Chapter 3

What Do We Mean By *in situ* Conservation of CWR?

There is a need for more effective policies, legislation and regulations governing the in situ and on farm management of PGRFA, both inside and outside of protected areas (Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture, 2010).

General and specific aims of *in situ* species conservation

It might appear to be a simple matter to explain what is meant by *in situ* conservation, but it has proved extremely hard to provide a clear and generally agreed definition of this key component of biodiversity conservation. As noted in the introductory chapter, most countries have not attempted to conserve CWR *in situ*. The reasons for this are various and complex, but there are two basic explanations for such neglect: the first lies in the difference in perceptions by the conservation and genetic resources sectors as to what *in situ* conservation means, how it is practised and why it is undertaken; the second is simply the complexity of the process and the wide degree of interdisciplinary cooperation it requires.

In situ conservation is a term that is applied to a variety of situations (see Box 3.1). It deals principally with (a) the conservation of natural habitats, notably in protected areas and other kinds of reserves; and (b) the conservation, maintenance or recovery of viable population of species in their natural habitats. In the case of CWR, the conservation of the widest range of genetic traits of potential use in plant breeding is of great concern and the term *genetic conservation* is often applied (see below).

Box 3.1 The various forms of *in situ* conservation

- conservation of natural or semi-natural ecosystems in various types of reserves or protected areas;
- conservation of agricultural biodiversity, including entire agroecosystems and the maintenance of domesticates (on-farm);
- conservation and maintenance of target species in their natural or semi-natural habitats;
- genetic conservation;
- species recovery programmes; and
- habitat restoration.

Long-term aims of *in situ* conservation of CWR

The main general aim and long-term goal of *in situ* conservation of target species is *to ensure their survival, evolution and adaptation to changing environmental conditions such as global warming, changed rainfall patterns, acid rain and habitat loss, through taking steps to protect, manage and monitor selected populations in their natural habitats so that the natural evolutionary processes can be maintained, thus allowing new variation to be generated in the gene pool.*

Most importantly, according to Frankel et al (1995), '*in situ* conservation is the method that preserves biological information on genetic diversity in context. Not only does it conserve the genetic diversity relevant to intra-specific and inter-specific interactions among organisms and their associated pests and beneficial species, it is also present in populations that are or have been host to the relevant biotypes of the pathogen or symbiont'.

In addition, various additional specific goals may be recognized (see Box 3.2):

In situ conservation of exploited species

Many of the species that may be targeted for *in situ* conservation because of their economic use are subject to exploitation, among them wild fruit trees, and medicinal and aromatic plants. It should not be assumed that the conservation objective is simply to maintain the species in such a way that they will continue to evolve as natural viable populations; it may be that the emphasis will be more on sustaining the use of the species itself for the benefit of various stakeholders, and this will affect the management objectives. As a recent review of sustainable use and incentive-driven conservation points out, these management objectives may include the conservation of the species (or its populations), the ecosystem in which they occur, or the livelihoods that depend on the species' exploitation (Hutton and Leader-Williams, 2003).

On-farm conservation

In the case of domesticates or cultivated species, *in situ* conservation refers to the maintenance of landraces or cultivars, not of wild species, in the surroundings

Box 3.2 Specific goals for *in situ* conservation of CWR

- Ensuring continuing access to these populations for research and availability of germplasm; for example, native tree species may be important plantation species within the country or elsewhere and thus *in situ* conservation will allow access to these forest genetic resources in the future, if needed.
- Ensuring continuing access to or availability of material of target populations maintained and used by local people, as in the case of medicinal plants, extracted products (e.g. rubber, palm hearts), and fuelwood.
- Selection for yield potential, i.e. genetic potential that confers desirable phenotypic traits (Hattemer, 1997), for example in forest trees, fruit- or nut-producing trees (Reid, 1990).
- Conserving species that cannot be established or regenerated outside their natural habitats, such as: species that are members of complex ecosystems (e.g. tropical forests, where there is a high degree of interdependency between species); species with recalcitrant seeds or with fugacious germination; or species with highly specialized breeding systems (e.g. those dependent on specific pollinators, which in turn depend on other ecosystem components) (FAO, 1989).
- Enabling some degree of conservation of other species occurring in the same habitats as the CWR, some of which may be of known economic value or of importance in maintaining a healthy ecosystem. This may provide additional justification for single-species conservation programmes.
- Minimizing human threats to genetic diversity and supporting actions that promote genetic diversity in target populations (Iriondo and De Hond, 2008).
- Minimizing the risk of genetic erosion from demographic fluctuations, environmental variation and catastrophes (Iriondo and De Hond, 2008).

where they have developed their distinctive properties, along with their pollinators, soil biota and other associated biodiversity; this is commonly referred to as '**on-farm conservation**'[1] (see Box 3.3). On-farm conservation has been defined as 'the sustainable management of genetic diversity of locally developed traditional crop varieties, with associated wild and weedy species or forms, by farmers within traditional agricultural, horticultural or agri-silvicultural cultivation systems' (Maxted et al, 1997). It is a form of conservation of agricultural biodiversity but is quite distinct from the conservation of CWR and is not considered further in this manual.

National and international mandates for *in situ* species conservation

The conservation of species and their populations *in situ* is mandated by the Convention on Biological Diversity (CBD), which includes, in Article 8, '…*the conservation of ecosystems and natural habitats and the maintenance and recovery of*

Box 3.3 *In situ* conservation on-farm

In situ conservation on-farm, sometimes referred to as 'on-farm conservation', has been defined as 'the continuous cultivation and management of a diverse set of populations by farmers in the agroecosystems where a crop has evolved' (Bellon et al, 1997). On-farm conservation concerns entire agroecosystems, 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. Within this definition, it is possible to identify a wide range of objectives that may shape an on-farm conservation programme. These include:

- to conserve the processes of evolution and adaptation of crops to their environments;
- to conserve diversity at different levels – ecosystem, species and within species;
- to integrate farmers into a national plant genetic resources system;
- to conserve ecosystem services critical to the functioning of the earth's life-support system;
- to improve the livelihood of resource-poor farmers through economic and social development;
- to maintain or increase farmers' control over and access to crop genetic resources.

Source: Jarvis et al, 2000

viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties'. Specifically, *in situ* conservation is also addressed by the CBD's Global Strategy for Plant Conservation (GSPC) by both target vii, '60 per cent of the world's threatened species conserved *in situ*' and target viii, '10 per cent of threatened plant species included in recovery and restoration plans'. However, as Heywood and Dulloo (2005) note, none of the CBD's decisions or work programmes have specifically focused on how the *in situ* conservation or maintenance of viable populations of species is to be achieved, even though it is recognized in the Preamble to the Convention as a fundamental requirement for the conservation of biological diversity. Likewise, efforts to address this subject through the GSPC under targets vii and viii have not made much progress and are currently (September 2010) under review.

The Global Plan of Action (GPA) on Plant Genetic Resources for Food and Agriculture (FAO, 1996), together with the first report on the *State of the World's Plant Genetic Resources for Food and Agriculture*, was adopted by representatives of 150 countries during the Fourth International Technical Conference on Plant Genetic Resources, held in Leipzig, Germany from 17 to 23 July 1996. The report presents a global strategy for the conservation and sustainable use of plant genetic resources and, to some extent, complements the provisions of the CBD. The GPA specifically recognizes the need to promote *in situ* conservation of wild crop relatives and wild plants for food production (Priority Activity Area 4: Promoting

Box 3.4 Promoting *in situ* conservation of wild crop relatives and wild plants for food production

The long-term objective of this activity is to promote the conservation of genetic resources of crop wild relatives and wild plants for food production, in protected areas and on other lands not explicitly listed as protected areas. The Plan calls for some recognition of the valuable role crop wild relatives and wild plants play in food production, which should be taken into account in planning management practices. In addition, the importance of women in terms of their knowledge of the uses of wild plants for food production and as sources of income is acknowledged. Another important objective is to create a better understanding of the contribution of plant genetic resources for food and agriculture to local economies, food security and environmental health, and to promote complementarity between conservation and sustainable use in parks and protected areas by broadening the participation of local communities as well as other institutions and organizations engaged in *in situ* conservation. The importance of conserving genetic diversity for these species in order to complement other conservation approaches is also highlighted.

The activities of the International Treaty (ITPGRFA) relevant to *in situ* conservation are (see Article 5 – *Conservation, exploration, collection, characterization, evaluation and documentation of plant genetic resources for food and agriculture*):

- **Survey** and inventory plant genetic resources for food and agriculture, taking into account the status and degree of variation in existing populations, including those that are of potential use and, as feasible, assess any threats to them;
- **Promote** *in situ* conservation of crop wild relatives and wild plants for food production, including in protected areas, by supporting, *inter alia*, the efforts of indigenous and local communities;
- **Monitor** the maintenance of the viability, degree of variation and the genetic integrity of collections of plant genetic resources for food and agriculture.

Source: FAO, 1996

in situ conservation of wild crop relatives and wild plants for food production – see Box 3.4). The GPA notes that:

- Natural ecosystems hold important plant genetic resources for food and agriculture, including endemic and threatened wild crop relatives and wild plants for food production.
- Many such ecosystems and resources are not managed sustainably.
- This genetic diversity, because of interactions that generate new biodiversity, is potentially an economically important component of natural ecosystems and cannot be maintained *ex situ*.
- Unique and particularly diverse populations of these genetic resources must be protected *in situ* when they are under threat.

- Most of the world's 8500 national parks and other protected areas, however, were established with little specific concern for the conservation of crop wild relatives and wild plants for food production.
- Management plans for protected and other areas are not usually broad enough to conserve genetic diversity for these species to complement other conservation approaches.

While both the GPA and ITPGRFA recognize the importance of conserving CWR, the former has no dedicated funding mechanism for any of its activities and the latter does not have a specific funding arrangement for *in situ* conservation, as opposed to *ex situ* conservation, of plant genetic resources, including CWR. In view of the major contribution that CWR make to enhanced food production through the provision of genetic materials for breeding improved crops, as recognized by the Consultative Group on International Agricultural Research (CGIAR) in its latest draft strategy (CGIAR, 2009),[2] it would be appropriate to create a new fund to finance a major global initiative in this area, comparable to the Global Crop Diversity Trust. Without such a fund, it is highly unlikely that significant progress will be made in conserving CWR.

At a country level, there is considerable variation in national mandates for *in situ* conservation of target species. In some countries (e.g. several European countries, the US, Australia) considerable attention is paid to this topic and management or recovery plans are in place for some species, while in others there is an avowed interest but little action; in yet others, the subject is not even recognized in national conservation/biodiversity strategies. The GSPC should serve to focus attention on this issue through target vii.

Strategic planning for *in situ* species conservation

Until the recent interest displayed by the time-limited targets of the European Union, Millennium Commission and CBD, little attention has been paid to the strategic needs for species conservation. An exception is the very perceptive essay by Woodruff (1989) on the problems of conserving genes and species in the volume *Conservation for the Twenty-First Century* (Western and Pearl, 1989). He writes:

> *If we are really serious about species conservation, we might launch a Species Defence Initiative (SDI). The goals of the programme would include conserving selected species to prevent further environmental degradation. … The SDI would require a planning policy shift toward maintaining the evolutionary potential of species. This will, in turn, shift the emphasis from simple censuses to determining the genetic quality of the managed populations.*

He then goes on to say that 'far more population-level intervention will be required to conserve most species'. This contrasts with the widely expressed view that, for most wild species, little if any specific conservation action is needed unless the species are seriously threatened. Such a hands-off approach, which is discussed in more detail below, was predicated on the premise that plant and animal diversity (biodiversity as we now call it) is safely protected in the world's ecosystems and that when a particular habitat or species became threatened, appropriate protective action could be taken. While this may have been true 50 years ago, we now face a situation in which it is estimated that about a quarter of the world's plant species are threatened and the proportion will only worsen, largely as a result of the widespread and continuing degradation, fragmentation, simplification and loss of terrestrial and aquatic habitats, caused by population movements and growth, changes in disturbance regimes, spread of invasive species, urbanization, industrialization, expanding agriculture and over-consumption and, of particular concern today, climate change. As discussed in Chapter 14, the problems of relying on a static system of protected areas in a period of accelerated climate change are causing us to reconsider traditional conservation strategies.

In such a situation, a static approach to species conservation is no longer justified. With a 100,000, or possibly more, threatened plant species today, many of these being CWR, action must be taken to ensure that threats are contained, if not removed; this represents a major global challenge. Also, we cannot take comfort in the likelihood that the remaining 300,000 species will continue to be safe in their natural habitats. For one thing, in many cases we simply do not know what their status is or the threats they now face and or will face in the coming decades.

On the other hand, when one considers that most biodiversity probably occurs outside existing protected areas – although precise data are not available – it follows that reliance on protected areas alone is not a viable approach. The *in situ* management of species outside protected areas represents a major challenge and demands considerable innovation and thinking. This is discussed in detail in Chapter 11.

In situ conservation in context

The underpinning of the conservation strategies of most countries is a protected areas system; this is reflected in the CBD where the main thrust of *in situ* biodiversity conservation is through the development of a system of protected areas. This has been criticized by some as being a somewhat restricted or protectionist approach to conservation with little regard for the interests of local communities (Mathews, 2005). As Adams and Mulligan (2003) comment, 'international conventions like the Convention on Biological Diversity (CBD) have come to drive a protectionist programme, including reinforcing the protected area strategy based largely upon a U.S. model of national parks and wilderness reserves …'. The adoption by the CBD of the so-called 'ecosystem approach', discussed below, addresses these concerns to some extent.

In situ conservation of target species covers a broad spectrum of activities including the preparation and implementation of detailed single-species recovery

Box 3.5 Key distinguishing features of the ecosystem approach

- It is designed to balance the three CBD objectives of conservation, sustainable use and equitable sharing of benefits.
- It places people at the centre of biodiversity management.
- It extends biodiversity management beyond protected areas while recognizing that they are also vital for delivery of the objectives of the CBD.
- It engages the widest range of sectoral interests.

Source: Smith and Maltby, 2003, http://data.iucn.org/dbtw-wpd/edocs/CEM-002.pdf

plans, in the case of those species that are critically endangered; single-species management plans; monitoring for those species that are rare, not threatened or only vulnerable; multi-species recovery plans; and management plans and habitat protection. It should be viewed in the context of a mosaic of land-use options, each of which requires its own range of management approaches: it may be undertaken in nature reserves and other protected areas; in private and publicly owned natural forests, plantations and other types of habitat; as trees, shrubs and herbs in agroforestry systems of various types, including home gardens; in homesteads; and along rivers and roads.

Moreover, as we shall see (in Chapter 12), various forms of *ex situ* conservation may be needed to supplement *in situ* actions, such as conservation collections in arboreta and botanic gardens, properly sampled accessions in seed banks, clone banks, field trials and seed production areas (Palmberg-Lerche, 2002).

In recent years, it has been increasingly recognized by conservation practitioners that because of the limitations of both species-based and ecosystem-based approaches, integrative (sometimes called **holistic** or **complementary**) methods for deciding conservation strategies should be adopted. Essentially, this recognizes that one should adopt whatever scientific and social techniques or approaches (such as *in situ*, *ex situ*, *inter situs*, reintroduction or population reinforcement) are judged to be appropriate to a particular case and circumstances. A similar, but less unambiguous, strategy has been endorsed by the CBD in its promotion of the 'ecosystem approach', in which what is essentially a holistic approach is adopted. The ecosystem approach is defined by the CBD as 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Application of the ecosystem approach will help to reach a balance of the three objectives of the Convention' (Box 3.5). It aims to put people and their natural resource-use practices at the centre of decision-making and can be used to seek an appropriate balance between the conservation and use of biological diversity in areas where there are both multiple resource users and important natural values (Masundire, 2004). The core concept of the approach has been described as 'integrating and managing the range of demands we place on the environment, such that it can

Box 3.6 Differences between an ecosystem approach and *in situ* conservation

- There may be more human interventions in *in situ* approaches.
- Ecosystem approaches are more process- or function-oriented.
- *In situ* conservation may be more species-specific and species-centred than ecosystem approaches.
- *In situ* approaches are geographically more restricted.
- Ecosystem approaches primarily conserve habitats, often with little or no knowledge of the genetic resources present in those habitats, whereas *in situ* approaches often target specific genetic resources.

Source: Poulsen, 2001

indefinitely support essential services and provide benefits for all without deterioration to the natural environment' (UK Clearing House Mechanism for Biodiversity).[3]

An annotated bibliography of the ecosystem approach is available at: http://www.icsu-asia-pacific.org/resource_centre/Ecosystem%20Approach%20Annoted%20Bibliography2004.pdf (accessed 23 November 2010).

In situ conservation differs from an ecosystem approach in a number of ways (Box 3.6). In the case of CWR it is much more species-oriented than a purely ecosystem approach.

Complementary conservation strategies, combining *in situ* and *ex situ* approaches, may be necessary in cases where species are highly threatened and/or very valuable. *Ex situ* conservation involves the conservation of the components of biological diversity outside their natural habitats (see Chapter 12) and can act as an insurance policy in case *in situ* measures are unsuccessful and the target species becomes unviable or extinct. Complementary approaches are becoming increasingly important in light of climate change: populations of many species are unlikely to be able to keep evolutionary pace with the rate of change or to migrate to climatically suitable areas.

Interplay between species and habitats

The conservation of species *in situ* logically requires that the sites in which they occur are themselves effectively protected, a condition that does not often apply. Likewise, if threatened species are to be effectively conserved within the boundaries of protected areas, it requires that they be adequately managed and monitored. Unfortunately, as a World Wide Fund for Nature (WWF) survey notes (WWF, 2004), very few protected areas report having comprehensive monitoring and management programmes.

In practice, the conservation of species *in situ* is critically dependent on identifying the habitats in which they occur and then ensuring the protection of both the habitat and the species through various kinds of management and/or monitoring. In the case of threatened species, conservation *in situ* also requires that threats are removed or at least contained. Thus, although *in situ* species conservation is essentially a species-driven process, it also necessarily involves habitat protection. In terms of *in situ* conservation of target species, there is a very close relationship between taking action at the area/habitat level and action at the species population level (Heywood, 2005).

Coarse and fine filter approaches

The targets of conservation range from genes, populations and species to communities, habitats, ecosystems, landscapes and bioregions. In establishing biodiversity conservation goals, either a coarse or fine filter approach may be adopted. The conservation of genes, populations and species is sometimes known as the '**fine filter**' approach whereas the conservation of communities and habitats is known as the '**coarse filter**' approach. The original coarse filter concept of conserving entire plant and animal communities in reserves was viewed as an efficient approach to conserving biodiversity that would protect 85–90 per cent of all species, without requiring inventories or the planning of reserves for those species, individually.

In effect, setting aside entire ecosystems in reserves is considered an efficient way to maintain biodiversity because large numbers of species are protected. The idea behind using a coarse filter for ecosystems management is that if intact functioning ecological communities are maintained, the species living in those communities will thrive. To this extent, the coarse filter approach relates to the ecosystem approach but with a much more restricted focus. While it has been suggested that the coarse filter approach protects a large majority of species, this seems highly unlikely today, given the pressures on habitats from various components of global change. In addition, a coarse filter approach neglects a proportion of species and does not address the conservation needs of target species which require a specific and tailored conservation strategy. A complementary fine filter must then be applied to those species that slip through the coarse filter, to ensure their protection. Examples of species needing a fine filter approach are those exploited by humans, such as medicinal plants, CWR or rare species that have a specialized ecology that the coarse filter approach may well not capture.

The dilemma is that most conservationists would argue the number of species requiring some form of targeted conservation action is so great that entire communities rather than single species need to be the focus of conservation efforts. This is almost certainly true for CWR, where a single country may house scores to hundreds of CWR. In Bolivia, for example, nearly 200 CWR have been identified while in Armenia, 2518 CWR species have been inventoried (http://cwr.am/index.php?menu=list).

There is no obvious solution to this dilemma and each country must determine its own CWR conservation strategy. As we discuss later (in Chapter 7), some form of triage is usually employed, giving priority to those wild relatives that are closely related to crops, those that are endangered and therefore in need of urgent action if they are to survive, and so on. Even so, some countries will find themselves in a situation whereby there are still too many priority species to manage. If appropriate conservation action cannot be organized locally, and given that CWR in any country may be relevant to the crops of other countries, the problem assumes an international dimension. In other words, if it is decided that particular CWR are of such importance that their conservation is a global imperative, then international agencies must step in. At present, there is no provision made for such action even though it should logically fall under the mandate of the ITPGRFA.

Active and passive conservation

The assumption is often made that if a species is found to occur within a protected area then, provided the area is adequately managed, the continued survival of the species is likely without further intervention or management action. This is referred to as *passive* conservation, or the 'hands-off' approach, in that the existence of a particular species is coincidental and passive, and not the result of active conservation management. It contrasts with active conservation, which requires positive action to promote the sustainability of the target taxa and the maintenance of the natural, semi-natural or artificial (e.g. agricultural) ecosystems that contain them, thereby implying the need for associated habitat monitoring. Certainly, this assumption is likely to be valid in areas (whether protected or not) that are not subjected to unusual or exceptional pressure and provided the target species is not threatened by other factors. As Simberloff (1998) puts it, 'keep the ecosystem healthy … and component species will all thrive'. This was regarded as the norm until recently. Unfortunately, it is now increasingly unlikely due to accelerating human-induced environmental pressures characterized collectively as global change (see Box 3.7); much more management intervention is necessary to ensure the survival of viable populations of target species. The implications of global change for CWR are discussed in detail in Chapter 14.

Without effective management, the populations of target species in existing protected areas are at risk of change in size and genetic composition because of the dynamics involved, and the habitats themselves are being put at risk through population pressure or movements, deforestation, the increasing demand for land for growing crops and other forms of anthropogenic change, or by the effects of climate change (see Chapter 14). As a consequence of these changes, the number of threatened species, although not known with any precision, is likely to increase substantially over the coming decades.

Referring specifically to the conservation *in situ* of wild species that are actual or potential genetic resources, Frankel et al (1995) comment that conservation in their natural habitats, within the communities of which they form a part, is the best option and that only when such communities, or individual species within them, are threatened, may some form of protection be necessary – in forestry

Box 3.7 CWR and protected areas

… presence in a protected area, provided the area is adequately managed, will afford some degree of protection to the species housed within it, and by definition it obviates the need to seek and place an area under reserve for the target species concerned. Obviously, if the target species is dominant in its ecosystem, such as forests of Cedrus *or* Abies *in Lebanon and Turkey, then the conservation of the habitat will effectively safeguard it and it will logically be included in the area's management plan. For species that are threatened or endangered, the removal or containment of the factors causing the threat means that some form of intervention is necessary so that a hands-off approach is not appropriate. But even if the wild populations of target CWR taxa selected for* in situ *conservation need little management, the processes involved in the assessment of their distribution, ecology, demography, reproductive biology and genetic variation, and in the selection of number and size of populations and sites to be conserved, are still onerous.*

Source: Heywood, 2008

reserves, genetic reserves or *ex situ*. They consider, however, 'that the genetic resources of the majority of species used by humans can be regarded as reasonably safe in at least a proportion of their natural habitats, although in some instances there is a need for protection, in others for continuing watchfulness'. Such an optimistic perspective can no longer be justified today for the reasons mentioned above. Many CWR are already threatened to some degree and the numbers are almost certain to increase considerably under conditions of global change, notably accelerated climate change. Monitoring of the status of CWR ('continuing watchfulness') will need to be undertaken on a much more extensive and substantial scale than has been customary hitherto. If the target species is threatened, the absence of any management intervention to counter the threats (i.e. passive conservation) will compromise its longer-term survival. Consequently, for such species, habitat protection will need to be supplemented by action at the species/population level.

Moreover, it should be noted that the ways in which protected areas and their component ecosystems are managed varies widely and may not favour the maintenance of populations of the target species. For example, if management is focused on processes or on ecosystem health, it would appear that losses of species would be permitted so long as they did not greatly affect processes like nutrient-cycling.

Genetic conservation/genetic reserve conservation

As noted above, the term '**genetic conservation**' (Frankel, 1974)[4] is often used for the conservation of CWR,[5] and a commonly used approach is known as 'genetic reserve conservation'. It may be defined as '*the location, management and monitoring of genetic diversity in natural wild populations within defined areas designated for long-term conservation*' (Maxted et al, 1997). The focus is on the conservation and utilization of genetic diversity. A *genetic reserve* is essentially a protected area managed in such a way as to maintain suitable ecological conditions for the conservation needs of one or more target species. The goal is to make available as much of the gene pool of the target species as possible for actual or potential use, with a specific focus on conserving genetic traits of potential use in plant breeding, rather than on maintaining as wide a range as possible of the biodiversity of the target species/populations.

Traditionally, in the sampling and conservation of plant genetic resources, the focus has been on maximizing the conservation of genes and alleles of potential value in plant breeding. As Maxted et al (1997) and Iriondo and De Hond (2008) state, the purpose of CWR conservation is to maintain the potential of existing genetic diversity in CWR populations for crop breeding to obtain cultivars that better suit the needs of humankind at each moment. In conservation biology and species recovery programmes, the emphasis has been on the maintenance of the genetic diversity of the population(s) so as to ensure its survival and continued evolution. In light of global change, there are many uncertainties as to what parts of the genetic variation of a species will be of potential value, and this distinction is probably no longer valid. Nonetheless, in the case of both CWR and threatened species, the following actions apply:

- minimize the risk of extinction from demographic fluctuation, environmental variation and catastrophes;
- maintain genetic diversity and potential for evolutionary adaptation;
- minimize human threats to target populations;
- support actions that promote a positive balance between births and deaths in target populations.

Additional actions that apply to CWR (Iriondo and De Hond, 2008) are:

- support actions that promote genetic diversity in target populations;
- ensure access to populations for research and plant breeding;
- ensure availability of material of target populations that are exploited and/or cultivated by local people.

Genetic reserve conservation, as practised so far,[6] has tended to focus more on groups of species occurring together in selected areas rather than on single target species, largely on the grounds of cost-effectiveness, given that the number of target species is likely to exceed available resources for a species-by-species approach. This parallels the multi-species approach recently adopted for recovery programmes by Australia, Canada, the United States and some European Union countries (through the Habitats Directive), although previously the single-species approach has been the norm. The scientific rationale behind the use of

Box 3.8 Examples of genetic reserves and gene management zones

Costa Rica – Corcovado National Park; genetic reserve for avocado (*Persea americana*), nance (*Byrsonima crassifolia*) and sonzapote (*Licania platypus*).

India – National Citrus Gene Sanctuary, Nokrek Biosphere Reserve, Garo, Meghalayas; known for preserving a rich diversity in indigenous citrus varieties including Indian wild oranges (*Citrus indica*, *C. macroptera*).

Palestine – Wadi Sair Genetic Reserve, Hebron; for legumes, fruit trees.

Syria – Sale-Rsheida Reserve; for *Triticum dicoccoides*, *Hordeum* spp.

Turkey – Ceylanpinar State Farm; includes seven genetic reserves for wild wheat relatives *Aegilops* spp., *Triticum* spp.

Kasdagi National Park; includes ten genetic reserves for wild plum (*Prunus divaricata*), chestnut (*Castanea sativa*), *Pinus brutia*, *P. nigra* and *Abies equi-trojani*.

Bolkar Mountains; includes five genetic reserves for *Pinus brutia*, *Pinus nigra* subsp. *pallasiana*, *Cedrus libani*, *Abies equi-trojani*, *Juniperus excelsa* and *Castanea sativa*.

Vietnam – Gene Management Zone in Huu Lien Nature Reserve, Lang Son Province; for *Colocasia* (Taro), litchi, longan, rice, *Citrus* spp. and rice bean.

Uzbekistan – Nurata State Reserve for walnut (*Juglans regia*) stands.

multi-species plans is mainly the assumption that the target species share the same or similar threats. On the other hand, the effectiveness of multi-species recovery conservation programmes for CWR has yet to be sufficiently assessed, but there is evidence from surveys of multi-species plans for wild species undertaken in Australia, Canada and the United States, that insufficient attention/detail is given to individual species within multi-species plans and that to be effective, as much effort would need to be placed on each species as in a series of single-species plans. One report found that nearly half of the multi-species plans failed to display threat similarity greater than that for randomly selected groups of species and concluded that, as currently practised, multi-species recovery plans are less effective management tools than single-species plans (Clark and Harvey, 2002). Another report (Sheppard et al, 2005) concluded that the effectiveness of multi-species recovery planning has yet to be sufficiently assessed and that the primary criticism is the lack of adequate attention to detail being paid to individual species within multi-species plans. In the case of CWR, the limited experience of multi-species genetic reserves means that their longer-term effectiveness has yet to be demonstrated and they should therefore be employed with caution.[7]

Genetic reserves, also referred to as gene management zones (Tan and Tan, 2002) or gene sanctuaries, are usually located in existing protected areas or may be established *de novo* on state-owned or privately owned land that is not currently protected. For examples see Box 3.8.

Special requirements for forestry species

Forests are estimated to cover over a quarter of the land surface of the globe (Kanowski, 2001); however, even though timber trees play a major role in the world economy, in practice, only a limited number are used commercially on an extensive scale. The situation may be summarized as follows (Heywood and Dulloo, 2005):

- Commercial timber is increasingly obtained from intensively managed plantations of a small number of species.
- A relatively small forest area is devoted to enterprises such as agroforestry and urban forestry, which play a small role commercially in global terms but are important nationally in poverty alleviation, in the provision of fuelwood, fruit trees, medicinal plants and other useful products.
- The vast bulk of forest is wild, natural or semi-natural, and not managed.

The conservation of forest genetic resources is often considered a special case and has tended to follow a different and wider set of approaches than those used for CWR and other exploited wild species (Hattemer, 1997). It includes not only the setting aside of areas of natural forest habitat as reserves, but also the regeneration or rehabilitation of forests that have been affected by logging or depleted through other causes, both stochastic and human-induced (see Box 3.9). However, as highlighted by Thomson et al (2001), 'artificial regeneration and establishment of plantations can expose trees to conditions that are very different from those under which they develop in natural forest'. The conservation of forest genetic resources has been described as being at the interface between the conservation of the genetic resources of cultivated species and the conservation of sites (Lefèvre et al, 2001).

The different approaches to forest genetic resource conservation reflect both the nature and special characteristics of trees and their economic role. For example, trees often contain greater genetic diversity than other species (Müller-Starck, 1995; 1997); there may be poor differentiation between and within populations with respect to nuclear markers; there is generally high differentiation among populations for adaptive traits; and the individuals often have long lifespans. It should also be noted that the tree crop and the wild relative are often

Box 3.9 *In situ* conservation of forestry species

In situ *conservation means the conservation of the genetic resources of a target species 'on site', within the natural or original ecosystem in which they occur, or the site formerly occupied by that ecosystem. Although frequently applied to populations regenerated naturally,* in situ *conservation may include artificial regeneration whenever planting or sowing is done without conscious selection and in the same area where the seed or other reproductive materials were randomly collected.*

Source: Palmberg-Lerche, 1993

the same species. In other words, many of the cultivated forms of tree species are usually particular provenances or ecotypes that have been selected from within the natural stands of the species.[8]

There is a need, of course, to distinguish between the conservation of forests as such and their wide range of economic, social, productive and protective values and the genetic management of targeted forestry species. The prospects for *in situ* conservation of forestry species has been reviewed by Namkoong (1986) who concludes that even for the relatively small number of forestry species that have a currently recognized commercial value, the amount of genetic management is limited and 'only very meagre funding is available for any but the most important commercial species in industrialized forestry'. Given that the vast majority of forest plant species have little known or potential commercial value or function that is not served by other species, he believes it is simply not feasible or desirable to consider conserving these on a species-by-species basis; in practice, the management objective most often followed is likely to be that of ensuring the continued existence of a sample of these populations or species in protected areas such as reserves or parks. Even this may be difficult to achieve in view of the lack of information available on the precise distribution and ecology of the species concerned, not to mention their demography, reproductive biology and other key attributes. Based on this view, it follows that the widespread *in situ* conservation of target species is not seen to be practicable, and therefore unlikely to be attempted, by forest authorities.

Despite the somewhat pessimistic assessment by Namkoong cited above, if we adopt a wider conservation perspective (Kanowski, 2001), many tree species play an important part in local economies, either for their wood or for a variety of non-timber forest products (NTFPs) (Ruiz Pérez and Arnold, 1996; Emery and McLain, 2001), although their potential is not always realized. To what extent these lesser-used species should be the subject of targeted *in situ* conservation action is a matter that has to be decided at national or local level.

Protected areas and forest conservation

Setting aside specific areas of forest to protect the features for which they are valued, including particular species, is an ancient and widespread practice. Many forestry species are found in various kinds of protected areas which serve, to some extent, as genetic reserves for these species, even though they are seldom sufficient or adequate for this purpose. It is widely agreed that conservation of forest species requires not only a series of protected areas or genetic reserves, but a comprehensive multi-scale approach that includes both reserves and non-reserve areas, as well as management of the wider matrix in which forestry species occur, from the landscape to the individual stand (Lindenmayer and Franklin, 2002).

Kanowski (2001) summarizes the advantages and limitations of protected areas for effective forest conservation:

> *It is clear that existing protected areas make important contributions to forest conservation, that they do protect many forest values, and that they represent very considerable effort and achievement on the part of all concerned in their establishment and management. It is also clear, however, that existing protected areas are not, in themselves, sufficient to achieve or sustain forest conservation goals. Many are in the wrong place, of inadequate size or inappropriate configuration, too disconnected from their surrounding environment, and inadequately protected from pressures that impact adversely on their conservation values. They seldom comprise more than 10% of any forest ecosystem, seldom protect forests on tenures other than public lands, and are often culturally inappropriate. They are subject to a range of social and economic pressures which may not be compatible with the protection of their conservation values, and which many cannot sustain.*

A considerable number of commercially important forest tree species have been the subject of *in situ* conservation/management action (FAO/DFSC/IPGRI 2001; FAO/FLD/IPGRI, 2004). In fact, some of the most detailed *in situ* genetic conservation studies have been made on forestry species such as the Monterey pine (*Pinus radiata* D. Don) and have been published by the University of California Genetic Resources Conservation Program (Rogers, 2002). In addition to a detailed account of the biology and genetics of this species, the publication contains a series of principles and recommendations for species' *in situ* conservation. The European Forest Genetic Resources Programme (EUFORGEN) network (see http://www.euforgen.org) also deals with a range of species for which management guidelines have been produced. For further information on such guidelines see Heywood and Dulloo (2005, Annex 3).

The term gene conservation forest is sometimes applied to forested areas reserved with the objective to protect the genetic resources of local tree species. An example is the Khong Chiam *In Situ* Gene Conservation Forest (GCF) in the Ubon Ratchathani Province of northeast Thailand. The GCF was set aside specifically to conserve the lowland form of *Pinus merkusii*, one of only six known lowland populations in Thailand, all of which are highly threatened (Granhof, 1998).

Economic and social considerations

Although strong arguments can be made for the conservation of CWR (see Chapter 1), these are often not obvious to either the general public or to local stakeholders. Setting aside large areas of land for the conservation of species whose economic potential is uncertain or cannot be easily perceived is difficult to justify and can be a serious constraint when selecting target species. This is discussed by Rubenstein et al (2005) who note that, 'because the full economic values of wild relatives can rarely be captured by landowners, the use of land to preserve habitats for wild relatives remains undervalued compared with alternative uses such as clearing for agricultural or urban use'. In most cases, the involvement and acquiescence of local inhabitants, farmers, officials and other interested parties is crucial for the successful implementation of *in situ* conservation projects (Damania, 1996); examples of participatory approaches to conservation of CWR are given in Chapter 5.

Further sources of information

Frankel, O.H., Brown, A.H.D. and Burdon, J.J. (1995) *The Conservation of Plant Biodiversity*, Cambridge University Press, Cambridge (see Chapter 6).

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, International Plant Genetic Resources Institute (IPGRI), Rome, Italy

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Notes

1. Jarvis and Hodgkin, 1998; Jarvis et al, 2000.
2. In *Progress Report No. 4: Toward a Strategy and Results Framework for the CGIAR* (CGIAR, 2009), which identifies as one of the proposed mega-programmes – Crop Germplasm Conservation, Enhancement, and Use.
3. http://uk.chm-cbd.net/Default.aspx?page=7707

4. The term genetic conservation was apparently introduced by Erna Bennett (Fowler and Mooney, 1990).
5. It also covers the conservation of traditional crop varieties (on-farm) as well as wild species (Frankel, 1974).
6. Most genetic reserve conservation has been undertaken in Turkey and other countries in the Middle East/SW Asia. For example, see Al-Atawneh et al (2008), Tan and Tan (2002).
7. For a detailed summary of strengths and weaknesses of multi-species and ecosystem-based approaches see Table 1 in Sheppard et al (2005) and Table 3.14 in Moore and Wooller (2004).
8. The same is also true of many medicinal, aromatic and ornamental species.

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