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of wild plant species
a critical global review of good practices

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Introduction to the Series

The Technical Bulletin series is targeted at scientists and technicians managing genetic resources collections. Each title will aim to provide guidance on choices while implementing conservation techniques and procedures and in the experimentation required to adapt these to local operating conditions and target species. Techniques are discussed and, where relevant, options presented and suggestions made for experiments. The Technical Bulletins are authored by scientists working in the genetic resources area. IPGRI welcomes suggestions of topics for future volumes. In addition, IPGRI would encourage, and is prepared to support, the exchange of research findings obtained at the various genebanks and laboratories.

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Foreword

Jan Engels (IPGRI) and Douglas Williamson (FAO)

Plants are of fundamental importance to life on earth. They form the backbone of Earth's ecosystems and provide a wide range of ecosystem goods and services. The benefits they provide include food, medicines, genetic material for crop improvement, clothing and shelter, and they have great economic and cultural value. They thus make an important contribution to human well-being.

Over the last hundred years the trends observed in the loss of plant biodiversity have been a matter of great concern. Despite all the efforts made to conserve plant diversity, the situation today is still very alarming. Up to one-quarter of the estimated 400 000 species of plants are believed to be threatened worldwide.

The Convention on Biological Diversity (CBD), which came into force in December 1993, has been the major global instrument to rally world-wide efforts for the effective conservation of biological diversity. It calls for mechanisms to be put in place for both *in situ* and *ex situ* conservation (see Articles 8 and 9).

A **Global Strategy for Plant Conservation (GSPC)** has subsequently been developed and was adopted at the Sixth Meeting of the Conference of Parties to the CBD held in The Hague in April 2002 (Decision VI/9). This strategy provides an innovative framework of 16 outcome-oriented targets aimed at achieving a series of measurable targets by 2010, of which targets 7, 8 and 9 relate to *in situ* and *ex situ* conservation of target species. Target 7 of the GSPC calls for "60% of the world's threatened species to be conserved *in situ*". This is taken to mean that populations of the species are effectively conserved in protected areas or through other *in situ* management measures. To be able to achieve this target of the GSPC, a major effort will be required to augment existing tools and methodologies for the effective conservation of plant biodiversity. The different approaches to *in situ* conservation that have been developed to date have been widely applied to a range of situations, but seldom to target species of wild plants.

For many plant species of value to agriculture, including crop wild relatives, efforts to conserve threatened germplasm have led to a massive *ex situ* collection of over 6 million accessions conserved in over 1500 genebanks world-wide. *In situ* conservation efforts world-wide have mostly focused on establishing protected areas and taken an ecosystem-oriented rather than a species-oriented approach. Protected areas are seldom established for individual species, unless they are highly charismatic.

Existing protected areas are often poorly managed and some have no management at all, as was revealed at the Fifth World Park Congress held in Durban, South Africa, in 2003. Effectiveness of protected area management depends on adequate human and financial resources, which in many places are not available. In addition to making up for existing inadequacies, protected area managers will have to face new threats such as invasive species, habitat degradation and destruction, as climate change and other global changes become apparent.

In the past, priority has been given to the conservation of crop landraces 'on-farm', which the CBD defines as a form of *in situ* conservation in the place where the domesticated or cultivated species have developed their distinctive properties. There is an urgent need to also pay attention to the many economically important wild species that are neither on-farm nor in protected areas. The populations of many of these wild species are under heavy pressure due to over-exploitation, habitat degradation and invasive species. Their effective *in situ* conservation will be difficult to accomplish and therefore presents a huge challenge to conservationists.

This review volume makes a valuable contribution to the understanding of *in situ* conservation of target species of different types, including medicinal and aromatic plants, crop wild relatives, fruit trees and shrubs, ornamental and other valuable species. It provides readers with an in-depth discussion of the different methodological options for *in situ* conservation and presents a number of case studies to illustrate some examples of good practice.

Preface

V.H. Heywood and M.E. Dulloo

The aim of this book is to provide readers with a broad understanding of the concept and methodologies of *in situ* conservation for target plant species. The book is based upon a global survey, undertaken by the first author, of existing guidelines, methodologies, case studies and other relevant literature on the *in situ* conservation of plant species, as well as current activities in this area by national and international agencies. This global review was undertaken as part of a UNEP/GEF project (EP/INT/204/GEF) entitled 'Design, Testing and Evaluation of Best Practices for *In Situ* Conservation of Economically Important Wild Species', for which FAO was the executing agency. In preparing the review for publication as a book, we have taken the opportunity to revise the text and add further examples in order to make it suitable for the general reader interested in the subject of *in situ* conservation of species. We have tried to include examples from as many countries as possible, although much of the work in this area has up until now been undertaken in temperate regions. We have also provided an extensive bibliography which will allow the reader to explore many of the topics covered in the text in more depth.

This book is divided into four parts. **Part I** deals with the concept, approach and actors of species-based *in situ* conservation and attempts to clarify the ambiguity of the concept of *in situ* conservation as it relates to target species. In the minds of many people, *in situ* conservation is taken to mean the creation of protected areas and implies a narrow ecosystem approach, with the inclusion of local communities and conservation of species being incidental. This concept is now rapidly changing, as more focus is placed on individual target species and the needs and well-being of local communities and people are beginning to receive more consideration. It is also clear that *in situ* conservation cannot be the sole mode of conservation: it will not be possible to turn the location of every population of wild plants into a protected area, due to cost considerations or other land-use reasons. *In situ* conservation will need to be complemented by *ex situ* conservation where appropriate and, in particular, some sites will need to be managed with local stakeholders in a participative manner. Global changes in population growth, land-use patterns and climate change will also affect the ways in which *in situ* sites are designed and managed (see Section 1.5). This part also discusses the most important international instruments which govern the conservation of wild plant species, notably the Convention on Biological Diversity and the Global Plan

of Action, as well as other regional initiatives, and the role of major UN and international agencies dealing with wild species.

Part II of the book focuses on *in situ* conservation methodologies and describes the various approaches of *in situ* conservation and the main steps needed for developing a conservation strategy for target species *in situ*. A number of initial steps are required before *in situ* conservation sites can be effectively planned and established. These include setting priorities for target species, establishing an information baseline through the carrying out of ecogeographical surveys, and estimating the amount and pattern of genetic diversity. Once this information becomes available, it is possible to prioritize conservation areas for protection and/or management. This part also describes the different types and the role of protected areas in species conservation, and discusses the conservation of species outside protected areas. Of even more importance is the management and monitoring of *in situ* conservation and populations: this aspect is one of the most neglected in protected areas management, as many protected areas do not have management plans or are not adequately managed, especially for target species. These issues need to be given more prominence by policy-makers.

The global survey of *in situ* conservation activities is described in **Part III**. Examples of *in situ* conservation of various types of taxa, such as threatened species, medicinal and aromatic species, forestry species, crop wild relatives, fruit trees and shrubs, and ornamental and other miscellaneous groups across the world are provided as illustrations of their effective conservation *in situ*. Detailed information about specific case studies is provided in boxes throughout the text. Finally, **Part IV** offers some conclusions and recommendations.

It is hoped that this book will provide managers of protected areas, conservation officers and government officials, as well as all stakeholders involved in *in situ* conservation, with valuable information and an in-depth understanding of *in situ* conservation methodologies. It should also be a valuable guide for students of ecology and others engaged in the study of plant genetic resources.

Acknowledgements

Part I: Concept, approach and actors of species-based *in situ* conservation

> *The potential conservation utility of these* [in situ] *programs has not been realized and may not be for many years* (National Research Council 1991).

> *The main problem in achieving* [in situ] *conservation goals is, at present, the lack of institutional and political frameworks under which adequate land use and operational management choices, fair to all stakeholders, can be considered and efficiently implemented in the short as well as in the long term* (FAO 2002a).

1.0 Introduction

It is clear from reviewing the literature on biodiversity, conservation biology and genetic conservation that the concept of *in situ* conservation targeted at species, as opposed to the ecosystems in which they occur, is ambiguous and has been subject to a wide range of interpretations by different interest groups. Also noteworthy is the widespread interpretation of the term '*in situ* conservation' itself as meaning the creation of protected areas or habitats, as opposed to *ex situ* conservation. The latter has been largely equated with the preservation of samples of species in seed banks or botanic gardens (and zoos). Even Frankel and colleagues in their excellent book, *The Conservation of Plant Biodiversity* (Frankel et al. 1995) remark that programmes for *in situ* conservation at the level of an individual species seem to be a contradiction in terms, as "Strictly speaking, *in situ* conservation is conservation of the whole ecosystem", i.e. of the community in its natural location without focus on any particular species. Likewise, in a review by the US National Research Council (1991) of the management of genetic resources of forest trees, in the section on *in situ* conservation, it is stated that:

> Although much of the literature is couched in terms of conserving particular populations, *in situ* conservation in reality involves preserving whole communities. The number of populations and species that require some protective measure in the wild is so large that it is impractical to design *in situ* conservation programs on the basis of individual species and their populations.

The ambiguities concerning *in situ* conservation of species reflect the long-standing dichotomy in ecological and conservation thinking between ecosystem- and species-based approaches. There has been a tendency to dichotomize nature into species and ecosystems (Soulé and Mills 1992). This reflects the traditional dichotomy between ecosystem and population/species ecology; subjects which for almost three decades have ploughed their own independent furrows and developed their own paradigms, approaches and questions, as Lawton and Jones (1993) famously commented. It also reflects the tensions that are often observed in the conservation community between those who address their efforts to species as opposed to those who feel that the ecosystem is the proper focus of one's attention. These should not, however, be seen as alternatives, as we discuss below (see Section 1.1).

The definition of *in situ* conservation given by the Convention on Biological Diversity (CBD 1992) is, however, quite clear and comprehensive, covering both ecosystems and species:

> … the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

Despite this, nearly all the Convention's activities regarding *in situ* conservation have been focused on ecosystems and habitats. With the exception of the preparation of recovery plans for some highly endangered species by a number of countries, there has been little subsequent follow-up by CBD through the Conference of the Parties, its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) or other groups as regards species conservation *in situ*. Woodruff (1989) wrote some 15 years ago that "present commitments to species conservation are clearly inadequate", and with the increasing threats to species and their habitats in the intervening years, the situation has become even more urgent.

Again, in the fields of crop genetic resources and agricultural biodiversity, little attention has been paid to species conservation *in situ*, although there has been a revival of interest in the past decade in conservation of landraces 'on-farm'. Yet the principles of *in situ* conservation of genetic resources have been well established for some years (see e.g. Ingram 1984; Wilcox 1984; FAO 1989). On the other hand, forestry in Europe and North America, for example, has long been based on empirical approaches to management of natural resources, including target species, and a theoretical basis for this has been recognized in recent years. It is noteworthy that Aldo Leopold's

essay 'The conservation ethic' was published in the Journal of Forestry (Leopold 1933) and in his *A Sand County Almanac* (Leopold 1949), which has been called 'the bible of the environmental movement', he wrote:

> Some species of trees have been 'read out of the party' by economics-minded foresters because they grow too slowly, or have too low a sale value to pay as timber crops: while cedar, tamarack, cypress, beech, and hemlock are examples. In Europe, where forestry is ecologically more advanced, the non-commercial tree species are recognized as members of the native forest community, to be preserved as such, within reason. Moreover some (like beech) have been found to have a valuable function in building up soil fertility. The interdependence of the forest and its constituent tree species, ground flora, and fauna is taken for granted.

The view has been expressed (Hawkes 1991; see also Maxted et al. 1997a) that *in situ* genetic conservation techniques are still in their infancy and that we are not methodologically well equipped to proceed with the genetic conservation of plant diversity in its natural surroundings. While this is to some extent true, we will show in this review that much information does exist which could be applied, and it is widespread ignorance of what has been achieved for different groups of plants that is largely responsible for our present poor record of species-based *in situ* conservation.

In situ conservation of individual target species, whether of economic importance or not, of necessity involves various levels of biodiversity, from genes and alleles to populations, ecotypes, species, and ecosystems, landscapes and ecoregions. It requires a broad perspective and cooperation between specialists of many different disciplines and between many different agencies. It is also largely dependent on the close and active cooperation and participation of local stakeholders.

1.1 The concept of *in situ* conservation

To make matters clear, the range of different situations covered by the notion of *in situ* conservation is as follows:

1. **Conservation of natural or semi-natural ecosystems in various types of protected area**, with various management aims such as: maintaining ecosystem diversity, biodiversity in general or special landscapes; and providing habitat for target species such as megavertebrates, birds, forest species, medicinal plants, or for concentrations of endemic species. Today this type of

conservation is often interpreted as meaning conservation of the area and, non-specifically, the biodiversity contained therein.

2. **Conservation of agricultural biodiversity**, which may be defined as "the maintenance of the diversity present in and among populations of the many species used directly in agriculture, or used as sources of genes, in habitats where such diversity arose and continues to grow" (Brown 1999). This includes:

    • Entire agroecosystems, including immediately useful species (such as food crops, forages, and agro-forestry species), as well as their wild and weedy relatives that may be growing in nearby areas—see item 3 below.

    • Maintenance of domesticates such as landraces or local crop varieties in farmers' fields, often referred to as 'on-farm' conservation (Maxted et al. 2002), '*in agro*' or '*inter situ*' (Blixt 1994).[1]

3. **Conservation and maintenance of selected/target individual species** in their natural habitats/ecosystems through conservation or management plans. This differs from general conservation of biodiversity in that particular (target) species are the subject of conservation attention or action. In the case of species of economic importance, the terms 'genetic conservation', 'gene conservation' or 'genetic reserve conservation' are commonly used (Yanchuk 1997). The areas where such conservation takes place are also known as gene or genetic reserve management units, gene management zones, gene/genetic sanctuaries, and crop reservations. This type of conservation may be defined as "the location, management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long-term conservation" (Maxted et al. 1997b). Detailed protocols for genetic conservation have been prepared.

4. **Recovery programmes for nationally or subnationally threatened, rare or endangered wild species** (whether of economic importance or not). Species recovery programmes are a special case of *in situ* conservation of target species. They may often require recovery of their habitats.

5. **Restoration, recovery or rehabilitation of habitats**. With the widespread ecological destruction now occurring around the world, habitat restoration has attracted growing attention and often environmental legislation requires habitat rehabilitation or restoration of areas affected by activities such as mining to be undertaken to mitigate the damage caused.[2] Likewise, species recovery programmes may require not only management and reinforcement of populations but also rehabilitation or restoration of the habitats in which the often fragmented populations occur.

In situ conservation therefore covers not only species and ecosystems but also genetic variability. Unless we recognize the diversity of approaches involved in *in situ* conservation, we risk overlooking or obscuring some of the key issues involved. In practice, however, conservation of wild species or populations *in situ* is widely interpreted as meaning their presence within a protected area or habitat, i.e. with the focus primarily on the ecosystem. However, this may also involve the preparation and implementation of rescue, recovery or management plans for target species that are seriously endangered at the local, national or global level, to prevent their becoming extinct in the wild.

Although this review is focused on *in situ* conservation of species and intra-specific genetic diversity, in practice, this depends on identifying the habitats in which they occur and then protecting both the habitat and the species through various kinds of management and/or monitoring. Thus, although *in situ* species conservation is essentially a species-driven process, it also necessarily involves habitat protection.

In fact there is a case to be made for treating species conservation holistically, following the now widely accepted complementary or integrated approach (now a tenet of the CBD through the so-called 'ecosystem approach') and not considering *in situ*, *inter situs* and *ex situ* approaches separately as discussed in Section 1.4.

1.2 Aims and purpose of *in situ* conservation of target species

This review is largely concerned with those plant species that have been selected (targeted) for particular conservation attention or action and which are commonly known as target species (also known as 'candidate species' or 'priority species').

Most of the detailed literature that has been published on *in situ* conservation of species refers to nationally rare or endangered native species, irrespective of their actual or potential use, and extensive experience of conserving such species has been acquired in many countries. This target group is defined solely by being threatened or endangered, although such a designation involves a complex series of selection procedures, as discussed in Section 3.2. This group of species constitutes by far the largest number of those for which *in situ* conservation projects or recovery plans have been planned or implemented.

On the other hand, most of the work on conserving species of economic interest refers to three groups of target species: crop wild relatives, forestry tree species, and medicinal and aromatic plants.

Many factors can be taken into account in deciding on which of these species to select as targets.

The amount and type of phenotypic, and genetic variation and the number of populations selected for *in situ* conservation will depend on the nature of the species and the objectives of gene conservation in any particular case. It is widely accepted that it is desirable to conserve as wide a range of genetic and other variation as possible so as to ensure the maintenance and functioning of viable populations of the species concerned, even in a changed environment (i.e. genetic adaptability, see Box 1). However this will be effective only if the changes in environmental conditions are gradual enough to allow adaptations to occur through evolutionary processes such as mutations, natural selection, or genetic drift.

Box 1: Purpose and goal of *in situ* conservation of target species

The main general aim and long-term goal of *in situ* conservation of target species is to protect, manage and monitor the 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 that will allow the species to adapt to gradual changes in environmental conditions such as global warming, changed rainfall patterns, or acid rain.

On the other hand, many of the species that may be targeted for *in situ* conservation because of their economic use are subject to exploitation. 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 itself for the benefit of the various stakeholders (Freese 1997) and this will affect the management objectives. As a recent review of sustainable use and incentive-driven conservation points out (Hutton and Leader-Williams 2003), these management objectives could be the conservation of the species (or its populations), the ecosystem in which they occur, or the livelihoods that depend on the exploitation. The complexities involved in devising management systems for exploited species can be illustrated by a recent study of the palm açaí (*Euterpe oleracea* Mart.) harvested commercially for its palm hearts in the Amazon basin largely from natural stands (Clay 1997). Natural stands may be managed sustainably so as to maintain a steady supply of palm hearts, or to allow the fruit to be harvested as well as palm heart extraction, but these different approaches have cost implications for the processes of extraction, processing and distribution which may not be acceptable. Different management practices will also affect biodiversity adversely to different degrees.

In situ conservation requires a focus on the biodiversity, dynamics and conservation of all components of the ecosystem. A recent review (Damania 1994) warns that

> As long as genetic conservation and crop improvement are directly linked, any form of conservation will be judged by its short-term benefits to breeders, and *in situ* methods will attract considerable opposition. ***However, on-site conservation is more plausible if these two goals are decoupled***, making biodiversity conservation an end in its own right [emphasis added].

On the other hand, the same author reminds us that to fulfil their objectives, *in situ* conservation projects should be politically viable and share broad national development goals such as generating increased farm income. The involvement and acquiescence of local inhabitants, farmers, officials and other interested parties is crucial for the successful implementation of *in situ* conservation projects in most cases (Damania 1996). 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.

Some specific aims of *in situ* species conservation that have been identified include:

- Ensuring continued 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 (Rogers 2002).
- Ensuring continuing access to or availability of material of target species populations that are exploited 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 which 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, for instance those dependent on specific pollinators, which in turn depend on other ecosystem components (FAO 1989).

• Enabling some degree of conservation of associated species
which may or may not be of known economic value and which
may be of importance in maintaining the healthy functioning
of the ecosystem. This may provide additional justification for
single-species conservation programmes.

1.3 Species-based or ecosystem-based approach to *in situ* conservation?

A focus on species conservation is readily comprehensible, since
most people find it easy to empathize with biodiversity inherent
in species, especially if they are charismatic or flagship species.
Moreover, such a focus may well serve the interests both of
conservation and of those who exploit species (Hutton and Leader-
Williams 2003). The question that has to be addressed is whether
a species-based approach to *in situ* conservation is feasible or even
desirable. It is often stated that such an approach to conservation is
not possible because of the sheer numbers of entities involved and
the continuing rise in the numbers of threatened species (see Ricklefs
et al. 1984), whereas a habitat/ecosystem-based approach allows a
large number of species to be given some form of protection at the
same time. There is, moreover, an increasing tendency today to shift
the focus away from species and to view biodiversity conservation
and sustainable use through the lens of the ecosystem, with an
emphasis on maintaining the healthy functioning of the system.

There is a great deal of justification for such a position, given
that it is clearly unrealistic within the limited resources available to
envisage wholesale programmes of *in situ* conservation of all those
species for which a case could be made. However, this oversimplifies
the situation. In many cases there is no substitute for focusing effort
on species, as in the case of the large numbers of economically,
culturally or socially important plants where it is the particular
target species which are of direct concern. These include agricultural
and horticultural crops, medicinal and aromatic plants, locally
important wild food and fibre plants, non-woody timber products,
and so on (Heywood 1993). Current actions to conserve *in situ* a
substantial number of such target species of priority importance
are very limited and patchy and a much greater effort is needed if
a serious attempt is to be made to address these problems.

The number of plants used by humans is in fact very much
greater than is commonly realized (see Table 30.1 in Padulosi et al.
2002). Although it is true that only a few hundred plant species form
the basis of our agricultural crops, about 7000 species have at some
stage been cultivated and the total number of wild species that are

used by humans in local or traditional agricultural systems or that are collected from the wild for food, fibre, oil, etc. runs into tens of thousands (Heywood 1999a). Then we must add those that are grown or collected as ornamentals. The number of plant species that are used in traditional medicines is not known with any accuracy but has been variously estimated at from 20 000 to 80 000, depending on the definition of medicinal plant employed (Heywood 1999b). The conservation needs of these species presents a major but, hitherto largely unaddressed, challenge.

Then there are ecologically important species such as keystone, umbrella and focal species, whose presence is necessary in order to maintain the healthy functioning of the ecosystem and which may be used as surrogates for biodiversity conservation (see Andelman and Fagan (2000) for a critical review).

As regards forestry species, the issue of whether or not to include a wide range of these in *in situ* conservation has been addressed in a thoughtful review by Namkoong (1986; see also discussion in Section 3.4). The author notes that even for the relatively small number of forestry species which have a recognized current 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". As the vast majority of forest plant species have little known or potential commercial value or function that is not served by other species, it is simply not feasible or desirable to consider conserving these on a species-by-species basis and 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.

The above considerations reflect the current situation in forestry (P. Sigaud, FAO, personal communication) which may be summarized as follows:

- 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.

It follows, therefore, that *in situ* conservation of all but a small number of target species is not practicable or likely to be attempted by forest authorities.

The vast majority of species are either of marginal utilitarian value or have little or no commercial value. Any value that would be gained from their genetic management would be of such a generalized nature and of such long-term interest only, that the general public would be the primary beneficiaries. In the light of this, it has been suggested that for the vast majority of species of no direct use we would have to look to international agencies involved in nature conservation, such as IUCN, for investment in *in situ* conservation programmes (Namkoong 1986), although it would be unrealistic to expect any direct financial support from such quarters.

If we accept that targeted *in situ* conservation, with all the in-depth work that is required, is unlikely to be undertaken for very large numbers of species in the foreseeable future because of the financial and human resources costs involved, it is a matter of critical concern to establish just how effective habitat-based approaches are likely to be. The evidence is far from unequivocal as we shall see.

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. If the species is threatened as a consequence of habitat loss, as is increasingly common, then it is clearly essential to ensure that the remaining habitat is secured and, additionally, population reinforcement and other measures may be required.

It is clear, however, that for many wild species the best that we can hope for is not some targeted form of action but simply to ensure their presence in some form of protected area where, provided the area itself is not under threat, and subject to the dynamics of the system and the extent of human pressures, some degree of protection may be afforded. But the fact is that most species occur outside currently protected areas and we need to look carefully at ways in which the owners of such land might be persuaded to undertake some form of non-destructive management. As the following section explains, targeted *in situ* species conservation must be viewed as part of a holistic conservation strategy.

1.4 Putting species-based *in situ* conservation in the context of the ecosystem approach

It must be emphasized that *in situ* conservation of target species is only one aspect of a broader strategy that may be required for the

successful maintenance of a given species and its genetic variability. It is increasingly recognized that biodiversity conservation, whether of genes, species or ecosystems, should be viewed in the context of a mosaic of land-use options (Wilcox 1990, 1995), each of which will require its own range of management approaches. Thus the conservation of target species may be undertaken in nature reserves and other protected areas; in private and publicly owned natural forests and 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.

Various forms of *ex situ* conservation may also be needed to supplement the *in situ* action, 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 situ conservation thus covers a wide range of different activities and goals. The clear distinction between *in situ* and *ex situ* conservation traditionally recognized by conservationists (exemplified by protected areas and botanic gardens, respectively) breaks down when applied to crop and forest genetic resources where a range of situations occurs, reflecting the complete spectrum between wild and completely domesticated species (Heywood 1999). It has been suggested (Bretting and Duvick 1997) that it would be better to distinguish between the different approaches according to their specific objectives. Thus it has been proposed that the term 'static conservation' could be used to substitute for *ex situ* conservation and 'dynamic conservation' for *in situ* conservation.[3] Another dimension that can be used is the extent of deliberate intervention needed to achieve a specific conservation objective (T. Hodgkin, personal communication 2003; see also Lleras 1991).

Similarly, the distinction between species conservation *in situ* and ecosystem conservation is by no means clear-cut, as the two are interdependent. For example, the term '*circa situm*'[4] has been used to refer to a type of conservation that emphasizes the role of regenerating saplings in vegetation remnants in heavily modified or fragmented landscapes, such as those of traditional agroforestry and farming systems (Cooper et al. 1992; Barrance 1997, 1999). Thus in the south of Honduras, small farmers manage naturally regenerated trees of *Cordia alliodora*, *Gliciridia sepium* and *Leucaena salvadorensis* in their fields, pruning them as necessary to reduce competition with the local crops (Barrance 1997). Trees may also be transplanted from native habitats and managed within an *in situ* on-farm system using traditional sylvicultural techniques. The material is effectively managed within traditional farming systems

by local farmers. *Circa situm* has also been termed "conservation though use" (Stewart 2001).

In recent years, it has been increasingly recognized 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, population reinforcement) that are judged 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' (see Box 2) in which what is essentially a holistic approach is adopted.[5] Key distinguishing features of the ecosystem approach are as follows (Smith and Maltby 2003):

- 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.

Box 2: Ecosystem approach

The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use of these resources in an equitable way – UNEP/CBD.

The ultimate goal is to ensure that wildland diversity and ecosystems are maintained and will survive as biologically intact and functional as possible for generations to come. An ecosystem approach broadly evaluates how people's use of an ecosystem affects its functioning and productivity. Implementation of an ecosystem approach will require a new look at ways of integrating human activities with conservation goals. National Parks and Protected Areas will have to fit within an overall strategy of landscape management that includes compatible human activities. An ecosystem approach has the following characteristics:

- *It is an integrated approach*. It considers the entire range of possible goods and services and attempts to optimize the mix of benefits for a given ecosystem and also across ecosystems.
- *It reorients the boundaries* that have traditionally defined our management of ecosystems. It emphasizes a systemic approach, recognizing that ecosystems function as whole entities and need to be managed as such, not in pieces.
- *It takes the long view*. It respects ecosystem processes at the micro level, but sees them in the larger frame of landscapes and decades, working across a variety of scales and time dimensions.
- *It includes people*. It explicitly links human needs to the biological capacity of ecosystems to fulfil those needs. Although it is attentive to ecosystem processes and biological thresholds, it acknowledges an appropriate place for human modification of ecosystems.
- *It maintains the productive potential of ecosystems*. An ecosystem approach is not focused on production alone but views production of goods and services as the natural product of a healthy ecosystem, not as an end in itself.

Such an approach presupposes that we know what values and functions we wish to maintain in the systems concerned. This poses a challenge, since both ecosystems and their component species are dynamic and will change over time due to the processes of evolution, which is indeed the main *raison d'être* for their conservation.

Partly based on *World Resources 2000–2001: People and Ecosystems* (World Resources Institute 2000).

The ecosystem approach, although widely advocated, does have its critics (Hutton and Leader-Williams 2003), and there may be circumstances in which its adoption may not be fully compatible with particular conservation aims such as, specifically, the conservation and sustainable use of a target species. As they note,

> … the potential for future conflicts around sustainable use is alarming when, within an ecosystem approach it is quite possible to use a species sustainably within its biological limits, but for this to be deemed unsustainable in terms of ecosystem structure or function….

This concern is highlighted when it comes to considering what management approach to adopt.

The distinction between an ecosystem approach and *in situ* approaches to conservation according to Poulsen (2001) are:
- there may be more human interventions in *in situ* approaches than in ecosystem approaches to conservation
- ecosystem approaches are more process- or function-orientated than *in situ* approaches
- *in situ* conservation may be more species-specific and species-centred than ecosystem approaches
- *in situ* approaches are geographically more restricted than ecosystem-based approaches
- 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.

1.5 *In situ* species conservation and global change

One of the major factors affecting biodiversity conservation today is global change—demographic, land-use and climatic[6] (see Table 1)—yet the biodiversity movement and most conservation planners have so far largely failed to factor global change into their planning models and strategies (Hannah et al. 2002). Global change is causing a major transformation of the Earth's environment as a result of the numbers and growth of the human population (Steffen et al. 2004) and will have effects on both ecosystems and species and their populations and genes, and consequently on efforts to conserve these. Degradation, fragmentation, simplification and loss of terrestrial and aquatic habitats, caused by urbanization, industrialization and expanding agriculture will place many species at risk and even lead to the possible collapse of major systems such

as the Amazon forest (Schellnhuber 2002) or of 'ecosystems' such as mangrove swamps.

Table 1. Main components of global change

• Demographic change

    – Human population movement/migrations

    – Demographic growth

    – Changes in population pattern

• Changes in land use and disturbance regime

• Climate change (IPCC definition)

    – Atmospheric change (greenhouse gases)

    – Temperature change

Population growth will intensify the demand for more food, some of which will be met by increased agricultural efficiency, and some by converting further land for agriculture, with inevitable consequences for biodiversity.

The ways in which ecosystems respond to climate change will be complex and varied and will depend on the location and extent of changes in temperature and other climatic parameters. It is now widely accepted that global climate change poses a critical threat to ecosystems, species and biodiversity in general (IPCC 2002). Current patterns of habitat loss, fragmentation and loss of species diversity will be exacerbated by climate change and, as far as species are concerned, the rates of global warming will exceed the migration capacity of many of those affected. Global warming is expected to increase extinction rates significantly. The interplay between ecosystems and the species they contain under these changing circumstances will lead to novel situations and assemblages that will challenge ecologists and conservationists. Responses at the genetic and physiological levels within species, populations and individuals require detailed case studies and long-term monitoring. Increased fragmentation of populations within ecosystem fragments will lead to significant losses of genetic diversity within species and will add to the pressure for *in situ* genetic conservation of target species while they still retain their diversity. With the disruption of habitats, an increase in invasive and weedy species and others with high dispersal abilities is likely and this will impact on native species and natural ecosystems.

Not only is it likely that global change will lead to an increased need for *in situ* species conservation but it will also have an effect on the way this is undertaken. It will, for example, have major

impacts on conservation strategies and facilities such as protected areas, botanic gardens, field genebanks, clonal collections, and seed forests, and even the survival of some of these will be placed in jeopardy in some regions. If protected areas are put at risk, then any species conservation actions being undertaken in them may be adversely affected.

The design of protected area systems will require serious rethinking and more flexibility in size and scale so as to provide a connected network of patches of different habitat types at various scales to allow species to migrate and adjust their ranges in response to the various kinds of change. The planning of *in situ* species conservation under such circumstances may well be difficult, if not impossible, in practice. The effects of global change on agricultural biodiversity and on agricultural patterns will be significant, but in some regions it will be possible to mitigate the adverse effects by adaptation much more effectively than in the case of natural ecosystems.

Reviews of global warming and terrestrial biodiversity decline (Malcolm and Markham 2000) and of global warming and species loss in globally significant terrestrial ecosystems (Malcolm et al. 2002) have been published by WWF. The effects of environmental change on forests are considered in a recent IUFRO report (Sidle 2002) and a report on Forests and Climate Change has been prepared for WWF International (Dudley 1998), while the World Bank has issued a working paper on global change and biodiversity (dos Furtado et al. 1999). A critical review of the issues that should be taken into account when using ecological niche modelling to anticipate climate change effects on the geographical distributions of species is given by Martínez-Meyer (2005).

1.6 The costs of conservation

An area of conservation that has been neglected is that of the costs involved. Many conservation strategies go into considerable detail about the actions planned or proposed but seldom provide an analysis or estimate of the finances required. Not only are there the direct costs of undertaking various conservation actions such as setting aside land as a protected area, collecting and maintaining seed samples in a genebank or drawing up and implementing a species recovery plan, but also the indirect or passive costs which often fall disproportionately on local stakeholders who may have to forgo the benefits they would otherwise have derived from an area set aside for conservation (Balmford and Whitten 2003). As Nicholls (2004) comments,

> Traditionally, conservation interests have talked up the benefits they will bring to the global community—saving species, habitats, ecosystems, and ultimately the planet. But conservation also has its costs, and these are usually borne by local people prevented from exploiting the resources around them in other ways.

We are only now beginning to understand the economics of conservation and the various issues involved. One area where much more documentation is needed is in determining the costs of different conservation actions. Little has been published on this, but the limited data available suggest enormous variations between the costs of field conservation in different countries and/or regions. Some estimates take into account the costs of acquiring and maintaining the habitat or areas to be protected while others do not. The legislative costs alone can amount to very substantial sums. One of the few examples showing the costs of effectively managing a protected area system is a study by Blom (2004) of the Niger Delta–Congo Basin Forest region, where it is estimated that this would require the gazetting of an additional 76 000 km² and an investment of over US$1000 million (billion) for the total system plus US$87 million per year to maintain this system over an initial 10-year investment.

Looking at the annual costs of 139 field-based conservation projects from around the world, Balmford et al. (2003) found that they ranged across seven orders of magnitude—from less than one dollar to more than a million dollars per square kilometre. Apart from establishment costs and recurrent expenditures of management of protected areas, Blom (2004) discusses other additional costs for such things as inventories, surveys, investment costs, technical assistance, national institutional capacity, training, monitoring and evaluation, all of which must also be considered in implementing an effective protected area.

A typical European EU LIFE Nature species management programme[7] costs €50 000–150 000 over a period of 5 years and this is in line with some US Fish and Wildlife recovery plans which run at around US$30 000 a year over up to 10 years. On the other hand, the cost of a 5-year EU LIFE project (2001–2005) for the conservation of the relictual Sicilian fir (*Abies nebrodensis*) in its only known locality, the Riserva Integrale in the Parco delle Madonie in Sicily, amounts to €1 161 535.

The question of financing the Natura 2000 Network of protected areas in Europe has been reviewed by an expert working group (see Article 8 Working Group Final Report).[8] On the basis of data generated by a literature review which was compared to and

combined with the estimates generated from a Member State questionnaire, a broad-brush range of average figures for the cost of managing Natura 2000 in the EU was between €3.4 billion and €5.7 billion per year between now and 2013. There are many reasons to believe that these estimates are conservative.

It is not possible to extract *in situ* species conservation costs as such from these and other estimates, but what it does highlight is the wide range of activities that may be involved, in addition to the conservation management or restoration measures required by the species and habitats themselves (see Box 3). It is also clear that the costs of *in situ* species conservation are species- and location-specific, as has been found for *ex situ* conservation and genebank operations (Saxena et al. 2003; see also Koo et al. 2002, 2003, 2004).

Box 3: Activities that may be involved in establishing and maintaining a network of protected areas

- Preparation of information and publicity material
- Scientific studies to identify and designate sites – survey including inventory, mapping, condition assessment
- Administration of selection process
- Consultation, public meetings, liaison with landowners, complaints
- Pilot projects
- Pre-designation phase
- Preparation and review of management plans, strategies and schemes
- Establishment and running costs of management bodies
- Provision of staff (wardens, project officers), buildings and equipment
- Consultation – public meetings, liaison with landowners
- Costs for statutory and case work (EIAs, legal interpretation, etc.)
- Management planning and administration
- Conservation management measures – e.g. maintenance of habitat or status of species
- Management schemes and agreements with owners and managers of land or water
- Fire prevention and control
- Research monitoring and survey
- Provision of information and publicity material
- Training and education
- Visitor management
- 'Ongoing' management actions and incentives
- Restoration or improvement of habitat or status of species
- Compensation for rights foregone, loss of land value, etc.
- Land purchase, including consolidation
- Infrastructure for public access, interpretation works, observatories and kiosks, etc.
- Habitat type survey and GIS data

From *Natura 2000* (see http://europa.eu.int/comm/environment/nature/home.htm)

Of course, as in all considerations of the costs of conservation, the question 'What are the costs of taking no action?' has to be asked, although in most cases this is even more difficult to estimate.

1.7 The international mandate: treaties and conventions

The two main international agreements that confer a mandate for the *in situ* conservation of wild plant species are the Convention on Biological Diversity (CBD) and the FAO Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (GPA).

1.7.1 The Convention on Biological Diversity

The Convention on Biological Diversity (CBD) treats *in situ* conservation of species upfront in the Preamble:

> … the fundamental requirement for the conservation of biological diversity is the *in-situ* conservation of eco-systems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings

and Article 8 of the CBD, which refers to *in situ* conservation of species reads:

> [Each contracting Party shall, as far as possible and as appropriate:…] (d) Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings.

Yet curiously little attention appears to have been paid subsequently by SBSTTA or COP to the part referring to "maintenance of viable populations of species in natural surroundings". In addition, Article 9(c), on *ex situ* conservation, reads

> Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions

thereby introducing an element of confusion, since recovery plans are essentially *in situ* and do not necessarily include an *ex situ* component. Although there may have been political reasons for including this clause under *ex situ* conservation, it does little to clarify the ambiguities surrounding *in situ* species conservation.

The *Handbook of the CBD* (CBD Secretariat 2001), in its consideration of Article 8(d) by the Conference of the Parties, notes:

> Most consideration of this issue is implicitly included in
> the discussion of protected areas above [consideration of
> articles 8(a-c) by the COP]

but there is no mention specifically of species or populations there.
It is only recently that countries have been faced with a specific
call to take action in this area through the Global Strategy for Plant
Conservation (GSPC), as agreed by the Conference of the Parties
to the CBD (CBD/COP Decision VI/9 2003), which includes as
Target 7: "60 per cent of the world's threatened species conserved
in situ", to be achieved by 2010 (CBD 2002a). The rationale behind
this is given as:

> *Conserved in situ* is here understood to mean that popula-
> tions of the species are effectively maintained in at least
> one protected area or through other *in situ* management
> measures. In some countries this figure has already been
> met, but it would require additional efforts in many
> countries. The target should be seen as a step towards
> the effective *in situ* conservation of all threatened species
> (CBD 2002a).

It is clear from this and subsequent GSPC discussion documents
(CBD 2002b, 2002c, 2002d, 2003) that the target requires considerable
clarification. It also seems that perhaps too much emphasis has
been given to the role of protected areas in meeting the target and
not enough to the actual mechanisms and procedures of *in situ*
conservation of species populations. An exception is the review of
the scope, terminology, baseline information, technical and scientific
rationale of the draft targets (CBD 2002e) which recognized for
Target 7 that, amongst other requirements:

> *in situ* information on these threatened species is needed.
> Few protected areas can produce a reliable inventory of
> either all plant species within the area, or just the threat-
> ened ones, and even less often information on numbers,
> genetic variability, population trends, and threats posed
> to these species. A concerted effort on producing this
> information is needed if threatened species are to be
> conserved *in situ*. Key information includes number and
> size of populations, the spatial distribution of populations,
> identification of important associates such as pollinators
> and seed dispersers, critical habitat identification, and

trend information that can be related to environmental changes and patterns of disturbance.

Echoing the CBD, Target 7 also overlaps substantially with the second component of Target 8: "…10% of [threatened plants] included in recovery and restoration programmes", which necessarily deals with the population-related information mentioned above. As already noted, species recovery programmes involve essentially *in situ* conservation of threatened species. The Target 8 Stakeholder Consultation Report notes that

> Through the implementation of coordinated restoration and recovery programmes, Target 8 can make a significant contribution to the implementation of Target 7 (BGCI 2003)

although proposed actions for this target focus mostly on *ex situ* conservation (CBD 2003).

There is also an overlap with Target 3: "Development of models with protocols for plant conservation and sustainable use, based on research and practical experience", which is extraordinarily wide-ranging.

Apart from these considerations, the implementation of Target 7 hinges to a large extent on an interpretation of 'effectively maintained'. Also, 'occurrence' within a Protected Area is by no means the same as 'successful protection'. Moreover, effective conservation of a species would require surveys of its distribution and ecology and of the extent and pattern of genetic variation within the species and its populations to allow an informed decision to be made about the number of individuals and the number of populations to be included to achieve this. Then action would need to be taken to remove or contain the threats to the species populations—the effectiveness of the conservation measures adopted can be judged by whether the species is any longer threatened (and vice versa). It is, therefore, perhaps misleading to claim, as some have done, that the target is already met by the UK (and other countries in a similarly fortunate situation of having a restricted flora but ample human and financial resources). The first published UK response to the GSPC (JNCC 2004) in fact lists a series of ongoing actions, and high, medium and low priority additional work that is needed to meet the target.

Furthermore, as pointed out below, many protected areas, especially in developing countries, are not adequately managed or even secure. These issues are discussed further in Part III.

The reference to threatened species in the GSPC Target 7 should be noted. The relevant article in the Convention itself does not restrict itself in this way but such a narrow focus is in line with most of the work on species conservation *in situ* that is undertaken by many countries, especially in the more developed ones. The reference to threatened species echoes the emphasis given by many countries to preparing Red Books and Red Lists of threatened species and giving protection to these through various forms of action including habitat and species action, management or recovery plans.

In fact Target 7 as a whole is far from clear: it makes no mention of which kinds of species are to be included, such as those of economic importance, although the CBD itself does make reference in Article 7 (Identification and Monitoring) to the indicative list of categories given in Appendix 1 which refers to: species which are threatened; crop wild relatives; species of social, economic, or cultural importance; or species of importance for the conservation and sustainable use of biological diversity, such as indicator species. Target 7 of the GSPC should therefore be interpreted in this context and its implementation should include species of economic importance.

Target 9 of the GSPC is that 70% of the genetic diversity of crops and other major socio-economically valuable plant species be conserved and associated indigenous and local knowledge maintained. It is clear that this will include *in situ* approaches so that close liaison with the activities envisaged under Target 7 will be needed.

1.7.2 The Global Plan of Action on Plant Genetic Resources for Food and Agriculture

The Global Plan of Action (GPA) on Plant Genetic Resources for Food and Agriculture (FAO 1996a) sets out a global strategy for the conservation and sustainable use of plant genetic resources for food and agriculture with an emphasis on productivity, sustainability and equity, and thus complements the CBD. This plan was instigated by The Food and Agriculture Organization of the United Nations (FAO) Commission on Plant Genetic Resources for the Fourth International Technical Conference on Plant Genetic Resources which was held in Leipzig, Germany from 17 to 23 July 1996. The GPA, together with the first report on the *State of the World's Plant Genetic Resources for Food and Agriculture*, were adopted by representatives of 150 countries during the Leipzig conference. The Conference of Parties of the CBD supported the development of the GPA at its second session in 1995 specifically for the subset of plant genetic resources pertaining to food and agriculture.

The report on the *State of the World's Plant Genetic Resources for Food and Agriculture* (FAO 1996b) forms the basis on which the GPA has been developed. The report describes the situation of plant genetic resources for food and agriculture at the global level at this time and, more importantly, identified the gaps and needs for their conservation and sustainable utilization as well as for emergency situations. The GPA was thus developed to fill the gaps, overcome constraints, and face emergency situations identified during this first global survey of the status of plant genetic resources for food and agriculture in the world, as well as helping to focus resources on identified priorities. One important aspect of the GPA is that it is a rolling plan, meaning that it will be periodically updated in order to adjust to changing priorities and to promote rationalization and coordination of efforts as may be recommended by the FAO Commission on Genetic Resources for Food and Agriculture.

The GPA is intended as a framework, guide and catalyst for action at community, national, regional and international levels. It seeks to create an efficient system for the conservation and sustainable use of plant genetic resources, through better cooperation, coordination and planning and through the strengthening of capacities. The GPA contains 20 priority activities grouped into four thematic areas: *in situ* conservation and development, *ex situ* conservation, use of plant genetic resources, and institution and capacity building. The Plan contains a specific recognition of the need to promote *in situ* conservation of wild crop relatives and wild plants for food production (Priority Activity Area 4: Promoting *in situ* conservation of wild crop relatives and wild plants for food production—see Box 4). The long-term objective for this activity is to promote the conservation of genetic resources of wild crop 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 that wild crop 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.

Box 4: Assessment of *in situ* conservation of wild crop relatives and wild plants for food production

- 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 are not managed sustainably.
- This genetic diversity, because of interactions which 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 wild crop 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.

Source: FAO (1996a).

The Plan also provides national and international policy guidance to enable the implementation of the priority activity. Governments are called upon to integrate conservation of plant genetic resources for food and agriculture into priorities for national parks and protected areas and other land-use plans, while at the same time involving farmers and communities who live near protected areas and recognizing the roles and rights of indigenous communities in managing wild crop relatives and wild plants for food production in protected areas. Partly as a result of this, there is now much more focus by many countries on the need to conserve target species of economic importance *in situ*.

1.7.3 Convergence between the CBD and the GPA

A significant development that followed from the CBD and the GPA was the convergence of interest between bodies such as FAO and IPGRI and conservation and development organizations and agencies such UNESCO-MAB, IUCN, WWF and ITDG (Heywood 2003b). One the one hand, the CBD recognized that agricultural biodiversity is a focal area in view of its social and economic relevance and the prospects offered by sustainable agriculture for reducing the negative impacts of biological diversity, enhancing the value of biological diversity and linking conservation efforts with social and economic benefits. On the other hand, it is recognized by FAO and IPGRI that the Global Plan of Action covers a number of multidisciplinary areas such as *in situ* conservation of wild plants and crop relatives in natural ecosystems that extend the traditional activities of sustainable agriculture and plant genetic resource conservation. Its successful implementation will require the development of new partnerships with a range of intergovernmental

and non-governmental organizations, as well as with indigenous and local communities.

The COP has welcomed the GPA and the contribution that it makes to the implementation of the CBD. Much of the CBD's work on agricultural biodiversity has been undertaken in cooperation with FAO, which plays a key role in the implementation of the CBD's Decision III/11: "Conservation and sustainable use of agricultural biological diversity" and its work programme by the Parties.

1.8 Regional and national mandates

In Europe, as well as the obligations that signatory countries have acquired under the CBD and GPA, there are regional mandates that include the protection of wild species and their habitats under the Bern Convention and the Habitats Directive of the European Union.

The Council of Europe's **Bern Convention**[9] is a binding international legal instrument in the field of nature conservation, which covers the whole of the natural heritage of the European continent. It has a threefold objective: to conserve wild flora and fauna and their natural habitats; to promote cooperation between states; and to give particular emphasis to endangered and vulnerable species, including endangered and vulnerable migratory species. A Group of Experts on the conservation of plants makes proposals to the Standing Committee on which species are in need of conservation and, if approved, these are listed in Appendix I of the Convention: "Strictly protected flora species".

The Convention's activities include monitoring species and encouraging conservation action with the long-term aim of recording the conservation status of the populations of species in the appendices of the Convention and detecting problem populations, so as to reverse negative trends. In the medium term it aims to draw up and follow Action Plans for threatened species, establish strategies for the protection of some groups of species, elaborate Red Lists, identify threats to biological diversity in different ecosystems, and strategies to combat invasive alien species. It is also responsible for the European Network of Biogenetic Reserves, the Emerald Network, and the proposed Pan-European Ecological Network. In total, 45 European (and some African States) as well as the European Community are parties to the Convention.

The **Habitats Directive of the European Union** (European Union Council Directive 92/43/EEC of 21 May 1992) establishes a common framework for the conservation of natural habitats and of wild fauna and flora species and provides for the creation of

a network of Special Areas of Conservation (SAC) called 'Natura 2000' to "maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest". Annex II(b) Plants, lists the plant (and animal) species of Community interest whose conservation requires the designation of Special Areas of Conservation.

The **European Plant Conservation Strategy** (EPCS) (Planta Europa 2002), developed by Planta Europa in association with the Council of Europe, is intended to provide a framework for wild plant conservation in Europe and contribute to the development of the CBD's Global Strategy for Plant Conservation. The long-term action (No. 11) concerning *in situ* conservation of species proposed in the European Plant Conservation Strategy is "Prepare and implement recovery plans for threatened plant species, with priority for those on the Bern Convention (Appendix I) and the Habitats Directive (Annex IIb)".

1.9 Initiatives of the UN and other international agencies

In situ conservation of target species is included in the mandate of a number of UN and other international agencies or organizations.

1.9.1 Food and Agricultural Organization of the United Nations (FAO)

In situ plant conservation is addressed to some extent by both the agriculture and forestry divisions of FAO.

Agriculture

In situ conservation of target species of economic importance has not been a major concern to FAO Agriculture, although several initiatives have drawn attention to the need for such actions, such as the International Undertaking, the International Treaty and the Commission on Plant Genetic Resources.

International Treaty on Plant Genetic Resources for Food and Agriculture

An International Undertaking on Plant Genetic Resources was adopted by the 22nd FAO Conference in October 1983. It recognized *in situ* conservation of plant genetic resources as an important component of its work. It also provided for the establishment of an FAO Commission on Plant Genetic Resources. Very little work in the area of *in situ* conservation resulted. After more than 10 years of negotiation, the Undertaking was replaced in November 2001 by

the International Treaty on Plant Genetic Resources for Food and Agriculture (IT PGRFA) which entered into force on 29 June 2004. The objectives of the Treaty are: the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of benefits derived from their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security (FAO 2002b).

The relevant activities of the IT PGRFA as regards *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 wild crop 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.

Commission on Genetic Resources for Food and Agriculture (CGRFA)

The CGRFA reviews and advises FAO on policy, programmes and activities related to the conservation, sustainable use and equitable sharing of benefits derived from the utilization of genetic resources of relevance to food and agriculture (see http://www.fao.org/ag/cgrfa/default.htm).

When dealing with the issue of *in situ* conservation, the FAO Commission on Plant Genetic Resources (later the Commission on Genetic Resources) expressed its concern at the lack of effort in this area and proposed a strengthening of work on this topic. However, the Commission's work has been focused largely on *ex situ* conservation of crop plants and the only *in situ* conservation activities have been on the conservation of primitive cultivars/landraces on-farm.

The role of FAO in developing awareness of the need for *in situ* conservation of wild species (other than in forestry) has been largely through the work commissioned and undertaken for the report on the *State of the World's Plant Genetic Resources for Food and Agriculture* prepared for the International Technical Conference (FAO 1996b). The preparatory process was country-driven and the Country and Regional Reports were major inputs into the process. An expanded

version of the report was subsequently peer-reviewed and published (FAO 1998). Chapter 2 is entitled 'The state of *in situ* management'. A second report is under preparation and one of the studies being undertaken in preparation is on the conservation of crop wild relatives which will build on the GEF UNEP/IPGRI project on the conservation of wild crop relatives (see Section 3.5).

Forestry

The FAO Forestry Department has played a major advocacy role over the past 25 years in developing awareness of the need for conservation of forest genetic resources *in situ* and has commissioned a series of reports on the subject (FAO 1968–1988, 1975, 1984, 1989, 1993; FAO/UNEP 1981, 1985, 1987). As early as 1980 it held an expert consultation jointly with UNEP on the *in situ* conservation of forest genetic resources (FAO/UNEP 1981). The relevant FAO activities in various aspects of forest genetic resources under the regular programme are described below.

Conservation of genetic resources

FAO's policy on the conservation of forest genetic resources covers both *in situ* and *ex situ* (i.e. in conservation stands, genebanks, arboreta, botanic gardens etc.) projects, and it has actively contributed to the elaboration of methodologies for both approaches. Since the early 1980s, *in situ* conservation has been emphasized. Collaboration with national institutes has continued in research and pilot activities, and in studies underpinning genetic conservation. Countries involved have included, among others, Bangladesh, Brazil, India, Mexico, Morocco, Myanmar, Peru, Senegal, Sri Lanka and Thailand. In collaboration with IPGRI, the DFSC (DANIDA Forest Seed Centre, Denmark, now Forest and Landscape, Denmark) and other partners, FAO is developing a practical guide on the conservation of forest genetic resources, which will complement earlier documents related to conservation (FAO/DFSC/IPGRI 2001).

Gathering and dissemination of information

FAO publishes an annual bulletin, *Forest Genetic Resources* (formerly *Forest Genetic Resources Information*) in English, French and Spanish, with a global distribution, also available on the Internet. In addition, FAO has continued developing the World-wide Information System on Forest Genetic Resources, REFORGEN, in close collaboration with national institutes and relevant international organizations. The system, which stores data on species and institutions, is intended to support policy and technical decisions for genetic conservation at national, regional and international levels.

Integrated strategies and action plans
At the request of the 13th Session of the Committee on Forestry (1997), FAO supports country-driven processes for the elaboration of strategies and action-oriented plans on forest genetic resources at a sub-regional and regional level. FAO joins forces with national and international partners to help organize regional workshops on the conservation, management, sustainable utilization and enhancement of forest genetic resources, which aim at reviewing the status and trends of the genetic resources of major and important tree and shrub species, and elaborating relevant programmes amenable to regional cooperation. The first of these workshops targeted the Sahelian sub-region of Africa and was held in Ouagadougou, Burkina Faso, in September 1998 (see FAO 2001a, 2001b). Similar workshops have been held in the South Pacific Islands (Apia, Samoa in 1999) (Sigaud et al. 1999; FAO 2001c) and Eastern and Southern Africa (SADC countries) in Arusha, Tanzania, June 2000 (see FAO 2003a), Central America (2002) (See FAO 2003b) and Central Africa (Pointe Noire, Central African Republic in 2003).

Networks
A recent FAO document on International Plant Genetic Resources Networks (FAO CGRFA-9/02/12, see Kalaugher and Visser 2002) notes that *in situ* conservation is addressed by regional PGR networks and by the *in situ*-oriented networks such as the MAB World-wide Network of Biosphere Reserves. It comments that, in general, linkages between such networks for *in situ* conservation are not obvious. It draws attention to the document *Progress Report on the Development of a Network of In Situ Conservation Areas* (FAO CGRFA-9/02/13) which reviews the Commission's considerations on *in situ* conservation.

1.9.2 UNESCO
The main involvement of UNESCO in *in situ* conservation is through its programme on Man and the Biosphere (MAB) (see http://www.unesco.org/mab/about.htm) and its system of Biosphere Reserves (UNESCO 1992). Since its inception in the early 1970s the conservation of natural areas and the genetic material they contain has been one of the component project areas of MAB. Several of the individual reserves are concerned with the conservation of target species *in situ* such as the Arganeraie MAB Biosphere Reserve, in the Souss Valley, Agadir region, Morocco, where the endemic argan tree (*Argania spinosa*) is of main conservation interest. Another is the Sierra de Manantlán, Biosphere Reserve, Mexico, which houses a maize wild relative

(*Zea diploperennis*) which is endemic to the area of the reserve. It was the discovery of this species in the mid-1970s that was a major stimulus to the subsequent denomination and designation in 1987 of Sierra de Manantlán as a biosphere reserve.

Other biosphere reserves that conserve target species include the Fenglin Biosphere Reserve in China, which houses *Pinus koraiensis*, or the various biosphere reserves in the Russian Federation and Central Europe which conserve wild fruit trees.

The Biosphere Reserve model, with its emphasis on sustainable use and conservation of biological diversity, and the improvement of the relationship between people and their environment, is an important one to take into account when planning *in situ* conservation programmes. The operation of Biosphere Reserves is detailed in the *Seville Strategy for Biosphere Reserves* (see http://www.unesco.org/mab/docs/Strategy.pdf), which identifies the specific role of biosphere reserves in developing a new vision of the relationship between conservation and development.

UNESCO is a key player in the WWF/UNESCO/Kew People and Plants Initiative (see http://peopleandplants.org/), which publishes *The People and Plants Handbook*, a source of information on applying ethnobotany to conservation and community development (Issue No. 7 is *Growing Biodiversity: People and Plant Genetic Resources*).

1.9.3 The World Bank

The World Bank is involved in *in situ* conservation through various projects on medicinal plants and implicitly in its Forest Strategy (World Bank 2002). As the Strategy notes,

> Bank client governments do not, by and large, wish to borrow funds for forest protection. The reality, therefore, is that, unless significant additional funds at highly concessional or grant terms blended from multiple sources can be made available for protection, or effective markets for the ecosystem values of forests developed, the problem is likely to worsen.

The World Bank and WWF, through the World Bank/WWF Alliance for sustainable forest conservation and use, are working together with governments, the private sector and civil society to achieve three targets by the year 2005: namely, 125 million acres of new forest protected areas, 125 million acres of existing but highly threatened forest protected area to be secured under effective management, and 500 million hectares of the world's production forests under independently certified sustainable management.

Through the Critical Ecosystem Partnership Fund, another major effort is under way to support the protection and management of particularly important areas of biodiversity.

However, as noted in the Bank's Forest Strategy

if these efforts are to lead to protection across the board in remaining natural forests, and not only in selected areas, perceptions of Protected Areas that would give high priority to setting aside discrete wilderness areas and biodiversity reserves and excluding them from all forms of human use will have to evolve. There are signs that this change in perception is happening. It is now widely recognized that local communities and forest-fringe farmers can play a key role in biodiversity preservation. There is a trend towards a wider definition of Protected Areas that embraces the concepts of IUCN Category VI (World Bank 2002).

1.9.4 The Ecosystem Conservation Group (ECG)

The Ecosystem Conservation Group (ECG) established in 1974 brings together United Nations agencies such as UNESCO, UNEP, FAO, secretariats of biodiversity-related conventions, and non-United Nations international institutions such as IPGRI and IUCN to advise its member organizations on the development and implementation of relevant ecosystems and genetic resources conservation activities and promote thematic joint programming. It established an *ad hoc* Working Group on *in situ* Conservation of Plant Genetic Resources, which at its first meeting in 1986 reviewed *in situ* conservation activities and needs, especially in the context of the FAO Commission on Plant Genetic Resources, the UNESCO Action Plan on Biosphere Reserves and the IUCN Bali Action Plan. Its work plan included the preparation of an information document on *in situ* conservation and this was published in 1989 (FAO 1989).

1.9.5 CGIAR (Consultative Group on International Agricultural Research)

Several of the International agricultural and forestry centres that are members of the CGIAR alliance, most notably IPGRI and CIFOR, include *in situ* conservation in their remit.

The mission of the International Plant Genetic Resources Institute (IPGRI) is to undertake, encourage and support research and other activities on the use and conservation of agricultural biodiversity, especially genetic resources, to create more productive, resilient and sustainable harvests. The aim is to promote greater well-being of

people, particularly poor people in developing countries, by helping them to achieve food security, to improve their health and nutrition, to boost their income, and to conserve the natural resources on which they depend (IPGRI 2004). The new mission of IPGRI puts the well-being of people at the centre of its agenda and aims to achieve this by conservation and deployment of agricultural biodiversity. It hopes to achieve its mission through six strategic areas (see Appendix 1). *In situ* conservation is a relatively new area for IPGRI. Much of the past work of IPGRI has been on the conservation of crop genetic resources through *ex situ* techniques. As regards *in situ* conservation, the work of IPGRI has focused mainly on:

- developing strategies and techniques such as ecogeographical surveying (IBPGR 1985) and guidelines for collecting plant diversity (Guarino et al. 1995)
- strengthening the scientific basis of on-farm conservation of local landraces
- conservation of useful wild species such as rattan and bamboo (with CIFOR)
- *in situ* conservation of forest genetic resources and management strategies.

Recently it has expanded its scope into crop wild relatives and medicinal plants. Specific activities on crop wild relatives include:

- implementing a UNEP/GEF PDFB project '*In Situ* Conservation of Crop Wild Relatives Through Enhanced Information Management and Field Application'
- producing an inventory of wild relatives of crop species in Bolivia, Sichuan and Paraguay
- compiling internationally available information sources for the development of *in situ* conservation strategies for wild species useful for food and agriculture (Thormann et al. 1999)
- understanding the population structure, dynamics and genetic variability within and between populations
- management of natural ecosystems, including establishment of genetic reserves, ecological restoration and species recovery plans.

In 1991, the CGIAR expanded its mandate to include forestry and agroforestry, with IPGRI's role covering forest ecosystems and genetic resources. Over the years, IPGRI, in close collaboration with relevant partners, has developed the basis for a comprehensive and coordinated research programme in this area.

The specific goal of IPGRI's Forest Genetics Resource programme is to ensure the continuous availability of forest genetic resources for present and future use, through *in situ* and *ex situ* measures that allow species adaptation and evolution to changing environments.

It focuses on two major areas:

• Strengthening institutional frameworks and contributing to international collaboration and policy making in the conservation and use of forest genetic resources

• Generating knowledge and developing appropriate methods and tools for conservation and use of forest genetic resources.

A major element of IPGRI's programme is increasing international collaboration through networking. In most cases their programmes of activities do not at present involve *in situ* species conservation, although some involve on-farm conservation, but some of them do recognize the need for such work. The EUFORGEN (European Forest Genetic Resources Networks) networks do address issues of forest genetic resource conservation, including *in situ* strategies, and some of the CWANA (Central and West Asia and North Africa) networks also address conservation of wild species medicinal and aromatic plants. *In situ* conservation is the specific concern of the ECP/GR *In situ* and On-farm Conservation Network, which was established and became operational in May 2000 with a joint meeting, held in Isola Polvese, Italy, of two task forces for Wild Species Conservation in Genetic Reserves and for On-farm Conservation and Management (Laliberté et al. 2000).

CIFOR has very similar objectives to IPGRI but focuses on conserving forests and improving the livelihoods of people in the tropics. It is an international research and global knowledge institution that helps local communities and small farmers gain their rightful share of forest resources, while increasing the production and value of forest products (see www.cifor.cgiar.org for a summary of CIFOR's activities). CIFOR's work on *in situ* conservation has previously been through its conservation programme, which was aimed at developing criteria and indicators to assess the changing status of biodiversity and ensure the conservation of forest-based biodiversity. Now there has been a paradigm shift towards environmental services and sustainable use of forests, with research now focusing on biodiversity as a means to sustainably manage and harvest forest products. CIFOR , IPGRI and ICRAF (International Centre for Research in Agroforestry, now the World Agroforestry Centre), have developed a joint programme on *in situ* conservation of forest genetic resources, whereby the role of each centre is better defined and complementary.

1.9.6 The International Union of Forest Research Organizations (IUFRO)

The Physiology and Genetics Division of IUFRO contains units on conifer breeding and genetic resources and on genetics, covering fields

such as population, ecological and conservation genetics, breeding theory and progeny testing, molecular biology and cytogenetics.

The terms of reference of its Task Force on Management and Conservation of Forest Gene Resources (FGR) include the gathering and synthesis of scientific information on:

- scientific knowledge necessary for the conservation of FGRs: management of base and breeding populations, maintenance of representative diversity, including rare populations
- case studies on *in situ* and *ex situ* conservation
- interaction between human activity and integrity of FRGs: silviculture, forest operations, agroforestry, forest and landscape management, and others
- effects of environmental factors on the integrity of FGRs: insect pests, diseases, air pollution.

1.9.7 The World Conservation Union (IUCN)

The parts of the Union that are most concerned with the topics of this review are described below.

The Species Survival Commission (SSC), with more than 7000 members, advises the Union on the technical aspects of species conservation, and mobilizes action by the conservation community for the conservation of species threatened with extinction and those important for human welfare. It has proposed a Plant Conservation Strategy 2000–2005 (see Appendix 2) which includes *in situ* conservation activities. Relevant activities of the SSC Plants Programme include:

- Participation in projects on specific conservation issues, such as the conservation of wild plants of importance for food and agriculture and other selected economic plants, and the study and mitigation of major threats by providing inputs to the development and implementation of these projects
- Collaboration in reviews and analyses of existing guidelines for *in situ* conservation of plants and their further development, utilizing the experience gained from *in situ* research and management
- Collaboration in projects on the conservation of wild relatives of crop plants, for example, in the development of a catalogue of wild relatives and the distribution and use of protected areas for their *in situ* conservation
- Participation through the Medicinal Plants Specialist Group in inter-agency collaboration on the conservation and use of medicinal plants with particular reference to sustainable production, benefit sharing and community participation.

The members of the 34 SSC Plant Specialist Groups cover a wide range of plant groups and geographical areas and undertake extensive

work on the conservation of rare and endangered species. Several of these groups have produced Action Plans that include conservation strategies such as those for palms (Johnson 1996), cycads (Donaldson 2003), cacti and succulents (Oldfield 1997), orchids (Hágsater and Dumont 1996) and conifers (Farjon and Page 1999).

The IUCN World Commission on Protected Areas (WCPA) consists of a global network of protected area specialists. It has set up a Task Force on Management Effectiveness which is addressing two issues: (1) the management of existing protected areas (Are the existing protected areas effectively managed?); and (2) the location and design of new protected areas (Will the protected area network represent and effectively retain both regional and national biodiversity?). It produces a series of Best Practice Protected Area Guidelines (see http://www.iucn.org/bookstore/pro-areas-2.htm) and, jointly with the IUCN/WWF/GTZ Forest Innovations Project I, it held an international Workshop on Management Effectiveness of Protected Areas, 14–16 June 1999 at CATIE, Turrialba, Costa Rica.[10]

The IUCN Commission on Ecosystem Management (CEM), as part of a joint working group with the Society for Ecological Restoration International (SERI), has prepared a joint rationale on why ecological restoration is a critical tool for biodiversity conservation and sustainable development (see http://www.iucn.org/themes/cem/ourwork/ecrestoration/index.html).

1.9.8. World Wide Fund for Nature (WWF)

The WWF is an international network and runs more than 280 projects which contribute to plant conservation worldwide. Many of these are concerned with the conservation of habitats rich in plant diversity, rather than with the conservation of individual plant species. WWF-India and WWF-South Africa are among the WWF national organizations that are most involved in plant conservation.

The Endangered Species Programme of WWF does not have an *in situ* component and like its Flagship Species Project is heavily biased towards animals. The International Plant Conservation Unit (see http://www.wwf.org.uk/filelibrary/pdf/plant_conservation_and_wwf.pdf) is the main focus of plant conservation activities. Much of its work on plant species comes under the People and Plants Programme, a joint initiative of WWF-UK, UNESCO, and the Royal Botanic Gardens, Kew, aimed at promoting the sustainable use of plant resources, and the reconciliation of conservation and development, by focusing on the interface between people and the world of plants.

Part II: *In situ* conservation methodologies

2.0 The components of a conservation strategy

In situ conservation strategies for target species involve a range of complex to simple pragmatic activities, depending on the species concerned and their characteristics, distribution, genetic variation, the habitat(s) occupied, economic importance, the degree of urgency (or threat), and the resources available. The main elements involved in developing a strategy for the conservation of target species *in situ* can be broadly divided as follows:

1. Priority setting for target species
    a) Selection criteria for target species
    b) Ecogeographical surveys, including estimation of the amount and pattern of genetic diversity
2. Planning, design and setting up *in situ* conservation areas for target species
    a) Target areas and populations selection
    b) Planning and design of conservation areas
3. Management and monitoring of *in situ* conservation areas and populations
    a) Species and site management plans
    b) Recovery plans
    c) Involving local and other relevant stakeholders
    d) Informing the public
4. Policy and legal support
    a) Incorporating the conservation strategy into the national biodiversity strategy and action plans.

The order in which these elements are applied may vary and not all components are essential. Although a model has been proposed as suitable for widespread application and is being tested in several projects around the world (Maxted et al. 1997c), a point that comes out clearly in this review is that there is no simple single strategy for genetic conservation of target species that is appropriate to all situations, or even generally applicable.

2.1 Priority-setting for target species

2.1.1 Selection criteria for target species

The number of wild plant species requiring specific conservation efforts is far too numerous to include all of them in conservation programmes (Sutherland 2001). Even within the main groups of

target species of economic importance (wild relatives, forest tree species, medicinal and aromatic plants), the number of species to consider is greatly in excess of any reasonable expectation of conservation possibilities. In the case of wild relatives, it has been suggested that the number of candidate species is presumably at least an order of magnitude higher than the crops to which they are related (Brown and Brubaker 2001) and it has even been suggested that "for practical purposes, this group alone, if fully investigated, represents more than can be attempted in the foreseeable future" (Holden et al. 1993). If a conservation strategy depends, as it often will, on the results of ecogeographical surveys and analyses of genetic and biological variation, all of which require considerable investments of time, money and expertise, not to mention any management interventions and monitoring, then effective action will not be possible for most of the species identified. This is even true even for such programmes as those for endangered species of the Center for Plant Conservation in the USA (Holsinger and Gottlieb 1991). It follows that the selection of target (candidate) species is a key element of any *in situ* programme. A useful review of the principles of priority setting in species conservation, although in an ornithological context, is included in a recent volume on conserving bird biodiversity (Mace and Collar 2002). The priority-setting systems applied most widely in the USA are those developed by The Nature Conservancy and the US Fish and Wildlife Service (see Elzinga et al. 1998a: pp. 29 *et seq.*).

Some general principles for the selection of target species are widely applied (Maxted et al. 1997d) (see Box 5). In addition there are special factors that may have to be taken into account in particular cases or types of plant (for example crop wild relatives, forest species, medicinal plants, ornamental plants etc.) and these may affect the selection process, or may be applicable only at a later stage, such as the extent of management needed. The main factors are:

Coverage and distribution: The coverage and distribution of the target species in time and space is an important factor to consider. The degree of coverage or the percentage of the total cover occupied by the species and their populations as well as their general distribution pattern (widespread, disjunct populations, narrow localized species, metapopulations) will affect the genetic architecture, population structure and the amount of variation. For example Millar and Libby (1991) discuss strategies for conserving variation in widespread species such as northern-hemisphere conifers. Furthermore, their occurrence in marginal habitats as opposed to optimal habitats will

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Box 5: General criteria for selecting target species

- Actual or potential economic use
  - Crop relative
  - Medicinal or aromatic herb, shrub, tree
  - Forest timber tree
  - Fruit tree or shrub
  - Ornamental herb tree, shrub
  - Agroforestry species
  - Forage species
  - Species used for habitat restoration or rehabilitation
  - Other
- Current conservation status: the degree and nature of threats
- Endemism
- Restricted range
- Recent rate of decline
- Rarity
- Threat of genetic erosion
- Ecogeographical distinctiveness
- Biological characteristics and importance
- Cultural importance or of high social demand
- Occurrence and frequency in current Protected Areas
- Status of protection
- Ethical considerations
- Taxonomic or phyletic uniqueness or isolation
- Focal or keystone status/ecosystem role
  - Indicator species
  - Umbrella species
  - Keystone
  - Flagship

Modified and amplified from Maxted and Hawkes (1997), Mace and Collar (2002)

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also determine the pressures affecting the populations and the types of conservation management intervention required.

Existence of variation: The existence of different types of variation (ecotypic/genecological, chemical and clinal) and how they are distributed will also be another major consideration to take into account. Special desirable features such as chemical variation (Heywood 2002) would need to be covered in the populations selected in the case of medicinal and aromatic plants.

Threat to genetic erosion: The degree to which species and their populations are under threat from genetic contamination might well affect their genetic integrity and would call for special consideration in the management of *in situ* populations. The competitive ability of the species to withstand invasion of their habitat by alien species may affect the degree of management intervention required and their capacity for natural regeneration.

Extent of utilization: The extent of utilization of the target species; whether it forms part of provenance and breeding programmes or is simply harvested from the wild or used by local communities, would also be important factors to take into account.

Biological characteristics: The successful *in situ* conservation of target species will depend a to a large extent on how much is already known about the species' biological characteristics (e.g. taxonomy, breeding system) and whether the species is unambiguously delimited, readily available and easy to locate and sample. Pragmatic decisions based on the above will be required in order to ensure the likelihood of conservation success and sustainability.

Conservation costs: The relative monetary costs of conservation actions would be yet another key determinant.

Selection approaches
Species selection can take two approaches, namely single target species or multiple species approaches. For single-species approaches, different criteria have been developed in relation to the forestry species and medicinal plants. For forestry species, there is no general forum for discussing and deciding on which species to select and which can be safely ignored (Namkoong 1986). However, the FAO statutory body, the Panel of Experts on Forest Gene Resources, whose role is to help plan and coordinate FAO's efforts to explore, utilize and conserve the gene resources of forest trees, includes in its recommendations lists of priority species by region, species and operations/activities. In assessing priority species, degree of threat is not the basis of selection but rather a balance of socio-economic, environmental and cultural values (Palmberg-Lerche 2001). The *FAO Draft Technical Guidelines for Identification and Definition of National Priorities* prepared for use in regional workshops on forest genetic resources (FAO 1999), includes a detailed discussion on the identification of target species according to perceived value and attributes/uses, present management and occurrence, and level of security and threats (see also Namkoong 1986, 1999; Namkoong and Koshy 1997; Koshy et al. 2002).

Medicinal plants
For medicinal plants, the following criteria have been proposed (Vieira and Skorupa 1993) to define priority:
• **species with proven medicinal value** including those containing known active substance(s) or precursor(s) used in the chemical–pharmaceutical industry with proven pharmacological action, or at least demonstrating pre-clinical and toxicological results

- **species with ethnopharmacological information** widely used in traditional medicine and which are threatened with extinction or are vulnerable
- **species with chemotaxonomical affinity** to botanical groups which produce specific natural products.

Other criteria

Other common criteria for selecting species include their endangerment status, the extent and pattern of their distribution, and their occurrence in protected areas or centres of plant diversity. Endangered species are a widely accepted focus for conservation attention both nationally and globally and are frequently afforded high priority. Lists of endangered species are compiled with little regard to the economic, social or scientific importance or the biology of the species involved. It has been pointed out that in the USA many 'endangered' species are peripheral (and often not viable) populations if the whole range of the species is taken into account (Godown and Peterson 2000; Peterson 2001) and this may well be true of other countries as well. If, however, the species are endemic to the country concerned then there is much greater justification to choose them as targets for conservation. An emphasis on threatened species is not just confined to national species recovery programmes for Red List species. Although endangerment is but one of many criteria that may be employed to determine conservation priorities, it is often employed as a filter after other factors have been considered. Thus in a review of work on collecting and research on wild potatoes (*Solanum* spp.) of the southwest USA (Bamberg et al. 2003), it is considered that future *in situ* research should involve precise documentation of the locations of living populations so as to provide "an essential platform for *in situ* projects to identify which populations are most valuable, and which are in danger of extinction or are otherwise threatened".

The presence of a target species in a recognized Centre of Plant Diversity or 'hotspot' (Myers et al. 2000) may be considered beneficial in that by definition these locations contain concentrations of endemic species and so the effective conservation of the habitat as a whole will be more likely (although by no means guaranteed). The IUCN/WWF three-volume *Centres of Plant Diversity* (Davis et al. 1994–1997) is a major source of information.

While many of the species targeted for *in situ* conservation are restricted in distribution, if not rare, attention has also been focused in some cases on species which are widespread and of economic importance, such as major forest trees (Millar and Libby 1991). Sampling and conservation strategies for such species may

involve including genetic core areas, important ranges of diversity, particular ecotypes or ranges of clinal variation, and outlier or marginal populations.

Most of the above considerations apply to single target species but in some cases an alternative strategy is to design a strategy that conserves the target species jointly with other species in the same ecosystem, as has been proposed for example in the case of ash (*Fraxinus* spp.) (Pliúra 2003). This is not the same as the incidental protection of other species as a by-product of the conservation of a target species—in such a case, any conservation of the non-target species is 'hands-off', and no specific strategy for them is involved.

The multi-species approach is suggested in the US National Research Council review of managing genetic resources of forest trees, which says that "There may exist well-correlated sets of co-occurrences of species that can for immediate conservation purposes be considered to be distinct assemblages, if not communities" (National Research Council 1991) but, as it goes on to say, in areas where several species are being conserved at the same time in a reserve, it is a problem to ensure that the number and distribution of the populations of the species concerned are adequate for maintaining genetic variability in either single or multiple reserves. Not only this, but joint species conservation strategies need to be based on the same principles as single target species, and in the case of *Fraxinus* spp. "should be dynamic, evolutionary oriented, and based on [the] multiple breeding system (MPBS) concept" (Pliúra 2003). The MPBS approach as applied to joint breeding and conservation strategies by Namkoong (1983, 1989) means that the gene resource population selected is split into small subpopulations over a range of environments and is thus exposed to natural selection, and in turn to evolution, in a variety of directions.

On the other hand, multi-species recovery plans for endangered species have been proposed by several countries, such as Australia, Canada, the UK and the USA. In the latter, recovery plans under the US Endangered Species Act include some in which several species have been grouped together under the same plan. The advantages of a local, multi-species or regional approach are

> that it can focus efforts on specific populations of animals and plants and can develop local community campaigns to help implement the necessary recovery actions. Further benefits include the avoidance of duplication, greater efficiency and cost-effectiveness, and the ability to bring

together a broader range of interested groups and indi-
viduals (Boyes 2001).

It should be noted, however, that a recent review indicates that the
decisions on which species to include have not been influenced by
the similarity of threats to which they are exposed but rather by their
taxonomic relatedness or geographical proximity (Clark et al. 2002)
and suggests that multi-species plans are less effective than single-
species plans, probably because less time and money is spent per
species (Boersma et al. 2001). Criteria for deciding whether single-
species or multi-species plans are more appropriate are suggested
in the South Florida Multi-Species Recovery Plan (Jewell 2000).

What is clear that there is no single factor that can be applied
unequivocally to all situations or groups of species. When different
variables are recognized, some kind of decision support system, such
as the application of qualitative or numerical values to the factors
chosen, and the use of a matrix so as to determine priorities, may
be employed (Yanchuk 1997).

2.1.2 Establishing an information baseline
Ecogeographical surveys
The first step in any *in situ* conservation programme for target
species is to establish a baseline of available information before other
activities are initiated. The process of gathering this information
is sometimes referred to as an ecogeographical survey or study
(Maxted et al. 1995) and is considered central to all issues of
conservation and a key requirement in the development of any
in situ conservation strategy (Ouédraogo 1997). Choosing species
to include in an *in situ* conservation programme requires that
adequate information is available to make proper decisions and
set the right priorities. Box 6 shows some of the different kinds of
information that should be gathered. A word of caution, however,
is needed. It is important to gather as much information as
possible from as many sources as possible, but the validity of this
information should then be double-checked (USDA 1999). Once the
knowledge baseline has been established, this will allow gaps in
the knowledge to be identified and will inform the implementation
of the subsequent steps.

The concept of ecogeographical surveys gained wide currency
after the publication of a booklet *Ecogeographical Surveying and* In Situ
Conservation of Crop Relatives by IBPGR (later IPGRI) in 1985. The term
applies to various systems of gathering and collating information on
the taxonomy, geographical distribution, ecological characteristics,
genetic diversity, and ethnobiology of the target species, as well as

Box 6: Elements needed for knowledge baseline

1. bring together information on the main wild species of economic use in the country or region on:
    *   the correct identity
    *   distribution
    *   reproductive biology
    *   breeding system
    *   demography
    *   conservation status
2. gather information on how they are used, including local traditional knowledge
3. gather information on the nature and extent of trade in these species
4. gather information on the extent to which (if relevant) they are harvested from the wild and the consequences of this on the viability of wild populations
5. gather information on their cultivation and propagation
6. gather information on their agronomy if cultivated
7. establish which of them occur in Protected Areas
8. gather information on the availability of germplasm and authenticated stock for cultivation
9. gather information of what (if any) other conservation activities (including *ex situ*, ecogeographical surveys) on the species exist

the geography, climate and the human setting of the regions under study (Guarino et al. 2002). Ecogeographical information can be used to locate significant genetic material and representative populations can be monitored to guide the selection of representative samples for conservation and utilization (IBPGR 1985).

IBPGR (1985) described ecogeographical surveying as the determination of:

*   distribution of particular species in particular regions and ecosystems
*   patterns of infra-specific diversity
*   relations between survival and frequency of variants and associated ecological conditions.

Maxted et al. (1995) have reviewed in detail the various steps involved in undertaking an ecogeographical study or survey, which in essence consists of three main phases: project design, data collection and analysis, and product generation (see Box 7). It involves the collation and analysis of large and complex data-sets obtained from the literature and from the passport data associated with herbarium specimens and germplasm accessions (Maxted and Kell 1998). The ecogeographical data analysis produces three basic products: the database, which contains the raw data for each taxon; the conspectus, which summarizes the data for each taxon; and the report, which discusses the contents of the database and conspectus (Maxted 1995; Maxted and Kell 1998). The results of the data analysis can be predictive and are prerequisite to better conservation of genetic resources of plants whether *ex situ* or *in situ*.

The results can be used to assist in the formulation of collecting and conservation priorities (Maxted et al. 1995).

Specific examples of the application of ecogeographical studies and surveys on crop and wild species germplasm include: *Vicia* (Maxted 1995; Bennett and Maxted 1997; Maxted and Kell 1998), *Hordeum* (von Bothmer et al. 1991), *Trifolium* (Bennett and Bullitta 2003), *Coffea* (Dulloo et al. 1999), annual legumes (Ehrman and Cocks 1990), *Corchorus* (Edmonds 1990), *Medicago* (Rihan 1988), *Phaseolus* (Nabhan 1990), *Lens* (Ferguson et al. 1996) and *Leucaena* (Hughes 1998). The different ecogeographical studies undertaken on the forage species of *Vicia* illustrate well the extent to which such studies can be applied. Maxted (1995) carried out a detailed ecogeographical study on the genus *Vicia* subgenus *vicia* throughout its geographical range, based on herbarium specimens held in 18 major international herbaria and supplemented by field trips. In his study, conservation priorities were defined and specific targets for *ex situ* and *in situ* were identified. Bennett and Maxted (1997) restricted their study on the *Vicia narbonensis* complex and *V. bithynica* to a herbarium survey and genebank accessions. Maxted and Kell (1998) focused on one geographical area, Turkey in this case, to illustrate the use of ecogeographical techniques in identifying centres for *in situ* conservation.

Box 7: Phases of ecogeographic study or survey

Phase I - Project design
- Project commission
- Identification of taxon expertise
- Selection of target taxon taxonomy
- Delimitation of target region
- Identification of taxon collections
- Designing and building of ecogeographic database structure

Phase II - Data collection and analysis
- Listing of germplasm conserved
- Survey of taxonomic, ecological and geographical data sources
- Collection of ecogeographical data
- Data verification
- Analysis of taxonomic, ecological and ecogeographical data

Phase III - Product generation
- Data synthesis
- Ecogeographical database, conspectus and report
- Identification of conservation priorities

Source: Maxted *et al*. (1995)

Bennett and Bullitta (2003) made an ecogeographical analysis of six species of *Trifolium* from Sardinia with the aim of designing

future collection missions and for the designation of important *in situ* reserves in Sardinia. A similar ecogeographical approach was used to map genetic diversity hotspots of wild *Coffea* species from Mauritius and as a basis for developing genetic reserves (Dulloo et al. 1999; Maxted et al. 1999).

Much of the initial work involved in undertaking an ecogeographical survey is desk-based and this then needs to be complemented by field work. Maxted and Guarino (1997) make a distinction between an ecogeographical study and an ecogeographical survey. A study involves a more detailed analysis and interpretation phase than a survey. For instance, Ehrman and Cocks (1990) were able to propose a detailed list of conservation priorities for annual legumes in Syria based on an ecogeographic study, including field work, which collated data over several years. At the other extreme, a brief period spent collecting ecogeographic survey data from herbarium specimens and germplasm accessions passport data, combined with information from the literature, provides the very useful and necessary background data for a single germplasm collecting expedition and subsequent *ex situ* conservation. The examination of herbarium specimens may be an important source of information (Pearce and Bytebier 2002) and is an important step in preparing an ecogeographical survey (Maxted et al. 1995). In a recent study on American wild potatoes (Bamberg et al. 2003), a survey of available herbarium material was undertaken to help determine the location and distribution of the species and collection potential sites; information was also obtained from local botanists. A simple herbarium-based ecogeographical survey of African *Corchorus*, *Hibiscus* and related species carried out by Edmonds (1990) showed the usefulness of ecogeographical surveys in locating potential wild species of jute for genetic improvement of this crop (Edmonds 1990).

While herbaria are often seen as a very good starting point for providing good sources of ecogeographical data, there are very often significant gaps in ecological data from herbarium specimens, especially older ones, and sometimes these also lack curatorial and geographical data such as collector's name, collecting date and locality details (Maxted 1990; Bennett and Maxted 1997; Dulloo et al. 1999). An ecogeographical study of *Coffea* species based on herbarium specimens found that data on soil type, altitude and habitat were present in only 0.8%, 2.4% and 6.5% of specimens recorded (Dulloo et al. 1999). Maxted et al. (1995) discusses in detail the value of herbaria in the collection of ecogeographical data and concludes, however, that often herbaria are the only sources of geographical information for determining distribution of target taxa, especially non-crop species,

for diversity and conservation studies. For less well-collected taxa, in particular wild species or wild relatives, a desk-based ecogeographical survey needs to be supplemented by field exploration (Maxted and Guarino 1997). However, herbaria have an important role to play in determining or verifying the identity of material sampled, although it must be noted that many herbarium specimens are misidentified, even in leading herbaria.

Correct identification of the target species is an essential step in any conservation strategy as it provides not only the key to the associated literature but establishes the basis for repeatability (Miller et al. 1989). The correct naming of the plant material sampled is also essential and a prerequisite for its proper use and conservation. Great caution should be exercised in the use of common names to identify material. They are often locally specific but not unique over larger areas, and are often inaccurately associated with scientific names (Kanashiro et al. 2002).

However, when dealing with species conservation, the choice of which units of biological diversity should be adopted is a matter of considerable debate (Bruford 2002). In most cases, the species is used as the basic unit, but the conservation focus may be more on infraspecific units or populations within the species targeted. Conventionally, plant species are defined in taxonomic terms, i.e. based on morphological or phenetic discontinuities that are believed to reflect breeding discontinuities, although the question of species concepts is still highly contentious and there are currently seven or eight different species concepts in use (phenetic, biological, recognition, ecological, cladistic, pluralistic, phylogenetic and evolutionary) and no agreement between the different practitioners about how to develop a coherent theory of systematics at the species level (Heywood 1998). In addition, species concepts differ from group to group and there are often national or regional differences in the way in which the species category is applied (Gentry 1990; Heywood 1991) which make comparisons difficult.

The methods used to determine the distinctiveness of species and other biological units will in turn determine whether or not they are selected for conservation action or legal protection (Olfelt et al. 2001). There is growing evidence to suggest that the use of conventionally defined species (taxonomic or biological) may not lead to the adequate conservation of the diversity with future evolutionary potential that is needed. Increasingly in conservation studies, mainly of animal groups such as birds, the concept of Evolutionarily Significant Units (ESU) rather than species, subspecies or ecotypes, is being employed as the basic unit for conservation management and establishing priorities (Ryder 1986; Waples 1995, 1998). For plants of agriculture whose

genetics and breeding relationships have been well studied, there may be serious discrepancies between conventional taxonomic treatments and classifications that reflect primary, secondary and tertiary genepools or similar systems based on degree of actual or potential gene exchange, such as the ecosystem/ecospecies/coenospecies/comparium hierarchy which is often used in biosystematic or genecological classifications (Spooner et al. 2003).

It is likely that in the majority of cases, however, a taxonomic species concept will be employed for identifying target species and in practical terms, the Standard Flora(s)[11] of the country should be used for their identification and the nomenclature adopted therein should be followed unless it is possible to determine the correct name (if different) through other sources. For examples, lists of Standard Floras exist for Europe (Tutin et al. 1964–1988, 1993) and the Mediterranean region (Heywood 2003c) as well as Euro+Med PlantBase for the combined Euro-Mediterranean region.[12] In addition, regional treatments such as the *Flora Europaea* (Tutin et al. 1964–1988, 1993) and *Med-Checklist* (Greuter et al. 1984, 1986, 1989) are also available. Furthermore, a comprehensive taxonomic database and information system for the combined region is currently at an advanced state of preparation.[13] If a monographic treatment exists, this should be followed. A guide to the standard Floras of the world has been compiled by Frodin (2001).

While it is likely that in the case of known rare and endangered wild species few problems of identification will arise, for widespread species which occur in more than one country, care should be taken, as the same species may occur under different names in different Floras in the different countries and in the absence of any agreed nomenclature, specialist taxonomic advice should be sought. This is not a trivial issue, as incorrect identification could have serious consequences. Infraspecific variants such as subspecies, ecotypes or chemical races or individual populations rather than species may be the focus of attention (Yanchuk 1997). Increasingly, molecular methods are now being used to identify or characterize populations and plant genetic resources (Graner et al. 2004).

With certain exceptions, the patterns of distribution and abundance of species and their populations is poorly known, especially in the tropics (Gentry 1992). A recent review of 10 years of collecting and research on wild potatoes of the south-western USA concluded that finding and precisely documenting locations of living potato populations in the USA provides an essential platform for *in situ* research projects to identify which populations are most valuable, and which are in danger of extinction or are otherwise threatened (Bamberg et al. 2003).

Geographical Information Systems (GIS) are increasingly used in ecogeographical surveys of target species. GIS can be defined as a "database management system that can simultaneously handle data representing spatial objects and their attribute data" (Jones et al. 1997). Examples include FloraMap (see Box 8) which was developed at CIAT (Jones and Gladkov 1999; Jones et al. 2002) and DIVA-GIS (Hijmans et al. 2001). A recent review surveys the use of spatial analysis of georeferenced data generated during the various processes involved in the conservation and use of genetic resources (Guarino et al. 2002) and a list of references on spatial analysis and GIS applied to genetic resources management has been compiled by IPGRI.[14]

Box 8: FloraMap – A software tool for predicting the distribution of plants and other organisms in the wild

FloraMap is the product of more than 20 years of research at CIAT. The program makes precise, detailed maps that eliminate much of the guesswork from the slow, expensive process of finding and recovering wild species. It was developed for predicting the distribution of organisms in the wild when little is known of the physiology of the species concerned.

With its user-friendly software linked to agroclimatic and other databases, biodiversity specialists can create maps showing the most likely distribution of wild species in nature. Such maps are extremely valuable for tasks such as planning collection expeditions and deciding where to locate projects for *in situ* conservation.

Early versions of the program have been used successfully to guide plant collecting, to study the taxonomic and genetic variation of particular species, and to map the distribution of crop pests and their natural enemies. The pre-release version was thoroughly evaluated by a select panel of genetic resources experts.

An example of its use is in mapping the probability distribution for each of the 68 wild species of *Arachis* across their geographical range in the whole of central South America to help determine conservation status and assess conservation priorities.

Source: CIAT (http://www.floramap-ciat.org/) and Jarvis et al. (2003)

The maps obtained by GIS can be used for prospecting and for identifying *in situ* conservation sites. A PowerPoint presentation on *Mapping the distribution of five species of* Passiflora *in Andean countries* is available (see http://www.floramap-ciat.org/ing/poster-ppt.htm). GIS has also been used in developing medicinal plant conservation parks in India.

Amount and pattern of genetic diversity

A detailed understanding of the structure of genetic variation in a species and its populations is needed if a strategy that captures a desired level of genetic variation is to be adopted. The pattern and way that the variation is organized will determine the conservation strategy in terms of which and how many populations are selected for inclusion in which areas. It would be misleading, however, to

suggest that such information is likely to become available for a large number of species in the foreseeable future. As has been pointed out by Graudal et al. (1997),

> A total survey of the genetic variation of all species identi-fied for genetic resource conservation is neither practical nor economically possible. The study of genetic variation in adaptive traits requires in general that the species should be tested for long periods and at many sites. A survey based on the use of ecological data in combination with biochemi-cal markers and data from already established field trials is probably a possible way to approach the problem for many species within a realistic time span. Such surveys are, however, not possible for all species. For the time being, the required number and the optimal geographic distribution of the conservation stands must be decided by other means.

And as has been commented recently (Kjær and Graudel 2000):

> Considering the thousands of tropical tree species, we dare say that for more than 99.9% of the potentially important tree species we have nothing but qualified guesses about their genetic structure. One can say that the dilemma is that an urgent need for conservation is recognised without really knowing what to conserve!"

Moreover, it is often difficult to assess the significance of the genetic variation information uncovered. In a study of *Solanum* in the USA, the comment has been made that

> we are at a pitiable state of ignorance about which popula-tions are most valuable … geographic or environmental clues are usually not too helpful. Our recent unpublished data shows that the genetic distinction of some popula-tions of *S. verrucosum* in Mexico is very well associated with proximity to other potato species. The two species are generally thought to not be very likely introgressors, but what if, in fact, the distinctive *S. verrucosum* popula-tions are really so only because they have common bands from *S. hjertingii*? So … physical clues to the vigor of a population are not very reliable, especially in the south-west USA. Location and environmental distinctions are not very indicative either. So we test DNA variation directly, but that also can give misleading conclusions if

> we have inappropriately set the genetic pool of study to a set of populations (Bamberg [29 May 2003, in litt.]).

The methods currently available for assessing the genetic variation in a species include studying morphological and metric features in the field and a range of biochemical and molecular markers in the laboratory. For example, in the case of wild grapes in the USA, the characterization of inter- and intra-population genetic variation by morphological and molecular analyses was able to determine which populations represented significant genetic resources (Pavek et al. 2001).

Good accounts of the ways in which genetic diversity in species can be measured are included in texts on biodiversity (Mallet 1996) and conservation (Newbury and Ford-Lloyd 1997). Molecular markers (RAPD, RFLP, AFLP, SSR) may be used for rapid surveys of genetic variation within and between populations (Hamrick 1994), but as they do not identify the distribution of adaptive traits, their value in guiding genetic conservation is limited (Theilade et al. 2000). A recent review concluded that genetic markers should be used with care unless combined with observations on quantitative traits such as growth and survival (Kjær and Graudel 2000).

Ecogeographical variation and genecological zonation

It is possible to predict to some degree the patterns of genetic variation from ecogeographical variation. It is generally accepted that similarity in ecological conditions implies similarity of genetic constitution (Theilade et al. 2000). A comparison of a species' distribution with well-defined ecological zones may provide an indication of the genetic variation within the species. Although this assumption is often made, it is not true in some cases; for example in natural populations of wild lentils (*Lens* spp.) (Maxted and Ford-Lloyd 2003).

An area within which it is acceptable to assume that populations are genetically similar is sometimes termed a 'genecological zone' (Graudal et al. 1997; Theilade et al. 2000). Genecological zonation is considered a practical tool for the selection of populations to be conserved (Theilade et al. 2000) (Box 9). In the absence of genetic studies, ecogeographical studies have been used to outline genecological zones for conservation of genetic variation in Zambesi teak (*Baikiaea plurijuga*) (Theilade et al. 2001).

2.2 Planning, design and setting up *in situ* conservation areas

The planning and design of conservation areas is an enormously complex issue about which a great deal has been written (see Soulé

Box 9: Genecological zonation

Genecological zonation is a practical tool in the selection of populations to be conserved. It consists of identifying areas with uniform ecological conditions and subject to none or limited gene flow from surrounding areas. Genecological zonation may be prepared as one common system for several species or as a specific system for one species. It is usually based on existing data on natural vegetation, topography, climate and soil. If available, information from provenance trials and genetic marker studies may be used to test the validity and adjust the zonation.

Compared to ecogeographic zones, genecological zones differ in at least one aspect. An ecogeographic zone may be composed of a group of ecologically similar but geographically separate areas. If the geographic separation constitutes barriers to gene flow, such areas should most likely be considered as different genecological zones. The close relationship between ecogeographic zones and genecological zones implies that the latter can be used as a starting point to develop genecological zones for Zambezi teak in Zambia. However, geographically separate areas included in the same ecogeographic or agro-ecological zone have to be considered different genecological zones. Genecological zonation should ideally be specific for individual species, or at least for major groups of species. Different target species in a given gene resource conservation programme may diverge in several ways. They may vary in reproduction biology, they may react differently to environmental clines, and they may reflect entirely different life histories in terms of evolution, migration, hybridization events, or human utilization. Thus species with the same distribution may show entirely different patterns of genetic variation within that area. Species-specific zonation will require the same basic data as common zonation. For economic reasons, and due to lack of species-specific data, such specific systems will generally be limited to species of major economic importance.

Source: Theilade *et al*. (2000)

1986; Maxted et al. 1997a; Sutherland 2001; FAO/FLD/IPGRI 2004). The primary determinant of the design must be the purpose(s) for which they are being proposed (Meffe and Carroll 1994; Cavalcanti et al. 1999; Sutherland 2001). These include:

- Conservation of large and significant parts of functioning ecosystems
- Conservation of biodiversity
- Conservation of target species or groups of species
- Protection of landscape values and resources
- Use by local indigenous communities (including cultural and religious values, e.g. sacred groves)
- Research.

Design principles are of course closely linked to the question of the amount of genetic variability it is aimed to conserve, as discussed above. The main design principles for ecological conservation reserves have been summarized in a recent review by Neel and Cummings (2003b) and they are also discussed in many published management plans. Although genetic diversity plays a significant role in the persistence of species and populations, most reserve selection and design efforts focus on ecological characteristics, species distribution patterns or on community-level diversity (Neel and Cummings 2003b). It is widely assumed that the application of ecological approaches to species conservation will also allow the conservation of genetic diversity but it should be noted that according

to a recent study, selecting populations according to ecological reserve guidelines generally did not capture more genetic diversity than selecting populations at random (Neel and Cummings 2003b). What is important is that the number of populations included in the reserves and the number of sites needed to capture all alleles may be substantially greater than the five that are currently recommended.

Genetic reserves (gene management zones/units) are a particular kind of reserve where the purpose is the long-term conservation of genetic diversity in wild populations of target species (see Section 2.2.5). Principles of genetic reserve design have been proposed (Maxted et al. 1997a) but they do not necessarily apply in particular cases, such as the Monterey pine (*Pinus radiata*), where there are too many habitat restrictions to allow their application (Rogers 2002).

A basic restraint is that reserves (of whatever type) are usually small parts or fragments of larger, more continuous, ecosystem or landscape units with all the consequences that fragmentation brings with it, both for the ecosystem and the constituent species and their populations.

2.2.1 The role of protected areas in species conservation

The main approach to biodiversity conservation is the setting aside of as much land as possible as protected areas. As agreed at the Fourth World Congress on National Parks and Protected Areas in 1992 (IUCN 1994), a protected area is defined as

> An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means.

In the medium to long term, protected areas only work if they really are protected (WWF 2004). The establishment of protected area systems by countries is the major component of most national biodiversity conservation strategies. According to the 2003 *United Nations List of Protected Areas* (Chape et al. 2003), globally there are more than 100 000 protected areas, covering more than 11% of the earth's terrestrial surface.

Public protected areas are supplemented in some countries by extensive private reserves or other forms of protection. In the USA, for example, the Nature Conservancy currently owns and manages approximately 15 million acres of the national territory and globally protects more than 116 million acres of the most ecologically important places in the USA and 28 other countries. A recent review notes that,

> in Amazonia and elsewhere, rural people are defending far bigger areas of tropical forest from unfettered defor-estation and logging than are parks, thereby conserving the ecological services provided by these forests and the majority of their component plant and animal species (Schwartzman et al. 2000).

Many of the populations of the target species selected for *in situ* conservation will be found to grow in one or more protected areas and consequently benefit from some degree of protection (but see below). On the other hand, in some countries the extent to which natural ecosystems have been destroyed or modified makes it impossible to design a protected area system that will cover a large proportion of the native flora. In Central America, for example, in southern Honduras the few remaining areas of continuous forest cover which have attracted conservation interest to date are highly dispersed and cumulatively represent only a very small proportion of the landscape within which they lie. The bulk of the germplasm of native tree species lies in the dominant 'agroecosystem' which surrounds and separates the forest fragments (Barrance 1999).

Yet the protected area approach often seems to be predicated on the belief that there is "some pristine Garden-of-Eden like state for all, ecosystems, from which they have been disturbed by human actions" (Lawton 1999). Ecosystems are continually changing and so the question of deciding what to conserve, what state of an ecosystem to conserve, is not a scientific question since there is no benchmark original state against which to measure it. The establishment by countries of protected area systems, however scientific one would like the selection of sites to be—for example so as to cover the maximum complementarity of biodiversity in the minimum area—is ultimately a politically determined process moderated by aesthetic, ethical, social and other considerations. Moreover, we have tended to overlook the dynamics of the ecosystem, the landscape and, overarching all, global change. As has recently been observed:

> the current paradigm of conservation management set against a static environment must be replaced by an approach that incorporates the realization of the dy-namic character of the environment and of the species assemblages (Huntley 1999).

There is in fact a triple dynamic: (1) that of the environmental factors (climatic, edaphic, biotic) that affect the ecosystem itself and today involves a new factor—that of global change; (2) that of the

ecosystem itself which may show considerable change over short periods of time; and (3) that of the populations of the species that make up the ecosystem that may fluctuate considerably in size, distribution, genetics and composition even from one year to another (Box 10).

Box 10: Triple dynamics of *in situ* conservation

- Environmental factors
    - Climatic, edaphic, biotic
    - Global change (demographic, land-use and disturbance regime, climatic)
- Ecosystem dynamics
- Component species' dynamics

2.2.2 Selection of target areas and populations

Once a decision has been made on which species to target for *in situ* conservation and basic information on the geographical distribution of the target species and the target areas in which they occur has been obtained, a decision has to be made on which areas should be chosen for detailed survey and sampling. This in turn will allow a decision to be made on how many populations and which populations are to be conserved, their size and proportions, how much genetic and other diversity they should contain, as well as their geographical distribution (Hodgkin 1997). The choice of precise sites for conservation of target species is an essential component of a conservation strategy and involves setting goals, targets and scales (Balmford 2002). Apart from technical considerations, priority may well be given to sites that are protected areas or centres of plant diversity or are centres of crop origins or diversification. In practical terms, the size of the sites in which the target species occur in is also an important consideration, as this may well determine viable population size.

With certain exceptions mentioned below, selecting some populations and some individuals from these populations will have genetic and conservation consequences.

The number of individuals needed to maintain genetic diversity within populations has been the subject of considerable work and a great body of literature exists on topics such as population viability analysis (PVA), minimum viable population size (MVP), minimum effective population size, and in the case of metapopulations, the minimum viable metapopulation size (MVM) and minimum available suitable habitat (MASH) (Hanski et al. 1996). The minimum available habitat is a relatively new concept which has great potential in restoration, sampling for alleles or heterozygosity. It would not

be appropriate to try and review these concepts here but they are defined in Box 11 and references given to key literature.

Box 11: Population and metapopulation viability concepts

Population viability analysis (PVA) is the methodology of estimating the probability that a population of a specified size will persist for a specified length of time. A comprehensive analysis of the many environmental and demographic factors that affect survival of a (usually small) population (Morris and Doak 2002).
The **minimum viable population** (MVP), a concept introduced by (Soulé 1986) to population biology, is the smallest population size that will persist some specified length of time with a specified probability.
The **minimum amount of suitable habitat** (MASH) is the number (as a rule of thumb 15–20) of well-connected patches needed for the long-term survival of a metapopulation (Hanski et al. 1996; Hanski 1999).
The **minimum viable metapopulation size** (MVM) is an estimate of the minimum number of interacting local populations necessary for long-term survival of a metapopulation (Hanski et al. 1996).

In any case, some of these concepts are empirically still poorly documented and almost untested and many of the 'rules' or guidelines suggested are only applicable in certain circumstances. The realities of the field situation often determine how many and how much. Although the generally accepted paradigm of *in situ* conservation of species is the maintenance in their natural habitats of viable populations that will allow the species to continue to maintain itself and evolve, in practice other factors can come into play. For example, the widely employed concept of minimum viable population (MVP) implies that within a given habitat there is a threshold of a number of individuals below which survival or persistence of the population is not possible (Menges 1991). Unfortunately there is no agreed MVP for most species or even groups of species, as this will vary according to factors such as the biology, life form and ecogeographical pattern of the species.

The primary concern of *in situ* conservation is to ensure that the population sizes selected are large enough to allow the long-term maintenance and continuing evolution of the target populations and their genetic diversity. In the case of more widespread species, the aim is to capture sufficient of the species so as to include the most significant variation. However, for rare or endangered species, the number of populations and individuals is often so reduced that there are no options other than to try and save what is available rather than any theoretically recommended minimum viable population. Indeed, population reinforcement is often employed as an option to try and ensure the survival of the remnants of the species.

Examples of species with dramatically reduced population sizes are found particularly in island floras such as that of the island of Rodrigues in the Indian Ocean (see Box 12). Examples of critically

endangered tree species being conserved in protected areas, and the threats to which they are subjected, are given in a recent review of forest genetic resources (Thomson and Theilade 2001); these include *Hibiscadelphus woodii* of which fewer than ten individuals remain in the Napali Coast State Park, Kaui, Hawaii, USA, and *Maillardia pendula*, which is known only from a few individuals on Grand Terre, in the Aldabra Strict Nature Reserve, Seychelles.

Box 12: The devastated flora of the island of Rodrigues

Rodriques in the Indian Ocean was once covered with a rich and luxuriant evergreen forest, but as a result of three centuries of human habitation all the original plant communities have gone and the island is today mainly barren hillsides, dotted with trees or covered with a usually monotypic shrub or thicket of introduced species; only a few areas of degraded native forest exist. According to the *Plant Red Data Book for Rodrigues* (Strahm 1989), at least 18 endemic plant species have become extinct, and of the surviving 36–38 endemic flowering plants, 19–21 are Endangered, 7 Vulnerable and 8 Rare, with 9 of these endangered species reduced to fewer than 10 individuals and 3 known from only a single wild individual. If the combined floras of Rodrigues and the neighbouring island of Mauritius are considered, 120 taxa are known from either fewer than 20 individuals or just one or two populations, and 28 species are known from fewer than 10 individuals in the wild (Strahm 1996). Despite this apparently hopeless situation, the work of Strahm and others during the last 15–20 years, through a programme of careful management, fenced-in areas, artificial propagation of both plants and animals, replantation, weeding and promotion of conservation awareness, plus the designation of several areas as nature reserves, has enabled many of these species to be rescued from total extinction (Dulloo et al. 1996).

Sources: Strahm (1989, 1996); Heywood (1999), Dulloo et al. (1996)

Unlike Red List wild species, where the selection of sites is seldom an issue because of the restricted distribution of the species, in the case of species of economic importance which are subject to human exploitation to a greater or lesser degree, selection of sites is an important consideration so as to include populations which contain important genetic, chemical or phenotypic variants. Moreover, enhancement of the genetic variation in populations may also be recommended, and often a combination of both natural *in situ* conservation units and managed *in situ* conservation units will be desirable (Lefèvre et al. 2001).

In the case of species that are fragmented and form metapopulations, rather than small, isolated stands, as in the case of *Populus nigra* in Europe, it is recommended that *in situ* conservation activities should not consider local sites or conservation units in isolation but should instead consider them as part of the complete network of interlinked local populations (Lefèvre et al. 2001). In such cases networks of natural and managed *in situ* conservation units should be established, covering the most important genetic resources of the target species throughout its whole area of distribution.

The number of populations needed to conserve the genetic diversity of a species will depend on the way that diversity is partitioned among the different populations as well as on the conservation aim. For *ex situ* conservation the five-population standard proposed for rare species has been widely adopted. Brown and Briggs (1991) suggested that sampling five populations would be sufficient to have a 90–95% probability of capturing all common alleles for *ex situ* conservation (see also Falk 1991). For plant genetic resources, the Marshall and Brown strategy of 50 populations is generally used but there is less agreement on the number of populations needed to conserve genetic diversity that should be selected specifically for *in situ* conservation.

A recent review (Neel and Cummings 2003a) questions the effectiveness of current conservation targets and concludes that in the absence of genetic diversity data it is necessary to conserve 53–100% of sampled populations to meet the standard for common alleles.

Likewise, the so-called SLOSS ('single large or several small') debate over whether it is better to have one large reserve or several smaller ones is often inapplicable simply because of the lack of suitable habitats, as in the case of the Monterey pine, where large contiguous genetic reserves are not possible for some or most populations (Rogers 2002).

2.2.3 The hands-off approach

As we have seen, the potential number of candidate species for *in situ* conservation is vastly in excess of the resources or finances available for this purpose. The strategy of protecting enough habitat so as to ensure the presence of viable populations of all the native species of a region, as has been suggested, is a laudable aim but seldom possible, and is fraught with difficulties. For most wild species the best that we can hope for is their presence in some form of protected area where, provided the area itself is not under threat and subject to the dynamics of the system and the extent of human pressures, some degree of protection may be afforded. This approach has been widely advocated and is known as the 'hands-off' or 'benign neglect' approach. In the words of Holden et al. (1993), "…for species which are not under threat of destruction, the most sensible and effective policy is to leave the material to conserve itself, in the wild…". It is also known as 'passive' conservation (Maxted et al. 1997a) in that the presence of particular species in the protected area is coincidental and passive, and not the result of active conservation. This approach can be contrasted with 'active' conservation in which positive action promotes the sustainability of the target taxa and the maintenance

of the natural, semi-natural or artificial (e.g. agricultural) ecosystems which contain these taxa. This latter approach implies the need for associated habitat monitoring.

If examined in detail, such a hands-off strategy is somewhat problematic and may frequently lead to the loss of those very species or assemblages whose conservation one wishes to ensure. The most obvious problem is that, even if not ostensibly under threat, many—if not most—protected areas are not effectively managed: as noted below, protected areas are very diverse as is their degree of management. A report commissioned by the World Bank/World Wildlife Fund (WWF) Alliance and carried out by IUCN revealed that less than one quarter of declared national parks, wildlife refuges, and other protected areas in ten key forested countries were well managed, and many had no management at all. This means that only 1% of these areas is secure from serious threats such as human settlement, agriculture, logging, hunting, mining, pollution, war, and tourism, among other pressures. A further report entitled *How Effective are Protected Areas?* undertaken by WWF provides a preliminary analysis of the management effectiveness of nearly 200 forest protected areas in 34 countries using a tracking tool developed by the World Bank and the IUCN World Commission on Protected Areas (WWF 2004).

Even when good management plans are in place, protected areas may still be at risk, as in the case of the Coto Doñana Biosphere Reserve, Spain, which has been subjected to a series of major threats in recent years from chemical pollution, adjacent urbanization and agriculture. Another example is the Sierra de Manantlán Biosphere Reserve, where the main threats to the biodiversity of the area include illegal logging, excessive harvest of firewood for fuel, forest fires caused by agricultural burns especially during dry seasons, overgrazing and browsing in forests, and poaching mammals and bird species to sell in the black market (Lobeira 1999).

Thus, the focus shifts from the target species to the state of endangerment of the ecosystem, given that without securing the conservation of the habitat, there is little chance of maintaining the species they contain. The well-documented large-scale loss and fragmentation of forest and other habitats worldwide simply emphasizes the need to take action to extend the protected area systems as far as possible; and in deciding which additional areas to target, the conservation of genetic diversity of wild species should be given much greater prominence than hitherto (Holden et al. 1993).

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. Moreover, protected areas in some regions will be put at risk as a result of global change (Malcolm and Markham 2000; IUCN 2003) and as global change intensifies, more areas and many of the species they house will be placed at risk. The mere presence of target species in a protected area is therefore no guarantee of its conservation. Frequently some form of intervention or management of the populations of the target species is needed to ensure its successful maintenance and continued evolutionary development.

Of course, many species that will be selected as targets do not occur in areas that are currently protected and the chances of setting up areas for them, even without proper species-orientated management, are very limited.

It may be concluded that while there is no doubt that protected areas play a significant role in strategies aimed at protecting target species, the maintenance of viable populations of species in their natural surroundings, identified by the CBD as a fundamental requirement for the conservation of biological diversity (Preamble and Article 8(d)), is very unlikely to be achieved in the short or medium term for most species. The target proposed in the Global Plant Conservation Strategy of 60 per cent of the world's threatened species conserved *in situ* by 2010 will require a series of actions that are not currently being addressed by most Protected Area managers. For example, a recent WWF survey (WWF 2004) notes that very few protected areas report having comprehensive monitoring and management programmes, yet these are just two of the kinds of activities that will be needed if threatened species are to be effectively conserved within their boundaries.

Although maintaining species that cannot survive outside natural or near natural conditions and providing an 'ark' for threatened species are now amongst the roles perceived today for protected areas, most of them were not set up with conservation of particular species in mind (nor do their management plans cover this) and in many, if not most, cases no proper inventory has been made of the species that they contain so that the occurrence of species of economic importance in them is often not known. It should be noted, however, that for the network of Biosphere Reserves, considerable efforts are under way to undertake inventories of the species they contain.

Another concern is that the representation of target species in protected areas is usually inadequate. For example, in a study of wild peanut (groundnut) (*Arachis* spp.) in South America it was found that the current state of *in situ* conservation areas poorly represents the distribution of the species, with only 48 of the 2175 georeferenced observations being from National Parks (Jarvis et al. 2003).

On the other hand, some Protected Areas *are* being developed so as to preserve the resources they contain. An example is the series of Natural Protectorates designated in Egypt to be managed to meet the requirements for *in situ* conservation of particular groups of species (see http://www.eeaa.gov.eg/English/main/Protectorates.asp). These include the Ras Mohamed Protected Area and National Park and the Nabq Protected Area, Sinai, which contain the unique northernmost mangroves in the world (*Avicennia marina*); the Elomayed Natural Protected Area in Matrouh Governorate, which contains numerous species of economic importance including medicinal plants, fuel, food, landscaping and soil stabilization; and the Saint Catherine Protected Area in south Sinai which houses 22–28 species that exist there alone and contains about 44% of Egypt's endemic flora. The latter area has been the subject of an EU-sponsored development programme that involves not just the protection of target species of plants and animals but maintenance of the Bedouin way of life and livelihoods. It includes a pioneering Bedouin Support Program:

> the inclusion of Bedouin as paid members of the protectorate staff. Seventeen men were selected to be '*haras al biaa*' (literally, keepers of the environment), or as they have come to be known, community guards, who will work hand in hand with park rangers. The candidates must be local Bedouin, acceptable to the both the community and the protectorate, not in paid employment requiring their presence outside the area, and, if possible, literate to some degree.

The project aims at creating a programme administered according to the Bedouin management system. In terms of *in situ* conservation, the Protected Area Management Unit [PAMU] has started a programme for monitoring and conserving the endemic species and 37 plant enclosures are used both for the conservation and monitoring changes of representative and endangered plant species. These enclosures are all in the mountains around St. Catherine and a team of botanists regularly monitors them. The St Catherine's Protectorate is now also included in a UNDP/GEF project on medicinal plants.

Another example is the National Parks of the Canary Islands, where the Park Master Plans and Recovery Plans include management of natural resources, especially threatened species (Bañares et al. 1995).

The role of protected areas and forest reserves in the conservation *in situ* of forest genetic resources is considered in several publications

(Cossalter 1991; FAO/DFSC/IPGRI 2001). A number of Protected Areas are, however, specifically managed to conserve genetic resources of forest trees, such as the Riserva Integrale in the Parco delle Madonie in Sicily—the only known locality of the Sicilian fir (*Abies nebrodensis*), which is reduced to a population of fewer than 29 adults and 20 saplings, according to a recent survey (Morandini et al. 1994; Farjon and Page 1999). A small number of Protected Areas have been set up in south-east Asia specifically to conserve genetic resources of forest trees such as the Khong Chiam *In Situ* Gene Conservation Forest in north-east Thailand, which was established to protect an important population of *Pinus merkusii* as well as affording protection to a number of other forest trees.

Sometimes it will be possible to enhance the capacity of protected areas to protect target species, provided that the management plans for the areas permit this. In the case of forest genetic resources, the sequence of stages that may be followed so as to achieve this improved conservation capacity is given in a review by FAO, DFSC and IPGRI (Thomson and Theilade 2001).

It should also be noted that the surroundings of an area that is protected or proposed for protection may be just as important as the reserve itself (Perfecto and Vandermeer 2002). If it is proposed to locate an *in situ* management project for a target species in a protected area, it is important before going ahead to assess the overall management effectiveness of the area, given that, as we have seen, many protected areas are non-viable. A framework for the assessment of the effectiveness of protected areas has been prepared for the IUCN World Commission on Protected Areas (Hockings et al. 2000) and the Nature Conservancy (1996, 1999, 2001, 2004).

2.2.4 Types of protected area
A great diversity of different types of protected areas exists, depending on the conservation objectives, the degree of human activity permitted and the extent of involvement of stakeholders. Some of these are specifically tailored for the genetic conservation of target species. The major types of protected areas include those of the IUCN Protected Area management categories, biosphere reserves, genetic reserves, sacred groves, sanctuaries, reserves and other systems involving local communities and specific plant species.

IUCN Protected Areas management categories
The IUCN Commission on Protected Areas has provided a classification of protected areas into six categories of (see Box 13). They may be of interest for *in situ* conservation of target species.

For example, an example of *in situ* conservation in a Category V Protected Landscape is the Parque de la Papa in Peru, where seven Quechua communities are planning to establish a 'Potato Park'—a community-based, agrobiodiversity-focused conservation area, which will help conserve native plant genetic resources, including landraces and wild relatives of domesticated plants and animals. It will be managed through an integrated landscape conservation model following the *Management Guidelines for Category V Protected Areas* (Phillips 2002).

Box 13: The IUCN Protected Area management categories

Category Ia: *Strict nature reserve/wilderness protection 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: protected 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: protected 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: protected 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, aesthetic qualities or cultural significance.
Category IV: *Habitat/species management area: protected 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: protected 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 protection, maintenance and evolution of such an area.
Category VI: *Managed resource protected area: protected 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.

Source: IUCN (1994) (http://www.iucn.org/themes/wcpa/theme/categories/categories.htm)

It should be noted that in practice many, if not most, countries use different or additional categories and definitions. As species do not recognize political boundaries, some of them occur in more than one country. A growing number of Transboundary Conservation Areas (TBCA) has been created during the past 15 years and the World Commission on Protected Areas has issued a series of *Guidelines for Transboundary Protected Areas* (Sandwith et al. 2001).

Centres of Plant Diversity

The identification of 'hot spots' or other centres of diversity is one of the approaches to establishing priorities for biodiversity conservation. Other approaches have been proposed based on complementarity or taxonomic or phyletic uniqueness. Hotspots are areas that feature exceptional concentrations of species and are experiencing exceptional loss of habitat. Following an earlier analysis of plant hotspots (Myers 1988), a later study (Myers 1990) has shown that as many as 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the earth. This, it is suggested, "opens the way for a 'silver bullet' strategy on the part of conservation planners, focusing on these hotspots in proportion to their share of the world's species at risk". Moreover these later findings accord well with other priority-setting analyses—showing a 68% overlap with Birdlife's International Endemic Bird Areas, 82% with the IUCN/WWF Centres of Plant Diversity, and 92% with the most critical and endangered ecoregions of WWF/US's Global 200 List. The number of hotspots has been increased in a recent revision from 25 to 34 (Mittermeier et al. 2005).

The Centres of Plant Diversity initiative, developed by IUCN and WWF, identified 234 major sites of plant diversity of global importance, based on their species-richness (and the area had to contain a large number of endemic species); additionally other characteristics such as diversity of habitat types present and presence of genetic resources of plants useful to human activities were applied.

A major drawback of such approaches is that they can lead to the neglect of areas that are ecologically important or otherwise deserving of conservation but do not contain a sufficiently large number of species to be selected. It is to address such concerns that projects such as the European Important Plant Areas project sponsored by Planta Europa has been developed (Anderson 2002) (see Box 14).

However, the success of any of these methods depends on the practicalities of their implementation. In the case of the 234 sites recognized by the Centres of Plant Diversity, worldwide, fewer than one in four (21%) are legally protected in full and only about one-third (35%) have more than 50% of their area occurring within existing protected areas. Even more serious is the fact that a large proportion of the sites that are officially protected are not effectively managed. For example in the south-east Asia region, of the 41 sites in this region only three are considered to be reasonably safe or secure (Davis 1995).

Even where the protected area system is fairly good (as in Borneo), because of the large number of endemic species and high level of diversity of plants and animals, some species will be missed by the parks, occurring in small areas or fragments, or simply not

Box 14: Important plant areas in Europe

Despite all the botanical knowledge in Europe we still cannot say, on a pan-European basis, where the most important places for plants are. The recent publication of the second edition of *Important Bird Areas in Europe* highlights the need for a similar project for plants. To meet this challenge, a project called *The Important Plant Areas Project* is being undertaken by Planta Europa, a network of organizations working for plant conservation in Europe, to identify the very best sites for plants across the continent of Europe. The project aims to identify (and ultimately protect) a network of sites, on a biogeographical scale, that are critical for the long-term viability of naturally occurring wild plant populations. Country by country listings of the IPAs will be produced, using selection criteria which allow the inclusion of sites with few very rare plants as well as those with larger numbers of threatened species. Pilot projects to identify IPAs have been carried out in a number of countries: Belarus, Czech Republic, Greece, Slovak Republic, Slovenia, Sweden and the UK.

An account of the *Important Plant Areas of Turkey* has recently been published: 122 areas have been selected from 200 candidate sites, equivalent to 13% of Turkey's total land area and they house 3045 rare and threatened taxa.

Source: *Plant Life*, and Özhatay et al. (2003)

incorporated in the protected areas system. Most tropical moist forest reserves in the Indo-Pacific region are not large enough to conserve entire ecosystems and maintain minimum viable populations of many of the species they house. Maintaining species in small reserves will often require intensive management to deal with the demographic, genetic and environmental threats of extinction which face the small isolated populations that grow there. The dilemmas associated with managing numerous small populations will be the legacy conservationists' brief for the next generation unless these reserves are incorporated into larger conservation units.

2.2.5 Special types of protected area for genetic conservation
Biosphere reserves
The type of protected area known as a biosphere reserve can play a major role in ensuring the *in situ* conservation of target species (Arora and Paroda 1991). The now classic structure of a zonation system of a biosphere reserve consists of:
- a legally strictly constituted **core area**(s) devoted to long-term protection, according to the conservation objectives of the biosphere reserve, and of sufficient size to meet these objectives
- a **buffer zone**(s) clearly identified and surrounding or contiguous to the core area or areas, where only activities compatible with the conservation objectives can take place
- an outer **transition area** where sustainable resource management practices are promoted and developed, can be applied to accommodate different types and intensities of human use (Batisse 1982; Bridgewater 2002).

There are 459 biosphere reserves in 97 countries (as of November 2004).

The biosphere model may enhance sustainable management of native forests by traditional dwellers. Examples include the sustainable extraction of allspice, *chicle* and *xaté* in the Maya Biosphere Reserve in Guatemala, and the production of valuable oil from the *Argania spinosa* woodlands in the Arganeraie Biosphere Reserve in Morocco. The biosphere reserve status ensures the technical structure and scientific backing for sustainable harvesting and efficient marketing, and creates a moral obligation for local authorities to invest the income in the rural communities.

On the other hand, it has to be noted that although there are 459 biosphere reserves, it has often proved difficult in practice to implement the model, especially the use of the buffer zone (Wells and Brandon 1993; Tuxill and Nabhan 2001).

Gene conservation forests

Gene conservation forests are forested areas that have been reserved with the objective of protecting the genetic resources of local tree species. An example is the Khong Chiam *In Situ* Gene Conservation Forest (GCF), in Ubon Ratchathani Province, north-east Thailand, which 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).

Genetic reserves

Genetic reserves can be defined as dynamic units of conservation of the genetic variability of particular populations of species of actual or potential use, including crop wild relatives, medicinal and aromatic plants, timber and fruit trees, and other species of socio-economic importance. The term 'gene conservation area' has been applied to areas that have been designated for conservation of the genetic variation found in populations of target species in natural or plantation forests (Graudal et al. 1999).

A gene management zone (GMZ) is a type of genetic reserve or long-term monitoring site that contains one or more diverse populations of target species designated for *in situ* conservation (Tan and Tan 2002). They were developed for a major GEF-supported project on *in situ* conservation of genetic diversity in wild species in Turkey. GMZs should consist of core and buffer zones and their selection criteria are:
- target species must be the primary consideration
- they should capture as much genetic variation as possible
- sites to be considered as GMZs should be accessible, sustainable and suitable for efficient population management

- their size and the number of target species should be determined in terms of evolutionary potential, genetic integrity and protection values
- they can be established in either natural or semi-natural environments.

Another example of the use of gene management zones is the GEF project on *in situ* conservation of landraces and their wild relatives in Vietnam. According to the project

> the aim of a GMZ is to maintain the natural evolution of plants for future generations. It is an *in situ* conservation and long-term monitoring site that contains one or more diverse populations of target species to be conserved. Each GMZ has specific management requirements adapted to different species and environmental conditions to ensure natural evolutionary processes, hence serving as an open laboratory, permitting continued evolution and conservation of the component species. A series of GMZs is often required to represent the ecogeographic ranges needed for the selected species and populations in order to support sufficient environmental heterogeneity. GMZs should be easily accessible, relatively isolated from exotic gene flow and include a wide range of biological diversity and of the genetic diversity of the target species. Important elements for determining the size include:
>
> - The current threats to the genetic resource: if there are major threats a larger area may be needed.
> - How the species reproduce: the area has to be large enough to support species reproduction.
> - What is known about the ability of the selected species to maintain its biological sustainability (Gene Management Zones. Available from: http://www.undp.org. vn/projects/vie01g35/gmz.htm.)

Gene parks or sanctuaries

Gene Parks or Sanctuaries are parks or reserves established specifically to conserve material of wild relatives of certain crops. The first gene sanctuary established was that set up in the Garo Hills, north-east India, to conserve populations of wild orange, *Citrus indica* (Gadgil and Vartak 1974; Singh 1981)*.*

Genetic resources management units

Genetic resources management units (GRMUs), a concept introduced

some 20 years ago (Riggs 1982), have been defined as "any designated forest area that meets minimum genetic management objectives".

Sacred groves and forests

An important type of traditional nature conservation, practised as part of the religion-based conservation ethos of ancient peoples in many parts of the world, is the protection of patches of forest as sacred groves or forests and of particular tree species as sacred trees (Saraswati 1998). It is characteristic of such traditional ecosystem approaches that they require a belief system which includes a number of prescriptions, such as taboos, that regulate human behaviour and lead to restrained resource use (Colding and Folke 1997; Gadgil 1998). An annotated bibliography of ethnoforestry with a detailed table of different kinds of indigenous forest management has been issued for comment (Narayan Pandey and Kumar 2000).

An international workshop on The Importance of Sacred Natural Sites for Biodiversity Conservation was held in Kunming and Xishuangbanna Biosphere Reserve (China) in February 2003 (see http://www.unesco.org/mab/docs/WorkshopReport.pdf). Participants decided to create an International Network on Sacred Natural Sites for Biodiversity Conservation with the scientific objective of better understanding the mechanisms of culture-based environmental conservation, using specific case studies and with the policy-relevant objective of preparing policy guidelines on the recognition and management of sacred natural sites based on the voluntary cooperation of local communities.

The Mahafaly and Tandroy communities of southern Madagascar, the local authorities and the Malagasy government are applying community-based sustainable management to sacred forests so as to conserve the biodiversity they contain, including medicinal plants, as an initiative of WWF (2003a). Another example is the Emberà, a group living in the forests on the Colombia–Venezuela border, who reserve large areas of old-growth forest in upper watersheds and along the crests of mountain chains which they regard as protected by spirits; the areas that benefit from this protection are remarkably similar to those typically set aside as protected areas (Harp 1994).

In Morocco, the sacred forests (*bois sacrés* or *forêts maraboutiques*) that are found around the *Qubbas* (holy places where the Marabuts are buried) house remnants of natural vegetation, including some important species. Although not legally conserved, they are protected from clearing by the local people on religious grounds (Deil 2000).

Extractive reserves

The term extractive reserve is applied to reserves where defined groups of local people are given exclusive rights to exploit and extract non-timber forest products, provided they adopt sustainable forestry practices and do not use clear-cutting except on a small scale for growing their own crops. Such reserves have been established in various parts of Meso-America, Kalimantan and in several states in Brazil. Best known are those in the Brazilian Amazon, which depend largely on rubber latex (*Hevea brasiliensis*) and Brazil nuts (*Berthelottia excelsa*). The effectiveness of extractive reserves as types of community-based conservation is debatable (Salafsky et al. 1993; Moegenberg and Levey 2002).

Other sanctuaries and conservation areas

There are also other sanctuaries and conservation areas named after the target plants they afford protection to. For example, areas rich in orchid species have been given protection as 'orchid sanctuaries' in various states of India such as Arunachal Pradesh, West Bengal, Sikkim, and Mizoram, and more are planned. Some of them are sacred forests and other are associated with orchid research centres and nurseries. Over 20 species of wild orchids are recorded in the Sessa Orchid Sanctuary, which extends over 100 km² in the Dafla Hills of Arunachal Pradesh.

The term 'Medicinal Plant Conservation Area' has been applied to the network of 54 *in situ* reserves, each about 200 ha, which captures inter- and intra-specific medicinal plant diversity and which has been set up across different forest types and altitude zones in five states of peninsular India. Five such areas have also been established in Sri Lanka.

The *in situ* conservation of crop/weed complexes that have developed in centres of origin or diversity of crop plants present special problems (Pickersgill 1981; Hammer 1991; Hammer et al. 1997). The weeds can be wild relatives of the crops with which they are associated and therefore candidates for conservation. Examples of crop/weed complexes are found in the Fertile Crescent and other areas in south-west Asia (*Hordeum*, *Triticum*/*Aegilops*) and in the Sierra de Manantlán (*Zea diploperennis*/*Z. mays*) (see Box 15). Situations where the cultivation of landraces' wild relatives co-occur may require a combination of both on-farm conservation and *in situ* protection, as in the case of rye and its wild relative (*Secale strictum*) in south Italy (Hammer and Perrino 1995).

Gene microreserves

Microreserves are small-scale protected areas, usually less than one or two hectares, with a high concentration of endemic, rare or

Box 15: Sierra de Manantlán and maize and its wild relatives

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

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

threatened species (Laguna et al. 1998; Laguna Lumbreras 2001b; Serra et al. 2004). They may be considered as an option in areas where the vegetation has been subject to fragmentation and the species populations they contain are similarly reduced or fragmented. Because of the small area they occupy and their frequent simplicity in legal and management terms, it may be possible for them to be established in great number and to complement the larger, more conventional, protected areas. On the other hand their long-term viability must remain in question, especially in the light of global change. The concept of microreserves was developed in the autonomous community of Valencia, Spain, where a large network of over 150 such areas has been created since 1991, and it is expected that this number will soon increase to about 250, covering the entire threatened Valencian flora (Laguna Lumbreras 2001b).

Participatory reserves (with local communities)

Increasingly, local communities are becoming involved in the planning and management of various types of protected area. The concept of People's Protected Area (PPA) (Sharma 2003) has developed in India: its aim is to address the core concerns of food security, health provision and assured employment through the adoption of an integrated ecosystem approach. In the state of Chattisgarh, 32 PPAs have been established as models of conservation through use. They involve community-based participatory management, resource assessment methodologies, non-destructive harvesting, biodiversity prospecting and partnerships, equitable benefit sharing, and enabling policy and legal framework.

Private area and community lands management

In the high valleys of the Himalayas, members of local communities are being encouraged to protect medicinal and aromatic plants in their private/community lands known as *dhangs*, which basically

serve as the areas for grazing and for collecting fodder. Women's groups in different villages are also being motivated to adopt neighbouring natural sites as *in situ* conservation areas for protecting them from excessive grazing and unscientific harvesting.

2.2.6 Conservation outside protected areas

Given that most species, and consequently many potential target species, occur in areas that do not currently receive any form of legal protection, i.e. outside public or private protected areas, consideration needs to be given to the policy options available for such cases, whether for strict *in situ* species conservation or for an untargeted or 'hands-off' approach. The maintenance of genetic resources outside protected areas has been carried out traditionally in forestry, albeit not consistently, nor in all cases consciously carried out as an act of conservation (C. Palmberg-Lerche, personal communication 2003).

According to the USDA, approximately 90% of global forest area lies outside of public protected areas and a World Bank study (Putz et al. 2000) notes that while existing parks and protected areas are the cornerstones of biodiversity conservation, they are insufficient on their own to assure the continued existence of a vast proportion of tropical forest biodiversity. Promoting more biodiversity-sensitive management of ecosystems outside protected areas, especially of those known to contain target species, needs to be given high priority. This is especially applicable to forests that are already subject to some form of management such as for timber production. Indeed Poore et al. (1999) suggest that there should be no forests without management and the World Bank study cited above suggests that priority must be given to ensuring that the greatest possible amount of biodiversity is conserved outside protected areas by changing logging or timber harvest patterns. Some of the key issues involved are discussed in an FAO review of conservation of forest genetic resources and tropical forest management, including strategies for *in situ* conservation in production forests (FAO 1993; see also Kemp 1992).

The conservation and management of plant resources outside protected areas is a major challenge and involves close collaboration with the relevant stakeholders. The USDA report also notes that

> Private landowners, including local communities, have often had little if any incentive to collaborate in conservation strategies because governmental 'command and control' conservation policies have not provided incentives for conservation

and suggests that private landowners will be more likely to employ conservation management practices if they are likely to benefit from implementing them.

The relevance of areas not under protection to the *in situ* conservation of target species resides in two aspects: on the one hand there is the need to address what actions may be taken to ensure that such areas, whether on public or private lands, do in fact afford a sufficient degree of protection to the selected species so as to ensure maintenance of viable populations. In a sense, in that such actions will amount to some form or degree of protection for the species concerned, the concept of conservation outside protected areas in such cases ceases to be valid. On the other hand, actions may be proposed so that many areas which are not protected as such and that are found to house target species will be maintained in such a way as to ensure their protection at the ecosystem or landscape level both by positive management policies and by the prevention of certain forms of activity. This may be done in such a way as to both involve the local community in their management, and to preserve their livelihoods and their rights to benefit from the biodiversity of these areas. Such a community-based management approach is based on the premise that renewable natural resources, such as woodlands, grazing and wildlife, can only be conserved if their management is firmly in the hands of those whose lives depend upon their continued availability.

Increasing attention is being paid to the role of communal lands in the conservation and sustainable use of biodiversity such as the CAMPFIRE (Communal Areas Management Programme for Indigenous Resources) programme in Zimbabwe mentioned later (see Section 3.9). Another important example is the Wildlife Integration for Livelihood Diversification Project (WILD) in Namibia and the application of Community-Based Natural Resource Management (CBNRM) in communal areas conservancies in the Kuneni and Caprivi regions of the country over the past 10 or so years (see Box 16; Long 2004). These communal area conservancies have contributed to the protection of wildlife species, some of which have actually increased in numbers, and to improved wildlife management practices. Although the focus at the species level has been on wildlife (i.e. animal) species, such approaches are also applicable to the forestry sector and by extension to other target plant species. Similar community-based management practices are also applied in other African countries such as Malawi, Mali, Uganda and Swaziland, and in Asia and tropical America and the Caribbean.[15] They are not without their problems or drawbacks, and in the case of Namibia run the risk of outstripping the capacity of both government and NGOs to provide the necessary support.

Box 16: Namibia: Wildlife Management, Utilization and Tourism in Communal Areas Policy of 1995 (Ministry of Environment and Tourism)

The objectives of the policy are:
- To establish ... an economically-based system for the management and utilization of wildlife and other renewable living resources on communal land so that rural communities can:
  - participate on a partnership basis with the Ministry of Environment and Tourism and other Ministries in the management of, and benefits from, natural resources
  - benefit from rural development based on wildlife, tourism and other NRM
  - improve the conservation of natural resources by wise and sustainable resource management and the protection of biodiversity.
- To redress the past discriminatory policies and practices which gave substantial rights over wildlife to commercial farmers, but which ignored communal farmers.
- To amend the Nature Conservation Ordinance of 1975 so that the same principles that govern rights to wildlife utilization on commercial land are extended to communal land.
- To allow rural communities on state land to undertake tourism ventures, and to enter into cooperative agreements with commercial tourism organizations to develop tourism activities on state land.

The policy states:
- The right to utilize and benefit from wildlife on communal land should be devolved to a rural community that forms a conservancy in terms of the Ministry's policy on conservancies.
- Each conservancy should have the right to utilize wildlife within the bounds of the conservancy to the benefit of the community. Once a quota for each available species has been set, the conservancy members may decide how these animals may be utilized. They may decide to allow hunting by members of the conservancy, culling of game for meat, the sale of animals for trophy hunting, or the live sale of game.

Source: Long (2004)

Other examples of approaches that contribute to biodiversity conservation outside protected areas are the use of easements—legal agreements that allow landowners to voluntarily restrict or limit the kinds of development that may occur on their land. Such agreements are legally binding and can afford permanent protection. They can be used to conserve land that houses biologically significant values, and at the same time the landowner can continue to own and use the property. An example is the Grassland Reserve Program administered by the USDA Natural Resources Conservation Service (NRCS) and USDA Farm Service Agency (FSA) in cooperation with the USDA Forest Service.[16] It is a voluntary programme that helps landowners and operators restore and protect grassland, including rangeland and pastureland, and certain other lands, while maintaining the areas as grazing lands. The programme emphasizes support for grazing operations, plant and animal biodiversity, and grassland and land containing shrubs and forbs under the greatest threat of conversion. The Nature Conservancy (TNC) and the National Cattlemen's Beef Association (NCBA) have created a programme with the same name to conserve native grasslands in the USA.

Another approach, albeit one that has sparked a great deal of controversy, which has been developed in the USA is the so-called

system of Habitat Conservation Planning (HCP). This was introduced under the Endangered Species Act to address the issue of landowners using their land for legitimate purposes in such a way that might unintentionally endanger a listed species (Nelson 1999). It allows private landowners who undertake development, logging, or other actions that negatively affect land known to house listed species to destroy some endangered species habitat through a permit system. They are required to design and implement a plan that will minimize and mitigate harm to the impacted species during the proposed project. HCP has been criticized for not providing adequate protection measures for many of the listed species they cover (see the review by Kareiva et al. 1999). As of 15 July 2003, 425 Habitat Conservation Plans have been approved, covering approximately 38 million acres and protecting more than 532 species.

In San Diego County, California, the Habitat Conservation Plan was taken a stage further because of the large number of sensitive and endangered species occurring there. This led to the development of the concept of a Multiple Species Conservation Program Plan to address a large number of species at the same time. It assessed 85 species of plants and animals that were already listed as rare and endangered, and involved the creation of a 69 500-ha preserve as the centrepiece to secure key areas of natural habitat (see http://www. dfg.ca.gov/nccp/mscp/mscp_faqs.htm). Note should be taken, however, of the findings of the review of US Endangered Species Act recovery plans, that putting species together in recovery plans may be better justified on the basis of the similarity of the threats to which they are exposed rather than on their taxonomic relatedness or geographical proximity (Clark et al. 2002).

The majority of wild species have of course managed to survive, at least up till now, outside protected areas, but the chances of their survival in the longer term in the face of global change and worldwide habitat loss and fragmentation will be enhanced if the areas in which they occur are managed or set aside for some non-conservation purpose or reason that does not cause harm to the ecosystem (Primack 1993). Examples include land that is set aside for military use, airport protection zones, and grounds of public and private institutions such as hospitals, universities and commercial companies. Some of the side-effects of war may also be beneficial for biodiversity, such as demilitarized zones or 'no-man's lands', some of which can be very substantial, such as the demilitarized zone of the Korean peninsula which provides a biodiversity sanctuary for many native species, including some that are elsewhere rare (McNeely 2003). Such survival is of course subject to the prevailing dynamics of the system and may not result in a sufficiently broad

or representative sample of the species being maintained. In a broad biodiversity conservation context, it is, however, valuable but cannot be regarded as full *in situ* species conservation.

Another issue that needs to be addressed is the effect, both direct and indirect, on protected areas and their component biodiversity, which management regimes and practices that are applied in areas outside them will have. Examples are pest management, fire and grazing regimes, and soil and water management. Although such considerations may seem somewhat divorced from *in situ* conservation of species, they could be critical in some cases if what happens outside protected areas adversely affects the health and functioning of the ecosystems within the protected areas in which target species occur; it may even impact upon the populations of the species themselves. For this reason, it is important to adopt a broad landscape or bioregional approach to *in situ* conservation and sustainable use, whereby all kinds of land use within the landscape matrix are taken into account. In other words, threats to the maintenance of protected areas and the species they house may come from outside their immediate territory.

Another reason to adopt a broad territorial perspective is highlighted by Miller (1996) in a review of the bioregional approach:

> Since the landscape is fragmented and much wildland has been converted to other use, the boundaries and coverage of some protected areas may not conform to the size and shape of the ecosystems that are to be maintained and managed ... Moreover, in landscapes where protected areas have not been established, key genetic, taxonomic, and ecological elements of diversity that once may have been found in wildlands, or extensive farm or forest operations, are now relegated to isolated patches in intensively managed farms, pastures, timber-harvesting sites, and suburban, urban, and industrial areas.

This problem is especially acute on islands, where no large areas of land are available to set aside as reserves.

2.3 Management and monitoring of *in situ* conservation areas and populations

2.3.1 Species and site management plans
Once conservation areas have been established, the populations of the target species within the protected areas or outside protected

areas must be managed and monitored so as to ensure the long-term sustainability of the populations. This involves the development of species management plans and site management plans. *In situ* conservation is a long-term objective and all conservation areas should have a management plan, their main purpose being to ensure that there is continuity and stability of management of the reserve. A management plan is a planning tool that contains a set of prescriptions and interventions to meet the objectives of the reserve area. The process of developing management plans and their content has been described by several authors. Hirons et al. (1995) provide a detailed description of the prescriptions to be included in to a management plan for an ecological reserve. Maxted et al. (1997a) describes how to prepare a management plan for a genetic reserve. The Nature Conservancy Council (1988) provides a guide for preparing management plans for national nature reserves. Thomson et al. (2001) also describe the formulation of a management for forest genetic resources.

The level of complexity of a management plan will depend on a case-by-case basis. However any management plan should contain, as a minimum, a fair description of the conservation site, an evaluation and the conservation objective of the site and the prescriptions of interventions planned, as well as location map and other miscellaneous useful information. Box 17 provides the elements of a minimum management plan. Management plans should not be construed as rigid frameworks for action but rather should be flexible to adapt to changes at the site; feedback mechanisms should be incorporated in the plan. They should also include control mechanisms that allow revision of the Plan for the short, medium and longer terms, and for this purpose a monitoring system is required. Maxted et al. (1997e) describe in detail the monitoring regime required for a genetic reserve and provide a schematic model (Fig. 1).

2.3.2 Biodiversity indicators

Increasingly, the use of targets is being employed to assess the success or failure of interventions in biodiversity conservation. Targets necessitate the use of indicators whose function is generally to simplify in order to make complex phenomena quantifiable, so that information can be communicated. Biodiversity indicators support communication about the state and trends of biodiversity and of the causal relationships for changes (Delbaere 2002). As the CBD notes, "Indicators of status, trends and causes of biodiversity loss as well as of the effectiveness of response options are needed to inform decision makers and civil society whether these targets

Box 17: Elements of a minimum management plan

STAGE 1   Description
• Location (name, status, area, grid ref, etc.)
• Tenure (type of holding, agreements, legislation, right of access)
STAGE 2   Evaluation and objectives
• Site description (habitat type, geology, ecology, flora and fauna)
• Operations likely to damage the special interest (fragility and impact)
• Evaluation (size, diversity, naturalness, rarity, recorded history, potential, intrinsic appeal etc.)
• Identification of important features
• Ideal management objectives
• Rationale
• Identification of operational objectives, selection of management options and outline prescription
STAGE 3   Prescription
• Project register and description (records, task, management, administration)
• Project groups (according to objectives of the MP)
• Work programme/Annual work plan
    • Maps
    • Owners(s)/occupiers
    • Habitat: existing state
    • Habitat: desired state
    • Management required

Source: Nature Conservancy Council (1988)

are being met" (for more information about biodiversity indicators, see Box 18 and http://www.biodiv.org/programmes/cross-cutting/indicators/default.asp). However, while some progress has been made in developing indicators for certain sectors such as forestry,[17] the situation for indicators of biological diversity is less advanced, partly due to the notorious difficulty of measuring biodiversity in a precise and consistent manner, partly to scientific uncertainty as a result of poor understanding of complex ecosystem processes and functions, and the limited availability of suitable time-series data.

Box 18: Biodiversity indicators defined

Biodiversity indicators are information tools, summarizing data on complex environmental issues to indicate the overall status and trends of biodiversity. They can be used to assess national performance and to signal key issues to be addressed through policy interventions and other actions. The development of indicators is, therefore, important for monitoring the status and trends of biological diversity and, in turn, feeding back information on ways to continually improve the effectiveness of biodiversity management programmes.

Source: CBD (http://www.biodiv.org/programmes/cross-cutting/indicators/default.asp)

Until recently, about the only widely reported biodiversity indicators were lists of endangered species, statistics on the amount

Monitoring objectives

Monitoring regime

Which taxa to monitor ?

Where to sample?

How to assess abundance?

Review monitoring methodology

How to sample?

How much to sample?

Data accumulation and statistical analysis

Feedback to reserve management plan and prescription
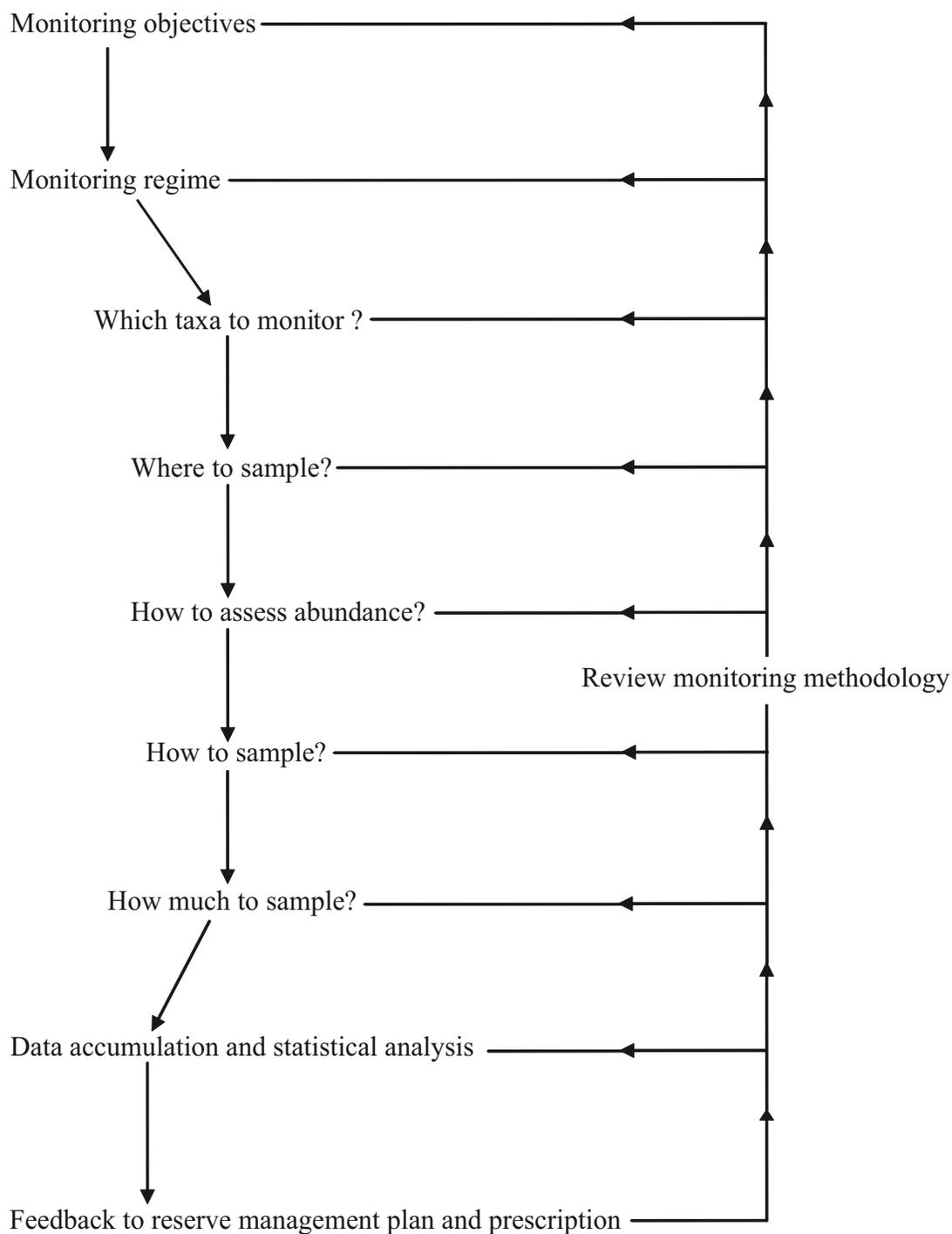
Figure 1. Schematic model of the monitoring procedures in a genetic reserve (Source: Maxted et al. (1997). With kind permission of Springer Science and Business Media).

of 'wilderness' areas left and the percentage of land afforded some degree of protection (Hammond et al. 1995). On the other hand, an enormous variety of indicators has been developed in the last few years to assess aspects of biodiversity at the national, international or global scale—indeed 655 biodiversity-related indicators are listed in a report for the European Environment Agency although only a limited number of them are actually used on a regular basis (EEA 2003). An important review of recent approaches to biodiversity indicators is given by Hansson (2001), who distinguishes between policy indicators and those used for management and monitoring. He also discusses single-species vs community indicators, statistical indicators and functional indicators, and refers to the suggestion by Noss (1990) that hierarchy theory should be applied in the selection of indicators. It is evident that to address the whole of biodiversity and its composition, structure and function, many different indicators need to be applied at the different levels of organization but, as Delbaere (2002) notes, "Despite the efforts that have been made to develop sound indicator sets and monitoring schemes, there is still a big discrepancy between the scientific development and policy requirements."

The CBD has developed a list of indicators covering a wide range of topics, many of which are relevant to *in situ* species conservation (see Box 19), although a special subset may need to be developed to address particular issues that are specific to this area.

2.3.3 Recovery programmes

One of the aims of many *in situ* species-orientated conservation programmes is the recovery of species, i.e. to achieve such a level of recuperation of the species concerned that their populations become secure and self-maintaining within their natural habitats and no longer in need of intervention or protection. Recovery of species (and the ecosystems in which they grow) is the ultimate goal of the US Endangered Species Act (see http://endangered.fws.gov/).

Recovery plans are concerned essentially with *in situ* conservation of threatened species. They are often complex documents: some idea of their diversity may be obtained from perusal of the list of species or populations with recovery plans of the US Fish and Wildlife Service, which is the largest system of its kind globally (see https://ecos.fws.gov/tess_public/TESSWebpageRecovery?sort=1#Q).

Recovery plans may cover single or multiple species: an outstanding example of the latter is the South Florida Multi-species Recovery Plan which covers 24 animal and 35 plant species (US Fish and Wildlife Service 1999). The recovery criteria for each of the listed species in this plan

consist of several or all of the following short, narrative statements: (1) a statement that requires amelioration of threats to the species or its habitat, (2) a statement of the probability of persistence for the species (that is, 95 percent probability of persisting for 100 years), (3) the rate of increase to measure over a specific period of time, (4) the minimum number of populations (or subpopulations) to establish, (5) a minimum population size, and (6) a habitat condition over a particular geographic area (or areas).

The Recovery actions at the species level fall into the following broad categories: (1) determining the distribution of the species in South Florida; (2) protecting and enhancing populations; (3) conducting research on biology/ecology; (4) monitoring populations; and (5) informing and involving stakeholders and the general public in the recovery process.

Box 19: Biodiversity indicators proposed by the CBD

- Status and trends of the components of biological diversity
  - Trends in extent of selected biomes, ecosystems and habitats
  - Trends in abundance and distribution of selected species
  - Coverage of protected areas
  - Change in status of threatened species
  - Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socio-economic importance
- Sustainable use
  - Area of forest, agricultural and aquaculture ecosystems under sustainable management
  - Proportion of products derived from sustainable sources
- Threats to biodiversity
  - Nitrogen deposition
  - Number and costs of invasive alien species
- Ecosystem integrity and ecosystem goods and services
  - Marine trophic index
  - Water quality in aquatic ecosystems
  - Application of the trophic index to freshwater and possibly other ecosystems
  - Connectivity/fragmentation of ecosystems
  - Incidence of human-induced ecosystem failure and cost
  - Health and well-being of communities who depend directly on local ecosystem goods and services
  - Biodiversity used in food and medicine
- Status of traditional knowledge, innovations and practices
  - Status and trends of linguistic diversity and numbers of speakers of indigenous languages
  - Other indicators of the status and indigenous and traditional knowledge
- Status of access and benefit-sharing
  - Indicator on the status of access and benefit-sharing
- Status of resource transfers
  - Official development assistance provided in support of the Convention
  - Indicator for technology transfer

Source: UNEP/CBD/SBSTTA/10/INF/7

Another significant multi-species recovery programme is the Recovery Plan for Oahu Plants which covers 66 plant taxa listed as endangered, all of which are endemic to the eight main Hawaiian islands (US Fish and Wildlife Service 1998).

A variety of procedures is used to recover listed species such as:

- protective measures to prevent extinction or further decline
- reintroduction or reinforcement of populations
- consultation to avoid adverse impacts of other activities
- habitat acquisition and restoration
- other on-the-ground activities for managing and monitoring endangered and threatened species, such as restoration of the ecological community in which the target species occurs; fencing to prevent damage by stock, vehicles, etc; rabbit control; weed control; assessing role of fire in e.g. regeneration, disease prevention; labelling, marking populations to advise the public.

Under the Australian revised recovery guidelines for nationally listed threatened species and ecological communities (Environment Australia 2002), the requirements of a recovery plan are that it:

- must provide for the research and management actions necessary to stop the decline, and support the recovery, of the listed threatened species or listed threatened ecological community concerned so that its chances of long-term survival in nature are maximized;
- will state what must be done to stop the decline, and support the recovery and survival, of the species or ecological community;
- must specify the actions needed to achieve the objectives;
- will state what must be done to stop the decline, and support the recovery and survival, of the species or ecological community, including action to manage and reduce threatening processes;
- must identify the habitats that are critical to the survival of the species or community concerned and the actions needed to protect those habitats;
- will state what must be done to stop the decline, and support the recovery and survival, of the species or ecological community, including action to protect and restore habitat;
- must identify any populations of the species or community concerned that are under particular pressure of survival and the actions needed to protect those populations;
- will state what must be done to stop the decline of, and support the recovery and survival of, the species or ecological community, including action to protect important populations.

Under the US Endangered Species Act, if recovery measures are deemed successful, species may be taken off the list but the

Service is required to monitor the populations for a minimum of
5 years to confirm that they are effectively self-maintaining. Two
plants have been delisted as a result of successful recovery, while
six have been removed as a result of taxonomic revision or other
new information.

Recovery plans have mainly been prepared for endangered wild
plant species and seldom applied so far to species of economic
value such as forest trees. However, some of the endangered
species which are the subject of recovery plans are of economic
importance, although this fact is not necessarily highlighted in the
documentation. Certainly the many published recovery plans are a
major source of information and contain pointers for the preparation
of management plans for target species of economic importance.
On the other hand, recovery plans by definition deal with species
which possess few remaining populations and usually little natural
habitat so that opportunities for genetic conservation are limited
(Rogers 2002).

2.3.4 Involving local and other relevant stakeholders

It is now widely accepted that local people need to share in the
benefits that can be derived from protected areas and this is best
achieved through their playing a role in the management and
protection of such areas. This is reflected in WWF's global work
on protected areas which has as its theme 'Partnerships for People
and Nature' (WWF 2003b) and in its participation in the People and
Plants Initiative along with UNESCO-MAB and the Royal Botanic
Gardens, Kew.

As noted in one of the regional preparatory reports for the
Leipzig Conference

> one of the shortcomings of the development of policies
> on plant resources … has been that formulation and
> implementation has largely excluded the local people …
> leading to lack of conservation responsibilities at com-
> munity level (FAO 1995)

and to negative attitudes emanating from feelings of alienation
of people from their resources. The involvement NGOs and
local communities adjacent to protected areas or those that
use these areas with *in situ* conservation is growing, and it is
becoming clear that full participation of the local people is just as
important as the development of practical strategies for integrated
resource conservation and its sustainable utilization by the primary
custodians. In addition, the involvement of local communities for

in situ conservation of species located outside protected areas is of even more crucial importance.

A very considerable literature on participatory management now exists and a Participatory Management Clearinghouse (PMC) was established in 2000 jointly by IUCN, WWF and the Bureau of the Convention on Wetlands (Ramsar). It is a global initiative that pools information regarding participatory management around the world, gathers grey literature as well as publications produced in Africa, Asia, Latin America and other regions so as to facilitate a free exchange of experiences and perspectives from local practice to global debates, through making relevant research reports and documents available beyond academia or the NGOs.

A review of the effectiveness of wildlife community-based management in terms of social, political, economic and environmental factors is given by Roe et al. (2000) and the role of people participation in protected area management is provided by Pimbert and Pretty (1995). An example of a co-management strategy is given by Metcalfe (1995) for Zimbabwe, illustrating the CAMPFIRE (Communal Areas Management Programme for Indigenous Resources) programme (Bonger 1999).

Although the role of local people has not figured highly in most examples of *in situ* conservation of rare and endangered species or in recovery plans, except perhaps as a nuisance factor, when we deal with species which have an economic or social value or otherwise impinge on the interests of local communities, such an approach is no longer tenable. This is especially true in the case of medicinal and aromatic plants where community involvement in the conservation and management of such species is becoming increasingly common. Examples are community participation in the management of *Prunus africana* in the Mount Cameroon region (Gabriel 2003), *in situ* conservation and use of medicinal plants by Afro-Colombian communities in Colombia (IDRC 2001), and community-based conservation of medicinal plants in Kenya. Other examples are given in Section 3.3.

In the case of forestry species, various initiatives have recognized the usufruct rights of local communities and their role in community or participatory management, for example in China (Lai 2003), Nepal, Thailand, Sri Lanka, Bangladesh, Mexico (Gómez-Pompa and Bainbridge 1993) and India. In India, some 35 000 villages participate in the Joint Forestry Management Programme (Pandey 2003).

The participation of people (and the role of government) in the conservation of forest genetic resources is the subject of a DFSC Guideline and Technical Note (Isager et al. 2002). This draws

attention to the fact that, in many countries, plans to protect forest resources in reserves and protected areas have often failed to take into account the needs and knowledge of local people who live in or on the edges of forests, especially in the tropics (Tuxill and Nabhan 1998). It considers that engaging in participatory processes and creating an appropriate legal and administrative environment for them to proceed are complementary aspects of forest genetic resource conservation. It offers a model that lists the steps that can be involved in the participatory process.

The precise role of local people in the development and implementation of *in situ* conservation programmes for target species will, of course, vary according to the particular circumstances and the nature of the operations involved. They are more likely to be involved in management and protection than in more technical issues but what is certain is that in many cases, without their active participation, conservation will be difficult to implement. Some of the problems of community participation in forestry conservation are discussed in a review by Donovan (2001).

It is essential that all relevant stakeholders should be identified and their needs and concerns taken into account when developing an *in situ* conservation strategy. General principles to be taken into consideration are as follows (Palmberg-Lerche 2002):

- build from the bottom up: review and consider the priorities and needs of the full range of local users and interested parties and, to the degree possible, incorporate them into national strategies for conservation and resource management;
- ensure feedback and links among all levels of users and interested parties;
- ensure links between conservation management and related activities in other sectors at both the local and national levels;
- give due consideration to regional and global needs and priorities.

This calls for greater efforts to create awareness among stakeholders of the concept and importance of *in situ* conservation. Although considerable publicity has been given by conservation agencies and NGOs to the plight of nationally rare or endangered wild species facing extinction, little public awareness exists about the need for conservation of wild species of economic importance. Much greater attention needs to be paid to informing the general public when conservation plans are being formulated for the *in situ* conservation of target species, and when local populations are directly affected their role as stakeholders should be clearly recognized and they should be involved in both planning and management whenever possible and appropriate.

2.4 Incorporating the conservation strategy into national biodiversity strategy and action plans

To be effective, any conservation strategy developed for the *in situ* conservation of target species should be incorporated into the appropriate policy instruments of national agencies. This is called for in several articles of the Convention on Biological Diversity (CBD 1992). In particular, Article 8 of this Convention deals specifically with *in situ* conservation and Section 8b calls on contracting parties to "regulate or manage biological resources important for conservation of biodiversity whether within or outside protected areas, with a view to ensuring their conservation and sustainable use". Further, Section 8k specifically requests contracting parties "to develop or maintain necessary legislation and/or other regulatory provisions for the protection of threatened species and populations".

Article 6 of the Convention, dealing with the general measures for conservation and sustainable use, obliges contracting parties to develop appropriate national strategies for the implementation of the Convention in accordance with their particular conditions and capabilities. Section 6a specifically states: "Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes which shall reflect, *inter alia*, the measures set out in this Convention relevant to the Contracting Party concerned". Section 6b further requires that biodiversity consideration be mainstreamed into all aspects of national planning: "Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies". Further, article 10(a) states that each Contracting Party shall, as far as possible and appropriate: "Integrate consideration of the conservation and sustainable use of biological resources into national decision-making".

To facilitate this process, several international organizations such as UNEP, UNDP, World Resources Institute and IUCN have developed guidelines for contracting parties to prepare National Biodiversity Strategies and Action Plans. In particular UNDP and UNEP in collaboration with the Institut de l'Énergie et de l'Environnement de la Francophonie and the Quebec Environment Ministry published a guide with the support of the Global Environment Facility fund to help member countries to prepare and implement national strategies and action plans (UNDP/UNEP 2000). To date (January 2005), 94 countries have published their National Biodiversity Strategies and Action Plans with the assistance from the CBD Secretariat, and many others are in the process of preparing theirs (see www.biodiv.org/

world/nbsaps.asp). For the *in situ* conservation of target species, it is important that appropriate national agencies should be informed (if they are not already involved) and conservation strategies for these species should be included in National Biodiversity Strategies and Action Plans. This does not yet appear to be common practice in many countries, although an exception is the case of forestry species, where a number of countries have national programmes for forest genetic resources.

Another important issue which should be considered in the policy and legal support of *in situ* conservation areas concerns the use of economically important wild species and the benefit-sharing arising from the use of local resources. The successful management of these conservation sites will depend on the cooperation of local communities, as the most important stakeholders, and the incentives provided to them to enable a sustainable protection and management of the resources. Policies are thus required to bring together the effective protection of conservation sites while ensuring that local communities are adequately motivated through economic or other incentives and benefits to ensure the success of the conservation of the resources.

2.5 Available guidelines on *in situ* conservation of wild species

A wide range of guidelines or planning documents relating to various aspects of *in situ* conservation of wild species, such as enhancing the effectiveness of protected areas to achieve this, for sampling, monitoring, species recovery and related topics, can be found in the literature.[18] These vary from the cursory to the highly detailed. Some of them are general conservation planning approaches that include targeted species as part of a whole planning process. Several countries have produced their own guidelines and although targeted at the national situation, they may be much more generally applicable and are therefore included here. Some of the guidelines are generally applicable to plant genetic conservation while others are aimed at particular groups of plants. Selected examples of guidelines are given Appendix 3.

Part III: Global survey of *in situ* conservation activities — good practices and case studies

3.0 Introduction

A survey was undertaken of the extensive literature on *in situ* conservation of species, as well as the data collected in the process of country reporting during preparations for the International Technical Conference on Plant Genetic Resources,[19] and the National Biodiversity Actions Plans and Strategies and National Reports prepared by Parties to the Convention on Biological Diversity (under Article 6). The main results are discussed in this section, as are examples given of good practice and case studies, illustrating the problems and issues involved in carrying out *in situ* conservation activities in different parts of the world and in different target groups of plants.

3.1 Main findings

The review found that only a small number of countries have active programmes that systematically address the *in situ* conservation of the whole range of target species such as forest tree species, medicinal and aromatic plants, fruit trees or crop wild relatives, although the activities for some groups may be limited. For example, while the USA has one of the world's most extensive recovery programmes for threatened species, action on forestry species and crop wild relatives is more sporadic. As the *USA Country Report to the FAO International Technical Conference on Plant Genetic Resources* notes

> At the present time, *in situ* conservation of wild crop relatives occurs fortuitously, for the most part, on protected lands and other wilderness areas … Greater efforts need to be made to promote *in situ* conservation of native crop genetic resources within the USA. The land management agencies in the USA should be alerted to the presence of wild crop genetic resources on their lands so that management of these lands can preserve these resources.

In the case of *in situ*-related work on wild potato relatives in the USA, undertaken by the USDA Agricultural Research Service, for the past decade,

the approach has been to begin with thorough documen-
tation and sampling of the existing populations, trying
to understand their genetic structure, reproduction and
what might threaten their diversity in the wild and
genebank. We have taken no active steps for protection,
although we have thought a lot about what factors would
make a site high priority for such work (J. Bamberg, per-
sonal communication 2003).

Another, larger, group of countries have undertaken preliminary
steps such as inventory and ecogeographical surveying of some target
species, but have not yet implemented conservation actions.

In many countries, *in situ* conservation activities are largely
restricted to ecosystem conservation and protected areas, and only
exceptionally with target species. For example, in East Africa, to
quote from the *Sub-Regional Synthesis Report for the FAO International
Technical Conference on Plant Genetic Resources* (FAO 1995):

> The conservation of genetic resources *in situ* has been
> primarily in the form of habitats and ecosystems
> conservation (Appendix 8). The *in situ* conservation and
> related programmes, projects and activities are diverse in
> nature and they include indigenous forest conservation
> and management programmes e.g. COMIFOR and
> KIFCON in Kenya; inventories of threatened habitats,
> *in situ* conservation sites and species e.g. in Kenya and
> Uganda; establishment and management of national
> parks and protected areas (Uganda, Ethiopia, Rwanda and
> Burundi); *in situ* conservation education and awareness
> creation (Uganda, Kenya, Ethiopia, Rwanda) and *in situ*
> conservation of wetlands plant species (Kenya, Uganda,
> Sudan). Many of these projects have benefited from
> financial and technical support from such international
> NGOs as IUCN, WWF, African Wildlife Foundation (AWF)
> and World Conservation International (WCI). There are
> also a number of programmes for in-situ conservation in
> the National Forestry Action plans in Kenya and Ethiopia.
> Natural forests management and conservation programmes
> and projects exist in all the countries in the region.

Likewise in the United States,

> For many economically important crop species native to
> the USA, such as blueberries, cranberries, pecans, and

> *Rubus* species, *in situ* conservation may be accomplished through the designation of existing parks, wildlife refuges, or other protected areas as *in situ* reserves. The status of species or populations conserved in these areas would have to be monitored and the information could be maintained in the Germplasm Resources Information Network (GRIN) database (USA Country Report 1996).

Many countries recognize the importance of *in situ* conservation and have identified the kinds of actions that are needed, as in the case of Vietnam (Nguyen 2003); others have no specific plans to take action. A report on neglected and underutilized species of Cyprus notes that

> Wild relatives of crops such as *Hordeum* spp., *Aegilops* spp., *Vicia* spp., *Avena* spp., *Lathyrus* spp. and others are found in abundance in Cyprus. However, no direct measures have been taken yet for protecting them in their natural habitats (Della 1999).

Frequently in the literature, attention is drawn to the need for *in situ* conservation of particular target species but action is planned for the future. Examples are the important medicinal rhizomatous herb *Podophyllum hexandrum* from Garhwal Himalaya, India, which is reported to be in need of immediate action (Bhadula et al. 1996); *Prinsepia utilis* Royle, a wild edible shrub of the higher Himalayas, India (Maikhuri et al. 1994); and ecotypes of grasses and fodder crops and some fruit trees in Czechoslovakia (Dotlacil et al. 2001).[20]

Some countries draw attention to the lack of understanding of the principles and methodology of *in situ* conservation, especially of target species, and on issues such as effective population sizes, recommended sizes and areas of *in situ* sites (FAO 1995), while many countries do not recognize *in situ* species conservation as an issue and make no direct reference to it in their National Reports.

On the other hand, many countries, especially in the developed world, have devoted very considerable efforts to the identification, management, maintenance and recovery of rare or endangered (Red List) wild species without regard to their economic importance, as discussed in Section 3.2.

As far as can be determined, no single country has a fully integrated policy for *in situ* conservation of wild species that covers rare and endangered (Red List) species and those of importance in agriculture and forestry. Even for those countries that do have a range of ongoing species-orientated conservation programmes, none

of them has a mechanism that covers all groups of species. This is probably because of the large number of different government departments and agencies that are involved for the different groups of species and activities. The Institute of Biodiversity Conservation and Research in Ethiopia (see http://www.telecom.net.et/~ibcr/index.htm), does, however, cover plant genetic resources (including field crops, pasture and forage, horticultural crops, medicinal plants and forest genetic resources), ecosystem conservation and ethnobiology.

A major constraint that affects the prosecution of species-orientated *in situ* activities is the range of disciplines involved, requiring a considerable amount of inter-agency cooperation. Even agencies within the same Ministries often do not have mechanisms for such joint action, or it may be difficult to reach agreement because of their different mandates. Cooperation between ministries can be even more difficult and these are issues that have to be addressed at a national planning level. Even planning to work within Protected Areas can lead to problems or lack of full cooperation.

The literature review and consultations make it quite clear that most effort on *in situ* conservation has been focused on two main groups of plants—rare and endangered wild species and forest trees. In addition, substantial work has been initiated recently on crop wild relatives and on medicinal and aromatic plants. Also, there is a body of work on fruit trees and shrubs and on various types of plants of economic importance including coffee, rattans, potatoes, multipurpose trees, onions, ornamentals, forages, etc. No precise estimate can be given for the total number of potential candidate species of all groups for *in situ* conservation but it runs into many tens of thousands; nor do we have reliable estimates for the individual groups (forestry, wild relatives, medicinal, etc). Currently, only about 1% of the total number of plant species (*c.* 400 000), are the subject of *in situ* conservation or recovery programmes or activities, most of them rare or endangered wild species identified by national Red List programmes, so that globally the situation is a matter of serious concern.

Not surprisingly, the level of activity or engagement in *in situ* conservation of species varies enormously, not only between developed and developing countries but within each bloc from country to country. With the exception of work on medicinal plants reported elsewhere in this review, there is little organized or structured *in situ* conservation activity targeted at plant species in most developing countries. On the other hand, a great amount of activity and many projects are reported in the more developed countries, especially on rare and endangered species.

The following examples or case studies of the way *in situ* species conservation is being tackled in the main target groups are given by way of illustration of the diversity of approaches. Some examples of the ways in which *in situ* conservation activities are organized at a national level are also given.

3.2 Rare and endangered (Red List) species

Globally, a large part of the effort that has gone into *in situ* conservation of species has been directed at rare and endangered species, often referred to as Red List species, through rescue or recovery programmes, and a very considerable literature on theoretical and methodological considerations has been published, much of it under the heading 'Conservation biology' (e.g. Soulé 1986, 1987; Falk and Holsinger 1991; Fiedler and Jain 1992; numerous articles in the journals Conservation Biology and Biological Conservation).

Most of these species are not of known economic importance and the main criterion that led to their selection was their state of endangerment, most of them occurring in national, regional or local Red Lists or Red Data Books or similar documents. On the other hand it should be noted that it has been suggested that a majority of rare US plant taxa are congeners of species of economic significance in agriculture, forestry, industry, pharmaceuticals or horticulture (Falk 1991). An example is *Zizania texana* (Box 20), a near relative of commercial wild rice, which was once a troublesome weed of irrigation ditches and is now reduced to a single population and is the subject of a recovery plan (US Fish and Wildlife Service 1995).

Many countries have produced national Red Lists or Red Data Books, although they are more common in temperate zones. Examples of Red Books or Lists for tropical or subtropical countries include those for Ecuador (see Box 21) (Valencia et al. 2000), India (Nayar and Sastry 1987, 1988, 1990; Ahmedullah 2001; Ahmedullah and Nayar 1999; cf Kameshwara Rao et al. 2003), Sri Lanka (Dela et al. 2001) and Vietnam (Ministry of Science, Technology and Environment 1992). The Southern African Botanical Diversity Network (SABONET) has produced a volume listing the threatened plants of ten southern African countries—Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe (Golding 2002)—in which about 4100 plant species are classified according to the older IUCN categories and criteria.

Most European countries have produced Red Data Books and they are usually a valuable source of information for *in*

Box 20: Conservation of *Zizania texana* (Texas wildrice)

Texas wildrice (*Zizania texana* Hitchc.) is a rare and endangered emergent aquatic grass whose natural distribution is limited to a 1½-mile length of spring-fed headwaters of the San Marcos River, Hays County, Texas to which it is endemic. Only 140 clumps exist in one unprotected population. It typically occurs adjacent to the deepest part of the river channel in gravel or soft, muddy sediments forming dense stands.

Texas wildrice is listed as an endangered species by both U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department. Factors which threaten its survival include reduced spring flow from the San Marcos springs, reduced water quality in the San Marcos River, competition and predation by non-native species such as Nutria (*Myocaster coypus*) and *Hydrilla verticillata*, absence of sexual reproduction in the wild, and alteration of sediments in the river bottom.

The Fish and Wildlife Service Recovery Plan recommends that a public education programme be established, aimed at minimizing recreational disturbance of wildrice in the San Marcos River. Ultimately, long-term protection will require a management programme to balance the water needs of the human population with the requirements of a healthy San Marcos River ecosystem.

Conservation research is being undertaken on genetics, demography and *ex situ* collections and conservation efforts have been focused on building an *ex situ* refugium from plants collected in different regions of the river and maintained in a fish hatchery raceway as a means of maintaining some of the genetic diversity (Richards 2004).

Texas wildrice is closely related to annual wild rice (*Zizania aquatica*), an economically important plant that grows abundantly wild in the northern, central, and eastern wetland areas of North America but not in Texas. It is probable that much of the genetic diversity that once occurred in the populations of the species may have already been irretrievably lost. Research is underway into its beneficial properties and efforts have been made to combine certain highly desirable genetic traits of *Zizania texana* with a native North American cereal, Indian (northern) wild rice (*Zizania palustris*), a commercially successful species, so that if these efforts succeed, it is likely that genes from *Zizania texana* could contribute to the wild rice industry.

Based on Eckhardt (1995) and Beaty (2002)

Box 21: Red Book of the Endemic Plants of Ecuador (Valencia et al. 2000)

This book, edited by Renato Valencia, Nigel Pitman, Susana León-Yánez and Peter Moller Jørgensen, represents the combined work of more than 40 authors and five institutions. It is the first to bring together all the information available about the endemic plants of Ecuador and covers 4011 species. It gives an overview of all the information needed for their study, management and protection and includes a synopsis of the abundance and distribution of each species, based on the history of the collection records, and determines their threat level according the latest IUCN categories.

The introductory chapters give a sorry synopsis of state of the endemic flora of the country:

• more than a third of the number of endemic species currently registered are known from a single population
• fewer than 25% of the species have been recorded from within the Protected Area system of Ecuador
• a majority of the endemic species are not represented in Ecuadorian herbaria and 282 of the endemic species are Critically Endangered
• three Galapagos species have been confirmed extinct and there is a high probability that 50 mainland Ecuadorian species have had a similar fate.

situ conservation, containing distributional and ecological data and information about the degree and nature of the threats. A good example is the recently published *Atlas and Red Book of the Threatened Vascular Flora of Spain: Priority Taxa* (Bañares et al. 2003) whose preparation involved 30 teams of botanists and ecologists in the study of threatened taxa, and 236 contributing authors.

The profiles for the individual species consist of a single page for the extinct (EX), the vulnerable (VU), near threatened (NT) and least concern (LC) taxa, while a double-page spread is given for the critically endangered (CR) and endangered taxa (EN). The information given includes, apart from the Family and scientific name, a brief description of the salient features of the taxon, a colour plate, paragraphs on identification, distribution, biology, habitat, demography, threats, conservation measures adopted and conservation actions proposed, a table listing populations identified, a box summarizing chorological data, a Red Fiche indicating the IUCN category of threat and the relevant legislation applying to the taxon, a box summarizing basic ecological and biological features, references and a distribution map using a UTM grid of 10×10 km squares (deliberately less than the sampling, which used a 500×500 m grid, so as to avoid precise localization of the populations) and an inset reference map, and references to literature. In addition, there are chapters on organization and methodology, including a commentary on the IUCN categories of threat and some interesting proposals for their refinement, an analysis of the state of conservation of the Spanish flora and proposals for future action, a catalogue of the important areas for the conservation of the Spanish flora and the issue of invasive plant species as a new problem in conservation strategies.

By way of contrast, the first volume so far published of the *Red List of Phanerogams of Colombia* (Calderón et al. 2002), one of the world's richest countries for plant diversity (*c.* 50 000 species), covers an evaluation of the status of only 222 species and includes up-to-date information on the biology of 71 threatened species belonging to three families, Chrysobalanaceae, Dichapetalaceae and Lecythidaceae, and representing less than 1% of the total flora of the country. About half of the threatened species are endemic to Colombia and 24% of these are known from only a single locality (about half from the type specimen only).

Lists of endangered species are critical foci of conservation attention and receive special attention in priority-determining systems for conservation, whether at national or international level. The various editions of the *IUCN Red List of Threatened Species* (IUCN 2004) constitute the only available global factual summary of threatened species, although seriously incomplete in their coverage, and serve as an indicator of likely species loss. An in-depth analysis of the data contained in the 2004 IUCN Red List has been undertaken and the results are presented in a separate publication: *A Global Species Assessment* (Baillie et al. 2004). The numbers of globally threatened plant species (in 2004) are given in Table 2.

Table 2. Summary of threatened plant species

Plants	Number of described species	Number of species evaluated	Number of threatened species in 2004	Species threatened as % of species described	Species threatened as % of species evaluated
Mosses	15 000	93	80	0.5	86
Ferns and allies	13 025	210	140	1	67
Gymnosperms	980	907	305	31	34
Dicotyledons	199 350	9 473	7025	4	74
Monocotyledons	59 300	1 141	771	1	68
Subtotal	287 655	11 824	8321	2.89	70

Source: IUCN (2004)

At a national level, inclusion on an endangered list can have important consequences, as in the USA, where the Endangered Species Act (ESA) affords immediate protection to areas known to hold populations of endangered species.

The way in which the designation, conservation and recovery of threatened species is structured varies considerably from country to country. Likewise the range of conservation actions is diverse and includes survey, monitoring, *ex situ* sampling and cultivation so as to build up stocks for population reinforcement, as well as *in situ* maintenance.

Perhaps the most developed system is to be found in the USA, where the management and conservation of rare and endangered species is enormously complex, with responsibilities and legislation at both Federal and State level. In California, for example, the management of the State's rare plants has been described as being under "a tangled web of laws, regulations, policies and agencies" (Roberson 2001). Thus lands under Federal management, or projects under Federal control, are subject to laws that include the Federal Clean Water Act, National Forest Management Act, the National Environmental Policy Act and the Federal Endangered Species Act. The landmark Endangered Species Act is also complex and controversial, and a useful summary has recently been published (Villa-Lobos 2003).

The conservation of endangered species is dealt with by a number of Federal programmes such as the US Fish and Wildlife Service, the Endangered Species Act and the Bureau of Land Management, and by a large number of programmes at State level. In addition, the Nature Conservancy, whose mission is to "preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive", plays a major role in the long-term conservation of biodiversity in

the USA through land acquisition, public land management and conservation funding (including debt for nature swaps).

Under Section 4 of the US Federal Endangered Species Act, the Fish and Wildlife Service is directed to develop recovery plans for all listed species. Several hundred of the listed species and populations have Recovery Plans as of 5 May 2003 (see http://ecos.fws.gov/tess_public/TESSWebpageRecovery?sort=1#Q) but there is no legal requirement that the plans be implemented. In fact a shortage of budgetary resources means that for many species, the recovery plans often gather dust (Roberson 2001). These should not be confused with Habitat Conservation Plans, which are tools to resolve conflicts between land developers and species conservation. They are "regulatory and legal documents, not biological documents" (Moser 2000) and have been the subject of considerable controversy since their introduction.

The USA Bureau of Land Management's (BLM) Threatened and Endangered Species Management Activity addresses the conservation and protection of plants and animals that are listed, proposed for listing, or are candidates for listing under the Endangered Species Act (ESA), as well as species designated by the BLM as 'sensitive'. BLM public lands support at least 306 Federally listed species (171 Federal endangered, 114 Federal threatened, 13 proposed endangered, and 8 proposed threatened), 59 Federal candidate species, and an additional 1500 BLM sensitive species. Collectively termed special status species, these occur over significant areas of the 264 million acres of public land managed by the BLM.

The BLM carries out programmes for threatened, endangered, proposed, and candidate species and the ecosystems upon which they depend, with the ultimate goal of bringing these species and their habitats to a point where the protective provisions of the ESA are no longer necessary. Section 102(a) (8) of the Federal Land Policy and Management Act requires the BLM to manage the public lands in a manner that protects resource values (such as scientific, historical, ecological and scenic) while allowing appropriate land uses. This Activity funds inventory and monitoring of special status species populations; development of recovery plans and conservation strategies; implementation of recovery plan actions and conservation strategies; and restoration.

In addition, an important player is the Plant Conservation Alliance (PCA), which is a consortium of ten federal government Member agencies and over 145 non-federal collaborators representing various disciplines within the conservation field: biologists, botanists, habitat preservationists, horticulturists, resources management consultants, soil scientists, special interest clubs, non-profit organizations, concerned

citizens, nature lovers, and gardeners, who work collectively to solve the problems of native plant extinction and native habitat restoration, ensuring the preservation of the ecosystems of the USA. Then there are 28 State Wild Flower Societies which undertake a wide range of conservation or conservation-related activities, including *in situ*.

Numerous programmes exist for the *in situ* conservation of rare and endangered species in various countries in Europe. These programmes may be at a national or subnational level, an example of the latter being the UK, where there are separate arrangements for England, Scotland, Northern Ireland and Wales. In Spain, responsibility has been devolved to the autonomous governments (*Autonomías*) and programmes for the conservation of threatened species are well developed. For example, in the autonomous community of Andalucía, where a large part of the threatened flora is officially protected (Hernández Bermejo and Clemente Muñoz 2001), recovery plans or programmes have been made for 50 endangered or vulnerable species. In the autonomous community of Valencia, an extensive series of programmes is in place for the conservation of the flora, including *in situ* actions such as a network of microreserves (Laguna Lumbreras 2001a); a similar situation obtains in the Balearic Islands (Gradaille 2001), and in the Canary Islands, where over 20 species are the subject of recovery plans within the well-developed protected area system (Bañares et al. 2001; García Casanova 2001). The *in situ* activities form part of integrated conservation programmes in which botanic gardens such as those of Córdoba, Las Palmas, Sóller, and Valencia play a major role.

A novel and unique approach has been taken by the French Ministry of Ecology and Sustainable Development to the conservation of rare and endangered plants through the creation of a network

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Box 22: Conservatoires Botaniques Nationaux, France

The **Conservatoires Botaniques Nationaux** comprise a network of specialized centres for the conservation of threatened wild plant species that grow on French national territory. They have an agreement with the Ministry of Ecology and Sustainable Development under which they are responsible for an area consisting of a group of Départements with common biological and geographical features to:
- gather detailed knowledge of the local flora and habitats of the region for which they are responsible
- conserve by all appropriate means of the species identified as rare and threatened both in their natural or semi-natural habitats (*in situ*) and by cultivating them or building up stocks of seed (*ex situ*)
- act as centres of scientific assistance to local public and territorial bodies and undertake expert missions regarding natural and semi-natural habitats
- develop information systems and public education to encourage respect for the country's plant heritage.

Some of the conservatoires are also botanic gardens, others are associated with research centres or national parks. Together they form a federation which coordinates and harmonizes their working methods and motivates national programmes for the knowledge and conservation of the wild flora and its habitats. Between them, the conservatoires are involved in *in situ* conservation activities for a diverse range of species – see, for example, the website of the *Conservatoire botanique national du Basin parisien* at the Muséum National d'Histoire Naturelle (http://www.mnhn.fr/mnhn/cbnbp/).

Box 23: The Conservatoire botanique national de Mascarin, La Réunion Island (Indian Ocean)

The **Conservatoire botanique national de Mascarin** (CBNM) is located on the tropical volcanic island of La Réunion, about 50 km west of Mauritius and 780 km east of Madagascar, in the Indian Ocean. The flora is rich, with *c*. 240 fern species and more than 500 flowering plant species described. About 160 of these species are endemic to La Réunion (an endemism level of nearly 30%) and six endemic genera are recognized.

The Conservatoire, originally created in 1986, is a garden of approximately 12.5 ha. Until 1996, the main goal of CBNM was primarily focused on *ex situ* conservation; the cultivation and the propagation of rare and threatened plants endemic to La Réunion, and managed to bring 60% of the endangered flora of Réunion into cultivation in the garden as well as material from the other Mascarene islands of Mauritius, Rodrigues and Madagascar. It is currently devoting much of its efforts to the management and monitoring of species and populations in their natural habitats, including the study and control of invasive plants which are recognized as one of the major threats to island native floras.

Among the completed and ongoing conservation programmes are:
*   field surveys and botanical investigations, which have resulted in a significant increase in the number of locations for rare endemics such as the highly endangered *Ruizia cordata,* Sterculiaceae (from one known location to five) and *Carissa xylopicron,* Apocynaceae
*   assessment of natural areas of high conservation value for their protection or sustainable management by local authorities
*   a recovery programme for the endangered species *Lomatophyllum macrum* (Liliaceae), including *in situ* population reinforcement (or restocking)
*   the study of the seed germination and reproductive biology of endemic plants such as the rare tristylous liana *Hugonia serrata* (Linaceae), or the lavaflow pioneer shrub *Antirhea borbonica* (Rubiaceae), in collaboration with the Université de La Réunion.

Future projects include:
*   the publication of an atlas of 15 protected plant species which are considered highly endangered in La Réunion (based on the 'Mascarine' database), with their status, present and past distribution
*   seed storage of threatened endemic plants, and the creation of an arboretum (field genebank) in the gardens of the CBNM
*   collaboration with the Université de La Réunion on population genetics of rare endemic plants
*   the setting up a 'Green List' of native and endemic plants for replanting on a wider scale in urban areas, as an alternative to the cultivation of potential or known invasive species, and in order to reduce pressure on plants in the wild.

Information/education of the public (local people and tourists, children and adults) is an important role for the CBNM, and the scientific team contributes to this effort by preparing posters, giving talks, training a network of about 60 local amateur botanists on plant identification, and promoting nature conservation.

The CBNM is viewed as a conservation tool for local and French authorities, and a link between theoreticians (researchers) and practitioners (land managers, foresters, horticulturists) on La Réunion.

Based on Meyer (2001)

of Conservatoires Botaniques Nationaux (Box 22). There are eight in mainland France and one in the island of Réunion (Box 23) and others are planned.

At a regional European level, the Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention) is a binding international legal instrument. Its aims are to conserve wild flora and fauna, especially endangered and vulnerable species, and their natural habitats and to promote European cooperation in that field. In Recommendation No. 30 (1991) on conservation of species in Appendix I to the Convention, paragraph No. 4 reads

as a matter of urgency, formulate and implement conservation or recovery plans for endangered and, if necessary, vulnerable species listed in Appendix I, giving priority to *in situ* conservation action.

To date, the number of recovery plans which have been implemented is disappointingly low.

The Habitats Directive of the European Union[21] has as its central aim conservation of biodiversity across the area of the Community. Under the Directive, Member States have a responsibility to preserve habitats and species of Community interest and to identify and designate, as Special Areas of Conservation (SAC), sites which are important for the protection of the species and habitats covered by the Directive. In addition, the European Union recognizes "priority species of Community interest" (Council Directive 92/43/EEC, Annex II) and an example of a conservation action programme, under the Life-Nature Project LIFE99 NAT/IT/006217, is *EOLIFE99* which addresses the conservation of such priority plant species in the Aeolian Islands (Box 24) (also see http://web.tiscali.it/no-redirect-tiscali/ecogestioni/eolife/summauk.html).

Box 24: Conservation of priority plant species in the Aeolian Islands, Sicily, Italy

The priority species selected are*:*
* ***Cytisus aeolicus* Guss.** (Fabaceae), a small tree endemic to the Aeolian Islands
* ***Bassia saxicola* (Guss.) A.J. Scott** (Chenopodiaceae), whose known populations occur only in three small islands in the Tyrrhenian Sea
* ***Silene hicesiae* Brullo and Signorello** (Caryophyllaceae) described on plants from Panarea and recently reported for Alicudi and one site in Sicily
* ***Ophrys lunulata* Parl.** (Orchidaceae), an endemic orchid occurring in Sicily.

All of these species have numerically small populations with very narrow distributions and high biological value. Their loss would cause (in one case at least) the global extinction of the species. The project aims at ensuring the survival of the four target species through *in situ* (gathering field data) and *ex situ* actions (establishment of seed banks, propagation with the aid of biotechnology, cultivation), and 'pilot' re-introductions to reinforce natural populations, reducing the risks linked to direct or indirect human activities. On the whole, they are complementary actions external to the sites where the target populations occur. All of these sites were proposed as SCI (*Sites of Community Interest*) and most of them are included in Protected Areas (*Regional Natural Reserves*).

The situation in Australia for the conservation and recovery of threatened species is also well developed. The conservation of threatened plant (and animal) species *in situ* is covered by the Australian *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The EPBC Act provides for:
* identification and listing of Threatened Species and Threatened Ecological Communities

- development of Recovery Plans for listed species and ecological communities
- recognition of Key Threatening Processes, and where appropriate reducing these processes through Threat Abatement Plans.

All States have had involvement in the preparation and implementation of recovery plans, often in cooperation with the Commonwealth's Endangered Species Programme. Several hundred species are included in recovery plans that have been adopted, are under review or in preparation.[22] These include a wide range of species—herbs, shrubs and trees—and ecological communities such as threatened species-rich shrublands. There are 39 plant species with management, monitoring or recovery plans in South Australia (as at September 2000). The programmes are focused on single species or in some cases are multi-species, as in the case of the threatened plants of the Tiwi Islands, North of Darwin, Australia (see Box 25).

The Australian Network for Plant Conservation (ANPC) has as its major aim the integration of all approaches to plant conservation. Membership of the Network includes botanic gardens, conservation agencies, mining companies, community groups (Landcare, Society

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Box 25: Recovery Plan for the Threatened Plants of the Tiwi Islands, Northern Territory of Australia 2004–2009

The recovery plan covers 20 listed threatened mainly rainforest plant species, nine of which are endemic to the Northern territories, found on the Tiwi Islands.

The objectives of the recovery plan are:
- to increase knowledge of the species and their management requirements
- to monitor existing populations in a manner that allows the detection of any changes in the status and distribution of species
- to assist in the long-term protection of the rainforest habitats where 15 of these species are found
- to develop and apply sound conservation management practices for existing populations as well as any further populations found to ensure that the wild populations are conserved in both number and extent
- to promote Tiwi Land Council involvement in, and awareness and ownership of, the conservation of these species and their habitats.

Recommended recovery actions are:
- to control or eradicate the recently discovered population of feral pigs on Melville Island
- to fence two populations of *Burmannia* D61177 Bathurst Island and monitor the effects of exclusion of disturbance by pigs
- to collect propagation material of *Dendromyza reinwardtiana*, *Garcinia warrenii* and *Tarennoidea wallichii* and establish these species in the George Brown botanic gardens
- to establish five sampling stations at each of three locations for 16 of the species (i.e. a maximum of 240 stations) to determine the ecology, health and trends in the populations of these species. The other four species included under the plan will be adequately monitored under the Plantation Forestry Strategic Plan
- fire management to be informed by the results of monitoring of the health of populations via the monitoring programme under the Plantation Forestry Strategic Plan
- to eradicate known infestations of gamba grass.

From Gibbons and Taylor (2003)

for Growing Australian Plants), researchers, local government, power authorities and farmers.

3.3 Medicinal and aromatic plants (MAPs)

Since the publication of the Chiang Mai Declaration (see Akerele et al. 1991, p. xix), issued by the 1988 WHO/IUCN/WWF Consultation on the Conservation of Medicinal Plants, which drew attention of the United Nations, its agencies and Member States, other international agencies and their members and non-governmental organizations to the vital importance of medicinal plants in health care and of the need to take the necessary steps to ensure their continuing availability, there has been a considerable increase in initiatives aimed at the conservation of medicinal and aromatic plants both *in situ* and *ex situ*. The International Council for Medicinal and Aromatic Plants (ICMAP) (see http://www. icmap.org), which is a scientific activity of IUBS, was established in 1993 with the general objective of promoting international understanding and cooperation between national and international organizations on the role of medicinal and aromatic plants in science, medicine and industry, and to improve the exchange of information between them. Its activities include the promotion of conservation of genetic resources both *in situ* and *ex situ* of medicinal and aromatic plants species. The Species Survival Commission of IUCN created in 1994 a Medicinal Plants Specialist Group (MPSG) (see http://iucn.org/themes/ssc/sgs/mpsg/) which is a global network of experts contributing within their own institutions and in their own regions to the conservation and sustainable use of medicinal plants. Its programme includes the following objectives:

- to identify priority medicinal plant taxa and habitats threatened by non-sustainable harvest, high levels of trade, environmental degradation, and other factors contributing to loss of species and genetic diversity
- to work with local, regional, national, and global partners to design and implement conservation action plans for priority medicinal plant taxa and habitats
- to support the development of tools and methods needed for a coordinated effort on medicinal plant conservation at all relevant levels, such as data management systems, research methods and guidelines, and basic research, monitoring, and networking tools (bibliographies, directories, etc.).

A number of examples of programmes or projects that have been instituted at a national level are given below.

In Indonesia, the FAO/IBPGR/UNEP project on The Conservation of Biodiversity of Medicinal Plants by Partnerships Approach in Meru Betiri National Park, East Java, Indonesia includes:

- an inventory of biodiversity of medicinal plants, research on active chemical components
- study on marketing, study on ecology of species priority, study on cultivation techniques
- study on harvesting from nature techniques, and study of socio-economic conditions of the community living around the National Park.

More than 25 formula folk medicine and health drinks have been developed with women, local people and the local health division, to produce folk medicine for hypertension, reduction of blood lipids, diabetes, etc. Starting in 1999, medicinal plants have been cultivated as an agroforestry system in partnership with the local people (*c.* 1500 people/families) in an area of 2000 ha (rehabilitation land of Meru Betiri National Park). Now the local Government, especially the Ministry of Health, has decided to use folk medicine for the Centre of Village Health in Jember District.

In Sri Lanka: the Sri Lanka Conservation and Sustainable Use of Medicinal Plants Project was the first approved by the World Bank that is focused exclusively on the conservation and sustainable management of medicinal plants. Originally to be implemented between 1998 and 2002, it was been extended to 2004. The World Bank is the implementing agency for the fund (see Box 26).

In India, the *in situ* conservation group of the Foundation for Revitalization of Local Health Traditions (FRLHT) has been

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Box 26: The Sri Lanka Medicinal Plants Project

The objective of the project is to secure the active conservation of globally and nationally significant medicinal plants, their habitats, species and genomes, and promote their sustainable use through three initiatives to:

- **Establish five medicinal plant conservation areas** (MPCAs) where plant collection from the wild is particularly intensive and develop a conservation strategy for each; implement village action plans to reduce dependency on harvesting from the wild; collect basic socioeconomic and botanical data; and promote extension and education on medicinal properties of species within these conservation areas.
- **Increase nursery capacity** to develop the cultivation potential of select species and support research on propagation and field planting techniques.
- **Collect and organize existing information** on plant species and their use and promote an appropriate legal framework through production of draft regulations to ensure the protection of intellectual property rights.

This project is expected to yield important environmental and social benefits. It will help conserve more than 1400 medicinal plant species used in Sri Lanka, of which 189 are found only there and at least 79 are threatened. It will spread knowledge about sustainable growth, crop yields, biological cycles, and the danger of depleting plant resources; maintain critical habitats for medicinal plants; and increase the diversity and quantity of threatened species.

The project will also preserve indigenous knowledge about medicinal plants and their use, promote policy and legal reforms, involve tribal people and local communities in efforts to reduce dependency on wild resources, and generate alternative income opportunities for the rural population.

Source: *Medicinal Plants: Local Heritage with Global Importance*. The World Bank Group (see http://lnweb18. worldbank.org/sar/sa.nsf/0/fae63d87e2bd14038525687f0057e0d1?OpenDocument)

coordinating a pioneering medicinal plant conservation programme on Strengthening the Medicinal Plants Resource Base in India in the Context of Primary Health Care that has been implemented by the state forest departments of Tamil Nadu, Kerala and Karnataka since 1993, and Andhra Pradesh and Maharashtra since 1999. The project, supported by DANIDA, focused on the conservation of medicinal plants both *in situ* and *ex situ*.

This *in situ* conservation initiative has resulted in the setting up of a network of 54 Medicinal Plant Conservation Areas (MPCA) across different forest types and altitude zones in these five states of peninsular India. For all the MPCA sites, detailed floristic information on medicinal plant diversity, including the threatened, traded and endemic plants, is documented. The network of 54 Medicinal Plants Conservation Areas captures around 2000 medicinal plant species. These represent 50% of the medicinal plant diversity of the five States, and significantly include over 75% of the Red Listed species of the States.

Particular emphasis has been given to the so-called 'Maharastra initiative' which involves:
- identification of 10 Medicinal Plants Conservation Areas (MPCAs) in the State of Maharashtra. Each site is on average 250–300 ha
- detailed floristic studies of the 13 MPCAs
- prioritizing medicinal plants for focused conservation action by undertaking rapid threat assessment following IUCN guidelines
- developing action plans for specific recovery and enrichment programmes in MPCAs for critically endangered and economically valuable species
- involving local communities in the conservation of medicinal plants while ensuring community benefits through innovative schemes for sustainable utilization of medicinal plants.

In Brazil, a recent report (Vieira 1999) notes that

> In the last decade, serious efforts to collect and preserve the genetic variability of medicinal plants have been initiated in Brazil. The National Centre for Genetic Resources and Biotechnology (CENARGEN), in collaboration with other research centres of Embrapa (Brazilian Agricultural Research Corporation), and several universities, has a program to establish germplasm banks for medicinal and aromatic species. Most *in situ* conservation has focused in forest species, with some medicinal species included, such as *Pilocarpus microphyllus* and *Aniba roseodora*. The establishment of genetic reserves in Brazil has relied on National Parks

and conservation areas established by the environmental protection agency of Brazil, Ibama.

Thirty-one species of medicinal and aromatic species with high priority for germplasm collection and conservation in Brazil have been identified, of which 12 are conserved *in situ* (see Table 2 in Vieira 1999).

An example of a medicinal plant which has attracted a great deal of publicity and research is the African species *Prunus africana.* It illustrates the difficulties of implementing effective conservation even when the situation is well understood (Box 27).

Box 27: Conservation and sustainable use of *Prunus africana*

A great deal of attention has been paid to *Prunus africana*, a small tree that is a well-known medicinal plant species. It occurs in scattered populations in Afromontane forest islands in mainland Africa and in outlying islands such as Madagascar. An extract from its bark is used for the treatment of benign prostatic hyperplasia, with a substantial international trade. It is used locally for medicine, timber, furniture, poles, fuelwood, charcoal, and as tools, and has been a major source of income for local people for the last 35 years. It is subject to heavy exploitation in some parts of its area, notably in Cameroon, and the level of harvesting is unsustainable.

Much research is carried out into its distribution, local use, harvesting, genetic variation, trade and protection but only a limited amount of *in situ* conservation of this tree has been carried out (Cunningham 1996; Dawson et al. 2000; Dawson and Powell 1999; Ewusi et al. 1997; Jaenicke et al. 2002).

Scientists with the Nairobi-based *International Centre for Research in Agroforestry* (ICRAF) are working to establish a sustainable source of *Prunus africana* through conservation of wild tree populations. However, despite various *in situ* and *ex situ* conservation efforts, the tree is still at risk of extinction because of increased demand. In the Mount Cameroon region, consultations led to an action plan that put in place a community management model (Gabriel 2003). This has greatly checked unsustainable *Prunus* exploitation in the region and will allow the resource base to be maintained for some years.

3.4 Forestry species

Conservation of genetic resources of forest trees has followed a different approach from that employed for other groups of species (Hattemer 1997). It is often suggested that the conservation of genetic resources of forest trees is a special case and various kinds of *in situ* conservation have traditionally been practised, although in a wider sense than that adopted for other groups of plants (Palmberg-Lerche 1993). Thus it covers 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. 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. 2000).

Forest tree genetic resources are defined in a recent feasibility study on the state of forest genetic resources in the world (Bariteau 2003) as "the set of trees having an actual or potential value as a pool (reservoir) of genetic diversity". Forest trees have special characteristics, such as:

• they often contain greater genetic diversity than other species (Müller-Starck 1995, 1997)
• there may be poor differentiation with respect to nuclear markers
• there is generally high differentiation among populations for adaptive traits
• the longevity of the individuals.

In a review of genetics and forests of the future, Namkoong (1986) makes a distinction between three groups of forestry plant species in terms of the kind of genetic management required:

1. Species of current socio-economic importance and management for commercial development
2. Species with clear potential or future value and management for potential commercial use
3. Species of unknown value given present knowledge and technology, and management of non-commercial populations.

With regard to the third group, Namkoong points out that "The vast majority of forest plant species have little recognized current or future commercial value, or no function that is not otherwise served by other species".

A considerable number of forest tree species have been the subject of *in situ* conservation/management action. Many examples are found in the review of forest genetic resources management published by FAO/DFSC/IPGRI (2001). The EUFORGEN Networks (see http://www.ipgri.cgiar.org/networks/euforgen/) also deal with a range of species for which management guidelines are produced. Other examples of regional or national initiatives are given below.

A series of networks has been developed by IPGRI in different regions of the world and some of these engage in *in situ* conservation activities (see Appendix 4 and http://www.ipgri.cgiar.org/catalogue/theme.asp?theme=5). In these and other such networks, the focus is often almost entirely on plantation forestry or agroforestry, while management of genetic resources in natural forests has received little networking attention. The ECP/GR *In situ* and On-farm Conservation Network mentioned above deals specifically with the preparation of guidelines for the *in situ* conservation of plant genetic resources.

In the South Pacific Region, a forestry network, the South Pacific Regional Initiative on Forest Genetic Resources (SPRIG), exists for a number of island states. Funded by the Australian Agency

for International Development (AusAID), the network deals with practical aspects of forest and tree management and an important goal is to develop strategies for the conservation and sustainable management of priority species (Thomson 1998). Ten priority indigenous trees have been selected for conservation strategies, three of which have already been prepared (for *Agathis silbae* and *Endospermum medullosum* in Vanuatu and *Dacrydium nausoriense* in Fiji). A strategic plan for heilala (*Garcinia sessilis*), the national tree of Tonga, has also been prepared.

In Korea, 33 natural forest stands have been set aside for *in situ* conservation of forest genetic resources of 19 species (Lee 2002).

In Zambia, the Dry Forest Management Project initiated in 1987 under the Forest Research Division provides the best example of *in situ* activities carried out in the country. The project was located within the teak production forests of Western Province in Sesheke district.[23] A complete list of species included and their respective uses is given in Box 28.

A programme for the provision of practical advice on *in situ* gene conservation stands of forest tree species to assist countries in the planning and implementation of conservation of genetic resources of forest tree species was initiated in 1996/97 by FAO, Danida Forest Seed Centre (DFSC) and relevant national institutions. It was agreed that conservation plans for four tropical tree species would be developed, focusing on *in situ* conservation, and the plans for three of these—for Zambezi teak in Zambia (Theilade et al. 2001), for *Pinus merkusii* in Thailand (DFSC 2000) and for teak (*Tectona grandis*) in Thailand (Graudal et al. 1999)—have been published.

Box 28: Species included for *in situ* conservation in the Dry Forest Management Project, Zambia

Botanical name	Major uses
Baikiaea plurijuga	Timber, general construction, mining timber, parquet
Pterocarpus angolensis	Timber, handicrafts, dyes, medicines
Guibourtia coleosperma	Timber, handicrafts, edible seeds
Afzelia quanzensis	Timber, handicrafts
Entandrophragma caudatum	Timber, tannin, construction, veneers
Erythophleum africanum	Timber, general construction
Albizia versicolor	Timber, parquet construction
Ricinodendron rautanenii	Handicrafts, canoes, pulp and edible fat from seeds
Burkea africana	Joinery, mining timber, construction
Brachystegia speciformis	Timber, veneers, handicrafts, boat building
Julbernardia	Timber, handicrafts and implements

Source: Malaya (1990)

In Thailand, *Pinus merkusii* is afforded legal protection at most of its remaining natural sites and the eastern populations are conserved in the Khong Chiam *In Situ* Gene Conservation Forest (GCF), located in Ubon Ratchathani Province in the north-east of the country—one of the few areas in south-east Asia which has been set aside specifically for the conservation of forest genetic resources. In 1983, an area of about 700 ha was reserved, with the objective of protecting the genetic resources of local tree species, especially the lowland form of *Pinus merkusii*. Other important tree species conserved in the Khong Chiam include *Anisoptera costata*, *Dalbergia cochinchinensis*, *Dipterocarpus costatus*, *Ivingia malayana*, *Peltophorum dasyrachis*, *Pterocarpus macrocarpus* and *Schima wallichi* (Granhof 1998; Isager et al. 2002).

3.5 Crop wild relatives

Wild relatives of crops are a group of target species that has attracted considerable interest in recent years. A series of workshops on the conservation of wild relatives of European cultivated plants was held under the aegis of the Council of Europe and the Proceedings published (Valdés et al. 1997) as well as a catalogue of the wild relatives of cultivated plants native to Europe (Heywood and Zohary 1995). A survey of work on crop relatives was commissioned by IPGRI as part of a UNEP/GEF PDF/B project (Meilleur 2001; Meilleur and Hodgkin 2004) (see also Section 3.9).

An example of work on the *in situ* conservation of genetic diversity in crop wild relatives is the series of studies produced by the Bureau des Ressources Génétiques, France, on *Beta vulgaris*, *Brassica insularis*, *B. oleracea* and *Olea europaea* (Soupizet 2002).

The landmark studies on the *in situ* conservation of wild relatives of cereal crops in the Near East, known as the Ammiad Project (Box 29), on wild emmer wheat (*Triticum dicoccoides*) (Safriel et al. 1997) are perhaps the most extensive published to date.

A wide range of crop wild relatives was selected as target species for *in situ* conservation in a major project on conservation of genetic diversity in Turkey (Firat and Tan 1997; Tan 1998; Tan and Tan 2002).

The Erebuni Reserve, which is located not far from Yerevan City, Armenia, is reported to be the only reserve in the world established specifically to protect wild relatives of grain crops. It was established in 1981 and covers some 89 ha on either side of the road from Yerevan to Garni and houses populations of *Triticum araraticum, T. boeoticum, T. urartu, Secale vavilovii* and *Hordeum spontaneum.* Unfortunately it is inadequately fenced, lacks a buffer zone, and is

Box 29: The Ammiad Project for the Dynamic Conservation of Wild Emmer Wheat in Israel

Triticum dicoccoides (*T. turgidum* var. *diococcoides)* is the wild tetraploid wheat species which is considered to be the progenitor of most cultivated tetraploid and hexaploid wheats. It occurs in patches throughout much of the Fertile Crescent in the Middle East. In 1984 the Israeli Ministry of Science and Technology commissioned a multidisciplinary 5-year scientific project named *Dynamic Conservation of the Wild Wheat in Israel*, which undertook a series of studies on the genetic diversity and conservation of a *Triticum dicoccoides* population at Ammiad, a mountainous rocky, pastureland belonging to a farming settlement in eastern Galilee. The site is very small (1 ha) but has been subjected to extensive studies and analysis of spatial and temporal population dynamics, phenotypic and genotypic variability, phenotypic plasticity and sensitivity to pathogens. It was found that groups of genes exist as stable clusters or complexes associated with specific geographical features, such as north-facing slopes. The results obtained give an unrivalled insight in to the nature of the population and the issues that are important for the management of a population of this type.

Based on Anikster et al. (1997) and Safriel et al. (1997)

being encroached upon by urban development. There is currently no active management, or even a management plan.

Extensive work on the genetics and demography of wild bean populations (*Phaseolus*) has been undertaken by IPGRI, the University of Gembloux, and the University of Costa Rica. This has given some insight about two critical aspects when contemplating *in situ* conservation: the genetic identity and distinction of populations and the minimum size of populations for retaining a certain amount of genetic diversity and thus the potential for further evolution (D. Debouck, personal communication 2003; see also Zoro Bi et al. 2003 and references therein).

A worldwide survey of *in situ* conservation of wild relatives of *Lathyrus* has been undertaken (Maxted et al. 2003).

The US National Germplasm System has initiated a series of pilot projects on *in situ* conservation of the wild relatives of various native crops:
- *Vitis rupestris* Scheele, *V. shuttleworthii* House, *V. monticola* Buckl (Pavek et al. 2001, 2003)
- *Allium columbianum, A geyeri, A. fibrillum* (Hannan and Hellier in Pavek and Garvey 1999; Hellier 2000)
- *Lathyrus grimesii* R.C.Barneby (Hannan and Hellier in Pavek and Garvey 1999)
- *Carya floridana, C. myristiciformis* (Grauke in Pavek and Garvey 1999)
- *Capsicum annuum* var. *aviculare* (Dierbach) D'Arcy and Esbaugh (Tewksbury et al. 1999)
- *Solanum jamesii, S. fendleri* (Bamberg in Pavek and Garvey 1999).

A celebrated case study of wild relatives is the work undertaken on the conservation of *Zea diploperennis¸* a wild relative of maize, in the Sierra de Manantlán Biosphere Reserve (see Box 15).

3.6 Fruit trees and shrubs

During the past 25 years there has been growing interest in the conservation of germplasm and wild relatives of fruit trees and shrubs (for a review of the issues involved see Arora and Ramanatha Rao 1998; Smith et al. 1992). In most tropical regions the rich diversity of native tropical fruit species is an important and valuable resource in enhancing nutritional security, reducing poverty and protecting the environment, although many of the species are currently underutilized (van den Hurk 1998). Many of the species concerned are threatened or vulnerable because of loss of habitat or overexploitation. For example, a high degree of genetic erosion has been recorded for jackfruit, *Citrus* spp. and *Litchi chinensis* (Haq 1994).

In Asia, the Pacific and Oceania, IPGRI is undertaking several activities on conservation and use of diversity of priority fruit species. Early work was carried out in 1986–1988 by IBPGR/WWF, which undertook ecogeographical surveys of the wild mangoes of Borneo and west Malaysia and found that a significant fraction of the rich genepool, including wild and semi-cultivated species, was already then on the verge of disappearance, notably *Mangifera blommesteinii*, *M. leschenaulitii*, *M. superba* and *M. paludosa* (Kostermans and Bompard 1993). It concluded that adequate practical measures needed to be rapidly implemented to ensure the long-term survival of mango genetic resources, by both *ex situ* and *in situ* conservation (Bompard 1993). Some wild species of mango and their relatives occur in biosphere reserves, national parks or other reserves in India, Indonesia, Singapore, the Philippines, Thailand and Sri Lanka, but little targeted *in situ* genetic conservation is being carried out.

In 1998, a comprehensive project on Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia was developed by IPGRI, in collaboration with ten Asian countries, namely Bangladesh, China, India, Indonesia, Malaysia, Nepal, the Philippines, Sri Lanka, Thailand and Vietnam, and funded by the Asian Development Bank (ADB). The fruit species in the project included mango, citrus, rambutan, mangosteen, jackfruit and litchi and work was carried out on germplasm collecting, characterization and evaluation, documentation, identification of elite lines, *ex situ* and *in situ* conservation, socio-economic analysis, human resource development and capacity building, as well as regional and international collaboration.

This ADB-funded project also facilitated the establishment of the Asia Fruit Genetic Resources Network (AFGRN). The network has helped to promote regional cooperation among the members to

access and share the information through its website (http://www. afgrn.net).

In Europe, the Fruit Network established by the ECP/GR in 1999 (see http://www.ecpgr.cgiar.org/Networks/Fruit/fruit. htm) includes in its activities discussions on establishing uniform standards for the conservation of fruit germplasm and of the most appropriate methods for fruit tree conservation (such as cryopreservation, *in vitro* growth, *in situ*, *ex situ*, etc.). Strategies for *ex situ* and *in situ* conservation of wild *Malus* germplasm in Kazakhstan have been proposed (Hokanson et al. 1998) and a survey of the European wild relatives of *Prunus* fruit crops is given by Hanelt (1997) and of wild apples and pears by Zohary (1997).

A series of case studies on the collection, utilization and preservation of fruit crop germplasm in the USA was presented at the 96th International Conference of the American Society for Horticultural Science (ASHS) and includes species of *Prunus*, *Vaccinium*, *Fragaria*, *Malus* and *Rubus* (Hokanson 2001).

Several countries have initiated *in situ* conservation activities for *Citrus* wild relatives. In India, there is an *in situ* gene sanctuary for citrus in the Garo Hills located in Nokrek National Park in the north-east of the State of Assam. This 10 000-acre sanctuary was set up to safeguard populations of the wild orange or 'ghost orange' as it is known locally (*Citrus indica*) (Singh 1981). It is surrounded by a buffer zone which provides the local people with fuelwood and other resources, so reducing the impact on the core area. This was apparently the first reserve set up specifically for the purpose of genetic conservation of a tropical shrub (Smith et al. 1992). In Vietnam, *Citrus* spp. are included in six Gene Management Zones (GMZs) whose aim is to maintain the natural evolution of plants for future generations.[24] As explained above, a GMZ is an *in situ* conservation and long-term monitoring site that contains one or more diverse populations of target species to be conserved. Each GMZ has specific management requirements adapted to different species and environmental conditions to ensure natural evolutionary processes, hence serving as an open laboratory, permitting continued evolution and conservation of the component species. A series of GMZs is often required in order to represent the ecogeographical ranges needed for the selected species and populations so as to support sufficient environmental heterogeneity.

Because of their frequent use by local people, either for the target species or for other components of the ecosystem, the maintenance of genetic reserves for tropical fruit trees and shrubs will often depend to a considerable degree on community participation in their management. An example is the conservation of yamamomo (*Myrica*

rubra), which occurs in southern China, Taiwan and central Japan. The fruits are eaten fresh or used for making a wine or liqueur. A forest genetic reserve exists at Ukiyamma on the Izu Peninsula, Japan. The management of this forest was under the direct control of the Samurai government in the 19th century and only the local inhabitants were permitted to harvest the ripe fruits. Because of the economic importance of the crops, the penalty for cutting a trunk or even a shoot was death by decapitation. Resort to such drastic measures to conserve the trees is no longer the practice there or elsewhere, and today *Myrica rubra* is protected through a common property agreement by the local villagers.

3.7 Ornamentals

Although ornamental plants are a large, diverse and economically important group, very few efforts have been made to conserve ornamentals, especially *in situ* (Heywood 2003a). As Metzger (1996) comments,

> The genetic conservation of ornamental plant species, whether *in situ* or *ex situ* has been poorly served. Genetic materials for ornamental plants are not centrally collected and maintained anywhere in the world.

Attention is, however, being paid to the conservation needs of some ornamental species in the Mediterranean region, such as bulbous monocotyledons like *Narcissus*, *Cyclamen*, *Galanthus*, *Tulipa*, *Leucojum* and *Crocus* in Turkey, which are exported on a large scale and are at risk of becoming rare or endangered:[25] *Tulipa sprengeri* for example, is extinct in the wild as a result of overharvesting by commercial collectors. However, most of the steps taken to counter these threats are focused on regulation of collection and export and on cultivation, but *in situ* measures such as genetic reserves for such species are rare although studies on population size and the effects of collecting on some species are being undertaken (Entwistle et al. 2002).

Many cacti and succulents are commercially important ornamentals. Some of them are the subject of recovery or management plans such as the spineless hedgehog cactus (*Echinocereus triglochidiatus* var. *inermis*) in the States of Colorado and Utah in the USA where it has endangered status (US Fish and Wildlife Service 1986). In Mexico, many attractive ornamental species of cacti are being placed at risk because of habitat destruction or conversion, uncontrolled tourism and poaching, which make their

often small populations vulnerable to extinction (Rojo and Peters 2003). A number of actions that favour *in situ* conservation are being taken at Federal, State and local level both in Mexico and in the adjacent USA. Examples are the creation of Natural Protected Areas in Mexico, the Tehuacán-Cuicatlán Biosphere Reserve near Mexico City, the Pinacate and Altar Biosphere Reserve in the USA–Mexico border area, the Vizcaino Biosphere Reserve in Baja California Sur, and the Fauna and Flora Protection Areas in neighbouring Texas, which are rich in cactus species. Most cactus species occur outside such protected areas and these may benefit from a new Protected Area Management model being implemented by the Mexican government—the Sistema de Unidades de Manejo para la Conservación de Vida Silvestre (SUMA—System of Management Units for the Conservation of Wildlife). The SUMA programme attempts to integrate economic development with environmental conservation and local participation in Mexico's undeveloped areas (Garpow 2001). However, these UMAs are focused on animal species, and cacti and other plant species are protected only incidentally and it appears that no *in situ* management or recovery plans targeted at these cacti are planned so far.

One of the few reserves for ornamental species is the orchid sanctuary maintained by the Botanic Garden, Orchid Research and Development Centre, Tippi, Arunachal Pradesh, India, and there are other such orchid sanctuaries in the country. The *in situ* conservation of target ornamental species within ecosystems is still in its infancy and the effectiveness and viability of gene sanctuaries or microreserves is still largely untested.

3.8 Miscellaneous target groups

Examples of other groups of target species which have been the subject of *in situ* conservation include:

Incense: A project is under way to make a Protected Area of Wadi Doka (Dhofar, Oman), with the aim of preserving and restoring the natural habitat where approximately 1200 trees of *Boswellia sacra* (frankincense), one of the frankincense-producing trees, grows (Raffaelli et al. 2003a, 2003b). The Oman Government has shown interest in the creation of a Natural Park in the area, already listed by UNESCO (2000) as one of the World Heritage Sites, and in order to set up suitable protection for the Park, it has recently begun a project with the Italian Mission to Oman that aims to prevent damage by human activity, monitor incidental parasite attacks and restore the natural area by saving the present plants and future seedlings.

Bamboo and rattan (Rao and Ramantha Rao 2000; also see http://www.ipgri.cgiar.org/regions/apo/inbar.html): A project to conduct studies on the species of *Johannesteijsmannia* H.E. Moore (Palmae) to provide information necessary to effectively manage the conservation as well as sustainable exploitation of the species is being undertaken by the Department of Biological Sciences of The National University of Singapore, the Forest Research Institute, Malaysia, and the Royal Botanic Gardens Kew. Work is in progress on the genetic diversity of *Johannesteijsmannia altifrons* and this will be extended for all four species in the genus for all known and accessible populations in east and west Malaysia and southern Thailand. So far no conservation management has been undertaken (Hugh Tan Tiang Wah, personal communication 2003). IPGRI's work programme on the conservation of genetic resources includes work on bamboo and rattan species (Hong et al. 2001).

Coffea **spp.**: a project to assess the amount of variability present in wild *Coffea* taxa in the Mascarene Islands (Mauritius and Réunion) at the genetic and taxonomic level using molecular and morphometric tools has been carried out as a basis to develop a sound conservation strategy. The project also carried out an in-depth ecogeographical study of coffee species and examined the effectiveness of protected areas in conserving genetic diversity of coffee (Dulloo et al. 1998, 1999). Another project, funded by BMZ (Germany), on the conservation and use of wild populations of *Coffea arabica* in the montane rainforest of Ethiopia, aims to assess the diversity and the economic value of the Ethiopian coffee genepool and to develop a model for conservation and use of the genetic resources of *Coffea arabica* in its centre of diversity in Ethiopia, based on the conservation of the montane rain forests as the natural habitat of the wild coffee populations, and the traditional use of the wild coffee populations in the forest coffee systems (Denich et al. 2002; Gole et al. 2002).

In situ conservation of several major food crops is virtually unknown. For example, referring to banana, Sharrock and Engels (1997) wrote:

> There are no known records of wild *Musa* species being conserved in existing protected areas. The method must surely have potential however for the conservation of species known to exist in the rainforests of Southeast Asia and the Pacific, such as *Musa ingens*. Before embarking on such *in situ* conservation programmes for *Musa* however, there is a need for more information on the distribution of wild *Musa* species, on minimum habitat size and on population dynamics. The establishment of

good links between those responsible for the management of protected areas (typically Ministries of the Environment or Forestry), and those responsible for the conservation of crop genetic resources (usually Ministries of Agriculture) will also be essential.

3.9 Global Environment Facility (GEF) projects that involve *in situ* conservation of target species

In addition to the UNEP/GEF PDFB project EP/INT/204/GEF, Design, Testing and Evaluation of Best Practices for *In Situ* Conservation of Economically Important Wild Species, already mentioned, a number of other GEF-supported projects involve to a greater or lesser extent *in situ* conservation action for target species.

Central America and Caribbean: Biodiversity Conservation and Integration of Traditional Knowledge on Medicinal Plants in National Primary Health Care Policy in Central America and Caribbean. This project will contribute to the conservation and management of medicinal plants in globally significant ecoregions of Central America and the Caribbean. The primary focus of this project will be on forest ecosystems and indigenous and local knowledge. It aims to support the conservation and sustainable use of forest ecosystems in the region by identifying conservation and management needs of medicinal plants within key forest ecosystems, and integrating these issues into the broader management of selected forest ecosystems. Specific objectives are:

- to assess the conservation status and management needs of medicinal plants
- to work with indigenous and local communities to develop appropriate management strategies
- to work with research institutions, NGOs, and national government agencies to integrate conservation and management of medicinal plants with rational use of traditional remedies in primary health care (PHC).

Egypt, Sinai: Conservation and Sustainable Use of Medicinal Plants in Arid and Semi-arid Ecosystems. The focus of this project is on the medicinal plants used by the Bedouin who live in St Catherine's Protectorate in Sinai, Egypt, and who have developed, over the centuries, extensive knowledge of their uses. It will include *in situ* conservation of target species, introduce small-scale community-based cultivation, processing and marketing to relieve pressure on wild sources, and protect community intellectual property rights (see http://www.undp.org.eg/programme/env/medical_plants.htm).[26]

Turkey: *In Situ* Conservation of Genetic Diversity in Turkey. This major 5-year project on *in situ* conservation of agrobiodiversity in Turkey was initiated in 1993. The goal of the project was to develop *in situ* gene conservation programmes for target plant species selected from wild relatives of crop, fruit tree and globally important forest tree species in selected pilot sites (Tan and Tan 2002). A list of the target species is given in Box 30. The main activities undertaken were:

- Surveys and inventories conducted to help identify and assess suitable sites in Turkey containing wild crop relatives, focusing on wheat, chickpea, lentils and barley as priority species, but also including other herbaceous and woody species.
- A species-specific inventory conducted at various sites for species abundance, distribution, and management needs.
- A few select germplasm samples collected for *ex situ* conservation to support a complementary approach for *in situ* and *ex situ* conservation.
- Several types of reserves selected for management. These represented the ecogeographical ranges needed for targeted wild relatives to support sufficient environmental heterogeneity for wild crop woody and non-woody species.
- Species incidence and diversity monitored and different approaches to gene management for particular species and ecosystems evaluated.
- Institutions strengthened, focusing on professional development and training of implementing agency staff, Turkish scientists, and students, through specialized workshops, technical assistance, and training courses in topics such as conservation biology, biosystematics, survey and inventory techniques, and geographical information systems.
- A data management system developed for the three agencies involved in implementation.

Box 30: Target species of wild relatives for *in situ* conservation in Turkey

Aegilops speltoides   *Vicia johannes*
Triticum tauschii   *Castanea sativa*
Triticum boeoticum   *Prunus divaricata*
Triticum tricoccoides   *Abies equitrojana*
Lens ervoides   *Abies cilicica*
Lens orientalis   *Pinus brutia*
Pisum sativum sensu lato   *Pinus nigra*
Vicia sativa sensu lato

Source: Tan and Tan (2002)

- Development of a national plan for *in situ* conservation supported.

  Regional: Wild Relatives. The GEF/UNEP project on *In Situ* Conservation of Crop Wild Relatives through Improved Information Management and Field Application: a PDF-B project involving Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan has been successfully completed and the full project has been approved by the GEF Council; implementation began in June 2004. The full project will pool existing information from a wide variety of sources on crop wild relatives in each of the five countries and an information exchange network will be set up, allowing scientists and breeders to identify promising traits for improving crop production. The project will pinpoint ways on how to best conserve the rich genetic resources of the countries concerned and will enhance conservation measures already undertaken and make available resources in order to build upon these. The project will:
- Develop national information systems for crop wild relatives, drawing together information from national sources and including aspects of species biology, ecology, conservation status, distribution, crop production potential, local community uses and existing conservation actions.
- Bring together information from national and international sources on the identity, status, distribution and potential use of crop wild relatives in the five participating countries.
- Create an international information system accessible through the World Wide Web to link global and national information resources and to allow determination of conservation status and needs for specific crop wild relatives.
- Explore and optimize procedures to link information on species distribution, spatial data and information from ecogeographical surveys so as to make better conservation decisions for these species.
- Identify conservation actions for species and populations identified as having highest priority for interventions and develop national plans for conserving crop wild relatives.
- Develop action plans for *in situ* conservation of crop wild relatives involving local communities so as to combine security for the crop relatives with improved use and benefits for local people.
- Develop management plans for crop wild relatives in protected areas.
- Raise awareness within the countries of the importance of crop wild relatives and their value for improving agricultural production.

  Ethiopia: Conservation and Sustainable Use of Medicinal Plants. The project will include an inventory of medicinal plants and *in situ* conservation activities in the Bale Mountains Massif and

National Park, one of the most important conservation areas in Ethiopia. It aims to facilitate development of safe and efficacious healthcare relying on traditional medicine and medicinal plants while protecting the resource base and implementing measures to reduce pressure on wild populations of rare and endemic species.

Regional: Conservation and Sustainable Use of Dryland Agrobiodiversity in Jordan, Lebanon, Syria and the Palestinian Authority. This project aimed at promoting the conservation of wild relatives and landraces of important agricultural species in the Fertile Crescent (Near East region), by introducing and testing *in situ* and on-farm mechanisms and techniques to conserve and sustainably use agrobiodiversity. Selected sites in each of the participating countries (Jordan, Lebanon, the Palestinian Authority and Syria) were used for the *in situ* conservation of 16 target crops or crop groups of global significance and their wild relatives. Among these field crops are *Triticum*, *Hordeum*, *Lens*, *Vicia*, *Lathyrus*, *Medicago*, *Trifolium* and *Allium* species. The project also planned to conserve wild and local varieties of *Olea* (olive), *Prunus* spp. (apricot, cherry, plum, almond), *Pyrus* (pear), *Pistacia* (pistachio) and *Ficus* (fig) that originated in the Near East.

Jordan: Conservation of Medicinal and Herbal Plants Project. This conservation project will support Jordan's capacity to sustainably manage the wild genetic resource base of its medicinal and herbal plants, diminish threats to the species, and identify and protect key biodiversity areas. A total of 485 species of medicinal plants, which belong to 330 genera and 99 families, has been recorded in Jordan. The project will also establish an operational database, genepool and monitoring system, improve the livelihood of rural communities, promote public awareness and environmental education on medicinal/herbal plants, and engage local communities in conservation, management and income-generating programmes. *In situ* conservation of these plants will take place at three pilot sites in Jordan. In addition, the project will establish a long-term plan for conserving and managing these plants, while strengthening the capacity of local and national institutions to meet the objectives of the conservation plan. An important element of this project will be the participation of women from local communities, who play a key role in conserving these ecosystems and in identifying curative and healing characteristics of plants.

Central Asia: 1. GEF/World Bank. Central Asia Transboundary Biodiversity Project in Kazakhstan, the Kyrgyz Republic, and Uzbekistan. This project will improve habitat management and species protection in the Protected Area Network of the West Tien Shan, a mountain range shared by the three countries located on

the western edge of the Himalayan mountain system that includes wild relatives of horticultural, agricultural, and medicinal plants.

2. In Situ/On-farm Conservation of Agrobiodiversity (Horticultural Crops and Wild Fruit Species) in Central Asia. Following a successful PDF-B operation, this project will, *inter alia*, develop methods and guidelines for analysis, documentation, and *in situ*/on-farm management of horticultural crops and wild fruit species and these will be made available to stakeholders in the five project countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan). It will focus on crops selected during the PDF-A phase and tested during the PDF-B phase: apricot (*Prunus armeniaca*), alycha (*Prunus cerasifera*), grapevine (*Vitis* spp.), pomegranate (*Punica granatum*), pear (*Pyrus* spp.), fig (*Ficus carica*), almond (*Amygdalus communis*), sea buckthorn (*Hippophae* spp.), walnut (*Juglans regia*), peach (*Persica vulgaris*), pistachio (*Pistacia vera*), and apple (*Malus* spp).

Peru: *In-Situ* Conservation of Native Cultivars and Their Wild Relatives. This project will target 11 important crop species such as lima beans, peppers and tomatoes, including several local varieties and wild relatives, for conservation of their genetic diversity within functioning agroecosystems. Genetically important areas (micro gene centres) or 'hot spots' were selected according to the following criteria:
- presence of a significantly large number of native varieties of one or more of the 11 target species
- species endemism
- existence of conservation-oriented farmers or communities that manage a number of species and varieties
- presence of traditional agricultural systems
- include diverse agroecological zones
- some traditional form of seed exchange through 'seed routes'.

Sri Lanka: Conservation and Sustainable Use of Medicinal Plants. The project will design and implement a medicinal plants conservation programme. It will support the following activities for five botanical reserves where medicinal plants are collected from the wild: baseline research, monitoring, conservation planning, community organizing, enrichment plantings, research on traditional medicinal plant knowledge, sustainable economic activities relating to medicinal plants or taking pressures off wild resources, improved marketing of such plants, and education.

Vietnam: *In-situ* Conservation of Native Landraces and their Wild Relatives in Vietnam. This project concerns the conservation of six important crop groups (rice, taro, tea, litchi–longan, citrus and ride bean), including native landraces and wild relatives, in three ecogeographical areas of Vietnam: the northern mountains,

the northern midlands, and the north-west mountains. Its main components are:
- establishment of Genetic Management Zones (GMZs) through the creation of an appropriate enabling environment
- operationalization of GMZs through capacity building, training, and removal of barriers
- targeted research, information management and analysis in support of GMZ establishment and operationalization
- public awareness, education and information dissemination in support of the replication of the GMZ approach.

The expected outcomes are that:
- native landraces and wild relatives will be conserved in dynamic agriculture/forest landscapes
- replicable models will be established of community-based Gene Management Zones (GMZs)
- an enabling environment will be established to support conservation of agrobiodiversity.

Zimbabwe: Conservation and Sustainable Use of Traditional Medicinal Plants in Zimbabwe. The Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) is an approach to development and conservation in Zimbabwe.[27] The essence of the CAMPFIRE approach is that it gives some ownership, control and benefits of wildlife to the local community rather than central control. The concept includes all natural resources, although the focus has been upon wildlife management in communal areas, particularly those adjacent to National Parks, where people have to live with the costs of having wildlife in the area. Under the GEF project, it will be adapted to the conservation of medicinal plants in four districts where CAMPFIRE is already operational. Floristic surveys will be conducted to establish the distribution of endemic medicinal plant species and the degree of threat in the pilot areas. Local communities, through their traditional leaders, will be encouraged to map out no-use zones, corridors, and buffer zones in areas that are rich in the threatened medicinal plants, using physical barriers, and to formulate local bye-laws that regulate the use of the areas where endangered medicinal plants are particularly over-exploited. In these areas, sites may be chosen for enrichment planting of appropriate medicinal plants by the local people, using seed from non-degraded areas. This component will also promote the adoption of a benefit-sharing mechanism for plants on common property (through CAMPFIRE principles). The adoption of a CAMPFIRE approach to benefit-sharing will ensure that local communities are sufficiently motivated to participate in the activities.

Part IV: The way forward, conclusions and recommendations

4.0 The way forward

As has been noted several times in this book, the number of candidate species for *in situ* conservation is far in excess of those for which human and financial resources are likely to be made available for the preparation and implementation of management, action or recovery plans for them. The Convention of Biological Diversity, in recognizing that

> the fundamental requirement for the conservation of biological diversity is the *in-situ* conservation of eco-systems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings

does not suggest restricting action to those species that are threatened. But threatened plant species alone are estimated at around 80 000–100 000, which again is such a high figure that even restricting effective conservation action to these is very unlikely to be possible. It is clear, therefore, that if a major impact is to be made on this problem, a range of different conservation scenarios needs to be considered and a multi-level strategy will have to be adopted.

A first requirement is that lists of priority species at global, regional and national levels need to be agreed for each of the major target groups of species—e.g. forestry, medicinal, aromatic, crop relatives, ornamentals, industrial—and then filtered according their degree of endangerment so that efforts can initially be directed preferentially at these. Secondly, the presence of these priority species within protected areas should be recorded. Then a strategy needs to be devised that will provide at least some degree of *in situ* protection for as many species as possible, whether threatened or not, even though this falls short of full effective conservation.

Although presence in a protected area(s) is a preferred option for *in situ* conservation, this is not a prerequisite nor in itself a necessary guarantee that any particular species will be adequately protected. The present coverage of protected areas is insufficient to include most species in need of *in situ* conservation. In addition, protected areas are seldom selected with the conservation of individual plant species in mind; they are often sited in marginal areas; the populations that occur within them are often not representative of the genetic diversity of a species; their management plans do not

normally address individual species or groups of particular species; and their management effectiveness is often poor. It is likely that this situation will improve in time but not significantly in short- and medium-term planning horizons.

On the other hand, the very presence in a protected area affords some degree of protection, at least in the short term, for the species that they house, and so another high priority is to ensure that the area is *effectively* managed and conserved. As a recent report on the effectiveness of protected areas observes (WWF 2004) "…in the medium to long term, protected areas only work if they really are protected".

In adopting a multi-level strategy, a number of different situations will be found to occur, depending on whether the species is known to be threatened or not, whether or not it occurs in a protected area and whether it is of economic importance or not. Thus:

- For widespread species which are not currently known to be threatened and of no known particular economic importance, a minimum goal is identification and monitoring of the populations of the species concerned and effective management of any protected area(s) in which they occur; or monitoring their presence and the habitat conditions if they occur outside any protected areas .
- For species of known economic importance that are not threatened, ecogeographical surveying should be undertaken to establish the amount and distribution of genetic variation and how much of it is represented in protected areas, and an assessment of conservation and monitoring needs undertaken.
- For threatened species, whether of known economic importance or not, which occur in protected areas, ecogeographical surveying should be undertaken, the extent of the genetic representation in the protected area assessed, and further areas for eventual protection identified to ensure that an adequate representation of the diversity is covered. Then action should be taken to control or remove the factors that cause the threats and, if the species is considered of sufficient priority, any necessary further conservation action that is needed, such as detailed management or recovery, should be planned and implemented. Priority-determining mechanisms for determining which species to select for priority conservation management and the various steps that such management may involve are described in the appropriate sections of this volume. Clearly, the more threatened the species is, the more intensive the conservation interventions needed are likely to be. Multi-species as opposed to single-species plans are an option, provided that the different species face the same or

similar threats, although experience suggests that for many such plans this is not the case and their effectiveness is in proportion to the amount of time and money that is devoted to the individual species.

- In the case of threatened species that are found outside protected areas, if considered of sufficiently high priority, efforts should be made to protect a sufficient amount of the area in which they occur so as to allow the representation of viable populations that cover a sufficient sample of the genetic variation. If this is not possible, alternative means of protection, including community participation, easements or habitat conservation planning should be considered (see Section 2.4).

The *in situ* conservation of target species of economic importance, often termed genetic conservation, normally requires a much more structured and focused approach, as described in Part II of this review, than that for species of no known economic value. The exception is those species for which recovery actions need to be implemented if they are to continue to survive as viable populations.

4.1 Conclusions and recommendations

- Conservation of species or populations *in situ* is a widely misunderstood process and covers a range of different situations that includes wild population and species, domesticates, ecosystems, agroecosystems, landscapes and bioregions. Conservation *in situ* of target species in natural or semi-natural habitats should be seen as but one component of an overall species conservation strategy; for many species, where no structured *in situ* conservation is possible, alternative approaches should be considered.
- The maintenance of viable populations of species in their natural surroundings is identified as a fundamental requirement for the conservation of biological diversity by the Convention on Biological Diversity. However, effective *in situ* conservation of target species can be a complex, multidisciplinary, time-consuming and expensive process, often involving different agencies, which because of the restricted resources and finance available, can only be applied to a small minority of species, even those that are endangered. Consequently, it cannot be considered for the majority of species for which various less formal (and usually less effective) approaches may be adopted.
- The number of potential candidate species that might be selected for *in situ* conservation in the various target groups such as forestry, medicinal, aromatic, ornamental and industrial species,

crop relatives, and species of scientific importance, is so high (tens of thousands) that effective conservation management of only a small selection of those that are identified as targets is possible. Priority mechanisms for selecting target species is therefore a critical process and the criteria adopted will depend on the group of species, national priorities, and economic and environmental considerations. It is likely that within any group greatest priority will be given to species that are known to be threatened.

- Even if the wild populations of target species selected for *in situ* conservation need little direct management or intervention, 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, as well as undertaking monitoring and containing or eliminating any threats to their survival, are onerous.

- For the majority of potential target species, therefore, no formal conservation management strategy is possible and for these the burden of effort must fall on Protected Area systems and managers and on local communities. At a minimum, awareness of the presence of target species in protected areas should lead to some form of monitoring if no further action can be taken towards meeting the conservation needs of the species.

- The target of 60 per cent of the world's threatened species conserved *in situ* by 2010 proposed in the Global Plant Conservation Strategy will not be practicable in a formal sense (management, action or recovery programmes) except for a minority of these. For the majority of threatened species (which have been recently estimated as numbering roughly 80 000–100 000), other kinds of action, such as strengthening the role of protected areas in which they occur, surveying and monitoring of populations, moderating or removing the source of the threats, may afford some degree of protection. Local communities should be expected to play a significant role in these actions in many cases. It is recommended that the SBSTTA and the CBD review the whole issue of *in situ* species conservation as a matter of urgency.

- A key requirement for assessing the requirements for *in situ* conservation of species is an adequate information base. This is not available for most countries and no global assessment of *in situ* conservation needs exists.

- National lists of target species in the various priority groups should be prepared and then information gathered on the distribution, ecology, demography, variation patterns and conservation status of the species listed.

- A review of the literature and discussions with experts reveal that the number of cases of effective practical *in situ* conservation of target species is still small and mainly confined to developed countries in temperate and Mediterranean regions of the world, such as the USA, most European countries, Australia and New Zealand. It is likely that the number of species which are currently the subject of active *in situ* conservation action represents less than 1% of the total plant species (*c.* 400 000), most of them being rare or endangered wild species identified by national Red List programmes.
- The two main groups of species that have been the subject of most *in situ* conservation action to date—nationally or locally rare and endangered Red List species and forestry species—have both attracted a large body of literature referring to theoretical and practical aspects of priority determination, selection, sampling, management and conservation strategies. Unfortunately those involved in such areas have tended to pay little attention to each other's work. It is strongly recommended that each sector should take active steps to learn from the experience of the others. This review should provide an introduction to what literature is available and what kind of work is currently being undertaken.
- Species recovery programmes have been instituted for hundreds of species globally, mainly in temperate-climate countries. They are complex, time-consuming and expensive, and it is too early to judge how successful they will be in the longer term.
- This review also reveals that for economically important species three main groups have been the focus of *in situ* conservation: forestry tree species, wild crop relatives, and medicinal and aromatic plants. Conservation of forest genetic resources *in situ* in natural or semi-natural forests is a long-standing tradition and considerable practical experience has been gained during the past 50 years. This experience is largely unknown outside forestry and has been largely overlooked by other sectors involved in *in situ* species conservation. Similarly the very extensive theoretical and practical background gained in species recovery programmes is often overlooked by the agricultural and forestry sectors.
- Most of the efforts that have been invested in crop genetic resources have been directed at conservation in *ex situ* facilities such as seed banks. Until recently, the only form of *in situ* conservation at the species and infraspecies level practised or even recognized has been that known as 'on-farm', for landraces of crops.

- On the other hand, there is greatly increased awareness of the need for *in situ* conservation of species following the publication of the CBD and the FAO's Global Plan of Action. Consequently, in a growing number of countries considerable effort is going into establishing baseline information on which species are candidates for selection for *in situ* conservation action and undertaking ecogeographical surveying that will allow such programmes to be planned. Many countries, however, have no plans to take action in this area. Likewise, most conservation organizations have not given *in situ* conservation of species much prominence, other than for those that are on Red Lists.
- In priority-determining strategies, many factors can be taken into account, some of them obvious, some of them more complex, while others may only be applicable in particular cases or types of plant; others may be applicable only at a later stage of the process, such as degree of management needed.
- Degree of threat or endangerment is widely adopted as a filter for all groups of target species, including those of economic importance. Although this is understandable, it does run the risk of excluding conservation measures being taken for widespread species of major economic importance, such as forestry species or crop wild relatives, where the need to preserve particular values such as alleles, genotypes or ecotypes for present and future use, while they still exist, is justified. It should also be recognized that information on which species are threatened and the nature of the threats is not available for most species that occur in tropical biomes.
- Protected areas play a major role in the *in situ* conservation of species of economic importance, as habitats where many of them will be found to occur. A first requirement is that the long-term protection of such areas should be effective. It should be emphasized that simple presence in a protected area is not sufficient to constitute an adequate conservation plan for the target species, as this would require a selection to be made of which and how many populations and individuals in each population are needed to ensure the maintenance, survival and continued evolution of a significant part of the genetic variability of the species concerned.
- Most protected areas were not set up with conservation of particular species in mind and even the presence in the area of those that are identified as target species will not be known in many cases. Floristic inventories of protected areas should be given priority as part of national strategies for *in situ* species-orientated conservation.

- Protected Area managers should consider the possibility of enhancing the level of protection to be afforded to the populations of species of economic importance that are found to occur within their reserves, through modifying the management of the area where possible. Although this would fall far short of effective *in situ* conservation of such species, it would contribute to the overall goal.
- Apart from the different categories of protected areas recognized by IUCN, a wide range of specialized types of protected areas designed for genetic conservation exists, but much more work needs to be undertaken to establish their effectiveness.
- In the case of species of economic importance that are directly harvested or consumed (such as medicinal plants or fruits), *in situ* conservation needs to be closely integrated within an overall framework of sustainable resource management.
- The *in situ* conservation of species outside protected areas, where the majority of them occur, is a subject that deserves much further consideration by conservation agencies. While the very act of taking steps to protect, manage or conserve species populations in such areas effectively brings them under the umbrella of protected areas, there are other indirect means, such as easements, whereby some degree of protection to the species can be afforded through agreements to reduce the level of exploitation or to contain threats. Much greater attention should be paid in engaging local communities in protecting species in their natural habitats and in their sustainable utilization.
- Promoting more biodiversity-sensitive management of ecosystems outside protected areas, especially of those known to contain target species, needs to be given high priority. National authorities should be encouraged to develop regulatory mechanisms to ensure the conservation and sustainable use of these resources, in line with Article 8b of the Convention on Biological Diversity.
- Numerous guidelines exist for the various components of *in situ* conservation strategies; some are general while others are highly detailed; some apply to particular classes of target species while others are focused on particular species. It is not possible to make a useful synthesis of these guidelines apart from some basic elements they have in common, and great care needs to be taken when adopting any particular set of guidelines to ensure that they are appropriate to the species involved. It is clear from this review that the circumstances and requirements in each particular case of *in situ* conservation of target species is unique and that there is no single set of procedures which can be applied, although of course some general principles apply.

- The future effects of the various components of global change on *in situ* conservation programmes are difficult to predict but it seems likely that in some regions, not only will the individual species but the ecosystems in which they are occur or are conserved *in situ* be put at risk.

Appendix 1: IPGRI's new vision and mission

Extract from *IPGRI's New Strategic Directions—Diversity for Well-being: Making the Most of Agricultural Biodiversity* (IPGRI 2004)

Our vision
People today and in the future enjoy greater well-being through increased incomes, sustainably improved food security and nutrition, and greater environmental health, made possible by conservation and the deployment of agricultural biodiversity on farms and in forests.

Our mission
IPGRI undertakes, encourages and supports research and other activities on the use and conservation of agricultural biodiversity, especially genetic resources, to create more productive, resilient and sustainable harvests. Our aim is to promote the greater well-being of people, particularly poor people in developing countries, by helping them to achieve food security, to improve their health and nutrition, to boost their incomes, and to conserve the natural resources on which they depend. IPGRI works with a global range of partners to maximize impact, to develop capacity and to ensure that all stakeholders have an effective voice.

The purpose of IPGRI's work is to ensure that individuals and institutions are able to make optimal use of agricultural biodiversity to meet the current and future development needs of people and societies. To achieve this purpose, and in support of its mission, IPGRI will carry out a range of activities to meet six broad objectives.

Demonstrating the benefits: Demonstrating the social, economic and environmental benefits of agricultural biodiversity.

Biodiversity for income and food security: Ensuring that agricultural biodiversity is conserved, characterized and used to improve productivity.

Researching agricultural biodiversity: Generating knowledge about agricultural biodiversity through research and making such knowledge available.

Enabling and empowering: Developing human and institutional capacity to conserve and make effective and sustainable use of agricultural biodiversity.

Supportive policies: Analysing policies and fostering an environment that supports the conservation and use of agricultural biodiversity.

Getting the word out: Raising awareness of the values of agricultural biodiversity and the importance of the conservation of genetic resources.

Appendix 2: IUCN/SSC plant conservation strategy 2000–2005

Goal: The extinction crisis is acknowledged as a global problem, and the current rate of loss of plant diversity is decreased

Objective 1: Sound interdisciplinary scientific information underpins decisions and policies affecting plant diversity

OUTPUT 1.1: The SSC Plants Programme promotes conservation of important plant areas by refining the criteria for identification of Centres of Plant Diversity and other priority plant areas, and assisting in implementing programmes to conserve such sites at appropriate regional, national and local scales.

Activity 1: Undertake a review of criteria for selecting priority plant conservation areas involving appropriate stakeholder groups, with a view to refining criteria at a range of geographical scales.

Activity 2: Develop a *Centres of Plant Diversity and Important Plant Areas* booklet, that provides guidelines and criteria for selection (along the lines of the Red List Criteria), together with models for associated conservation action.

Activity 3: Through workshops encourage the process of selecting important plant areas at regional, national and local levels, in association with IUCN members, IUCN regional offices and other appropriate organizations and agencies.

Activity 4: Through partnerships with national, regional and local networks, facilitate one or more workshops for the development of site-based Action Plans for priority plant areas and plant area clusters, and ensure that these plans are available to local groups.

Activity 5: Promote and develop appropriate monitoring programmes for tracking action and implementation of site-based Action Plans.

OUTPUT 1.2: The SSC Plants Programme participates in projects on specific conservation issues, such as the conservation of wild plants of importance for food and agriculture and other selected economic plants, and the study and mitigation of major threats by providing inputs to the development and implementation of these projects.

Activity 6: The SSC Plants Programme collaborates in reviews and analyses of existing guidelines for *in situ* conservation

of plants and their further development, utilizing the experience gained from *in situ* research and management.

Activity 7: The SSC Plants Programme collaborates in projects on the conservation of wild relatives of crop plants, for example, in the development of a catalogue of wild relatives and the distribution and use of protected areas for their *in situ* conservation.

Activity 8: Particular attention is paid to building capacity to combat major threats to plants, with particular emphasis on the growing global problem of invasive alien species.

OUTPUT 1.3: The SSC Plants Programme should assist the functioning, implementation, and growth of programmes and information networks which facilitate effective and rigorous listing of conservation status of plants.

Activity 9: The SSC Plants Programme will promote, in collaboration with other interest groups, the concept of indicators which provide periodic and regular 'global state of biodiversity' assessments by tracking extinction, changes in overall threats and numbers of taxa under threat, action effectiveness, and data on critically threatened sites.

Activity 10: The SSC Plants Programme vigorously seeks, in cooperation with the SSC Red List Programme and other like-minded organizations, to establish funding to ensure ongoing security for plant listing programmes including the listing process itself.

Activity 11: Conservation status information provided (especially) by the work of the SSC Specialist Groups is integrated into and provides guidance for the SSC Red Listing Programme, and is used to help determine conservation priorities.

Objective 2: Collaboration and strategic alliances, including local and national organizations outside the SSC, are increasingly used within the plant conservation community to achieve plant conservation success

OUTPUT 2.1: In developing and implementing the SSC Plants Programme, strategic alliances with appropriate international, national, and local organizations outside the SSC are formed and nurtured as part of an expanding global network.

Activity 12: The SSC Plants Programme identifies existing partnerships and gaps, and actively seeks and establishes international, national and local partnerships to develop and implement its Plants Programme.

Activity 13: The SSC Plants Programme develops and nurtures partnerships which lead to funding for plant conservation activities.

Activity 14: The SSC Plants Programme encourages the involvement of Programme members at relevant conferences and meetings to promote SSC activities and programmes, the development of a calendar of such meetings, and the identification of participation opportunities.

OUTPUT 2.2: Partnerships and working collaborations are formed among the SSC Plants Programme and other sectors of the SSC and the IUCN, while the SSC Plants Programme maintains and strengthens its own network.

Activity 15: SSC members and other parts of IUCN develop integrated and effective ways to ensure that the needs of plants are fully recognized within all appropriate SSC/ IUCN programmes, including such initiatives as *Plant-Link* (working with animal-based SSC Specialist Groups), and participation in the Species Information Service (SIS) and the Biodiversity Conservation Information System (BCIS).

Activity 16: The SSC continues to create and implement its Plants Programme as a core activity and to plan plant conservation actions primarily through Plant Specialist Groups, which are encouraged to seek their own strategic alliances with appropriate local groups (both within and outside IUCN).

Objective 3: Modes of production and consumption that result in the conservation and restoration of plant diversity are adopted by users of plant resources

OUTPUT 3.1: Activities promoting the sustainable use of plant resources are identified and supported through the SSC by Specialist Group programmes and strategic links to other SSC and IUCN activities and appropriate non-IUCN partnerships.

Activity 17: Maintain and develop collaboration with appropriate organizations and programmes (such as the Sustainable Use Specialist Group) to achieve standards for assessing and managing the impact of use on wild plant resources.

Activity 18: To promote the dissemination of the sustainable use concept for plants and ensure inclusion in national, regional and local planning documents, and ensure that Action Plans and activities involving plants take into account the sustainable use of plants.

Activity 19: The SSC Plants Programme participates through the Medicinal Plants Specialist Group in inter-agency collaboration on the conservation and use of medicinal plants with particular reference to sustainable production, benefit-sharing and community participation.

Objective 4: SSC's plant policy recommendations, guidelines, and advice are valued, adopted, and implemented by relevant audiences

OUTPUT 4.1: The SSC Plants Programme targets conservation professionals and institutions as part of its outreach activity.
Activity 20: SSC Plants Programme outputs are made widely available through an established and comprehensive network of professionals, practitioners and institutions, with the Programme becoming a clearing house for information on plant conservation, especially through its website.

OUTPUT 4.2: The SSC Plants Programme builds resources and helps others to build resources to support awareness campaigns on priority plant conservation sites, threatened species, and related issues.
Activity 21: Existing links with widespread and effective disseminating media are used and strengthened; new media relationships are vigorously developed, including regular and effective press releases and articles on plant conservation needs, challenges, and achievements.
Activity 22: Capacity is built to create, review, and promote documented Top 50 plant lists with a view to promoting conservation action from global to local levels, linking this with the IUCN Commission on Education and Communication.

OUTPUT 4.3: The SSC Plants Programme promotes an integrated plant conservation philosophy and methodology that includes the concept of sustainable use as well as protection, and this integration is increasingly strengthened by appropriate collaboration with *in situ* and *ex situ* organizations, both nationally and internationally.
Activity 23: Integrated conservation messages, stressing the combined values of *in situ* and *ex situ* conservation, and promoting the roles of research, education, habitat restoration and species recovery are incorporated into all SSC Plants Programme documents, relevant IUCN publications, and consultations.
Activity 24: As a general principle, the SSC Plants Programme promotes rapid response to changes in conservation priorities and needs, and the adoption of appropriate new

concepts and methodologies by plant research, management and conservation communities.

Objective 5: Capacity to provide long-lasting, practical solutions to plant conservation problems is markedly increased

OUTPUT 5.1: Well-funded training, technology transfer, personnel exchanges, and information availability are encouraged by the SSC Plants Programme as principal plant conservation capacity-building measures for lesser-resourced nations.

Activity 25: The SSC Plants Programme identifies and works in partnership with existing international, national, and local plant conservation training programmes, promoting within-country capacity building and the identification of training gaps.

Activity 26: The SSC Plants Programme promotes the concept of 'best practice', the identification of 'best practice' case studies, and the dissemination of this information to conservation practitioners through publications and websites (including the SSC plant website).

OUTPUT 5.2: Research in conservation biology, sustainable plant use, off-site techniques, and the management of plants and their habitats (especially when linked to management and restoration of landscapes, ecosystems and natural resources), is vigorously promoted and facilitated by the SSC Plants Programme.

Activity 27: The SSC Plants Programme collaborates with other plant conservation interest groups to formulate and promote a collaborative agenda of global research priorities leading to practical application at the local level.

OUTPUT 5.3: Programmes for conservation of plants are vigorously pursued at appropriate and linked scales from global to local, with overall capacity and levels of both discretionary and targeted funding raised.

Activity 28: A project for linking funding sources and new initiatives is developed to facilitate both the operation of the SSC Plants Programme and effective linkages to related programmes and initiatives.

Appendix 3: *In situ* conservation guidelines

General guidelines

An integrated conservation approach, called 'Conservation by Design', has been proposed by the Nature Conservancy (*Conservation by Design: A Framework for Mission Success*. Nature Conservancy 1996, 2004), comprising four basic components:

- Setting priorities through ecoregional planning
- Developing strategies to conserve both single and multiple conservation areas
- Taking direct conservation action
- Measuring conservation success.

The concepts, standards, and procedures for these steps (except taking action) are encapsulated in two practitioners' handbooks: *Setting Priorities—Designing a Geography of Hope: Guidelines for Ecoregion-Based Conservation*, which presents the methodology and guidelines for conservation planning at the ecoregional scale, and *Developing Strategies: The Five-S Framework for Site Conservation—A Practitioner's Handbook for Site Conservation Planning and Measuring Conservation Success*, which sets out a framework for site-based conservation, including strategic conservation of medicinal plants. Although aimed specifically at TNC's own policy approach, these documents are a valuable guide and source of information for anyone developing and implementing a conservation strategy.

A series of papers outlining scientific experiences and implications for institutions and national policies on *in situ* conservation of agrobiodiversity, based on a meeting held in Lima, Peru, is in press (Prain 2003; G. Prain personal communication 2004).

One of the earliest reviews of *in situ* conservation of wild plant genetic resources was undertaken by IUCN in 1984 (IUCN 1984). The Proceedings of a series of workshops held under the aegis of the Council of Europe on the conservation of wild relatives of European cultivated plants contains a wide ranging review of the issues and problems and includes a series of case studies (Valdés et al. 1997).

The *ad hoc* Working Group on *In Situ* Conservation of Plant Genetic Resources established by the Ecosystem Conservation Group (FAO, UNESCO, UNEP, IUCN and IBPGR (later IPGRI) included the preparation of an information document on *in situ* conservation in its work programme. This led to the preparation of a booklet *Plant Genetic Resources: Their Conservation In Situ for Human Use* by FAO, which contains valuable guidelines for *in situ* conservation (FAO 1989).

The edited volume *Plant Genetic Conservation: The In Situ Approach* (Maxted et al. 1997a) is a valuable resource with chapters by experts covering most aspects of *in situ* conservation.

The IUCN Species Survival Commission has commissioned a series of Action Plans which contain conservation strategies/guidelines for a number of plant groups such as palms (Johnson 1996), cycads (Donaldson 2003), cacti and succulents (Oldfield 1997), orchids (Hágsater and Dumont 1996) and conifers (Farjon and Page 1999).

Endangered wild species

Genetic sampling guidelines for conservation collections of endangered plants have been proposed by the US Center for Plant Conservation (Center for Plant Conservation 1991). Although these are aimed at *ex situ* collections, they are partly relevant to *in situ* conservation.

Medicinal plants

The *Guidelines for the Conservation of Medicinal Plants* (WHO/IUCN/ WWF 1993) arising from the WHO/IUCN/WWF International Consultation on Conservation of Medicinal Plants, Chiang Mai, 21–26 March 1988, were the first to be specifically aimed at medicinal and aromatic plants. Although in need of revision, they are still a useful source of information.[28]

The US Plant Conservation Alliance Medicinal Plant Working Group (http://www.nps.gov/plants/medicinal/index.htm) is engaged in what it terms an 'evolving strategy' for medicinal plant conservation.

Forest genetic resources

A considerable number of guidelines and methodologies for genetic conservation of forest trees has been issued. The first appears to have been that published by FAO in 1975 (FAO 1975), including a substantial section on *in situ* conservation. An important contribution is Volume 2 in the series *Forest Genetic Resources: Conservation and Management* (FAO/DFSC/IPGRI 2001; see also Patiño-Valera 2002) which contains guidance and a checklist for developing a programme of *in situ* conservation of target species or a group of species, based on local conditions and specific objectives, and includes a step-by-step approach to enhancing the conservation of role of protected areas for forest genetic resources. Criteria and indicators for sustainable forest management which "includes a balance of productive, protective, environmental and social components", as it relates to forest genetic diversity, are summarized in a paper on status and trends of forest genetic diversity (McKinnell 2002). More specifically genetic aspects are reviewed in an FAO working paper (Namkoong et al. 2002) on criteria and indicators for sustainable forest management in terms of assessment and monitoring of genetic variation.

The Committee on Managing Global Genetic Resources: Agricultural Imperatives of the National Research Council, US National Academy of Sciences, published an assessment of the need to manage the world's forests, and conserve tree genetic resources and the methods and technologies available (National Research Council 1991). It is a valuable reference source and includes a section on *in situ* methods.

Members of EUFORGEN Networks are producing a set *of Technical Guidelines for Genetic Conservation and Use* (see http://www.ipgri.cgiar.org/networks/euforgen/Technical_Guidelines. asp). These are already available for nine species (*Picea abies*, *Pinus brutia*, *Pinus halepensis*, *Pinus pinaster*, *Acer pseudoplatanus*, *Alnus glutinosa*, *Fraxinus excelsior*, *Prunus avium* and *Sorbus domestica*) and it is planned that altogether about 30 will be published.

A Technical Bulletin on the European black poplar (*Populus nigra*), gives information and provides guidance for the *in situ* conservation and management of this pioneer tree species of the riparian forest ecosystem (Lefèvre et al. 2001). It is the result of the collaborative activities of European countries within the *Populus nigra* Network of the European Forest Genetic Resources Programme (EUFORGEN).

Management guidelines for *in situ* conservation of wind-pollinated temperate conifers such as Norway spruce (*Picea abies*) have been produced (Koski 1996; Koski et al. 1997).

National guidelines or strategies have been produced by several European countries for the genetic conservation of forest tree species or those of economic importance, for example Denmark, Finland, France.

Conservation guidelines for a number of native South Pacific trees have been prepared (Thomson 1998).

A very detailed account of the *in situ* genetic conservation of the Monterey pine (*Pinus radiata* D. Don) has 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, it contains a series of principles and recommendations for its *in situ* conservation.

Crop wild relatives

The Plant Germplasm Operations Committee of the USDA-ARS National Germplasm System (NPGS) has produced a set of *in situ* conservation guidelines for the American wild relatives of crops (USDA 1999) based on work on a number of groups. They focus on natural populations in undisturbed or relatively undisturbed ecosystems and cover principally:

- selection of target taxa
- compiling species information
- field and laboratory procedures
- proposing preserves.

A set of recommendations on *in situ* conservation of wild relatives was made to the European Symposium on the Implementation of the Global Plan of Action in Europe, Braunschweig, Germany 1988 (Heywood and Firat 1999).

Although not in the form of Guidelines, the Proceedings of the three workshops on Conservation of the Wild Relatives of European Cultivated Plants: Developing Integrated Strategies (Valdés et al. 1997), held under a Council of Europe initiative, contain articles on most aspects of in situ conservation, as noted above.

Fruit germplasm

A review of *in situ* conservation of tropical fruit germplasm, including a series of guidelines, is included in the workshop on Tropical Fruits in Asia: Conservation and Use (van den Hurk 1998).

Conservation strategies and management guidelines for wild *Prunus* genetic resources have been prepared for Spain (Vivero et al. 2001).

Ornamentals

A recent review (Heywood 2003a) notes that

> the conservation and sustainable use of those wild species that may have potential for introduction as new ornamental crops or as sources of genetic material that can be used in the development of existing crops, needs a much more coherent strategy than at present exists.

This should be implemented at a national level and cover areas such as:

- surveying at national level of the various holdings, both in cultivation and in seed banks, of the different categories of species of ornamental or amenity value
- An assessment of the conservation status and needs of these resources
- information and documentation resources and needs
- identification of priority species or other taxa in need of urgent conservation action
- assessment of the role of protected areas for the *in situ* conservation of target ornamental species
- sampling methodologies

- the capacity of germplasm banks, botanic gardens and other institutions for the exploration and maintenance of genetic resources of ornamentals
- the role of the nursery trade in the conservation of ornamentals
- research on germination, propagation and regeneration of seeds of ornamental species
- setting achievable targets.

Genetic resources in protected areas

A set of recommendations for the Conservation of Genetic Resources in Protected Areas was made at a Workshop held at the IV World Congress on National Parks and Protected Areas, Caracas (Heywood et al. 1993).

The sequence of steps involved in enhancing the management of protected areas that contain genetic resources of forest tree species, so as maintain the target species as well as the ecosystem, is given in a recent review of the conservation and management of forest genetic resources (Thomson and Theilade 2001).

Monitoring

The most comprehensive set of guidelines on measuring and monitoring plant populations is that produced by the US Bureau of Land Management—*Measuring and Monitoring Plant Populations* (Elzinga et al. 1998a; see also Elzinga et al. 1998b). This is a major technical reference work that should be widely available for consultation on many aspects of species conservation, not just monitoring. The various chapters cover, in 477 pages, topics such as setting priorities and selecting scale, management objectives, principles of sampling, sampling objectives and design, field techniques for measuring vegetation, data management, communication and monitoring plans, statistical analysis, demography and reporting results.

Biosphere reserves and buffer zones

A guide for the management of biosphere reserves has been published as a UNESCO MAB Digest (Bioret et al. 1998). A set of guidelines for the buffer zones in tropical forests has been prepared by IUCN (Sayer 1991)

Participatory process

A review and set of guidelines for the participatory approach in the conservation of forest genetic resources is published in the DFSC Guidelines and Technical Notes series (Isager et al. 2002). The Proceedings of an international seminar on Participatory

Approaches to the Conservation and Use of Plant Genetic Resources has been published by IPGRI (Friis-Hansen and Sthapit 2000).

Reintroductions

The Re-introduction Specialist Group of the IUCN's Species Survival Commission has prepared the *IUCN/SSC Guidelines for Re-Introductions* (IUCN/SSC 1995). These policy guidelines were prepared as a response to the growing occurrence of reintroduction programmes worldwide. Although now somewhat dated, they still provide a useful summary.

A handbook for reintroduction of plants to the wild has been published by Botanic Gardens Conservation International (Akeroyd and Wyse Jackson 1995).

A *Reference List for Plant Re-introductions, Recovery Plans and Restoration Programmes* was prepared by Royal Botanic Gardens Kew in 1995 but has not been subsequently updated (Atkinson et al. 1995).

In 1998, the Plant Conservation Alliance initiated a project to create a comprehensive *Restoration Directory* which includes both restoration experts and native plant sources. It is currently available on the Society for Ecological Restoration International's website (http://www.ser.org/about.asp).

The Australian Network for Plant Conservation (ANPC) (Mill 2002) has published *Guidelines for Germplasm Conservation* for the conservation, recovery and management of threatened flora (ANPC 1997a; see also Stephens and Maxwell 1998) and for the translocation of threatened plants in Australia (ANPC 1997b), that have been supported by the Standing Committee on Conservation of the Australia and New Zealand Environment and Conservation Council (the Council of Australian and New Zealand Environment and Conservation Ministers). *Recovery Plan Guidelines for Nationally Listed Threatened Species and Ecological Communities* have been published for Australia by the Federal Government (Environment Australia 2002).

A valuable introduction to restoration genetics has been prepared for the Society for Ecological Restoration (Falk et al. 2001) and a useful volume on strategies for the reintroduction of endangered plants has also been published (Falk et al. 1996).

A 400-page manual *Plant Conservation: Approaches and Techniques from an Australian Perspective*, a practical guide of issues and methods prepared by a series of experts for the Australian Network for Plant Conservation (ANPC) has been published (Brown et al. 2003).

Appendix 4: IPGRI's networks

AMS Networks
REDARFIT, REMERFI, TROPIGEN, PROCISUR, CAPGERNet, NORGEN

APO Networks
EA-PGR, RECSEA-PGR, SANPGR
- Regional Network for Conservation and Utilization of Plant Genetic Resources in East Asia (EA-PGR)
- Asian Network for Sweet Potato Genetic Resources (ANSWER)
- International Network on Bamboo and Rattan (INBAR)
- Regional Cooperation in Southeast Asia for Plant Genetic Resources (RECSEA-PGR)
- South Asia Network on Plant Genetic Resources (SANPGR)

COGENT
International Coconut Genetic Resources Network

CWANA Networks
CA-TC/PGR, WANANET

ECP/GR
European Cooperative Programme for Crop Genetic Resources Networks

EUFORGEN
European Forest Genetic Resources Network
- EUFORGEN *Populus nigra* Network
- EUFORGEN Conifers Network
- EUFORGEN Mediterranean Oaks Network
- EUFORGEN Noble Hardwoods Network
- EUFORGEN Temperate Oaks and Beech Network

INIBAP
International Network for the Improvement of Banana and Plantain

SGRP
System-Wide Genetic Resources Programme

SINGER
System Wide Information Network for Genetic Resources

SSA Networks
GRENEWECA, SPGRC, EAPGREN, MUSACO, BARNESA, SAFORGEN

Endnotes

1. The term should be, correctly, *inter situs* (between sites); in fact the term *situs* (fourth declension masculine), according to Stearn (1973), means 'position occupied by an organ', while site in the sense of place is *locus* (second declension masculine) but the terms *in situ* and *ex situ* are entrenched in the literature.
2. It is important to distinguish between the terms rehabilitation and restoration. The former refers to the re-establishment of a functioning ecosystem not necessarily with the same set of species that were present at the site, while restoration technically means reproducing the community or ecosystem that was once present with extant species or their analogues (Bradshaw 1987).
3. The term is, however, ambiguous in that it covers both the conservation of wild relatives of crops in their natural habitats and the creation of artificial populations that are grown on a large scale in farmers' fields or in experimental areas, which allow the various ongoing human and natural selection pressures to operate on them.
4. Also referred to as *circum situm* and, incorrectly, as *circum situ* or *circa situ*—cf. Note 1.
5. The consistent use by the CBD of the term 'the ecosystem approach' is somewhat misleading, as it recognizes that there is no single way to implement it, depending as it does on local, provincial, national, regional or global conditions. It is also mades clear that it "does not preclude other management and conservation approaches such as biosphere reserves, protected areas and single-species conservation programmes, but could, rather, integrate all these approaches and other methodologies to deal with complex situations" and also states that "there are many ways in which ecosystem approaches may be used as the framework for delivering the objectives if the Convention in practice" (CBD/COP Decision V/6 Annex A; see also UNESCO 2000).
6. IUCN (2003) adopts a wider definition, which includes biophysical (climate change, sea level rise, habitat loss and fragmentation, invasive alien species), socio-economic (growing population, intensified land and resource use, changing values of ecosystem services) and institutional change (globalization, democratization, decentralization) components.
7. LIFE, the Financial Instrument for the Environment, introduced in 1992, is one of the spearheads of the European Union's environmental policy. LIFE Nature is one of its areas of action and is aimed at the conservation of natural habitats and the wild fauna and flora of European Union interest, according to the Birds and Habitats directives.
8. Full details available at http://europa.eu.int/comm/environment/nature/nature_conservation/natura_2000_network/financing_natura_2000/art8_working_group/pdf/final_report_en.pdf
9. The Convention on the Conservation of European Wildlife and Natural Habitats, adopted in Bern on 19 September 1979 at the 3rd European Ministerial Conference on the Environment, came into force on 1 June 1982.

10. See http://www.iucn.org/themes/forests/protectedareas/ MaindocCatieProceedings.pdf. A summary is given in a special issue of Arborvitae on Management Effectiveness of Protected Areas (January 2000).

11 The term 'Standard Flora' refers to works that are the most generally acknowledged by botanists in the country or region concerned as the most reliable source of information on the plants that occur there. In some cases there is more than one Standard Flora for a country or region.

12. *Euro+Med PlantBase: A guide for contributors of initial taxonomic accounts*. Version 2.0 July 5, 2002 (see http://www.euromed.org.uk/d_ocuments/5.7.02_revision_ guidelines.pdf).

13. See the Euro+Med PlantBase website at http://www.euromed.org.uk for up-to-date information.

14. See References on spatial analysis and GIS applied to genetic resources management at http://www.ipgri.cgiar.org/regions/Americas/programmes/ gisreferences.htm

15. For a list see the Community-Based Natural Resource Management Network at http://www.cbnrm.net/

16. See the *Grassland Reserve Program Fact Sheet* Electronic Edition (June 2003) (http://www.fsa.usda.gov/pas/publications/facts/html/GRP03.htm).

17. A review of the status and trends in the development of indicators of forest genetic diversity is given by McKinnell (2002).

18. See Flora Bank Guideline 10: Seed Collection Ranges For Revegetation 1999 (http://www.florabank.org.au/Default.htm).

19. These are reviewed in the State of the World's Plant Genetic Resources for Food and Agriculture (FAO 1998).

20. "…'*in situ*' conservation in a few valuable selected localities is planned, on the basis of systematic mapping of the Czech territory. Ecotypes of grasses and fodder crops as well as some fruit trees will be the target materials. In some cases these genetic resources are located in protected areas and '*in situ*' conservation is actually provided by existing national authorities (e.g. in the national parks Sumava or Krkonose)."

21. EU Council Directive 92/43/EEC of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna and Flora.

22. A list can be found at http://www.deh.gov.au/biodiversity/threatened/ recovery/index.html

23. See Table 4.1 in http://www.fao.org/WAICENT/FAOINFO/AGRICULT/ AGP/AGPS/Pgrfa/pdf/zambia.pdf

24. See *UNDP In Situ Conservation of Native Landraces and their Wild Relatives in Vietnam*. VIE/01/G35 (available at http://www.undp.org.vn/projects/ vie01g35/gmz.htm).

25. The CITES quota for 2001 for *Galanthus elwesii* from Turkey was 6 million bulbs and for *Galanthus woronowii* 2 million.

26. Participatory approaches to biodiversity management and conservation in this region based on the Bedouins' technologies is included as one of the goals of the

Sinai subglobal assessment of the Millennium Ecosystem Assessment (http://www.millenniumassessment.org/2/subglobal.sinai.aspx).

27. See the Wildlife and Development series of articles at: http://wildnetafrica.co.za/bushcraft/articles/document_campfire1.html

28. A revision of the guidelines has in fact being carried out by WHO, IUCN, WWF and TRAFFIC together with many medicinal plant experts world-wide and will be published in 2005.

References

Ahmedullah, M. 2001. Country report on Red Listing of plants in India. In: Balakrishna, P. (ed.), Using the IUCN Red List Criteria at the National Level: A regional consultative workshop for south and southeast Asia. IUCN Regional Biodiversity Programme Asia, Colombo, Sri Lanka. pp. 20–22.

Ahmedullah, M. and Nayar, M.P. 1999. Red Data Book of Indian Plants, Vol. 4. Botanical Survey of India, Calcutta, India.

Akerele, O., Heywood, V. and Synge H. (eds.) 1991. Conservation of Medicinal Plants. Proceedings of of an international consultation, 21-27 March 1988, held at Chaiang Mai, Thailand. Cambridge University Press, Cambridge, UK.

Akeroyd, J. and Wyse Jackson, P. (eds.) 1995. A Handbook for Botanic Gardens on the Reintroduction of Plants to the Wild. Botanic Gardens Conservation International, London, UK.

Andelman, S.J. and Fagan, W.F. 2000. Umbrellas and flagships: efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences of the USA 97:5954–5959.

Anderson, S. 2002. Identifying Important Plant Areas. Plantlife International, London, UK.

Anikster, Y., Feldman, M. and Horovitz, A. 1997. The Ammiad experiment. In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 239–253.

ANPC. 1997a. ANPC Germplasm Conservation Guidelines for Australia: An introduction to the principles and practices for seed and germplasm banking of Australian species. ANPC Germplasm Working Group. Australian Network for Plant Conservation, Canberra, Australia. Available from: http://www.anbg.gov.au/anpc/books.html#Germplasm

ANPC. 1997b. Guidelines for the Translocation of Threatened Plants in Australia. ANPC Translocation Working Group. Australian Network for Plant Conservation, Canberra, Australia. Available from: http://www.anbg.gov.au/anpc/books.html#Translocation

Arora, R.K. and Paroda, R.S. 1991. Biosphere reserves and *in-situ* conservation. In: Paroda, R.S. and Arora, R.K. (eds.), Plant Genetic Resources: Conservation and management. International Board for Plant Genetic Resources, Regional Office for Southeast Asia, New Delhi, India. pp. 299–314.

Arora, R.K. and Ramanatha Rao, V. (eds.) 1998. Tropical Fruits in Asia: Diversity, maintainance, conservation and use. Proceedings of the IPGRI-ICAR-UTFANET Regional Training Course on the Conservation and Use of Germplasm of Tropical Fruits in Asia held at Indian Institute of Horticultural Research, 18–31 May 1997, Bangalore, India. IPGRI Office for South Asia, New Delhi, India.

Atkinson, P.J., Maunder, M. and Walter, K.S. 1995. A Reference List for Plant Reintroductions, Recovery Plans and Restoration Programmes. Version 1, September 1995. Royal Botanic Gardens, Kew, UK.

Baillie, J.E.M., Hilton-Taylor, C. and Stuart, S.N. (eds.) 2004. 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN, Gland, Switzerland. 215 pp.

Balmford, A. 2002. Selecting sites for conservation. In: Norris, K. and Pain, D. (eds.), Conserving Bird Biodiversity: General principles and their application. Cambridge University Press, Cambridge, UK. pp. 74–104.

Balmford, A. and Whitten, T. 2003. Who should pay for tropical conservation, and how could the costs be met? Oryx 37(2):238–250.

Balmford, A., Gaston, K.J., Blyth, S., James, A. and Kapos, V. 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. Proceedings of the National Academy of Sciences of the USA 100:1046–1050.

Bamberg, J., del Rio, A., Huaman, Z., Vega, S., Martin, M., Salas, A., Pavek, J., Kiru, S., Fernandez, C. and Spooner, D. 2003. A decade of collecting and research on wild potatoes of the southwest USA. American Journal of Potato Research 80:159–172.

Bañares, A., Carque, E. and Marrero, M. 1995. The implementation of recovery plans in the Canary Islands National Parks: methods and criteria. In: Newton, J. (ed.), Planta Europa Proceedings. PlantLife, London, UK. pp. 145–149.

Bañares, A., Marrero, M., Carque, E. and Soa, P. 2001. Biología de la conservación de la flora amenazada en los parques nacionales canarios In: Gómez Campo. C. (ed.), Conservación de Especies Vegetales Amenazadas en la Región Mediterránea Occidental: Una perspectiva desde el fin de siglo. Fundación Ramón Areces, Madrid, Spain. pp. 35–62.

Bañares, Á., Blanca, G., Güemes, J., Moreno, J.C. and Ortiz, S. (eds.) 2003. Atlas y Libro Rojo de la Flora Vascular Amenazada de España: Taxones Prioritarios. Dirección General de Conservación de la Naturaleza, Madrid, Spain.

Bariteau, M. 2003. The State of Forest Tree Genetic Resources in the World: Feasibility study and work options. Discussion Paper. FAO Panel of Experts on Forest Gene Resources, 13th Session, Rome, 10–12 November. Forestry Department, FAO, Rome, Italy.

Barrance, A.J. 1997. Forest Genetic Resources in Central America: The challenges of conservation. Rural Development Forestry Network Paper 21f. Overseas Development Institute, London, UK.

Barrance, A.J. 1999. *Circa situm* conservation of multi-purpose tree species diversity in Honduran dry forest agroecosystems. In: *In Situ* 99 e-Conference (Moderators: Miguel Holle, CIP/CONDESAN, and Ana Maria Ponce, InfoAndina, CONDESAN). Available from: http://www.condesan.org/e-foros/insitu99/1412.htm

Batisse, M. 1982. The biosphere reserve: a tool for environmental conservation and management. Environmental Conservation 9(2):101–111.

Beaty, H.E. 2002. Texas Wild Rice. The Handbook of Texas Online. Available from: http://www.tsha.utexas.edu/handbook/online/articles/view/TT/ttt1.html

Bennett, S.J. and Bullitta, S. 2003. Ecogeographical analysis of the distribution of six *Trifolium* species in Sardinia. Biodiversity and Conservation 12(7):1455–1466.

Bennett, S.J. and Maxted, N. 1997. An ecogeographic analysis of the *Vicia narbonensis* complex. Genetic Resources and Crop Evolution 44(5):411–428.

BGCI. 2003. Global Strategy for Plant Conservation Implementing Target 8 of the Global Strategy for Plant Conservation: 60% of threatened plant species in accessible *ex situ* collections, preferably in the country of origin, and 10% of them included in recovery and restoration programmes. Report of the Stakeholder Consultation on Target 8 of the Global Strategy for Plant Conservation, 15 September 2003. Available from: http://www.bgci.org/files/7/777/GSPC%2 0Target%208%20Stakeholder%20Consultation%20Report.pdf

Bhadula, S.K., Singh, A., Lata, H., Kunlyal, C.P. and Purohit, A.N. 1996. Genetic resources of *Podophyllum hexandrum* Royle, an endangered medicinal species from Garhwal Himalaya, India. Plant Genetic Resources Newsletter 106:26–29.

Bioret, F., Cibien, C., Génot, J.-C. and Lecomte, J. (eds.) 1998. A Guide to Biosphere Reserve Management: A methodology applied to French biosphere reserves. MAB Digest 19. MAB Programme, UNESC0, Paris, France.

Blixt, S. 1994. Conservation Methods and Potential Utilization of Plant Genetic Resources in Nature Conservation. Integration of Conservation Strategies of Plant Genetic Resources in Europe, Band 0. Available from: http://www.genres. de/IGRREIHE/IGRREIHE/DDD/120.pdf

Blom, A. 2004. An estimate of the costs of an effective system of protected areas in the Niger Delta–Congo Basin Forest Region. Biodiversity and Conservation 13:2661– 2678.

Boersma, P.D., Kareiva, P., Fagan, W.F., Clark, J.A. and Hoekstra, J.M. 2001. How good are endangered species recovery plans? BioScience 51(8):643–649.

Bompard, J.M. 1993. The genus *Mangifera* re-discovered: the potential contribution of wild species to mango cultivation. Acta Horticulturae 341:69–77.

Bonger, T. 1999. The CAMPFIRE programme in Zimbabwe: institutional innovation and implications for environmental governance. In: Okoth-Ogendo, H.W.O. and Tumushabe, G.W. (eds.), Governing the Environment: Political change and natural resources management in eastern and southern Africa. African Centre for Technology Studies (ACTS), Nairobi, Kenya. pp. 253–290.

Boyes, B. 2001. Multi-species Local Recovery Planning: Benefits and impediments. Nature Conservation Council of New South Wales, Community Biodiversity Network. Available from: http://www.nccnsw.org.au/member/cbn/projects/ LifeLines7.1/Bioreg_Sp.html

Bradshaw, A.D. 1987 The reclamation of derelict land and the ecology of ecosystems. In: Jordan, W.R., Gilpin, M.E. and Aber, J.D. (eds.), Restoration Ecology: A synthetic approach to ecological research. Cambridge University Press, Cambridge, UK. pp. 23–50.

Bretting, P.K. and Duvick, D.N. 1997. Dynamic conservation of plant genetic resources. Advances in Agronomy 61:1-51.

Bridgewater, P. 2002. UNESCO's Man and the Biosphere programme: addressing forest biodiversity. Unasylva 53(209) [online].

Brown, A.H.D. 1999. The genetic structure of crop landraces and the challenge to conserve them *in situ* on farms. In: Brush, S.B. (ed.), Genes in the Field: Conserving plant diversity on farms. Lewis Publishers, Boca Raton, FL, USA. pp. 29–48.

Brown, A.H.D. and Briggs, J.D. 1991. Sampling strategies for genetic variation in *ex situ* collections of endangered plant species. In: Falk, D.A. and Holsinger, K.E. (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA. pp. 99–119.

Brown, A.H.D. and Brubaker, C.L. 2001. Indicators for sustainable management of plant genetic resources. In: Engels, J.M.M., Ramanatha Rao, V., Brown, A.H.D. and Jackson, M.T. (eds.), Managing Plant Diversity. CABI Publishing, Wallingford, UK. pp. 249–262.

Brown, C.L., Hall, F. and Mill, J. (eds.) 2003. Plant Conservation: Approaches and techniques from an Australian perspective. Australian Network for Plant Conservation, Canberra, Australia. Available from: http://www.anbg.gov.au/anpc/books.html#PlantConservation.

Bruford, M.W. 2002. Biodiversity: evolution, species, genes. In: Norris, K. and Pain, D.J. (eds.), Conserving Bird Biodiversity: General principles and their application. Cambridge University Press, Cambridge, UK. pp. 1–19.

Calderón, E., Galeano, G. and García, N. (eds.) 2002. Libro Rojo de Plantas Fanerógamas de Colombia. Volume 1: Chrysobalanaceae, Dichapetalaceae y Lecythidaceae. Serie Libro Rojo de Especies Amenazadas de Colombia. Instituto Alexander von Humboldt, Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Ministerio del Medio Ambiente, Bogotá, Colombia.

Cavalcanti, R.B., Pinto, L.P. and Cardoso da Silva, J.M. 1999. Criteria for establishing protected areas. Paper presented at the International Experts Meeting on Protected Forest Areas, San Juan, Puerto Rico, 15-19 March 1999. 14 pp. Available from: http://www.mma.gov.br/port/sbf/reuniao/doc/criteria.pdf

CBD. 1992. Convention on Biological Diversity. Interim Secretariat for the Convention on Biological Diversity, Geneva, Switzerland.

CBD. 2002a. Global Strategy for Plant Conservation. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD. 2002b. Global Strategy for Plant Conservation: Follow-up on SBSTTA Recommendation VII/8 Paragraph 2 on the Refinement of the 16 Draft Targets included in the Proposed Strategy. UNEP/CBD/GSPC/1/2. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD. 2002c. Addendum. Global Strategy for Plant Conservation of the Convention on Biological Diversity. Technical review of the targets and analysis of opportunities for their implementation. UNEP/CBD/COP/6/12/Add.4. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD. 2002d. Global Strategy for Plant Conservation: Technical review of the targets and analysis of opportunities for their implementation: report of the

meeting of technical experts on the Global Plant Conservation Strategy, Gran Canaria, 11–13 February 2002. UNEP/CBD/COP/6/INF/21. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD. 2002e. A Review of the Scope, Terminology, Base-Line Information, Technical and Scientific Rationale of the 16 Draft Targets Included in the Proposed Global Strategy for Plant Conservation, with Particular Reference to the Quantitative Elements They Contain. UNEP/CBD/COP/6/INF/21/ADD1. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD. 2003. Report of the Expert Meeting on the Global Strategy for Plant Conservation. UNEP/CBD/SBSTTA/9/INF/24. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

CBD Secretariat. 2001. Handbook of the Convention on Biological Diversity. Earthscan, London, UK. 600 pp.

Center for Plant Conservation. 1991. Genetic sampling guidelines for conservation collections of endangered plants. In: Falk, D.A. and Holsinger, K.E. (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA. pp. 225–238.

Chape, S., Blyth, S., Fish, L., Fox, P. and Spalding, M. (compilers) 2003. 2003 United Nations List of Protected Areas. IUCN, Gland, Switzerland. 44 pp.

Clark, J.A., Hoekstra, J.M., Boersma, P.D. and Kareiva, P. 2002. Improving U.S. Endangered Species Act recovery plans: key findings and recommendations of the SCB Recovery Plan Project. Conservation Biology 16(6):1510–1519.

Clay, J.W. 1997. The impact of palm heart harvesting in the Amazon estuary. In: Freese, C.H. (ed.), Harvesting Wild Species: Implications for biodiversity conservation. Johns Hopkins University Press, Baltimore, MD, USA. pp. 283–314.

Colding, J. and Folke, C. 1997. The relations among threatened species, their protection, and taboos. Conservation Ecology 1(1):6. Available from: http://www.consecol.org/vol1/iss1/art6

Cooper, D., Vellvé, R. and Hobbelink, H. 1992. Growing Diversity: Genetic resources and local food security. Intermediate Technology Publications, London, UK.

Cossalter, C. 1991. Conservation *in situ* des ressources génétiques forestières tropicales: la contribution des aires protégées et des réserves forestières. In: Rejdali, M. and Heywood, V.H. (eds.), Proceedings Conservation des Ressources Vegetales, Rabat, Morocco, 22–26 April 1987. Actes Editions, Institut Agronomique et Vétérinaire, Rabat, Morocco. pp. 141–153.

Cunningham, A.B. 1996. People, Park and Plant Use: Recommendations for multiple-use zones and development alternatives around Bwindi Impenetrable National Park, Uganda. People and Plants Working Paper 4. UNESCO, Paris, France.

Damania, A.B. 1994. *In situ* conservation of biodiversity of wild progenitors of cereal crops in the Near East. Biodiversity Letters 2:56–60.

Damania, A.B. 1996. Biodiversity conservation: a review of options complementary to standard *ex situ* methods. Plant Genetic Resources Newsletter 107:1–18.

Davis, S.D. 1995. Identifying sites of global importance for conservation: the IUCN/ WWF Centres of Plant Diversity project. In: Primack, R.B. and Lovejoy, T.E. (eds.), Ecology, Conservation and Management of Southeast Asian Rainforests. Yale University Press, New Haven, CT, USA. pp. 176–203.

Davis, S.D., Heywood, V.H. and Hamilton, A.C. (eds.) 1994. Centres of Plant Diversity. A guide and strategy for their conservation. Volume 1. Europe, Africa, South West Asia and the Middle East. IUCN and WWF, Gland, Switzerland. 354 pp.

Davis, S.D., Heywood, V.H. and Hamilton, A.C. (eds.) 1995. Centres of Plant Diversity. A guide and strategy for their conservation. Volume 2. Asia, Australasia and the Pacific. IUCN and WWF, Gland, Switzerland. 578 pp.

Davis, S.D., Heywood, V.H. and Hamilton, A.C. (eds.) 1997. Centres of Plant Diversity. A guide and strategy for their conservation. Volume 3. Americas. IUCN and WWF, Gland, Switzerland. 562 pp.

Dawson, I.K. and Powell, W. 1999. Genetic variation in the Afromontane tree *Prunus africana*, an endangered medicinal species. Molecular Ecology 8(1):151.

Dawson, I.K., Were, J. and Lengkeek A. 2000. Conservation of *Prunus africana*, an over-exploited African medicinal tree. Forest Genetic Resources 28. Available from: http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/008/ x9662e/x9662e00.htm

Deil, U. 2000. Heilige Haine als Naturschutzgebiete? Zur Vegetation von Marabutwäldchen in Nordmarokko. Freiburger Geographische Hefte 60:147– 166.

Dela, J., Weerakoon, D., Seneviratne, I. and Silva, A. 2001. Sri Lanka case study on preparation of Nationally Threatened Species lists In: Balakrishna P. (ed.), Using the IUCN Red List Criteria at the National Level: A regional consultative workshop for south and southeast Asia. IUCN Regional Biodiversity Programme Asia, Colombo, Sri Lanka. pp. 92–104.

Delbaere, B. 2002. Biodiversity Indicators and Monitoring: Moving towards implementation. ECNC Technical Report Series. European Centre for Nature Conservation, Tilburg, The Netherlands.

Della, A. 1999. Neglected and underutilized species of Cyprus: use and conservation. In: Padulosi, S. (ed.), Priority-Setting for Underutilized and Neglected Plant Species of the Mediterranean Region. Report of the IPGRI Conference, 9–11 February 1998. ICARDA, Aleppo, Syria and IPGRI, Rome, Italy. pp. 86–93.

Denich, M., Virchow, D. and Bremer, S. 2002. Protecting coffee diversity in Ethiopia. *ZEFnews* 11(December):2.

DFSC 2000. Conservation of Genetic Resources of *Pinus merkusii* in Thailand. DFSC Series of Technical Notes TN56. Danida Forest Seed Centre, Humlebaek, Denmark.

Donaldson, J. 2003. Cycads: Status survey and conservation action plan. IUCN, Gland, Switzerland.

Donovan, D.G. 2001. Where's the forestry in community forestry? In: Victor, M. and Barash, A. (eds), Cultivating Forests: Alternative forest management practices

and techniques for community forestry. Proceedings of an International Seminar, September 23–25, 1998. RECOFTC, Bangkok, Thailand. pp. 3–23.

dos Furtado, J.R., Kishor, N., Rao, G.V. and Wood, C. 1999. Global Climate Change and Biodiversity: Challenges for the future and the way ahead. World Bank Institute, Washington DC, USA.

Dotlacil, L., Stehno, Z., Michalova, A. and Faberova, I. 2001. Plant Genetic Resources and Agri-Biodiversity in the Czech Republic. OECD Expert Meeting on Agri-Biodiversity Indicators, 5–8 November 2001, Zürich, Switzerland. OECD, Paris, France.

Dudley, N. 1998. Forests and Climate Change. Report for WWF International. WWF, Gland, Switzerland.

Dulloo, M.E., Jones, C., Strahm, W. and Mungroo, Y. 1996. Ecological restoration of native plant and animal communities in Mauritius, Indian Ocean. In: Pearson, D.L. and Klimas, C.V. (eds.), The Role of Restoration in Ecosystem Management. Society for Ecological Restoration, Tucson, AZ, USA. pp. 83–91.

Dulloo, M.E., Guarino, L., Engelmann, F., Maxted, N., Newbury, J.H., Attere, F. and Ford-Lloyd, B.V. 1998. Complementary conservation strategies for the genus *Coffea*: a case study of Mascarene *Coffea* species. Genetic Resources and Crop Evolution 45(6):565–579.

Dulloo, M.E., Maxted, N., Guarino, L., Florens, D., Newbury, H.J. and Ford-Lloyd, B.V. 1999. Ecogeographic survey of the genus *Coffea* in the Mascarene Islands. Botanical Journal of the Linnean Society 131(3):263–284.

Eckhardt, G. 1995. Endangered species of the Edwards aquifer system: Texas wild rice (*Zizania texana*) [online]. Available from: http://www.edwardsaquifer. net/species.html

Edmonds, J.M. 1990. Herbarium Survey of African *Corchorus* L. Species. Systematic and Ecogeographic Studies on Crop Genepools 4. IBPGR, Rome, Italy.

Ehrman, T. and Cocks, P.S. 1990. Ecogeography of annual legumes in Syria: distribution patterns. Journal of Applied Ecology 27:578–591.

Elzinga, C.L., Salzer, D.W. and Willoughby, J.W. 1998a. Measuring and Monitoring Plant Populations. BLM Technical Reference 1730–1. BLM/RS/ST-98/005+1730. Bureau of Land Management, National Business Center, Denver, CO, USA.

Elzinga, C.L., Salzer, D.W., Willoughby, J.W. and Gibbs, J.P. 1998b. Monitoring Plant and Animal Populations: A handbook for field biologists. Blackwell Science, London, UK.

Entwistle, A., Atay, S., Byfield, A. and Oldfield, S. 2002. Alternatives for the bulb trade from Turkey: a case study of indigenous bulb propagation. Oryx 36(4):333–341.

Environment Australia. 2002. Revised Recovery Plan Guidelines for Nationally Listed Threatened Species and Ecological Communities under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. Department of the Environment and Heritage, Canberra, Australia. Available from: http:// www.deh.gov.au/biodiversity/threatened/publications/recovery/guidelines/ index.html

EEA. 2003. An Inventory of Biodiversity Indicators in Europe. Technical Report 92. Office for Official Publications of the European Communities, Luxembourg.

Ewusi, B.N., Tako, C.T., Nyambi, J. and Acworth, J. 1997. Bark extraction: the current situation and sustainable cropping of *Prunus africana* on Mount Cameroon. In: Davies, G. (ed.), A Strategy for the Conservation of *Prunus africana* on Mount Cameroon. Technical Papers and Workshop Proceedings. Limbe Botanic Garden, Limbe, Cameroon, 21–22 February 1996. pp. 39–54.

Falk, D.A. 1991. Joining biological and economic knowledge for conserving plant genetic resources. In: Falk, D.A. and Holsinger, K.E. (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA. pp. 209–223.

Falk, D.A. and Holsinger, K.E. (eds.) 1991. Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA.

Falk, D.A., Olwell, M. and Millar, C. 1996. Restoring Diversity. Island Press. Columbia, USA.

Falk, D.A., Knapp, E.E. and Guerrant, E.O. 2001. An Introduction to Restoration Genetics. Science Policy Paper No. 1. Society for Ecological Restoration, Tucson, AZ, USA.

FAO. 1968–1988. Reports on Sessions 1-VI of the FAO Panel of Experts on Forest Gene Resources. FAO/FGR/Rep. 1–6. FAO, Rome, Italy.

FAO. 1975. The Methodology of Conservation of Forest Genetic Resources: Report on a Pilot Study. FAO:MISC/75/8. FAO, Rome, Italy.

FAO. 1984. *In Situ* Conservation of Plant Genetic Resources: The scientific and technical bases (based on the work of B. Ingram). FORGEN/MISC/84/1. FAO, Rome, Italy.

FAO. 1989. Plant Genetic Resources: Their conservation *in situ* for human use. FAO, Rome, Italy.

FAO. 1993. Conservation of Genetic Resources in Tropical Forest Management: Principles and concepts. Based on the work of R.H. Kemp, with scientific review by G. Namkoong and F. Wadsworth. FAO Forestry Paper 107. FAO, Rome, Italy.

FAO. 1995. Sustainable Utilization of Plant Genetic Resources in Eastern Africa: Sub-regional synthesis report. Annex 2 of the Report of the Sub-Regional Preparatory Meeting for Eastern Africa and Indian Ocean Islands. Nairobi, Kenya, 12–14 September 1995. FAO, Rome, Italy.

FAO. 1996a. Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. FAO, Rome, Italy.

FAO. 1996b. Report on the State of the World's Plant Genetic Resources for Food and Agriculture. FAO, Rome, Italy.

FAO. 1998. The State of the World's Plant Genetic Resources for Food and Agriculture. FAO, Rome, Italy.

FAO. 1999. Progress Towards the Development of Regional Action Plans on Forest Genetic Resources. Secretariat Note, 11th Session of the FAO Panel of Experts on Forest Gene Resources. Document FORGEN/99/5. Forest Resources Division, FAO, Rome, Italy.

FAO. 2001a. State of Forest Genetic Resources in Sahelian and North-Sudanian Africa and Sub-Regional Action Plan for their Conservation and Sustainable Use. Forest Genetic Resources Working Paper FGR/2E. Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy. Available from : http://www.fao.org/DOCREP/003/X6883E/X6883E00.htm

FAO. 2001b. Situation des Ressources Génétiques Forestières de la Zone Sahélienne et Nord-Soudanienne et Plan d'Action Sous-Régional pour Leur Conservation et Utilisation Durable. Note Thématique sur les Ressources Génétiques Forestières FGR/2F. Service de la Mise en Valeur des Ressources Forestières, Division des Ressources Forestières, FAO, Rome, Italy. Available from : http://www.fao.org/DOCREP/003/X6883F/X6883F00.htm

FAO. 2001c. State of Forest and Tree Genetic Resources in the Pacific Islands and Sub-Regional Action Plan for their Conservation and Sustainable Use. Based on the work of Suliana Siwatibau and Lex Thomson. Forest Genetic Resources Working Paper FGR/4E. Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy. Available from: http://www.fao.org/FORESTRY/FOR/FORM/FOGENRES/regions/Update/All%20Pac/allpac.stm

FAO. 2001d. International Action in the Management of Forest Genetic Resources: Status and challenges. Unpublished paper prepared by Christel Palmberg-Lerche, September 2000. Forest Genetic Resources Working Papers FGR/1. Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy.

FAO. 2002a. Progress Report on the Development of a Network of *In Situ* Conservation Areas. Commission on Genetic Resources for Food and Agriculture. CGRFA-9/02/13/Add.1. FAO, Rome, Italy.

FAO. 2002b. The International Treaty on Plant Genetic Resources for Food and Agriculture. FAO, Rome, Italy.

FAO. 2003a. State of Forest and Tree Genetic Resources in Dry Zone Southern Africa Development Community Countries. Document compiled by B.I. Nyoka. Forest Genetic Resources Working Paper FGR/41E. Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy. Available from: http://www.fao.org/DOCREP/005/AC850E/AC850E00.htm

FAO. 2003b. Estado de los Recursos Genéticos Forestales en América Central, Cuba y México, y Plan de Acción Regional para su Conservación y Uso Sostenible. Documento de Trabajo: Recursos Genéticos Forestales FGR/52S. Servicio de Desarrollo de Recursos Forestales, Dirección de Recursos Forestales, FAO, Rome, Italy.

FAO/DFSC/IPGRI. 2001. Forest Genetic Resources Conservation and Management. Vol.2. In Managed Natural Forests and Protected Areas (*In Situ*). IPGRI, Rome, Italy.

FAO/FLD/IPGRI. 2004. Forest Genetic Resources Conservation and Management. Vol.1. Overview, Concepts and Some Systematic Approaches. IPGRI, Rome, Italy.

FAO/UNEP. 1981. Report of the FAO/UNEP Consultation on *In Situ* Conservation of Forest Genetic Resources. FAO, Rome, Italy.

FAO/UNEP. 1985. Final Report: FAO/UNEP project on the Conservation of Forest Genetic Resources. FAO, Rome, Italy.

FAO/UNEP. 1987. Informe del Taller sobre Conservación *in situ* de Recursos Genéticos. Huaraz, Perú, Junio de 1987. Oficina Regional de la FAO para América Latina y el Caribe. FAO/RLAC, Santiago de Chile, Chile.

Farjon, A. and Page, C.N. 1999. Conifers: Status survey and conservation action plan. Species Survival Commission, IUCN, Gland, Switzerland.

Ferguson, M.E., Açikgöz, N., Ýsmaýl, A. and Cýnsoy, A. 1996. An ecogeographic survey of wild *Lens* species in Aegean and south west Turkey. Anadolu 6:159–166.

Fiedler, P.L. and Jain, D.K. 1992. Conservation Biology: The theory and practice of nature conservation, preservation and management. Chapman and Hall, London, UK.

Firat, A.E. and Tan, A. 1997. *In situ* conservation of genetic diversity in Turkey. In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 254–262.

Frankel, O.H., Brown, A.H. and Burdon, J.J. 1995. The Conservation of Plant Biodiversity. Cambridge University Press, Cambridge, UK.

Freese, C.H. 1997. The "use it or lose it" debate. In: Freese, C.H. (ed.), Harvesting Wild Species: Implications for biodiversity conservation. Johns Hopkins University Press, Baltimore, MD, USA. pp. 1–48.

Friis-Hansen, E. and Sthapit, B. (eds.) 2000. Participatory Approaches to the Conservation and Use of Plant Genetic Resources. IPGRI, Rome, Italy.

Frodin, D.G. 2001. Guide to the Standard Floras of the World (2nd edn.). Cambridge University Press, Cambridge, UK.

Gabriel, L. 2003. Community involvement in the management of *Prunus africana* in the Mount Cameroon region. Paper submitted to the XII World Forestry Congress 2003, Québec City, Canada. Available from: http://www.fao.org/docrep/article/wfc/xii/0456-b1.htm

Gadgil, M. 1998. Traditional resource management systems. In: Saraswati, B. (ed.), Lifestyle and Ecology. Indira Gandhi National Centre for the Arts (IGNCA) and D.K. Printworld, New Delhi, India.

Gadgil, M. and Vartak, V.D. 1974. The sacred groves of Western Ghats in India. Economic Botany 30:152–160.

García Casanova, J. 2001. Espacios naturales protegidos de Canarias: un herramiento para la conservación *in situ* de la flora amenazada del archipiélago. In: Gómez Campo, C. (ed.), Conservación de Especies Vegetales Amenazadas en la Región Mediterránea Occidental: Una perspectiva desde el fin de siglo. Fundación Ramón Areces, Madrid, Spain. pp. 17–33.

Garpow, W.J. 2001. A New Option for Protected Areas in Mexico's Riviera? Carolina Papers International Development No. 1 (Spring 2001). University Center for International Studies, The University of North Carolina at Chapel Hill, NC, USA.

Gentry, A.H. 1990. Herbarium taxonomy versus field knowledge. Flora Malesiana Bulletin 1(Special issue):31–35.

Gentry, A.H. 1992. Tropical forest biodiversity: distributional patterns and their conservational significance. Oikos 63:19–28.

Gibbons, A. and Taylor, R. 2003. Recovery Plan for the Threatened Plants of the Tiwi Islands in the Northern Territory of Australia 2004–2009. Northern Territory Department of Infrastructure Planning and Environment, Darwin, Australia.

Godown, M.E. and Peterson, A.T. 2000. Preliminary distributional analysis of US endangered bird species. Biodiversity and Conservation 9(9):1313–1322.

Golding, S. (ed.) 2002. Southern African Plant Red Data Lists. SABONET Report Series 14. SABONET, Pretoria, South Africa.

Gole, T.W., Denich, M., Teketay, D. and Vlek, P.L.G. 2002. Human impacts on the *Coffea arabica* genepool in Ethiopia and the need for its *in situ* conservation. In: Engels, J.M.M., Ramanatha Rao, V., Brown, A.H.D. and Jackson, M.T. (eds.), Managing Plant Genetic Diversity. CAB International, Wallingford, UK. pp. 237–247.

Gómez-Pompa, A. and Bainbridge, D.A. 1993. Talk with the people: listen to the trees. In: Lugo, A.E. and Lowe, C. (eds.), A Century of Tropical Forestry Research: Results from the first half, themes for the second. Elsevier, New York, USA.

Gradaille, J.L. 2001. Integración de métodos *in situ* y *ex situ* en la conservación de la flora Balear. In: Gómez Campo, C. (ed.), Conservación de Especies Vegetales Amenazadas en la Región Mediterránea Occidental: Una perspectiva desde el fin de siglo. Fundación Ramón Areces, Madrid, Spain. pp. 175–197.

Graner, A., Dehmer, K.J., Tiel, T. and Börner, A. 2004. Plant genetic resources: benefits and implications of using molecular markers. In: de Vicente, M.C. (ed.), The Evolving Role of Genebanks in the Fast-developing Field of Molecular Genetics. Issues in Genetic Resources No 11. IPGRI, Rome, Italy. pp. 26–32.

Granhof, J. 1998. Conservation of Forest Genetic Resources without People's Participation: An experience from Northeast Thailand. Royal Forest Department (RFD) and Forest Genetic Resources Conservation and Management Project (FORGENMAP), Bangkok, Thailand.

Graudal, L., Kjaer, E.D., Thomsen, A. and Larsen, A.B. 1997. Planning National Programmes for Conservation of Forest Genetic Resources. Technical Note 48. Danida Forest Seed Centre, Humlebaek, Denmark.

Graudal, L., Kjaer, E.D., Suangtho, V., Saardavut, P. and Kaosa-ard, A. 1999. Conservation of Genetic Resources of Teak (*Tectona grandis*) in Thailand. Technical Note 52. Danida Forest Seed Centre, Humlebaek, Denmark.

Greuter, W., Burdet, H.M. and Long, G. 1984. Med-Checklist. A critical inventory of vascular plants of the circum-mediterranean countries, Vol 1. Pteridophyta (2nd ed.), Gymnospermae, Dicotyledones (Acanthaceae-Cneoraceae). Conservatoire et Jardin Botanique de la Ville de Geneve, Switzerland, and the Botanical Garden and Museum, Berlin-Dahlem, Germany. 330 pp.

Greuter, W., Burdet, H.M. and Long, G. 1986. Med-Checklist. A critical inventory of vascular plants of the circum-mediterranean countries, Vol. 3. Dicotyledones

(Convolvulaceae-Labiatae). Conservatoire et Jardin Botanique de la Ville de Geneve, Switzerland, and the Botanical Garden and Museum, Berlin-Dahlem, Germany. 395 pp.

Greuter, W., Burdet, H.M. and Long, G. 1989. Med-Checklist. A critical inventory of vascular plants of the circum-mediterranean countries, Vol. 4. Dicotyledones (Lauraceae-Rhamnaceae). Conservatoire et Jardin Botanique de la Ville de Geneve, Switzerland, and the Botanical Garden and Museum, Berlin-Dahlem, Germany. 458 pp.

Guarino, L., Ramanatha Rao, V. and Reid, R. (eds.) 1995. Collecting Plant Genetic Diversity: Technical guidelines. CAB International, Wallingford, UK.

Guarino, L., Jarvis, A., Hijmans, R.J. and Maxted, N. 2002. Geographic information systems (GIS) and the conservation and use of plant genetic resources. In: Engels, J.M.M., Ramanatha Rao, V., Brown, A.H.D. and Jackson, M.T. (eds.), Managing Plant Genetic Diversity. CAB International, Wallingford, UK.

Hágsater, E. and Dumont, V. 1996. Orchids: Status survey and conservation action plan. Compiled by Alec Pridgeon. IUCN, Gland, Switzerland.

Hammer, K. 1991. Die Bedeutung von Kulturpflanze-Unkraut-Komplexen für die Evolution von Kulturpflanzen. In: Mahn, E.-G. and Tietze, F. (eds.), Agroökosysteme und Habitatinseln in der Agrarlandschaft. Beiträge Martin-Luther-Universität, Halle-Wittenberg, Germany. pp. 14–22.

Hammer, K. and Perrino, P. 1995. Plant genetic resources in South Italy and Sicily. Plant Genetic Resources Newsletter 103:19–23.

Hammer, K., Gladis, T. and Diederichsen, A. 1997. Weeds as genetic resources. Plant Genetic Resources Newsletter 111:33–39.

Hammond, A., Adriaanse, A., Rodenburg, E., Bryant, D. and Woodward, R. 1995. Environmental Indicators: A systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development. World Resources Institute, Washington DC, USA.

Hamrick, J.L. 1994. Genetic diversity and conservation in tropical forests. In: Proceedings from the International Symposium on Genetic Conservation and Production of Tropical Forest Tree Seed. ASEAN-Canadian Forest Tree Seed Centre Project, Muak-Lek, Saraburi, Thailand.

Hanelt, P. 1997. European wild relatives of *Prunus* fruit crops. In: Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.), Conservation of the Wild Relatives of European Cultivated Plants. Azienda Foreste Demaniali della Regione Siciliana, Palermo, Italy. Bocconea 7:401–408.

Hannah, L., Midgley, G.F. and Millar, D. 2002. Climate change–integrated conservation strategies. Global Ecology and Biogeography 11(6):485–495.

Hanski, I. 1999. Metapopulation Ecology. Oxford University Press, Oxford, UK.

Hanski, I., Moilanen, A. and Gyllenberg, M. 1996. Minimum viable metapopulation size. American Naturalist 147:527–541.

Hansson, L. 2001. Indicators of biodiversity: recent approaches and some general suggestions. Ecological Bulletin 50:223–229.

Haq, H. 1994. Analysis of questionnaire to select priority species for research and development in Asia In: Arora, R.K. and Ramanatha Rao, V. (eds.), Proceedings of Expert Consultation on Tropical Fruit Species of Asia, MARDI, Kuala Lumpur, Malaysia, 17–19 May. IPGRI Office for South Asia, New Delhi, India. pp. 31–43.

Harp, W. 1994. Ecology and cosmology: rainforest exploitation among the Emberà-Chocò. Nature and Resources 30(1):23–27.

Hattemer, H.H. 1997. Concepts and requirements in the conservation of forest genetic resources. In: Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.), Conservation of the Wild Relatives of European Cultivated Plants. Azienda Foreste Demaniali della Regione Siciliana, Palermo, Italy. Bocconea 7:329–343.

Hawkes, J.G. 1991. Dynamic *in situ* conservation of wild relatives of major cultivated plants: summary of final discussion and recommendations. Israel Journal of Botany 40:529–536.

Hellier, B. 2000. Genetic, morphologic, and habitat diversity of two species of *Allium* native to the Pacific Northwest, USA and their implications for *in situ* seed collection for the National Plant Germplasm System. Master's thesis. Washington State University, Pullman, WA, USA.

Hernández Bermejo, J.E. and Clemente Muñoz, M. 2001. Conservación de la flora Andaluza. Papel del Jardín Botánico de Córdoba. In: Gómez Campo, C. (ed.), Conservación de Especies Vegetales Amenazadas en la Región Mediterránea Occidental: Una perspectiva desde el fin de siglo. Fundación Ramón Areces, Madrid, Spain. pp. 115–130.

Heywood, V.H. 1991. Needs for stability of nomenclature in conservation. In: Hawksworth, D.L. (ed.), Improving the Stability of Names: Needs and options. Regnum Vegetabile 123:53–48. Koeltz Scientific Books, Königstein, Germany.

Heywood, V.H. 1993. Broadening the basis of plant resource conservation. In: Gustafson, J.P., Appels, R. and Raven, P. (eds.), Gene Conservation and Exploitation. 20th Stadler Genetics Symposium. Plenum Press, London, UK. pp. 1–15.

Heywood, V.H. 1998. The species concept as a socio-cultural phenomenon—a source of the scientific dilemma. Theory in Biosciences 117**:**203–212.

Heywood, V.H. 1999a. Use and Potential of Wild Plants in Farm Households. FAO Farm Systems Management Series 15. FAO, Rome, Italy.

Heywood, V. 1999b. Medicinal and aromatic plants as global resources. In: Proceedings of the Second World Congress on Medicinal and Aromatic Plants WOCMAP-2. Acta Horticulturae 500:21–29.

Heywood, V.H. 1999c. Is the conservation of vegetation fragments and their biodiversity worth the effort? In: Maltby, E., Holdgate, M., Acreman, M. and Weir, A.G. (eds.), Ecosystem Management: Questions for science and society. Royal Holloway Institute for Environmental Research, Royal Holloway College, University of London, UK. pp. 65–76.

Heywood, V.H. 2002. The conservation of genetic and chemical diversity in medicinal and aromatic plants. In: Sener, B. (ed.), Biomolecular Aspects of

Biodiversity and Innovative Utilization: Proceedings of the Third IUPAC International Conference on Biodiversity (ICOB-3), November 3–8, Antalya, Turkey. Kluwer Academic/Plenum Publishers, London, UK.

Heywood, V.H. 2003a. Conservation and sustainable use of wild species as sources of new ornamentals. In: Düzyaman, E. and Tüzel, Y. (eds.), Proceedings of the International Symposium on Sustainable Use of Plant Biodiversity to Promote New Opportunities for Horticultural Production Development. Acta Horticulturae 598:43–53.

Heywood, V.H. 2003b. Conservation strategies, plant breeding, wild species and land races. In: Ammann, K., Jacot, Y. and Braun, R. (eds.), Methods for Risk Assessment of Transgenic Plants. IV. Biodiversity and Biotechnology. Birkhäuser, Basel, Switzerland. pp. 143–159.

Heywood, V.H. 2003c. The future of floristics in the Mediterranean region. Israel Journal of Plant Sciences 50(Supplement):S5–S13.

Heywood, V.H. and Firat, E. 1999. *In situ* conservation of wild relatives: summary of the discussions and recommendations. In: Gass, T., Frese, L., Begemann, F. and Lipman, E. (eds.), Implementation of the Global Plan of Action in Europe: Conservation and sustainable utilization of plant genetic resources for food and agriculture. Proceedings of the European Symposium, 30 June–3 July 1988, Braunschweig, Germany. IPGRI, Rome, Italy. pp. 35–37.

Heywood, V.H. and Zohary, D. (eds.) 1995. A catalogue of the wild relatives of cultivated plants native to Europe. Flora Mediterranea 5:375–415.

Heywood, V.H., Ingram, G.B. and Olivier, L. 1993. Report on Workshop IV. 6: Managing protected areas to conserve genetic resources. In: Parks for Life. IV World Congress on National Parks and Protected Areas, Caracas, Venezuela, February 1992. IUCN, Gland, Switzerland. pp. 175–176.

Hijmans, R.H., Guarino, L., Cruz, M. and Rojas, E. 2001. Computer tools for spatial analysis of plant genetic resources data: 1. DIVA-GIS. Plant Genetic Resources Newsletter 127:15-19.

Hirons, G., Goldsmith, B. and Thomas, G. 1995. Site management planning. In: Sutherland W. J. and Hill D.A. (eds.), Managing Habitats for Conservation. Cambridge University Press, Cambridge, UK. pp. 22–41.

Hockings, M., Stolton, S. and Dudley, N. 2000. Evaluating Effectiveness: A framework for assessing the management of protected areas. IUCN, Gland, Switzerland.

Hodgkin, T. 1997. Managing the populations: some general considerations. In: Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.), Conservation of the Wild Relatives of European Cultivated Plants. Bocconea 7:197–205.

Hokanson, S.C. 2001. Collection, utilization, and preservation of fruit crop genetic resources: some case studies. HortScience 36(2):206–238.

Hokanson, S.C., Forsline, P.L., McFerson, J.R., Lamboy, W.F., Aldwinckle, H.S., Luby, J.J. and Djangaliev, A.D. 1998. *Ex situ* and *in situ* conservation strategies for wild *Malus* germplasm in Kazakhstan. EUCARPIA Symposium on Fruit Breeding and Genetics. Acta Horticulturae 484:85–92.

Holden, J., Peacock, J. and Williams, T. 1993. Genes, Crops and the Environment. Cambridge University Press, Cambridge, UK.

Holsinger, K.E. and Gottlieb, L.D. 1991. Conservation of rare and endangered plants: principles and prospects. In: Falk, D.A. and Holsinger, K.E. (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA. pp. 195–208.

Hong, L.T., Ramanatha Rao V. and Amaral, W. 2001. Research on rattan genetic resources conservation and use: the perspective and strategy of the International Plant Genetic Resources Institute. Unasylva 52(205) [online].

Hughes, C. 1998. The Genus *Leucaena*: A plant genetic resources manual. Tropical Forestry Papers 34. Oxford Forestry Institute, Oxford, UK.

Huntley, B. 1999. Species distribution and environmental change: considerations from the site to the landscape scale. In: Maltby, E., Holdgate, M., Acreman, M. and Weir, A.G. (eds.), Ecosystem Management: Questions for science and society. Royal Holloway Institute for Environmental Research, Royal Holloway College, University of London, UK. pp. 113–129.

Hutton, J.M. and Leader-Williams, N. 2003. Sustainable use and incentive-driven conservation: realigning human and conservation interests. Oryx 37(2):215–226.

IBPGR. 1985. Ecogeographical Surveying and *In Situ* Conservation of Crop Relatives. IBPGR, Rome, Italy.

IDRC. 2001. IDRC Support for Medicinal Plant Research. Regional Focus: Latin America. Factsheet Series 3 of 5. IDRC, Ottawa, Canada. Available from: http://www.idrc.ca/biodiversity

Ingram, G.B. 1984. *In Situ* Conservation Of Plant Genetic Resources: The scientific and technical bases. FORGEN/MISC/84/1. FAO, Rome, Italy.

IPCC. 2002. Climate Change and Biodiversity. IPCC Technical Paper V. IPCC, Geneva, Switzerland.

IPGRI. 2004. Diversity for Well-Being: Making the most of agricultural biodiversity. IPGRI, Maccarese, Rome, Italy.

Isager, L., Theilade, I. and Thomsen, L. 2002. People's Participation and the Role of Governments in the Conservation of Forest Genetic Resources. Guidelines and Technical Notes 62. Danida Forest Centre, Humlebaek, Denmark.

IUCN. 1984. *In Situ* Conservation of Wild Plant Genetic Resources: A status review and action plan. Based on work by R. and C. Prescott-Allen. FORGEN/MISC/84/3. FAO, Rome, Italy.

IUCN. 1994. Guidelines for Protected Areas Management Categories. IUCN, Gland, Switzerland.

IUCN. 2003. A Guide to Securing Protected Areas in the Face of Global Change: Options and guidelines. Draft Report by the Ecosystems, Protected Areas, and People Project. IUCN World Commission on Protected Areas, IUCN, Gland, Switzerland.

IUCN. 2004. 2004 IUCN Red List of Threatened Species. IUCN, Gland, Switzerland. Available from: http://www.redlist.org/

IUCN/SSC. 1995. IUCN/SSC Guidelines for Re-Introductions. SSC Reintroduction Specialist Group. Approved by the 41st Meeting of the IUCN Council, Gland Switzerland, May 1995. IUCN, Gland, Switzerland. Available from: http://iucnsscrsg.org/pages/1/index.htm

Jaenicke, H., Munjuga, M., Were, J., Tchoundjeu, Z. and Dawson, I. 2002. Propagation techniques for the conservation of an endangered medicinal tree in Africa: *Prunus africana* (Hook, f.) Kalkman. In: Maunder, M., Clubbe, C., Hankamer, C. and Groves, M. (eds.), Plant Conservation in the Tropics. Perspectives and practice. Royal Botanic Gardens, Kew, UK. pp. 383–394.

Jarvis, A., Ferguson, M.E., Williams, D.E., Guarino, L., Jones, P.G., Stalker, H.T., Valls, J.F.M., Pittman, R.N., Simpson, C.E. and Bramel, P. 2003. Biogeography of wild *Arachis*: assessing conservation status and setting future priorities. Crop Science 43(3):1100–1108.

Jewell, S.D. 2000. Multi-species recovery plans. Endangered Species Bulletin 25(3):30–31.

JNCC. 2004. Plant Diversity Challenge: The UK's response to the global strategy for plant conservation. JNCC, Peterborough, UK.

Johnson, D. 1996. Palms: Their conservation and sustained utilization. IUCN/SSC Action Plans for the Conservation of Biological Diversity. IUCN, Gland, Switzerland.

Jones, P.G. and Gladkov, A. 1999. FloraMap: A computer tool for the distribution of plants and other organisms in the wild. CIAT, Cali, Colombia.

Jones P.G., Beebe, S.E., Tohme, J. and Galwey, N.W. 1997. The use of geographical information systems in biodiversity exploration and conservation. Biodiversity and Conservation 6(7):947–958.

Jones, P.G., Guarino, L. and Jarvis, A. 2002. Computer tools for spatial analysis of plant genetic resources data: 2. FloraMap. Plant Genetic Resources Newsletter 130:1–6

Kalaugher, E. and Visser, B. 2002. A Summary and Analysis of Existing International Plant Genetic Resources Networks. Background Study Paper 16. Commission on Genetic Resources for Food and Agriculture. FAO, Rome, Italy.

Kameshwara Rao, C. et al. (compilers) 2003. Red List of Threatened Vascular Plant Species in India: Compiled from the 1997 IUCN Red List of Threatened Plants. ENVIS, Botanical Survey of India, Ministry of Environment and Forests, Kolkata, India.

Kanashiro, M., Thompson, I.S., Yared, J.A.G., Loveless, M.D., Coventry, P., Martins-da-Silva, R.C.V., Degen, B. and Amaral, W. 2002. Improving conservation values of managed forests: the Dendrogene Project in the Brazilian Amazon. Unasylva 53(209) [online].

Kareiva, P., Andelman, S., Doak, D., Elderd, B., Groom, M., Hoekstra, J., Hood, L., James, F., Lamoreux, J., LeBuhn, G. and others. 1999. Using Science in Habitat Conservation Plans. National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, CA, USA, and American Institute of Biological Sciences, Washington DC, USA.

Kemp, R.H. 1992. The Conservation of Genetic Resources in Managed Forests. Unasylva 43(169) [online].

Kjær, E.D. and Graudel, L. 2000. Genetic studies of interest for forest genetic resource conservation programmes in tropical countries: finding patterns of genetic differentiation. Presented at the SAFORGEN Regional Training Workshop on the Conservation and Sustainable Use of Forest Genetic Resources in Eastern and Southern Africa, Nairobi, Kenya, 6–11 December 1999. Available from: http://www.dfsc.dk/pdf/Conference%20papers/13.pdf

Koo, B., Pardey, P.G. and Wright, B.D. 2002. Endowing Future Harvests: The long-term costs of conserving genetic resources at the CGIAR centers. Report for the CGIAR Systemwide Genetic Resources Programme (SGRP) by IFPRI and the University of California, Berkeley, CA, USA. IPGRI, Rome, Italy.

Koo, B., Pardey, P.G. and Wright, B.D. 2003. The economic costs of conserving genetic resources at the CGIAR centres. Agricultural Economics 29(3):287–297.

Koo, B., Pardey, P.G., Wright B.D. and others. 2004. Saving Seeds: The economics of conserving crop genetic resources *ex situ* in the future harvest centres of the CGIAR. CABI Publishing, Wallingford, UK.

Koshy, M.P., Namkoong, G., Stella, A., Gandara, F. and Neves do Amaral, W.A. 2002. Decision making strategies for conservation and use of forest genetic resources. In: Engels, J.M.M., Ramanatha Rao, V., Brown, A.H.D. and Jackson, M.T. (eds.), Managing Plant Diversity. CABI Publishing, Wallingford, UK. pp. 263–271.

Koski, V. 1996. Management guidelines for *in situ* gene conservation of wind-pollinated temperate conifers. Forest Genetic Resources 24:2–7.

Koski, V., Skroeppa, T., Paule, L., Wolf, H. and Turok, J. 1997. Technical Guidelines for Genetic Conservation of Norway Spruce (*Picea abies* (L.) Karst.). IPGRI, Rome, Italy.

Kostermans, A.J.G.H. and Bompard, J.M. 1993. The Mangoes, their Botany, Nomenclature, Horticulture and Utilization. IBPGR, Rome, Italy, and the Linnean Society of London, UK.

Laguna, E., Crespo, M.B., Mateo, G., López, S., Fabregat, C., Serra, L., Herrero-Borgoñón, J.J., Carretero, J.L., Aguilella, A. and Figuerola, R. 1998. Flora Endémica Rara o Amenazada de la Comunidad Valenciana. Generalitat Valenciana, Valencia, Spain.

Laguna Lumbreras, E. 2001a. The Microreserves as a Tool for the Conservation of Threatened Plants in Europe. Nature and Environment 121. Council of Europe, Strasbourg, France.

Laguna Lumbreras, E. 2001b. Conservación de endemismos vegetales en la Comunidad Valenciana: La Red de microrreservas. In: Gómez Campo, C. (ed.), Conservación de Especies Vegetales Amenazadas en la Región Mediterránea Occidental: Una perspectiva desde el fin de siglo. Fundación Ramón Areces, Madrid, Spain. pp. 149–174.

Lai, Q. 2003. Community participation in the management of nature reserves: experiences and lessons from China. Unasylva 54(214/215) [online].

Laliberté, B., Maggioni, L., Maxted, N. and Negri, V. (eds.) 2000. ECP/GR In Situ and On-Farm Conservation Network. Report of a joint meeting of a Task Force on Wild Species Conservation in Genetic Reserves and a Task Force on On-farm Conservation and Management, 18–20 May 2000, Isola Polvese, Italy. IPGRI, Rome, Italy.

Lawton, J.H. 1999. What to conserve—species or ecosystems? In: Maltby, E., Holdgate, M., Acreman, M. and Weir, A.G. (eds.), Ecosystem Management: Questions for science and society. Royal Holloway Institute for Environmental Research, Royal Holloway College, University of London, UK. pp. 55–62.

Lawton, J.H. and Jones, C.G. 1993. Linking species and ecosystem perspectives. Trends in Ecology and Evolution 8:311–313.

Lee, S-W. 2002. Forest genetic resources conservation in the Republic of Korea. Forest Genetic Resources 30:40–51.

Lefèvre, F., Barsoum, N., Heinze, B., Kajba, D., Rotach, P., de Vries, S.M.G. and Turok, J. 2001. *In Situ* Conservation of *Populus nigra*. EUFORGEN Technical Bulletin. IPGRI, Rome, Italy.

Leopold, A. 1933. The conservation ethic. Journal of Forestry 31:634–643.

Leopold, A. 1949. A Sand County Almanac. Oxford University Press, New York.

Lleras, E. 1991. Conservation of genetic resources *in situ*. Diversity 7:72–74.

Lobeira, S. 1999. Biodiversity Implications of Growing Coffee in the Sierra de Manantlan's Biosphere Reserve. Available from: http://www.planeta.com/ planeta/99/0599coffee.html

Long, S.A. (ed.) 2004. Wildlife Integration for Livelihood Diversification (WILD) Project. Ministry of Environment and Tourism, Namibia.

Mace, G.M. and Collar, N.J. 2002. Priority-setting in species conservation. In: Norris, K. and Pain, D. (eds.), Conserving Bird Biodiversity: General principles and their application. Cambridge University Press, Cambridge, UK.

Maikhuri, R.K., Singh, A. and Semwal, R.L. 1994. *Prinsepia utilis* Royle: a wild, edible oil shrub of the higher Himalayas. Plant Genetic Resources Newsletter 98:5–8.

Malaya, F.M. 1990. Progress Report on the Dry Forest Management in Zambia. Paper prepared for the IDRC Project Leaders Workshop, Bulawayo, Zimbabwe.

Malcolm, J.R. and Markham, A. 2000. Global Warming and Terrestrial Biodiversity Decline. Report prepared for WWF. WWF, Gland, Switzerland.

Malcolm, J.R., Liu, C., Miller, L.B., Allnutt, T. and Hans, L. 2002. Habitats at Risk: Global warming and species loss in globally significant terrestrial ecosystems. WWF, Gland, Switzerland.

Mallet, J. 1996. The genetics of biological diversity: from varieties to species. In: Gaston, K.J. (ed.), Biodiversity: A biology of numbers and difference. Blackwell Science, Oxford, UK. pp. 13–53.

Martínez-Meyer, E. 2005. Climate change and biodiversity: some considerations in forecasting shifts in species' potential distributions. Biodiversity Informatics 2:42–55.

Maxted, N. 1990. An herbarium based ecogeographic study of *Vicia* subgenus *vicia*. Internal Report. IBPGR, Rome, Italy.

Maxted, N. 1995. An Ecogeographical Study of *Vicia* subgenus *vicia*. Systematic and Ecogeographic Studies on Crop Genepools 8. IPGRI, Rome, Italy.

Maxted, N. and Ford-Lloyd, B.F. 2003. Genetic diversity in wild lentils. In: Measuring Biodiversity for Conservation. Royal Society Policy Document 11/03. The Royal Society, London, UK. pp. 30–32.

Maxted, N. and Guarino, L. 1997. Ecogeographic surveys. In: Maxted N., Ford-Lloyd B.V. and Hawkes J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 69–87.

Maxted, N. and Hawkes, J.G. 1997. Selection of target taxa. In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 43–68.

Maxted, N. and Kell, S. 1998. Ecogeographic techniques and *in situ* conservation: a case study for the legume genus *Vicia* L. in Turkey. In: Zencirci, N., Kaya, Z., Anikster, Y. and Adams, W.T. (eds.), Proceedings of International Symposium on *In-Situ* Conservation of Plant Diversity. Central Research Institute for Field Crops, Ankara, Turkey. pp. 323–344.

Maxted N., van Slageren, M.W. and Rihan, J.R. 1995. Ecogeographic surveys. In: Guarino, L., Ramanatha Rao, V. and Reid R. (eds.), Collecting Plant Genetic Diversity. Technical guidelines. CAB International, Wallingford, UK. pp. 255-287.

Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.) 1997a. Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK.

Maxted, N., Ford-Lloyd, B.V., Hawkes, J.G. 1997b. Complementary conservation strategies. In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 15–40.

Maxted, N., Hawkes, J.G., Ford-Lloyd, B.V. and Williams, J.T. 1997c. A practical model for *in situ* genetic conservation. In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 339–367.

Maxted, N., Hawkes, J.G., Guarino, L. and Sawkins, M. 1997d. Towards the selection of taxa for plant genetic conservation. Genetic Resources and Crop Evolution 44(4):337–348.

Maxted, N., Guarino, L. and Dulloo, M.E. 1997e. Management and monitoring. In: Maxted N., Ford-Lloyd and Hawkes J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 144–159.

Maxted, N., Dulloo, M.E. and Eastwood, A. 1999. A model for genetic reserve conservation: a case study for *Coffea* in the Mascarene Islands. Botanica Lithuanica Supplementum 2:61–78.

Maxted, N., Guarino, L., Myer, L. and Chiwona, E.A. 2002. Towards a methodology for on-farm conservation of plant genetic resources. Genetic Resources and Crop Evolution 49(1):31–46.

Maxted, N., Guarino, L. and Shehadeh, A. 2003. *In situ* techniques for efficient genetic conservation and use: a case study for *Lathyrus*. Acta Horticulturae 623:41–60.

McKinnell, F.H. 2002. Status and Trends in Indicators of Forest Genetic Diversity. Forest Genetic Resources Working Paper FGR/38E. Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy. Available from: http://www.fao.org/DOCREP/005/AC786E/AC786E00.htm

McNeely, J.A. 2003. Conserving forest diversity in times of violent conflict. Oryx 37(2):142–152.

Meffe, G.K. and Carroll, C.R. 1994. Principles of Conservation Biology. Sinauer Associates, Sunderland, MA, USA.

Meilleur, B. 2001. *In Situ* Conservation of Crop Wild Relatives: Status and trends. Report to the International Plant Genetic Resources Institute for the UNEP/GEF PDF B Project '*In Situ* Conservation of Crop Wild Relatives through Enhanced Information Management and Field Application', July 2001. IPGRI, Rome, Italy.

Meilleur, B.A. and Hodgkin, T. 2004. *In situ* conservation of crop wild relatives: status and trends. Biodiversity and Conservation 13(4):663–684.

Menges, E.S. 1991. The application of minimum viable population theory to plants. In: Falk, D.A. and Holsinger, K.E. (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA. pp. 45–61.

Metcalfe, S.C. 1995. Communities, parks, and regional planning: a co-management strategy based on the Zimbabwean experience. In: IUCN and McNeely J.A. (eds.), Expanding Partnerships in Conservation. Island Press, Washington DC, USA.

Metzger, J. 1996. Quoted in Ohio Floriculture Online. Gene Bank proposed. Available from: http://floriculture.osu.edu/archive/aug96/genebnk.html

Meyer, J-Y. 2001. The Conservatoire Botanique National de Mascarin: plant conservation in action in La Réunion Island (Indian Ocean). BGCNews 3(7):41–43.

Mill, J. 2002. The Australian network for plant conservation. In: Maunder, M., Clubbe, C., Hankamer, C. and Groves, M. (eds.), Plant Conservation in the Tropics: Perspectives and practice. Royal Botanic Gardens, Kew, UK. pp. 91–113.

Millar, C.I. and Libby, W.J. 1991. Strategies for conserving clinal, ecotypic, and disjunct population diversity in widespread species. In: Falk, D.A. and Holsinger, K.E. (eds.), Genetics and Conservation of Rare Plants. Oxford University Press, New York, USA.

Miller, D.R., Rossman, A.Y. and Kirkbride, J. 1989. Systematics, diversity and germplasm. In: Knutson, L. and Stoner, A.K. (eds.), Biotic Diversity and Germplasm Preservation: Global imperatives. Kluwer Academic, Dordrecht, The Netherlands. pp. 3–11.

Miller, K.R. 1996. Balancing the Scales: Guidelines for increasing biodiversity's chances through bioregional management. World Resources Institute, Washington DC,USA.

Ministry of Science, Technology and Environment. 1992. Red Data Book. Vol. 1. Plants. Science and Technical Publishing House, Hanoi, Vietnam.

Mittermeier, R.A., Patricio Robles Gil, P.R., Hoffman, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and da Fonseca, G.A.B. (2005). Hotspots Revisited: Earth's biologically richest and most threatened terrestrial ecoregions. Conservation International, Washington DC, USA.

Moegenberg, S.M. and Levey, D.J. 2002. Prospects for conserving biodiversity in Amazonian extractive reserves. Ecology Letters 5(3):320–324.

Morandini, R., Ducci, F. and Menguzzato, G. 1994. *Abies nebrodensis* (Lojac.) Mattei, inventario 1992. Annals of the Istituto Sperimentale Selvicoltura d'Arezzo 22:5–51.

Morris, W.F. and Doak, D.F. 2002. Quantitative Conservation Biology: Theory and practice of population viability analysis. Sinauer Associates, Sunderland, MA, USA.

Moser, D.E. 2000. Habitat conservation plans under the US Endangered Species Act: the legal perspective. Environmental Management 26(suppl.1):S7–S13.

Müller-Starck, G. 1995. Protection of genetic variability in forest trees. Forest Genetics 2:121–124.

Müller-Starck, G. 1997. Protection of variability in forest tree populations: an overview.In: Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.), Conservation of the Wild Relatives of European Cultivated Plants. Bocconea 7:323–327.

Myers, N. 1988. Threatened biotas: 'hotspots' in tropical forests. Environmentalist 8: 1–20.

Myers, N. 1990. The biodiversity challenge: extended hot-spots analysis. Environmentalist 10:243–256.

Myers, N., Mittermeler, R.A., Mittermeler, C.G., da Fonseca, G.A.B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Nabhan, G.P. 1990. Wild *Phaseolus* Ecogeography in the Sierra Madre Occidentalis, Mexico: Areographic techniques for targeting and conserving species diversity. Systematic and Ecogeographic Studies on Crop Genepools 5. IBPGR, Rome, Italy.

Namkoong, G. 1983. Strategies for gene conservation in forest tree breeding. In: Yeatman, C.W., Kafton, D. and Wilkes, G. (eds.), Plant Gene Resources: A conservation imperative. Westview Press, Boulder, CO, USA. pp. 79–92.

Namkoong, G. 1986. Genetics and the forests of the future. Unasylva 38(152) [online].

Namkoong, G. 1989. Population genetics and the dynamics of conservation. In: Knitson, L. and Stoner, A.K. (eds.), Biotic Diversity and Germplasm Preservation: Global imperatives. Kluwer Academic, Dordrecht, The Netherlands. pp. 162–181.

Namkoong, G. 1999. Genecology and conservation of forest genetic resources in the tropics. In: Mariante, A.S. and Bustamante, P.G. (eds.), Proceedings of the 2nd International Symposium on Genetic Resources for Latin America and the Caribbean—SIRGEALC, 21–26 November 1999, Brazil. Proceedings published in CD-ROM.

Namkoong, G. and Koshy, M.P. 1997. Managing the genetic variance. In: Mátyás, C. (ed.), Perspectives of Forest Genetics and Tree Breeding in a Changing World. IUFRO World Series 6. IUFRO, Vienna, Austria. pp. 9–16.

Namkoong, G., Boyle, T., El-Kassaby, Y.A., Palmberg-Lerche, C., Eriksson, G., Gregorius, H.-R., Joly, H., Kremer, A., Savolainen, O., Wickneswari, R. and others. 2002. Criteria and Indicators for Sustainable Forest Management: Assessment and monitoring of genetic variation. Forest Genetic Resources Working Paper FGR/37E. Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy. Available from: http://www.fao.org/DOCREP/005/AC649E/AC649E00.htm

Narayan Pandey, D. and Kumar, N. 2000. Ethnoforestry: An annotated bibliography. International Network on Ethnoforestry in collaboration with Winrock International and Ford Foundation. Indian Institute of Forest Management, Bhopal, India.

National Research Council. 1991. Managing Global Genetic Resources: Forest trees. National Academy Press, Washington DC, USA.

Nature Conservancy Council. 1988. Site Management Plans for Nature Conservation. A working guide. Interpretive Services Branch, Peterborough, UK. 40 pp.

Nature Conservancy. 1996. Conservation by Design: A framework for mission success. The Nature Conservancy, Arlington, VA, USA.

Nature Conservancy. 1999. Measuring Success: The parks in peril consolidation scorecard manual—draft. The Nature Conservancy, Latin America and Caribbean Region, Arlington, VA, USA.

Nature Conservancy. 2000. The Five-S Framework for Site Conservation: A practitioner's handbook for site conservation planning and measuring conservation success. Vol. 1 (2nd edn.). The Nature Conservancy, Virginia, USA.

Nature Conservancy. 2004. Conservation by Design: A framework for mission success. Revised Fall 2004. The Nature Conservancy, Arlington, VA, USA.

Nayar, M.P. and Sastry, A.R.K. (eds.) 1987. Red Data Book of Indian Plants, Vol. 1. Botanical Survey of India, Calcutta, India. 367 pp.

Nayar, M.P. and Sastry, A.R.K. (eds.) 1988. Red Data Book of Indian Plants, Vol. 2. Botanical Survey of India, Calcutta, India. 273 pp.

Nayar, M.P. and Sastry, A.R.K. (eds.) 1990. Red Data Book of Indian Plants, Vol. 3. Botanical Survey of India, Calcutta, India. 271 pp.

Neel, M.C. and Cummings, M.P. 2003a. Effectiveness of conservation targets in capturing genetic diversity. Conservation Biology 17(1):219–229.

Neel, M.C. and Cummings, M.P. 2003b. Genetic consequences of ecological reserve design guidelines: an empirical investigation. Conservation Genetics 4(4):427–439.

Nelson, M. 1999. Habitat Conservation Planning. USFWS Endangered Species Bulletin XXIV, No. 6. November-December 1999. 2 pp. Available from: http://endangered.fws.gov/esb/99/11-12/12-13.pdf

Newbury, H.J. and Ford-Lloyd, B.V. 1997. Estimation of genetic diversity. In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (eds.), Plant Genetic Conservation: The *in situ* approach. Chapman and Hall, London, UK. pp. 192–206.

Nguyen, H.N. 2003. Conservation of forest genetic resources in Vietnam. Paper submitted to the XII World Forestry Congress 2003, Québec City, Canada. Available from: http://www.fao.org/docrep/article/wfc/xii/0040-b3.htm

Nicholls, H. 2004. The conservation business. PLoS Biology 2:1256–1259.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4(4):355-364.

Oldfield, S. 1997. Cactus and Succulent Plants: Status survey and conservation action plan. Species Survival Commission, Gland, Switzerland.

Olfelt, J.P., Furnier, G.R. and Luby, J.J. 2001. What data determine whether a plant taxon is distinct enough to merit legal protection? A case study of *Sedum integrifolium* (Crassulaceae). American Journal of Botany 88(3):401–410.

Ouédraogo, A.-S. 1997. Conservation and use of forest genetic resources. In: Proceedings of the XI World Forestry Congress, 13–22 October 1997, Antalya, Turkey. FAO, Rome, Italy. pp. 173–188.

Özhatay, N., Byfield, A. and Atay, S. 2003. Türkiye'nin Önemli Bitki Alanlari. WWF Türkiye, Istanbul, Turkey.

Padulosi, S., Hodgkin, T., Williams. J.T. and Haq, N. 2002. Underutilized crops: trends, challenges and opportunities in the 21st century. In: Engels, J.M.M., Ramanatha Rao, V., Brown A.H.D. and Jackson, M.T. (eds.), Managing Plant Diversity. CABI Publishing, Wallingford, UK. pp. 323–338.

Palmberg-Lerche, C. 1993. International programmes for the conservation of forest genetic resources. In: Proceedings of the International Symposium on Genetic Conservation and Production of Tropical Forest Seed. ASEAN/CANADA Forest Tree Seed Centre, Muak Lek, Thailand.

Palmberg-Lerche, C. 2001. International Action in the Management of Forest Genetic Resources: Status and challenges. Working Paper FGR/1. Forest Resources Division, Forestry Department, FAO, Rome, Italy. Available from: http://www.fao.org/DOCREP/003/X9818E/X9818E00.htm

Palmberg-Lerche, C. 2002. Thoughts on genetic conservation in forestry. Unasylva 53(209) [online].

Pandey, G. 2003. Forest management: changing paradigms. Paper submitted to the XII World Forestry Congress 2003, Québec City, Canada. Available from: http://www.fao.org/docrep/article/wfc/xii/ms21-e.htm

Patiño-Valera, F. 2002. Lineamientos para la elaboración de los documentos nacionales. Documentos de Trabajo: Recursos genéticos Forestales FGR/39S. Servicio de Desarrollo de Recursos Forestales, Dirección de Recursos Forestales, FAO, Rome, Italy.

Pavek, D. and Garvey, E. 1999. The American Wild Relatives of Crops: *In situ* conservation guidelines. *In situ* Subcommittee, Plant Germplasm Operations Committee, USDA-ARS. USDA, Beltsville, MD, USA.

Pavek, D.S., Lamboy, W.F. and Garvey, E.J. 2001. *In situ* conservation of America's wild grapes. HortScience 36(2):232–235.

Pavek, D.S, Lamboy, W.F. and Garvey, E.J. 2003. Selecting *in situ* sites for grape genetic resources in the USA. Genetic Resources and Crop Evolution 50:65-173.

Pearce, T.R. and Bytebier, B. 2002. The role of a herbarium and a herbarium database in supporting plant conservation. In: Maunder, M., Clubbe, C., Hankamer, C. and Groves, M. (eds.), Plant Conservation in the Tropics: Perspectives and practice. Royal Botanic Gardens, Kew, UK. pp. 49–67.

Perfecto, I. and Vandermeer, J. 2002. Quality of agroecological matrix in a tropical montane landscape: ants in coffee plantations in southern Mexico. Conservation Biology 16(1):174–182.

Peterson, A.T. 2001. Endangered species and peripheral populations: cause for reflection. Endangered Species UPDATE 18(2):30–31.

Phillips, A. 2002. Management Guidelines for IUCN Category V Protected Areas: Protected landscapes/seascapes. Best Practice Protected Areas Guidelines Series 9. IUCN World Commission on Protected Areas. IUCN, Gland, Switzerland.

Pickersgill, B. 1981. Biosystematics of crop–weed complexes. Kulturpflanze 35:377–388.

Pimbert, M.P. and Pretty, J.N. 1995. Parks, People and Professionals: Putting "participation" into protected area management. Discussion Paper 57. UNRISD/IIED/WWF, Geneva, Switzerland.

Planta Europa. 2002. European Plant Conservation Strategy. Planta Europa, London, UK.

Pliūra, A. 2003. Ash (*Fraxinus* spp.) Genetic Resources Conservation Strategy. EUFORGEN Noble Hardwoods Network. Available from: http://www.ipgri. cgiar.org/networks/euforgen/Networks/Noble_Hardwoods/Strategies/ FraxinusSppConsStrategy.htm].

Poore, D., Blaser, J., Bruening, E.F., Burgess, P., Cabarle, B., Cassels, D., Douglas, J., Gilmour, D., Hardcastle, P., Hartshorn, G. and others. 1999. No forests without management: sustaining forest ecosystems under conditions of uncertainty. ITTO Update 8:10–12.

Poulsen, J. (ed.) 2001. Genetic Resources Management in Ecosystems. Report of a workshop organized by CIFOR for the SGRP CIFOR, Bogor, Indonesia, 27–29 June 2000. CIFOR, Bogor, Indonesia for CGIAR SGRP, Rome, Italy. Available from: http://www.cifor.cgiar.org/publications/pdf_files/grme. pdf

Prain, G. (ed.) 2003. *In-Situ* Conservation of Agrobiodiversity: Scientific experiences and implications for institutions and national policies. International Potato Center, Swiss Agency for Development and Cooperation, Food and Agricultural Organization of the United Nations, and Systemwide Genetic Resource Program. CIP, Lima, Peru.

Primack, R.B. 1993. Essentials of Conservation Biology. Sinauer Associates, Sunderland, MA, USA.

Putz, F.E., Redford, K.H., Robinson, J.G., Fimbel, R. and Blate, G. 2000. Biodiversity Conservation in the Context of Tropical Forest Management. The World Bank Environment Department, Biodiversity Series—Impact Studies Paper 75. The World Bank, Washington DC, USA.

Raffaelli, M., Mosti, S. and Tardelli, M. 2003a. The frankincense tree (*Boswellia sacra* Flueck., Burseraceae) in Dhofar, southern Oman: field-investigations on the natural populations. Webbia 58:133–149.

Raffaelli, M., Tardelli, M. and Mosti, S. 2003b. The Wadi Doka Frankincense Park in Dhofar, Oman: First steps towards the safeguard and improvement of *Boswellia sacra* (Burseraceae). Erbario Tropicale di Firenze, Publication No. 93.

Rao, A.N. and Ramanatha Rao, V. (eds.) 2000. Bamboo: Conservation, diversity, ecogeography, germplasm, resource utilization and taxonomy. Proceedings of Training Course cum Workshop, 10–17 May 1998, Kunming and Xishuangbanna, Yunnan, China. IPGRI-APO, Serdang, Malaysia and INBAR, Beijing, China.

Reid, W. 1990. Eastern black walnut: potential for commercial nut-producing cultivars. In: Janick, J. and Simon, J.E. (eds.), Advances in New Crops. Timber Press, Portland, OR, USA. pp. 327–331.

Richards, C. 2004. Genetics, demography and *ex situ* conservation options: a case study of *Zizania texana.* In: Clary. K., Delmatier, C., Poole, J. and Oxley, F.M. (eds.), Texas Plant Conservation Conference 2002 Proceedings, Austin, Texas. pp. 29–30. Available from: http://www.wildflower.org/ama/orig/tpcc-3.pdf

Ricklefs, R.E., Naveh, Z. and Turner, R.E. 1984. Conservation of Ecological Processes. IUCN Commission on Ecology Paper 8. IUCN, Gland, Switzerland.

Riggs, L.R. 1982. Douglas-fir Genetic Resources: An assessment and plan for California. California Gene Resource Program, Sacramento, CA, USA.

Rihan, J.R. 1988. An herbarium-based ecogeographic survey of forages *Medicago* species in the Mediterranean and adjacent arid/semi-arid areas. Internal Report. IBPGR, Rome, Italy.

Roberson, E.B. 2001. Management of rare plants under state and federal endangered species law: a CNPS perspective. Freemontia 29:5–12.

Roe, D., Mayers, J., Grieg-Gran, M., Kothari, A., Fabricius, C. and Hughes, R. 2000. Evaluating Eden: Exploring the myths and realities of community-based wildlife management. Series Overview EE 08. IIED Biodiversity Group, IIED, London, UK.

Rogers, D.L. 2002. *In Situ* Genetic Conservation of Monterey Pine (*Pinus radiata* D. Don): Information and recommendations. Report 26. Genetic Resources Conservation Program, Division of Agriculture and Natural Resources, University of California, Davis, CA, USA.

Rojo, A. and Peters, E. 2003. Conserving cacti in México. Endangered Species Bulletin 28(3):10–11.

Ryder, O.A. 1986. Species conservation and systematics: the dilemma of subspecies. Trends in Ecology and Evolution 1:9–10.

Safriel, U.N., Anikster, Y. and Valdman, M. 1997. Management of nature reserves for conservation of wild relatives and the significance of marginal populations. In: Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.), Conservation of the Wild Relatives of European Cultivated Plants. Bocconea 7:233–239.

Salafsky, N., Dugelby, B.L. and Terborgh, J.W. 1993. Can extractive reserves save the rain forest? An ecological and socioeconomic comparison of nontimber

forest product extraction systems in Petén, Guatemala, and west Kalimantan, Indonesia. Conservation Biology 7(1):39–52.

Sandwith, T., Shine, C., Hamilton, L., Sheppard, D. and Phillips, A. (eds.) 2001. Transboundary Protected Areas for Peace and Co-operation. Best Practice Protected Areas Guidelines Series No. 7. World Commission on Protected Areas, IUCN, Gland, Switzerland.

Saraswati, B. (ed.) 1988. Lifestyle and Ecology. D.K. Printworld, New Delhi, India.

Saxena, S., Chandak, V., Ghosh, S.B., Sinha, R., Jain, N. and Gupta, A.K. 2003. Costs of conservation of agro-biodiversity in India. In: Virchow, D. (ed.), Efficient Conservation of Crop Genetic Diversity: Theoretical approaches and empirical studies. Springer-Verlag, Berlin, Germany. pp. 137-174.

Sayer, J. 1991. Rainforest Buffer Zones: Guidelines for protected area managers. IUCN, Gland, Switzerland.

Schellnhuber, H.J. 2002. Coping with earth system complexity and irregularity. In: Steffen, W., Jäger, J., Carson, D.J. and Bradshaw, C. (eds.), Challenges of a Changing Earth. Proceedings of the Global Change Open Science Conference, Amsterdam, 10–13 July 2001. Springer, Heidelberg, Germany. pp. 151–156.

Schwartzman, S., Moreira, A. and Nepstad, D. 2000. Rethinking tropical forest conservation: perils in parks. Conservation Biology 14(5):1351–1357.

Serra, L., Oérez-Rovira, P., Deltoro, V.I., Faabregat, C., Laguna, E. and Pérez-Botella, J. 2004. Distribution, status and conservation of rare relict plant species in the Valencian community. Bocconea 16:857–863.

Sharma, R.C. 2003. People's Protected Area (PPA): unlocking forests for people. Paper submitted to XII World Forestry Congress 2003, Quebec City, Canada. Available from: http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0480-A1.htm

Sharrock, S. and Engels, J. 1997. Complementary conservation. In: INIBAP Annual Report 1996. INIBAP, Montpellier, France. pp. 6–9.

Sidle, R.C. 2002. Environmental Change and Geomorphic Hazards in Forests. National University of Singapore, Singapore.

Sigaud, P., Thomson, L. and Hald, S. 1999. Pacific sub-regional workshop on forest and tree genetic resources. Forest Genetic Resources 27.

Singh, B. 1981. Establishment of First Gene Sanctuary in India for *Citrus* in Garo Hills. Concept Publishing, New Delhi, India.

Smith, N.J.H., Williams, J.T., Plucknett, D.L. and Talbot, P. 1992. Tropical Forests and their Crops. Comstock Publishing, Ithaca, NY, USA.

Smith, R.D. and Maltby, E. 2003. Using the Ecosystem Approach to Implement the Convention on Biological Diversity: Key issues and case studies. IUCN, Gland, Switzerland.

Soulé, M.E. (ed.). 1986. Conservation Biology: The science of scarcity and diversity. Sinauer Associates, Sunderland, MA, USA.

Soulé, M.E. (ed.). 1987. Viable Populations for Conservation. Cambridge University Press, Cambridge, UK.

Soulé, M.E. and Mills L.S. 1992. Conservation genetics and conservation biology: a troubled marriage. In: Sandlund, O.T., Hindar, K. and Brown, A.H.D. (eds.), Conservation of Biodiversity for Sustainable Development. Scandinavian University Press, Oslo, Norway. pp. 55–69.

Soupizet, F. 2002. Gestion *in situ* de la diversité génétique des espèces sauvages apparentées aux espèces cultivées. Etude de *Brassica* L., *Beta* L., *Olea* L. Les Etudes du BRG 2. Bureau des Ressources Génétiques, Paris, France.

Spooner, D.M., van den Berg, R.G., Hetterscheid, W.L.A., and Brandenburg, W.A. 2003. Plant nomenclature and taxonomy: an horticultural and agronomic perspective. Horticultural Review*s* 28:1–60.

Stearn, W.T. 1973. *Botanical Latin*. David and Charles, Newton Abbot, UK.

Steffen, W., Turner, B.L., II, Wasson, R.J., Sanderson, A., Tyson, P., Jäger, J., Matson, P., Moore, B., III, Oldfield, F., Richardson, K. and Schellnhuber, H.J. 2004. Global Change and the Earth System: A planet under pressure. Springer, Heidelberg, Germany.

Stephens, S. and Maxwell, S. (eds.) 1998. Back from the Brink: Refining the threatened species recovery process. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

Stewart, J.L. 2001. Variación genética en arboles forasteros. In: Conferencia Electrónica de la FAO sobre 'Agroforestería para la producción animal en Latinoamérica'. Available from: http://www.fao.org/ag/aga/agap/FRG/AGROFOR1/Agrofor1.htm

Strahm, W. 1989. Plant Red Data Book for Rodrigues. Koeltz Scientific Books, Konigstein, Germany.

Strahm, W. 1996. Conservation of the flora of the Mascarene Islands. Curtis's Botanical Magazine 13(4):228–238.

Sutherland, W.J. 2001. The Conservation Handbook: Research management and policy. Blackwell Science, Oxford, UK.

Tan, A. 1998. Current status of plant genetic resources in Turkey. In: Zrencirci, N., Kaya, Z., Anikster, Y. and Adams, W.T. (eds.), Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity. CRIFC, Ankara, Turkey. pp. 5–17.

Tan, A. and Tan, A.S. 2002. *In situ* conservation of wild species related to crop plants: the case of Turkey. In: Engels, J.M.M., Ramantha Rao, V., Brown, A.H.D. and Jackson, M.T. (eds.), Managing Plant Genetic Diversity. CAB International, Wallingford, UK. pp. 195–204.

Tewksbury, J.J., Nabhan, G.P., Norman, D., Suzán, H., Tuxill, J. and Donovan, J. 1999. *In situ* conservation of wild chiles and their biotic associates. Conservation Biology 13:98-107.

Theilade, I. Graudal, L. and Kjær, E. 2000. Conservation of the Genetic Resources of *Pinus merkusii* in Thailand. DFSC Technical Note 58. Danida Forest Seed Centre, Humlebaek, Denmark.

Theilade, I., Sekeli, P.M., Hald, S. and Graudal, L. (eds.) 2001. Conservation Plan for Genetic Resources of Zambezi Teak (*Baikiaea plurijuga*) in Zambia. DFSC Case Study 2. Danida Forest Seed Centre, Humlebaek, Denmark.

Thomson, L. 1998. SPRIG: South Pacific regional initiative on forest genetic resources. Forest Genetic Resources 26.

Thomson, L. and Theilade, I. 2001.Protected Areas and their role in conservation of forest genetic resources. In: FAO, DFSC and IPGRI (eds.), Forest Genetic Resources Conservation and Management. Vol. 2. In Managed Natural Forests and Protected Areas (*In Situ*). IPGRI, Rome, Italy. pp. 45–65.

Thomson, L., Graudal, L. and Kjaer, E. I. 2001. Selection and management of *in situ* gene conservation areas for target species. In: FAO, DFSC and IPGRI (eds.), Forest Genetic Resources Conservation and Management. Vol. 2. In Managed Natural Forests and Protected Areas (*In Situ*). IPGRI, Rome, Italy. pp. 5–12.

Thormann, I., Jarvis, D.I., Dearing, J.A. and Hodgkin, T. 1999. Internationally available information sources for the development of *in situ* conservation strategies for wild species useful for food and agriculture. Plant Genetic Resources Newsletter 118:38–50.

Tutin, T.G., Heywood, V.H. and others. 1964–1988. Flora Europaea, Vols. 1–5. Cambridge University Press, Cambridge, UK.

Tutin, T.G., Heywood V.H., Burges, N.A., Valentine, D.H. and Moore, D. (eds.) 1993. Flora Europaea, Vol. 1, Psilotaceae to Platanaceae (2nd edn.). Cambridge University Press, Cambridge, UK.

Tuxill, J. and Nabhan, G.P. 1998. Plants and Protected Areas. A guide to *in situ* management. Standley Thornes (Publishers), Cheltenham, UK.

Tuxill, J. and Nabhan, G.P. 2001. People, Plants and Protected Areas: A guide to *in situ* management. Earthscan, London, UK.

UNDP/UNEP. 2000. Guide to Developing a Biodiversity Strategy from a Sustainable Development Perspective. Institut de l'énergie et de l'environnement de la Francophonie (IEPF), Ministère de l'Environnement du Québec, United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), Québec, Canada.

UNESCO. 1992. Biosphere Reserves: Special places for people and nature. UNESCO, Paris, France.

UNESCO. 2000. Solving the Puzzle: The ecosystem approach and biosphere reserves. UNESCO, Paris, France.

US Fish and Wildlife Service. 1986. Spineless Hedgehog Cactus (*Echinocereus triglochidiatus* var. *inermis*) Recovery Plan. US Fish and Wildlife Service, Denver, CO, USA.

US Fish and Wildlife Service. 1995. San Marcos/Comal (Revised) Recovery Plan. Albuquerque, NM, USA.

US Fish and Wildlife Service. 1998. Recovery Plan for Oahu Plants. US Fish and Wildlife Service, Portland, OR, USA.

US Fish and Wildlife Service. 1999. South Florida Multi-Species Recovery Plan. US Fish and Wildlife Service, Atlanta, GA, USA. Available from: http://www. fws.gov/southeast/vbpdfs/execsum.pdf

USA Country Report. 1996. United States of America: Country Report to the FAO International Technical Conference on Plant Genetic Resources (Leipzig 1996). FAO, Rome, Italy.

USDA 1999. The American Wild Relatives of Crops: *In situ* conservation guidelines. *In Situ* Subcommittee, Plant Germplasm Operations Committee. USDA, Beltsville, MD, USA.

Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.) 1997. Conservation of the Wild Relatives of European Cultivated Plants. Azienda Foreste Demaniali della Regione Siciliana, Palermo, Italy. Bocconea 7.

Valencia, R., Pitman, N., León-Yánez, S. and Jørgensen, P.M. (eds.) 2000. Libro rojo de las plantas endémicas del Ecuador. Herbario QCA, Pontificia Universidad Católica del Ecuador, Quito, Ecuador.

van den Hurk, A. 1998. *In situ* conservation of tropical fruit germplasm In: Arora, R.K. and Ramanatha Rao, V. (eds.), Tropical Fruits in Asia: Diversity, maintenance, conservation and use. Proceedings of the IPGRI-ICAR-UTFANET Regional Training Course on the Conservation and Use of Germplasm of Tropical Fruits in Asia, 18–31 May 1997. IPGRI Office for South Asia, New Delhi, India. pp. 127–141.

Vieira, R.F. 1999. Conservation of medicinal and aromatic plants in Brazil. In: Janick, J. (ed.), Perspectives on New Crops and New Uses. ASHS Press, Alexandria, VA, USA. pp. 152–159.

Vieira, R.F. and Skorupa, L.A. 1993. Brazilian medicinal plants gene bank. Acta Horticulturae 330:51–58.

Villa-Lobos, J. 2003. Landmark legislation protects imperiled US plants. Plant Talk 32:34–37.

Vivero, J.L., Hernández Bermejo, J.E. and Prados Ligero, J. 2001. Conservation strategies and management guidelines for wild *Prunus* genetic resources in Andalucía, Spain. Genetic Resources and Crop Evolution 48(5):533–546.

von Bothmer, R., Jacobsen, N., Baden, C., Jorgensen, R.B. and Linde-Laursen, I. 1991. An Ecogeographical Study of the Genus *Hordeum*. Systematic and Ecogeographic Studies on Crop Genepools 7. IBPGR, Rome, Italy.

Waples, R.S. 1995. Evolutionary significant units and the conservation of biological diversity under the Endangered Species Act. In: Nielson, J.I. (ed.), Evolution and the Aquatic Ecosystem: Defining unique units in population conservation. Symposium 17. American Fisheries Society, Bethesda, MD, USA. pp. 8–27.

Waples, R.S. 1998. Evolutionarily significant units, distinct population segments, and the Endangered Species Act: reply to Pennock and Dimmick. Conservation Biology 12(3):718–721.

Wells, M.P. and Brandon, K.E. 1993. The principles and practice of buffer zones and local participation in biodiversity conservation. Ambio 22(2–3):157–162.

WHO/IUCN/WWF. 1993. Guidelines on the Conservation of Medicinal Plants. IUCN, Gland, Switzerland.

Wilcox, B.A. 1984. *In situ* conservation of genetic resources: determinants of minimum area requirements. In: McNeely, J.A. and Miller, K.R. (eds.), National Parks Conservation and Development. Smithsonian Institution Press, Washington DC, USA. pp. 639–647.

Wilcox, B.A. 1990. Requirements for the establishment of a global network of *in situ* conservation areas for plants and animals. FAO, Rome, Italy (unpublished).

Wilcox, B.A. 1995. Tropical forest resources and biodiversity: the risks of forest loss and degradation. Unasylva 46(181) [online]

Woodruff, D.S. 1989. The problems of conserving genes and species. In: Western, D. and Pearl, M. (eds.), Conservation for the Twenty-First Century. Oxford University Press, New York, USA. pp. 76–88.

World Bank. 2002. Forest Policy and Strategy. Available from: http://lnweb18.worldbank.org/ESSD/essdext.nsf/14ByDocName/ForestPolicyandStrategy

World Resources Institute. 2000. World Resources 2000–2001: People and Ecosystems: The fraying web of life. World Resources Institute, Washington DC, USA.

WWF. 2003a. The Sacred Forest of Sakoantovo and Vohimasio: Catalysing community-based forest management to conserve the biodiversity of southern Madagascar. Gift to the Earth 87, June 2003. WWF, Gland, Switzerland.

WWF. 2003b. Conserving Nature: Partnering with People. WWF's global work on protected area networks. WWF, Gland, Switzerland.

WWF. 2004. How Effective are Protected Areas? Preliminary analysis of forest protected areas by WWF—the largest ever global assessment of protected area management effectiveness. Report prepared for the Seventh Conference of the Parties of the Convention on Biological Diversity, February 2004. WWF, Gland, Switzerland.

Yanchuk, A.D. 1997. Conservation issues and priorities for the conifer genetic resources of British Columbia, Canada. Forest Genetic Resources 25.

Zohary, D. 1997. Wild apples and pears. In: Valdés, B., Heywood, V.H., Raimondo, F.M. and Zohary, D. (eds.), Conservation of the Wild Relatives of European Cultivated Plants. Azienda Foreste Demaniali della Regione Siciliana, Palermo, Italy. Bocconea 7:409–416.

Zoro Bi, I., Maquet, A. and Baudoin, J.-P. 2003. Population genetic structure of wild *Phaseolus lunatus* (Fabaceae), with special reference to population sizes. American Journal of Botany 90:897–904.

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