traditional *ex situ* collections. However, there are still problems with gene transfer and the current technology does not permit to regenerate original live organisms from isolated DNA.
- Botanical gardens and field gene banks maintain their plant material traditionally as living collections. Nevertheless, they are *ex situ* techniques as they do not conserve PGRFA in the surroundings where they have developed their distinctive properties.

Cross-references:

- Refer to sub-section 2.2.1. of lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty) for an explanation of **Article 5.1e) dealing with ex *situ* conservation** and to learn more about **characterization**.

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***In Situ* Conservation Techniques**

As mentioned above, *in situ* conservation is used mainly for wild species including CWR in wild habitats (*in situ* conservation in the strict sense), as well as for traditional and locally adapted varieties of crops on-farm (referred to as on-farm conservation).

In situ *Conservation of Wild Plant Species*

The aim of *in situ* conservation of wild plant species is to ensure that populations of targeted species are maintained in the natural habitats where they evolved and that their continued survival is not threatened. The most commonly used method for *in situ* conservation is to protect the natural habitats, by declaring these sites to be protected areas and taking appropriate measures to ensure their conservation. Depending on the purpose of conservation there are different types of protected areas, as defined by the International Union for Conservation of Nature (IUCN), as well as different levels of management interventions (see Box 1.3).[44]

In the broader context of conserving plant genetic diversity, *in situ* conservation may involve the creation of 'genetic reserves' where the ultimate goal is to ensure that the maximum possible genetic diversity is maintained and available for potential utilization.[45] It should be emphasized here that most protected areas around the world have been established to preserve particular ecosystems, exceptional scenery or habitats for particular charismatic species, but very seldom for CWR.[46] Nevertheless, a few examples exist: Erebuni State Reserve in Armenia was established in 1981 specifically to protect wild cereals;[47] the Sierra de Manantlán Reserve in Mexico was established specifically for the conservation of the endemic perennial wild relative of maize;[48] wild emmer wheat is conserved in the Ammiad reserve in Israel;[49] and various

44 Heywood and Dulloo (2005); Maxted *et al.* (2008); Stolton *et al.* (2006).
45 Maxted *et al.* (2008), p. 9.
46 *Idem*, pp. 13-15.
47 Avagyan (2008), p. 64.
48 FAO (2010), p. 34. The scientific name of this endemic wild relative of maize is *Zea diploperennis* H. H. Iltis *et al.*
49 Anikster, Feldmann and Horowitz (1997); Safriel, Anikster and Waldmann (1997). The scientific name of this wild emmer wheat is *Triticum turgidum* subsp. *dicoccoides* (Körn. ex Asch. & Graebn.) Thell.

Box 1.3: The IUCN Protected Area Management Categories

The IUCN has developed a series of definitions for different categories of protected areas:[50]

Category Ia Strict Nature Reserve: area managed mainly for science or wilderness protection – an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.

Category Ib Wilderness Area: area managed mainly for wilderness protection – large area of unmodified or slightly modified land and/or sea, retaining its natural characteristics and influence, without permanent or significant habitation, which is protected and managed to preserve its natural condition.

Category II National Park: area managed mainly for ecosystem protection and recreation – natural area of land and/or sea designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.

Category III Natural Monument or Feature: area managed mainly for conservation of specific natural features – area containing specific natural or natural/cultural feature(s) of outstanding or unique value because of their inherent rarity, representativeness or aesthetic qualities or cultural significance.

Category IV Habitat/Species Management Area: area managed mainly for conservation through management intervention – area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats to meet the requirements of specific species.

Category V Protected Landscape/Seascape: area managed mainly for landscape/seascape conservation or recreation – area of land, with coast or sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the area's protection, maintenance and evolution.

Category VI Protected Area with Sustainable Use of National Resources: area managed mainly for the sustainable use of natural resources – area containing predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while also providing a sustainable flow of natural products and services to meet community needs.

crop and forest CWR reserves have been established in Turkey.[51]

Whatever the type of protected area, in general, *in situ* conservation involves a range of activities which include:[52]

- setting priorities for target species and their populations and extent of genetic diversity;
- planning, design and setting up of conservation areas;
- management and monitoring of *in situ* populations; and
- policy and legal support.

The sheer numbers and diversity of CWR for any given crop requires some form of priority

50 IUCN (2008), pp. 7-23.
51 Firat and Tan (1997); Tan (1998); Tan and Tan (2002).
52 Heywood and Dulloo (2006); Iriondo, Maxted and Dulloo (2008).

Courtesy Flickr/Kew on Flickr

setting. This requires knowledge of the numbers of CWR for any given taxon, their distribution patterns, and variation between and within their *in situ* populations. Often these are gathered through ecogeographic surveys.[53] This in turn helps the design and planning of protected areas which takes into account the individual species' geographical, ecological and physiological (including reproductive biology) attributes, as well as activities of both human and other biotic components within and in the vicinity of the proposed reserves.[54] Figure 1.1 below illustrates global priority reserve locations for wild relatives of 12 selected food crops.

Prescriptions for management and mechanisms for monitoring populations of the targeted species form an integral part of *in situ* conservation.[55] This usually involves the establishment of management plans for the genetic reserve aimed at defining the management interventions required to safeguard the *in situ* population. This, for example, may involve getting rid of invasive species, as is the case in the conservation of wild coffee species in Mauritius[56] or controlling the collection of wild plants, as is the case for wild yams in Madagascar in the Ankarafantsika National Park, and wild cinnamon in the Kanneliya Forest Reserve, Sri Lanka.[57]

Protected area systems normally have institutional, legal and policy frameworks that provide the legal status of the protected area in question and ensure the long-term land tenure required for *in situ* conservation to be effective. Moreover, it is also important to develop effective working partnerships between agriculture, protected area staff and local and indigenous communities, without which *in situ* conservation would not be effective. Box 1.4 provides a good example of the importance of partnerships in the *in situ* conservation of CWR as illustrated by a CWR *in situ* conservation project of the United Nations Environment Programme (UNEP) and the Global Environment Facility (GEF), led by Bioversity International.

53 Maxted, Van Slageren and Rihan (1995).
54 Dulloo *et al.* (2008).
55 Maxted *et al.* (2008); Iriondo, Maxted and Dulloo (2008).
56 Dulloo *et al.* (1998).
57 Hunter and Heywood (2010). The scientific name of the wild cinnamon referred to is *Cinnamomum cappara-coronde* Blume.

Box 1.4: *In situ* Conservation of CWR through Enhanced Information Management and Field Application

This UNEP/GEF CWR project consisted of a partnership that included nearly 60 national and international agencies. Planning, implementation and monitoring was conducted through a series of local and national committees, coordinated and guided by Bioversity International through an international steering committee made up of representatives from all participant countries and international organizations. Partnerships at the national level brought together academia, government departments, protected area administrations, local and indigenous groups, civil society organizations, botanical gardens, natural history museums and research agencies. For example, two major sectors where there is traditionally not much collaboration, i.e. agriculture and biodiversity conservation, were brought to work together. Close collaboration with protected area authorities allowed to develop species management plans for CWR in selected protected areas.

Involvement of rural communities was essential to address overcollecting of wild plants in the Erebuni State Reserve in Armenia. The reserve is located near a highly urbanized area and is rich in biodiversity. It is home to 292 species of vascular plants, representing 196 genera from 46 families. Despite sustained conservation efforts, the distribution of wild plants in the protected area is under threat as wild plants are collected for food and medicinal purposes and for sale in Yerevan City markets. Plant collectors frequently trespass within the protected area to harvest wild crops. As a result, many species of plants existing in the area have been included in the Red Data Book of Threatened Plants of Armenia.

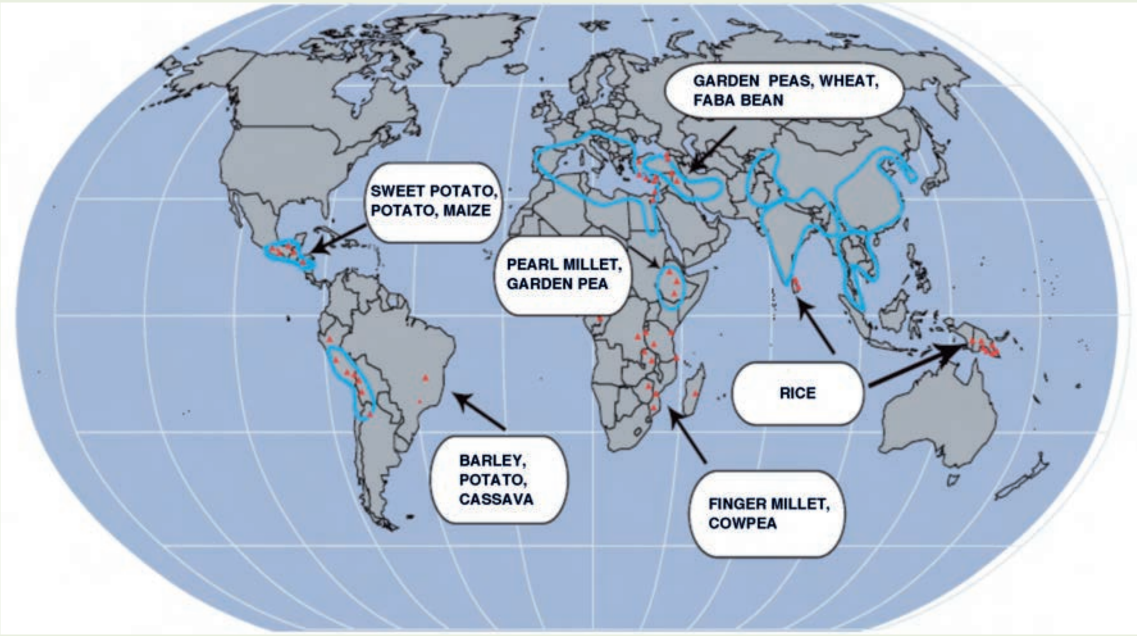
Through community consultations, a lack of awareness of the importance of CWR was identified as the major factor influencing overharvesting. For this reason, the UNEP/GEF CWR project, in 2007, implemented a series of workshops with local communities, followed by community surveys, to gather information about the collection, use and conservation of a range of wild plants. Discussions highlighted that rural communities, and women in particular, continue to collect a variety of wild plants for use in local dishes and for medicinal purposes. The participatory process, carried out over a one-year period, revealed the need to train local communities on the healthy utilization of certain plant species. The local communities surrounding the protected area are engaged and aware of the benefits of conserving CWR in their natural environments and the threats posed to their well-being by overharvesting.[58]

A significant number of wild species of PGRFA occur outside conventional protected areas and consequently do not receive any form of legal protection.[59] Cultivated fields, field margins, grasslands, orchards and roadsides may all harbour important CWR. Plant diversity in such areas faces a variety of threats including the widening of roads, removal of hedgerows or orchards, overgrazing, expansion in the use of herbicides or even just different regimes for the physical control of weeds.[60]

The effective conservation of PGRFA outside protected areas requires social and economic issues to be addressed. This may require, for example, specific management agreements to be concluded between owners of prospective sites and conservation agencies. Such agreements are becoming more common in North America and Europe, an example being the establishment of micro-reserves in the Valencia region of Spain.[61] Unfortunately there appear to be no agreements yet in place in most priority centres of CWR diversity.

58 Hunter and Heywood (2010).
59 Heywood and Dulloo (2005), pp. 69-73; Maxted and Kell (2009), p. 69.
60 Maxted and Kell. *Op. cit.*, p. 12.
61 Laguna (1999).

Figure 1.1: Global Priority Genetic Reserve Locations for Wild Relatives of 12 Food Crops



Source: FAO (2010), p. 10.

On-farm Conservation

In situ conservation on-farm, commonly referred to as on-farm conservation or on-farm management, can be understood as "the continuous cultivation and management of a diverse set of populations by farmers in the agro-ecosystems where a crop has evolved".[62] On-farm conservation concerns entire agro-ecosystems, including immediately useful species (such as cultivated crops, forages and agroforestry species), as well as their wild and weedy relatives that may be growing in nearby areas.

Practices that support the maintenance of diversity within agricultural production systems include agronomic practices, seed production and distribution systems, as well as the management of the interface between the wild and cultivated ecosystems. A widespread practice – or set of practices – that conserves traditional varieties is through production in home gardens. Farmers often use home gardens as a site for experimentation, for introducing new cultivars, or for the domestication of wild species. Useful wild species may be moved into home gardens when their natural habitat is threatened, e.g. through deforestation.

Informal seed systems are a key element in the maintenance of crop diversity on-farm, which in some countries can account for up to 90 percent of seed movement.[63] Informal seed systems are small-scale, farmer managed traditional systems developed over time in response to farmers demand for seed. They transmit planting material developed by farmers or previously developed, saved, and transferred by farmers. However, with policies often favouring improved varieties, farmers are cultivating less and less local landraces and traditional varieties. There is a need to provide incentives to farmers to continue to cultivate these varieties and maintain their diversity on-farm, for example through the creation of markets for local products

[62] Bellon *et al.* (1997).
[63] FAO (2010), p. 40.

derived from these varieties. Activities that directly support on-farm conservation are: community seed banks, local germplasm collections, reintroduction of traditional and locally adapted varieties, diversity fairs and community biodiversity registers.[64]

The interface between wild and agricultural plants and ecosystems is highly complex and can result in both positive and negative effects regarding the maintenance of genetic diversity. The natural transfer of new genes into crops can expand the diversity available to farmers. The natural transfer of genes between crop varieties and their wild relatives has been a significant feature of the evolution of most crop species and continues to be important today in the development and introduction of new genotypes by farmers.[65]

Many CWR species grow as weeds in agricultural, horticultural and silvicultural systems, particularly those associated with traditional cultural practices or marginal environments. In many areas such species may be particularly threatened as a result of the move away from traditional cultivation systems. Several governments in developed countries provide incentives, including financial subsidies, to maintain these systems and the wild species they harbour. While such options are largely unaffordable and unenforceable throughout most of the developing world, opportunities do exist for integrating on-farm management of landraces and farmer varieties with the conservation of CWR diversity.[66]

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64 For detailed information on these activities see Almekinders (2001); Jarvis *et al.* (2008); Sthapit *et al.* (2002).
65 Prescott-Allen and Prescott-Allen (1988).
66 FAO (2010), p. 35.

Key points to remember:

- *In situ* conservation is mainly used for wild species including CWR in wild habitats, as well as for traditional and locally adapted varieties of crops on-farm.
- The most commonly used method for *in situ* conservation is to protect the natural habitats, by declaring these sites to be protected areas.
- *In situ* conservation involves a range of activities, including:
  - setting priorities for target species and their populations and extent of genetic diversity;
  - planning, design and setting up of conservation areas;
  - Active management and monitoring of *in situ* populations; and
  - providing policy and legal framework
- Effective *in situ* conservation requires working partnerships between agriculture, protected area staff and local and indigenous communities.
- A significant number of CWR occur outside conventional protected areas, requiring specific management agreements to ensure effective conservation of PGRFA .
- On-farm conservation can be understood as the continuous cultivation and management of a diverse set of populations by farmers in the agro-ecosystems where a crop has evolved.
- Activities that directly support on-farm conservation include, *inter alia*, the production in home gardens, community seed banks, local germplasm collections, reintroduction of traditional and locally adapted varieties, diversity fairs and community biodiversity registers.
- A further key element to conserve crop diversity on-farm especially for smallholder farmers in developing countries are informal seed systems, i.e. small-scale traditional systems to transmit farmer-developed and/or previously saved seed.

Cross-references:

- For explanations of the **provisions of the International Treaty dealing with *in situ* and on-farm conservation**, refer to sub-section 2.2.1. of lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).
- To learn more about **options for on-farm conservation and management** refer to sub-section 4.2.3. of lesson 4 of this module (Implementation of Articles 5 and 6 from a Users' Perspective) and to Box 4.1 of lesson 4 of Module I (Main Components and Governance of the International Treaty).

1.2.3. The Complementary Roles of *In situ* and *Ex situ* Conservation

Traditionally, *in situ* conservation has been used for the conservation of forests, wild species and areas valued for their wildlife or ecosystems, while *ex situ* conservation has been a predominant method for the conservation of PGRFA.[67] The concept of *ex situ* conservation is fundamentally different to that of *in situ* conservation, however both are important complementary methods for conservation and both are referred to in Article 5 of the International Treaty. The principal difference (and hence the reason for the complementarity) between the two lies in the fact that *ex situ* conservation implies the maintenance of genetic material outside of the 'normal' environment where the species has evolved and aims to maintain the genetic integrity of the material at the time of collecting, whereas *in situ* conservation (maintenance of viable populations in their natural surroundings) is a dynamic system which allows the biological resources to evolve and change over time through natural or human-driven selection processes. It should be noted that *in situ* conservation on-farm requires the maintenance of the agro-ecosystem along with the cultivation and selection processes on local varieties and landraces, and *in situ* conservation in the wild involves the maintenance of the ecological functions that allow species to evolve under natural conditions.[68]

Articles 5 and 6 of the International Treaty refer to both methods, including the collection and *ex situ* conservation of PGRFA under threat or of potential use, on-farm management of farmers' PGRFA in their fields, and *in situ* conservation of CWR in protected areas. It is now widely accepted that the use of one single conservation strategy to conserve PGRFA diversity incurs a risk. For example, extreme weather conditions can cause the extinction of target populations in a protected area, prolonged power cuts can jeopardize germplasm conserved in a gene bank's cold store, and war and natural

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[67] Brown (2000).
[68] Dulloo, Hunter and Borelli (2010); Heywood and Dulloo (2005); Maxted, Ford-Lloyd and Hawkes (1997).

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catastrophes can affect diversity whether conserved *ex situ* or *in situ*.

A conservation strategy that uses a combination of *ex situ* and *in situ* techniques, taking into account their respective advantages and disadvantages (see Box 1.5 below) is therefore most likely to secure the diversity for future use. A complementary conservation strategy involves the combination of different conservation actions, which together lead to an optimum sustainable conservation of genetic diversity in a target gene pool.[69]

The ultimate purpose of germplasm conservation is to be able to use PGRFA now and in the future for agricultural research, plant breeding, cultivation and finally consumption, in order to ensure global food security. Consequently, any conservation strategy should include mechanisms that will also ensure access to the germplasm by relevant stakeholders (particularly breeders and farmers). It is not always evident that material conserved in gene banks can readily be made available to users of germplasm.

Article 10 of the International Treaty recognizes the sovereign rights of states over their own PGRFA, including the authority to determine access to these materials. It calls upon Contracting Parties to facilitate access to their PGRFA through the Multilateral System of Access and Benefit-sharing (hereafter "Multilateral System") of the International Treaty so that breeders, for example, can obtain the crop diversity they need for crop improvement and farmers can obtain varieties they need to meet their needs. Under the Multilateral System, the exchange of germplasm is facilitated through the Standard Material Transfer Agreement (SMTA). A conservation strategy should also include a proper documentation system that provides all the essential information attached to the accession in terms of passport information, collection, characterization and other socio-economic information.

[69] Dulloo *et al.* (2005).

Box 1.5: Relative Advantages and Disadvantages of *Ex situ* and *In situ* conservation

Advantages

***In situ* conservation**

- Avoids storage problems associated with field gene banks and recalcitrant seeds.
- Allows evolution and enhancement to continue through exposure to pests and diseases and other environmental factors.
- Indirect benefits, including ecosystem support.
- Sustainable use by local people.
- Does not require high-tech conservation facilities and laboratories.

***Ex situ* conservation**

- Rescue of threatened germplasm.
- Requires limited space to conserve large numbers of accessions.
- Conserves an adequate representative sample of CWR populations.
- Ease of accessibility and exchange of germplasm.
- Facilitates evaluation and documentation.
- No exposure to pests, diseases or other hazards (except for field collection and botanical gardens).
- Almost indefinite maintenance of germplasm.
- Cost-effectiveness.

Disadvantages

***In situ* conservation**

- Requires extensive areas for effective conservation.
- Generally has a limited coverage of the genetic diversity of the target species.
- Exposes natural populations to a wide range of natural catastrophic events.
- Materials cannot be readily used and may be difficult to access.
- Subject to conflict with management by landowners.
- Expensive to maintain.

***Ex situ* conservation**

- Freezes the evolutionary process.
- Difficult to ensure adequate sampling (intra-specific variability).
- Total genetic integrity cannot be ensured due to human error, selection pressure during re-generation.
- Only limited numbers of accessions can be conserved in field gene banks.
- Natural catastrophes could affect field gene banks.
- *In vitro* genetic instability and loss of capacity for tissues to regenerate into the plant.

Since the needs of users and conservation technologies may change over time, a conservation strategy should be flexible enough to allow such changes to be taken into consideration.[70]

[70] For a possible framework for developing a complementary conservation strategy using coconut as an example, see Dulloo *et al.* (2005). The process involves first defining the options for conservation of the target species, taking into account the feasibility of conserving it *in situ*, its seed storage behaviour, whether or not the species can be conserved as seeds, whether or not protocols for *in vitro* or cryopreservation are developed or whether the species can only be conserved as live plants in a field gene bank or botanical garden.

Key points to remember:

- The reason for the complementarity of *ex situ* and *in situ* conservation methods lies in their main difference: while the former implies the maintenance of genetic material outside of the 'normal' environment where the species has evolved and aims to maintain the genetic integrity of the material at the time of collecting, the latter is a dynamic system which allows the biological resources to evolve and change over time through natural or human-driven selection processes.
- Articles 5 and 6 of the International Treaty refer to both methods, including the collection and *ex situ* conservation of PGRFA under threat or of potential use, on-farm management of farmers' PGRFA in their fields, and *in situ* conservation of CWR in protected areas.
- A complementary conservation strategy involves the combination of different conservation actions, which together lead to an optimum sustainable conservation of PGRFA.
- The ultimate purpose of germplasm conservation is to ensure the ability to use PGRFA now and in the future for agricultural research, plant breeding, cultivation and finally consumption, for global food security. The International Treaty therefore provides for facilitated access to the genetic material included in its Multilateral System.

Cross-references:

- For an in-depth elaboration of the **contents of articles 5 and 6 of the International Treaty** refer to lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).
- To learn more about the **Multilateral System and the SMTA** refer to sub-section 4.2.3. of lesson 4 of Module I (Main Components and Governance of the International Treaty).
- To study the **Multilateral System in-depth** refer to the forthcoming Module IV (The Multilateral System of Access and Benefit-sharing).
- To learn more about **how the Multilateral System contributes to the conservation and sustainable use of PGRFA** refer to sub-section 3.2.2. of lesson 3 of this module (Further Components of the International Treaty Supporting Conservation and Sustainable Use).
- For more information of the **International Treaty's provisions dealing with collection, characterization and documentation of PGRFA**, refer to sub-section 2.2.1. of lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).

1.3. Conservation and Sustainable Use of Crop Diversity: Two Sides of the Same Coin

1.3.1. Concept of Sustainability and Meaning of Sustainable Use

In essence, 'sustainability' refers to the rational (or wise) use of any renewable resource in such a manner that the resource is not depleted for future use. The concept of sustainable use is derived from the Brundtland report's definition of sustainable development, i.e. "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".[71] In the context of PGRFA, sustainable use can be broadly defined as the use of genetic resources in support of sustainable agriculture, which requires a system of agriculture that produces and facilitates access to sufficient food for all people and contributes to livelihoods and socio-economic development while protecting the environment.[72]

Sustainable use of PGRFA is one of the three main objectives of the International Treaty, which devotes an entire article to it. Article 6 proposes a series of measures to promote sustainable use of PGRFA and calls upon Contracting Parties to develop and maintain appropriate policy and legal measures to that end. The proposed measures are targeted to ensure the maintenance of diverse farming systems, to maximise intra and inter-specific variation for the benefit of farmers, to promote participatory plant breeding, to broaden the genetic base of crops and the expanded use of local and adapted crops, to reduce genetic

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[71] Brundtland Commission of the United Nations (1987), chapter 2.
[72] Lipper and Cooper (2009), pp. 27-28.

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vulnerability and erosion and promote increased food production through the use of a wider diversity of varieties and species, and to review breeding strategies and regulations concerning variety release and seed distribution. Thus article 6 provides a broad framework for a policy environment that enables the sustainable use of PGRFA.

Let us discuss here more precisely what is commonly understood by sustainable use of PGRFA and in what ways PGRFA are deployed to ensure food security and to improve farmers' livelihoods. PGRFA can be used directly by farmers through selection of the crops and varieties they cultivate and maintain on their farms. This selection process by farmers has occurred over many generations in a sustainable way which has allowed local varieties to evolve over time, adapt to their local conditions and continue to be productive making full use of the natural variation in traits.

On the other hand, PGRFA can be sustainably used in crop improvement programmes through the breeding of high yielding improved varieties by breeders. The aim is to produce a sustainable crop production over time in different agro-ecosystems. This requires a wide range of crop genetic resources to provide resistance genes to biotic and abiotic stresses to adapt to particular environmental conditions. Plant breeding relies on using the genetic variation available naturally among individuals in a population of a particular species. This potentially includes germplasm from primary, secondary and tertiary gene pools, from elite material to distantly related species, which can be introduced into the breeding programme.

In conventional crop improvement, plant breeders make crosses between parents with desirable traits - usually found in well-adapted and agronomically desirable types. However, as traits of interest may not always be found in well-adapted elite varieties, breeders may need to look for traits in more distantly related species and genera. The process by which desirable traits are transferred from non-adapted sources like CWR is called 'pre-breeding'. They subsequently select progeny with incremental improvements in combinations of the sought-after specific traits such as yield, quality or pest resistance. Most breeding programmes focus on the improvement of major crops that can be adapted to grow in different agro-ecosystems by using external inputs, including irrigation and fertilizer. Biotechnology is also increasingly being used by breeders as complementary technique to conventional breeding to improve effectiveness and efficiency of breeding strategies. These may make use of a range of technologies including tissue culture, micro-propagation, mutation breeding, double haploids and the use of marker assisted selection.

Very few programmes address ‘subsistence crops’ (often underutilized species) which are important to resolve problems of hunger and poverty for resource poor farmers living in marginal areas. Therefore, plant breeding often leads to a narrowing of the genetic base, as materials are crossed and selected to obtain elite varieties with desirable traits. Thus there is a constant need to inject new germplasm to broaden the genetic base again in order to reduce genetic vulnerability to different stresses.

Farmer participation in the selection and breeding processes can help to tailor efforts to the needs of farmers and take advantage of their traditional knowledge. Participatory plant breeding activities aim at achieving crop development while at the same time ensuring on-farm conservation of local crop genetic diversity, including underutilized crops. Local seed systems also facilitate the sustainable use of local and adapted improved varieties, while playing an important role in maintaining and shaping crop diversity on-farm.[73] Initiatives such as on-farm seed production, distribution of seed kits, demonstration plots, seed fairs and community seed banks can significantly improve local seed supply.[74]

Key points to remember:

- Contracting Parties of the International Treaty commit themselves to take measures to promote the sustainable use of PGRFA. Article 6 of the International Treaty proposes a set of such measures.
- Sustainable use of PGRFA can be understood as the use of PGRFA in support of a system of agriculture that produces and facilitates access to sufficient food for all people and contributes to livelihoods and socio-economic development while protecting the environment.
- The ‘use’ of PGRFA commonly refers to either the selection of PGRFA by farmers through cultivation, or their use by scientific plant breeders in crop improvement programmes.
- Plant breeders make crosses between parents with desirable traits and subsequently select progeny with incremental improvements in combinations of the sought-after specific traits such as yield, quality or pest resistance.
- Conventional plant breeding often leads to a narrowing of the genetic base, as materials are crossed and selected to obtain elite varieties with desirable traits.
- Participatory plant breeding aims at achieving crop development while ensuring on-farm conservation of locally adapted and underutilized crop genetic diversity.

[73] Bellon *et al.* (1997).
[74] For detailed information on these activities see Almekinders (2001).

Cross-references:

- For the **Brundtland report** see: http://www.worldinbalance.net/intagreements/1987-brundtland.php
- For in-depth explanations of the **measures proposed under Article 6 of the International Treaty**, refer to sub-section 2.2.2. of lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).
- For **practical illustrations of options to promote sustainable use of PGRFA** refer to section 4.2. of lesson 4 of this module (Implementation of Articles 5 and 6 from a Users' Perspective).
- For more information on **pre-breeding** refer to sub-section 4.2.2. of lesson 4 of this module (Implementation of Articles 5 and 6 from a Users' Perspective).
- To learn more about the **International Treaty's provisions dealing with participatory plant breeding** refer to sub-section 2.2.2. of lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).
- For more information on different **methodologies and objectives for participatory plant breeding**, refer to section 4.2.2. of lesson 4 of this module (Implementation of Articles 5 and 6 from a Users' Perspective).

Linking Conservation to Sustainable Use

The essence of crop genetic resources conservation is not only for the conservation of the intra-specific diversity contained within them, but also for their sustainable use to improve agricultural production as described above. The improvements in agriculture have been possible due to the use of diversity within early crop varieties, including their wild relatives. However, as agriculture has progressed, the extensive use of uniform improved varieties has led to the loss of crop genetic diversity in the fields and has triggered a conservation movement focused on the collection and conservation of threatened PGRFA.[75] Pioneers like Nicolai Vavilov and Otto Frankel realized that improvements in agriculture will not be sustainable unless the crop diversity is properly conserved, characterized, evaluated and used. As we have seen above, much progress has been made in the last decades in conserving plant genetic diversity both *ex situ* and *in situ*.[76]

Although the diversity stored in gene banks is the raw material for plant breeding, it is not evident to what extent the conserved diversity is used by agricultural researchers, breeders and farmers. There are various reasons that may limit the utilization of these resources: on the one hand many accessions in gene banks are not well documented, characterized and evaluated, which is needed to allow breeders to identify accessions of potential use. On the other hand some breeders prefer to use their own breeding collections (often with a much narrower genetic diversity), which already have the right genetic background and do not require lengthy pre-breeding activities. Breeders are nevertheless recognizing that local varieties and CWR offer the breadth of genetic diversity needed to meet the novel challenges of climate change and rapidly-changing consumer demands. This calls for a greater linkage and integration between the needs for conserving diversity and actively seeking the valuable traits found within wild relatives and local varieties.

The environment in which we live is constantly changing and is subject to periodic natural calamities such as hurricanes, tsunamis, floods and droughts. The crop diversity we conserve in our gene banks and the crop varieties that are cultivated on farms may well have the required adaptive traits breeders are looking for to face these problems, as well as to resist new pests and diseases. Gene banks have a potential role to play in combating these risks by providing breeders with new diversity to make future varieties more resistant. In Ethiopia, for example, Bioversity International is undertaking a pilot project sponsored by the World Bank Development Marketplace on

75 Scarascia-Mugnozza and Perrino (2002).
76 FAO (2010), p. xix.

adaptation to climate change, which aims at demonstrating the value of gene bank material in providing options to poor farmers in adapting to climate change (see Box 1.6).

Gene banks can also provide germplasm material for restoration of lost crops after natural or man-made catastrophes. For example, after the tsunami in Malaysia in 2004, rice growers were able to obtain from gene banks salt-tolerant varieties of rice not normally grown in that area. Gene bank accessions of CWR are particularly valuable as gene providers, and many examples exist to show the use of CWR in crop improvement. For example, a recent study has shown that wild relatives of sorghum with different mechanisms of resistance can be used as sources of alternate genes to increase the levels and diversify the basis of resistance to shoot fly.[77] Scientists from the Agricultural Research Service of the United States Department of Agriculture have developed a new russet potato breeding line that naturally resists the attack of the Columbia Root-knot Nematodes, which inflicts huge losses on the potato industry.[78] These examples show how conservation efforts undertaken in the past can be used to resolve present problems and offer options for future food security.

Box 1.6: Seed for Needs – Adapting Agriculture to Climate Change in Ethiopia

Climate change poses a serious threat to future food security. Increases in temperatures and changes in rainfall patterns are expected to increase food shortages, especially in Africa. Ethiopia is a country where climate change will be the most affected in East Africa and has a rich heritage of local varieties of some crops, in particular wheat, barley and teff, that can be used to adapt to climate change. An award winning project supported by World Bank Development Marketplace 2009 aims to develop a low cost innovative approach to use locally adapted varieties conserved in gene banks to help women farmers cope with climate change.

The premise of the project is that farmers will require seeds of new varieties to sustain their crop production and continue to feed their families. Currently, farmers obtain their seeds principally from local seed systems over relatively very short distances. But with climate change they may have to go a long distance to obtain the local varieties that will grow in their new climate conditions. Seeds which are currently conserved in the national gene banks at the Institute of Biodiversity and Conservation (IBC) can provide a solution to farmers. These are seeds that have been collected all over Ethiopia and conserved in IBC. The collections represent a storehouse of diversity that, if properly evaluated with farmers in a participatory manner for adaptation to climate change and made easily accessible, can provide farmers with climate-ready varieties in much less time than is required for breeding and releasing new improved varieties. Thus, even in the face of uncertain future conditions, varieties suited to projected future climates can be selected from gene banks and be made available to farmers.

The project recognizes and seeks to strengthen the role of women farmers as seed custodians. This is accomplished by national and international scientists working side-by-side with women farmers to identify and evaluate locally adapted crop varieties better-suited for production in hotter, drier conditions. The project uses its findings to match and map different crop varieties to the predicted climate change scenarios in Ethiopia. The resultant map showing which crop varieties will perform well under new climatic conditions will be a useful tool for helping farmers select and plant crop varieties best suited to their local environmental and climatic conditions, with the assurance of good yields. The map will also serve as an important policy tool for the government, guiding design and implementation climate adaptation programmes.

[77] Kamala *et al.* (2009). The scientific name of the shoot fly is *Atherigona soccata.*
[78] Brown *et al.* (2009).

Key points to remember:

- The essence of conserving PGRFA is to maintain the ability to use the diversity of traits they contain in a sustainable way for improvements in agricultural production.
- For improvements in agriculture to be sustainable, crop diversity needs to be properly conserved, characterized, evaluated and used.
- Local varieties and CWR offer the breadth of genetic diversity needed to cope with the risks posed by novel challenges such as climate change.
- Gene banks have a potential role to play in combating these risks by providing breeders with new diversity to make future varieties more resistant.

Cross-references:

- For a working **definition of the concept of sustainable use** refer to section 2.3. of lesson 2 of Module I (Objectives, Scope and Basic Concepts).
- To learn more about the **linkages of the measures for conservation and sustainable use** that are put forward in the International Treaty, refer to lesson 2 of this module (The Provisions of Articles 5 and 6 of the International Treaty).
- For **practical illustrations of options to promote the conservation and sustainable use** of crop diversity, refer to section 4.2. of lesson 4 of this module (Implementation of Articles 5 and 6 from a Users' Perspective).

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1.4. Conclusive Summary

Crop diversity underpins agricultural production and has made a huge contribution to the improvement of crop varieties and to food security. Yet humankind still only relies on a tiny fraction of edible plants. Farmers' traditional and locally adapted varieties, developed over generations of selection, have contributed significantly to the increase in crop yields through their contributions as ancestors in the development of improved varieties. However, the expansion of improved varieties in production systems is one of the major drivers of loss in crop diversity. There are important risks of genetic vulnerability associated with the large-scale cultivation of highly uniform crops, thus the need for more diverse cropping systems to stabilize crop production. In addition to the changes in land use, replacement by improved varieties, increased human populations, poverty and land degradation, climate change is set to have a major impact on agriculture and food security. In order to help alleviate these impacts, it is critical to ensure the conservation and sustainable use of crop diversity.

Crop diversity needs to be conserved both *in situ* as well as *ex situ* as these two methods are complementary. Different *ex situ* techniques are used depending on the species biology and the objectives of conservation. Each has its advantages and disadvantages. Two kinds of *in situ* conservation are recognized (*in situ sensu stricto* and on-farm), depending on the target species and the selection pressures exerted on their populations. For wild species, including CWR, natural habitats are usually protected by the establishment of protected areas and preparation of management plans for the effective conservation of the target populations. On-farm diversity is largely under the management control of farmers.

The International Treaty aims at promoting both *in situ* and *ex situ* conservation. While quite some progress has been made over the last decades in both areas of *ex situ* and *in situ* conservation, quite a lot still remains to be done.[79] There is a need for greater rationalization among *ex situ* collections globally and many collections still lack adequate documentation, characterization and evaluation. With regard to *in situ* conservation, greater attention is required for developing appropriate policies, legislation and procedures for collecting CWR, for establishing protected areas and for better coordination of these efforts. Further, there is a need to improve farmers' management of diversity on farms. This is why on-farm conservation is one of the priorities for projects to receive funding under the Benefit-sharing Fund of the International Treaty.

Sustainable use of PGRFA contributes directly and indirectly to their conservation, just as increased and better use of PGRFA provides incentives for more effective conservation. Conservation is a strategy for ensuring food security and improving peoples' well-being and livelihoods; this requires an optimum use of both the diversity conserved in *ex situ* collections and existing on farms and in nature.

[38] FAO (2010), pp. 45-46, 87-88.

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