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Food**Stores**

Using protected areas to secure crop genetic diversity

A research report by WWF, Equilibrium and University of Birmingham, UK

Arguments for Protection

Food Stores: Using Protected Areas to Secure Crop Genetic Diversity

A research report by WWF, Equilibrium and the
University of Birmingham, UK

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Cover photographs: *Top*: Potatoes in Peru © WWF-Canon / Udo Hirsch
Bottom: Wild rice (*Oryza nivara*) © WWF-Canon / Vin J. Toledo

Foreword

Way back in 1982, at the 3rd World Parks Congress, in Bali, Indonesia, protected area managers were already concerned about the use of protected areas to conserve genetic diversity. One of the plenary presentations, by Robert Prescott-Allen, was entitled, “Park Your Genes: Protected Areas as *in situ* Gene Banks for the Maintenance of Wild Genetic Resources”[1]. At the same session, Cyril de Klemm gave a presentation entitled “Protecting Wild Genetic Resources for the Future: the Need for a World Treaty”[2]. This was the precursor to many of basic concepts of the Convention on Biological Diversity (CBD). I provide this brief historical background to indicate that the latest WWF *Argument for Protection*, developed and written with Equilibrium and the School of Bioscience at the University of Birmingham, UK, namely using protected areas to secure crop genetic diversity, has a distinguished pedigree. But a pedigree does not necessarily lead to action, and this report provides, at long last, practical guidance on how protected areas contribute to human welfare in the ways foreseen in Bali nearly 25 years ago.

Already, many protected areas have considerable in-holdings of agricultural land, containing numerous unique landraces that have been maintained by farmers for millennia, but also all too many exotic modern cultivars not native to the local region and hence can be seen as an intrusion into the protected area. On the other hand, protected areas are also reservoirs of wild genetic resources, and many of these are relatives of domesticated plants. The protected areas located in centres of crop diversity (sometimes called Vavilov Centres, in honour of the Russian plant geographer who did much to discover and popularize these centres) are especially valuable for conserving plant diversity. As the authors point out, this can also provide new justifications for maintaining the protected areas as sites of continuing evolution for the relatives of domesticated plants. But in order for these genetic resources to have value, appropriate management procedures need to be put into place to enable the genes to be harvested in ways that are consistent with the other objectives of the protected area. Fortunately, the harvesting of such genetic resources is typically non-intrusive, and does not require large collections to be made. The authors provide specific guidance on how individual protected areas can conserve crop genetic diversity, and the case studies lead to a set of highly practical recommendations.

Another important element to consider is the growing influence of biotechnology. As scientists come to better understand the mechanisms of the ways that plants develop, and which genes are likely to affect what characteristics of the plant, wild genetic resources are likely to increase in value. This again underlines the importance of the Convention on Biological Diversity as a means for ensuring that the benefits from using these genetic resources are equitably distributed, along with the increased knowledge that comes from mobilizing these genetic resources. Of course, moving genes between species also carries potential risks, and the CBD’s Cartagena Protocol on Biosafety provides an international mechanism for addressing at least some of these risks.

At a time when biodiversity loss is an increasing concern, the role of protected areas in maintaining this diversity becomes increasingly important. As this report points out so eloquently, the role that protected areas play in conserving plant genetic diversity is critical, and far greater support needs to be given to managing protected areas for the benefits they provide to agriculture. This will help to expand the supporters of protected areas to include farmers and agricultural scientists. Such a partnership is particularly useful in demonstrating the common interests between groups that often had been in conflict over land use. A landscape-scale approach to conservation that includes agricultural lands, protected areas, natural forests, managed forests, and grazing lands can offer a comprehensive approach that meets many human needs while addressing the ethical imperative to conserve biodiversity.

The series of reports being produced by WWF on Arguments for Protection are making ever-stronger cases for conservation, and this latest instalment is a particularly significant contribution.

Jeffrey A. McNeely, Chief Scientist, IUCN-The World Conservation Union, Gland, Switzerland

Preface

Plants help our ecosystem function; they fix nitrogen, sequester carbon dioxide and stabilise soils, as well as directly or indirectly providing us with medicines, building materials, lubricants, resins, waxes, perfumes, dyes, fibres and, of course, food[3].

It has been estimated that there are between 250 and 300 thousand species of flowering plants[4], of which only about 10 per cent have ever been evaluated for their medicinal or agricultural potential[5]. Wild plants continue to supply new medicinal drugs and provide alleles (viable DNA codings of the same gene) that confer desirable traits for cultivated crops. But the chances of discovering novel traits or uses for species are decreasing – just as we are increasing our knowledge of plant species and functions, so are our activities leading to their destruction. The 2004 edition of IUCN's *Red List*, for example, found that the numbers of threatened species are increasing across almost all the major taxonomic groups with the main pressures coming from habitat loss, competition from introduced species and over-exploitation, with human-induced climate change becoming an increasingly significant problem[6]. Although the IUCN *Red List* Criteria does not assess the loss of genetic diversity within species, this is equally being lost or eroded by the same factors, and gene pool shrinkage is largely taking place without being recognised or assessed.

Diversity, the foundation of our food security, is also decreasing within cultivated crops. The Food and Agriculture Organisation of the United Nations (FAO) estimates that about 75 per cent of the genetic diversity of agricultural crops has been lost in the last century due to the widespread abandonment of genetically diverse traditional crop landraces in favour of genetically uniform modern crop varieties[7]. The primary reason is that plant breeders throughout the world are engaged in developing better cultivars of crop plants. This involves the replacement of the generally genetically diverse, lower yielding, locally adapted crops grown traditionally, by generally higher yielding varieties deliberately bred for genetic uniformity. Thus uniformity is replacing diversity. These same plant breeders paradoxically are dependent upon the availability of a pool of diverse genetic material for success in their work, but are unwittingly causing the genetic erosion of the very plant diversity that they themselves need for future breeding.

Germplasm researcher recording characteristics of the rice variety Chuan-Chu-Ta-Veh-Tsao (Taiwanese) cultivated at the International Research Institute, Manila, Philippines

Credit: © WWF-Canon / Vin J. Toledo

The Green Revolution of the 1950s spread high yielding, disease and pest resistant new varieties across the developing world; by 1990 they covered half of all wheat lands and more than half of all rice lands – a total of some 115 million ha. As yields increased, the diversity of crops and varieties has decreased, reducing potential for adaptation to changing conditions. Today, it is widely stated that just nine crops (wheat, rice, maize, barley, sorghum/millet, potato, sweet potato/yam, sugar cane and soybean) account for over 75 per cent of the plant kingdom's contribution to human dietary energy[8]. There are however still many millions of small farmers, particularly in marginal agricultural environments unsuitable for modern varieties, who practice traditional agriculture by cultivating community-bred crops (or 'landraces') produced through cycles of sowing, harvesting and selection of seed for planting over many generations. The genetic diversity represented in these landraces remains a vital resource for global food security and economic stability.

An equally threatened global agro-biodiverse resource is the reservoir of genetic diversity found in the wild species that are closely related to crops, the so-called crop wild relatives (CWR). Farmers have for millennia benefited from the natural crossing between crops and their wild relatives introgressing beneficial traits into the crop that enable it successfully to counter evolving pest and diseases and environmental changes. Contemporary breeders are increasingly searching the gene pool of crop relatives for these desirable traits.

Both landraces and CWR thus serve as the world's repositories of crop genetic diversity and represent a vital source of genes that can ensure future food security. Their importance is increasing as human population growth and climate change alter environmental conditions and thus force the pace of agricultural change. This report reviews the importance, conservation and use of the genetic diversity found in CWR and landraces, and considers options for their conservation when associated with protected areas.

Contents

This book has been prepared by WWF working in close collaboration with the School of Biosciences, University of Birmingham, UK.

Executive Summary

Plant genetic resources are a threatened but invaluable resource for present and future generations. Crop genetic diversity – both in cultivated plants (landraces) and the wild plants from which our crops originate (crop wild relatives or CWR) – provide important resources for food security, environmental sustainability and economic stability. It is thus perhaps surprising, considering this socio-economic importance that the conservation of CWR has not been systematically addressed and the rapid declines in landraces have generated little international conservation concern.

Estimates of the global value associated with the use of plant genetic resources for food and agriculture vary from hundreds of millions to tens of billions of US dollars per year. Whatever the exact economic value, we do know that when agricultural disasters occur, plant genetic resources can provide solutions. For example, the corn blight which halved US yields in the 1970s was alleviated by use of genetic material from a wild relative. But these vital safeguards are under threat. As more and more land is converted to meet human needs, the natural world is lost … including in some cases our CWR. Landraces are also disappearing at alarming rates as agriculture becomes standardised and small farms are swallowed up in bigger developments. More insidious threats, such as climate change and contamination from genetically modified organisms, may further undermine our agricultural stability.

WWF's *Arguments for Protection* project aims to identify, and where possible quantify, a wide range of the benefits derived from protected areas, to increase support for protection, broaden and strengthen protected area management strategies and to reach new audiences and raise awareness of protected areas. The project recognises that sustainability for protected areas can only be enhanced by understanding the many roles that protected areas fulfil and by stimulating interest among stakeholders in the biodiversity located in protected areas.

Protected areas can play a role in *in situ* conservation strategies of agricultural genetic diversity. Although the links between food security and protected areas have rarely been made explicit, our research demonstrates that protected areas are important in maintaining stability in agricultural systems.
Just as botanic gardens in countries with colder climates often stimulate interest in the general public by including specimens of crops to show what a banana, coffee or rice plant looks like, so protected area managers can raise the profile of their protected areas by paying particular attention to native CWR species and advertising their presence to the potential user communities. Many protected areas also encompass cultivated lands and increasing recognition of the social, environmental and economic value of landraces adds an important dimension to the values of these areas. In particular, this report therefore looks at how protected area managers can find which CWR species are present in the protected area they manage and how they might adapt management practices to facilitate conservation of CWR and landraces.

The report also includes an analysis of the protection status of those ecoregions, as identified by WWF, which are particularly important for the conservation of crop genetic diversity. In total 29 (82 per cent) of the 34 ecoregions that include major centres of crop diversity have protection levels of under 10 per cent, and six areas (18 per cent) have protection levels of one per cent or less. Coupled with evidence of high levels of habitat conversion in many of these areas, it would seem that governments and the international community should be giving far higher priority to crop genetic diversity when deciding the location of protected areas.

Overall the messages from this report are:

- Many of the centres of diversity of our principal cultivated plants are poorly protected.

- The role of protected areas in conserving crop genetic diversity could be greatly increased by better understanding of this issue within protected area organisations.

- The promotion of the conservation of crop genetic diversity within existing protected areas may further enhance the public perception of protected areas and help to ensure longer term site security.

- There are already a few protected areas which are being managed specifically to retain landraces and CWR and there are many more protected areas that are known to contain populations essential to the conservation of plant genetic resources.

- By conserving locally important landraces, protected areas can contribute to food security, especially for the poorest people.

The need for *in situ* conservation of CWR and landraces is highlighted, as is the role of protected areas as an important conservation strategy. However at present is would seem that the current global protected areas network is inadequate for this task, both in terms of the location of protected areas and often also in the way in which they are managed. The following recommendations (see Chapter 7) outline a global strategy for addressing this shortfall.

Recommendations for Local Fora

- **Protected area / Agro-biodiversity**: Protected area managers should promote the conservation of crop wild relatives and landraces within their protected area. A detailed methodology to assist protected area managers to enact this requirement is provided in Chapter 5, but initial steps will involve the identification of priority national CWR and landrace diversity, producing an inventory of CWR and landrace diversity within the protected area, actively conserving that diversity and then promoting that diversity with the user stakeholder whether they be the general public or agri-business.

- **Protected area inventories**: It is recognised that many protected areas lack complete floristic inventories. This is necessary to highlight which CWR are present and should be extended, where applicable, to cover the landrace varieties traditionally grown in the protected area.

- ***Ex situ* duplication**: Once CWR and landrace diversity is identified in protected areas it should be routinely sampled and duplicated in *ex situ* collections as a safety back-up for its *in situ* conservation, and also as a means of promoting diversity utilisation. The routine duplication should be linked to a broader *in situ* and *ex situ* gap analysis of CWR and landrace diversity, as is discussed in Chapter 4 above.

- **Use of agro-biodiversity from protected areas**: It is widely recognized that conservation of agro-biodiversity is not an end in itself. To be effective and sustainable, conservation of agro-biodiversity needs to be linked to use. Therefore, it is vital to ensure that agro-biodiversity conserved in protected areas is made available to the user community.

- **Private industry**: The agri-business industry is the sector that most directly reaps the economic benefits from the genetic potential maintained in CWR and landraces. A thorough calculation of how much the main international corporations dealing with agribusiness invest in support to *in situ* CWR conservation is still to be done, but it would certainly reveal that it is infinitely smaller than the benefits that they reap from the use of the genetic material conserved in protected areas. Therefore they should be actively encouraged to take a partnership role in supporting protected areas, where this role does not clash with international treaties and conventions such as the CBD, International Treaty on Plant Genetic Resources for Food and Agriculture or CITES.

- **Non-governmental organisations**: Conservation organisations, particularly those that own or manage land for conservation, should include the conservation needs of agricultural biodiversity within their planning systems as well as methodologies for identification and management of protected areas. This could involve the establishment of community seed banks for locally unique landraces and wild harvested CWR to help ensure their continued availability and use.

- **Communities**: Protection is not necessarily confined to government-owned protected areas. Community Conserved Areas can play a fundamental role in protecting agricultural biodiversity and they should be supported in their efforts.

- **Benefit sharing**: many landraces and CWR exist on the lands of indigenous peoples and other ethnic minority groups. There is a need to ensure that their fundamental role in conserving this type of diversity is fully acknowledged, and their efforts supported. Current international legislation aims at ensuring that this will take place, but its actual implementation at the local level needs careful monitoring. The benefits that indigenous and local people could accrue from the use of 'their' genetic material for commercial purposes is so far ill defined, and the positive and real advantages for local people and their important biodiversity remain to be seen

Recommendations for National Fora

- **Protected area / plant genetic resources collaboration:** Traditionally the protected areas and plant genetic resources communities have tended to work in isolation as two independent conservation communities; this lack of communication and collaboration has undoubtedly been to the detriment of both communities and the elements of biodiversity they wish to conserve. This new initiative to bring to two communities closer together and engender cross-community collaboration will benefit both and should be actioned through closer institutional ties and joint fora.

- **Prepare national CWR strategic action plans**: Each country needs to nominate two national focal points one for CWR and one for landrace conservation, to prepare a national inventory for CWR and landrace diversity, prioritise taxa and traditional varieties, and write a national action plan for their conservation (highlighting the role of protected areas and *ex situ* collections), and sustainable use. A methodological approach to these issues is discussed in Chapter 4 above.

- **National governments in centres of crop diversity**: One of the findings of this report is that there are still some fundamental gaps in the representation of CWR under the current system of protected areas, and this gap is particularly prevalent in the centres of crop diversity. Countries should be encouraged to develop national strategies for CWR and landraces as outlined in this report, including assessing the potential of existing protected area networks for conserving crop genetic diversity and if necessary expanding and strengthening these networks.

- **National governments capable of providing support**: Donor countries could consider the role of support for protected areas in maintaining agricultural diversity in light of efforts to promote sustainable development, reduce the vulnerability of the poor and improve livelihoods. Further support is required, possibly through GEF or bilateral agencies, to develop protected area projects in those parts of the world where important CWR and landraces are currently under-protected. There is also a need to further disseminate the results of projects which are already underway to do this.

- **Market or economically-based actions**: There is a need to establish market or economically-based actions that will promote CWR and landrace maintenance, and identify and counter perverse incentives that result in the erosion of genetic diversity, particularly in relation to crop landraces.

- **Genetic pollution**: Urgent action is required to ensure that CWR and landraces are not contaminated by either genetically modified or modern crop varieties, as this can undermine the very concept of maintaining their unique genetic diversity. The planting of GMOs or modern cultivars near priority sites where CWR or landrace are being actively conserved should be avoided. National legislation and regulation regarding GMOs must account for this important priority.

- **Biopiracy**: Many governments are understandably concerned about the risks of losing genetic material through theft. Management of protected areas to protect genetic material should include effective means of ensuring that control of this material remains in the state in which it occurs naturally. However, this should be consistent with the application of the International Treaty on Plant Genetic Resources for Food and Agriculture which promotes the utilization of genetic resources for the good of humankind.

Recommendations for International Fora

- **Greater international, regional and national collaboration**: If CWR and landraces are to be more effectively conserved in protected areas there is need for increased collaboration and coordination to prioritise agro-biodiversity conservation in key protected areas. The 'Global Strategy for Crop Wild Relative Conservation and Use' recommends the identification at the national, regional and global level a small number of priority sites (global = 100, regional = 25 and national = 5) for the establishment of active CWR genetic reserves. These reserves should form an interrelated network of internationally, regionally and nationally important CWR genetic reserve sites for *in situ* conservation. Although the Global Strategy is focused on CWR conservation the principle could be equally applied to landraces conservation.

- **Additional Protected Areas**: there is an urgent need to increase the level of protection in centres of crop genetic diversity with inadequate levels of protection and / or rapid habitat destruction to uses incompatible with biodiversity conservation. Our initial research has identified the following examples of ecoregions where additional protected areas should be established in areas of particular agro-biodiversity importance:
    - Southern Korea evergreen forests (South Korea)
    - Sumatran lowland rain forests (Indonesia)
    - Eastern Anatolian deciduous forests (Iran, Turkey and Armenia)
    - Kopet Dag woodlands and forest steppe (Southern Turkmenistan and northern Iran)
    - Eastern Anatolian montane steppe (Iran, Turkey and Armenia)
    - Alai-Western Tian Shan steppe (Kazakhstan, Uzbekistan, and into Tajikistan)
    - Gissaro-Alai open woodlands (Kyrgyzstan, Tajikistan, and Uzbekistan)
    - Tian Shan foothill arid steppe (China, Kazakhstan, and Kyrgyzstan)
    - Beni savanna (Northern Bolivia)
    - Central Andean wet puna (Peru and Bolivia)

Each country needs to assess whether the existing network of protected areas adequately represents the full range of national CWR diversity, and suggest additional reserve locations where required.

- **International direction**: The CBD could consider developing additional guidance to its *Programme of Work on Protected Areas*, in collaboration with the Food and Agriculture Organization of the UN and the International Plant Genetic Resources Institute, encouraging Parties to include CWR and landraces within their ecologically-representative protected area networks.

- **Technical support**: The conservation of agro-biodiversity in protected areas is a relatively novel concept and clear methodological guidelines need to be developed and made widely available to protected area managers. Specifically the guidelines need to focus on managing protected areas for CWR and landraces, the integration of agro-biodiversity conservation with broader biodiversity conservation and also how best to enhance the benefits for local community from conserved areas that could provide useful resources, including sacred sites and other areas set aside from development. Certain regions of the world with experience in these applications should be encouraged to share their expertise by means of active programmes of technology transfer between countries and regions.

- **Legislation**: The CBD encourages individual countries to establish national biodiversity conservation, but there is a more specific need to develop and strengthen national and international wildlife protection legislation to promote the conservation of agro-biodiversity in protected areas**.** There is a need to review which CWR species are included in existing national, regional and global policy and legislative instruments, and where necessary initiate legislative protection for priority CWR taxa and landraces not already covered.

- **Professional and public awareness**: Encouragement of greater professional and public awareness of the vital role agro-biodiversity plays in global, national and local food security, and the pivotal role that protected areas can play in the long-term sustainability of agro-biodiversity.

- **Education**: General public awareness of the vital role agro-biodiversity in food security and wealth creation could be enhanced by the promotion of greater general environmental and specific agro-biodiversity and protected area conservation in education at primary, intermediate and higher levels.

- **IUCN**: Within IUCN, the World Commission on Protected Areas and the Species Survival Commission could help to provide leadership on these issues by setting up a joint task force on CWR and protected areas. It should also take the lead in red listing of CWR taxa.

- **Conservation outside of protected areas**: Finally is should be recognised that as many CWR favour disturbed habitats, their conservation outside the formal network of protected areas should also be encouraged, for example along roadsides and field margins. However, protected area managers may still play a role in advising those who manage these habitats on how best to promote the maintenance of the CWR diversity within these habitats.

Research requirements

- An expanded survey of global CWR occurrence in protected areas, particularly in centres of crop diversity, and identification of priority sites for the establishment of novel protected areas.

- Survey the landraces being grown in protected areas, possibly concentrating initially on IUCN Category V and VI protected areas, as these areas include overall management objectives to conserve traditional landscapes or areas of sustainable use.

- Survey community conservation areas outside of formal protected areas that play a major role in maintaining genetic material of agricultural value.

- Conduct population level research on selected CWR to aid IUCN Red List Category threat and conservation assessment.

- Examine the level of genetic erosion and genetic pollution threatening CWR and landrace diversity and its possible consequences on future food security.

- Establish and publish protocols for the complete genetic reserve location, establishment and routine maintenance process to act as templates for subsequent projects.

- Establish and publish protocols for the integration of CWR and landrace into established protected area management and how to promote the routine use of *in situ* conserved CWR and landrace diversity.

Chapter 1: Why Conserve Crop Genetic Diversity?

We start this chapter by discussing why crop genetic diversity is important and then examine why many of these plants are threatened. We look at the downward trend in the diversity of the food that we eat and the associated reduction in crop genetic diversity, both in terms of cultivated plants (landraces) and the wild plants from which our crops originate (crop wild relatives). Finally, we review recent calls for their increased conservation by, for example, the Convention on Biological Diversity.

Crop genetic diversity: a critical resource

Plant genetic resources have been defined as the "*genetic material of plants, which is of value as a resource for the present and future generations of people*"[9]. A wide range of genetic variation is needed within species to help them adapt to changing environment conditions and new pests and diseases. The plants we use as crops (either directly as food or as fodder for animals) are dependent in terms of resilience and adaptability, on the broad genetic base of variation that exists both in the crops developed over millennia of farmer experimentation, and from their wild relatives[10].

Almost all modern varieties of crops have been improved using genetic diversity derived directly from a wild relative. The Russian botanist Nikolai Ivanovich Vavilov recognised and championed the potential of crop wild relatives (CWR) for crop improvement in the 1920s and 1930s. Wild relatives were first routinely used by agricultural scientists to improve major crops in the 1940s and 1950s, and by the 1960s and 1970s this practice was leading to some major breeding successes[11].

Genes from wild relatives have been particularly important in providing resistance to pests and diseases. For example, CWR of potatoes (*Solanum* spp.) have been used to improve cultivated varieties since the 1900s, when genes from the Mexican *S. demissum* were used to breed resistance against the fungus that causes potato blight[12]. During the 1970s, grassy-stunt virus severely reduced rice yields across Asia; after four years of research, during which over 17,000 cultivated and wild rice samples were screened, disease resistance was found in one population of *Oryza nivara* growing wild near Gonda in Uttar Pradesh, India. Resistant rice hybrids containing the wild Indian gene are now grown across Asia[13]. Also in the 1970s, the US maize crop was severely threatened by corn blight. The blight destroyed almost US$1,000 million worth of maize and reduced yields by as much as 50 per cent[14]. The problem was solved through the use of blight resistance genes from wild varieties of Mexican maize[15].

Genes from wild relatives can also improve crop performance. For example, genes from a wild relative of the tomato have contributed to a 2.4 per cent increase in solid content in commercial tomatoes. This increase has been valued as being worth approximately US$250 million in California alone[16]. A wild relative of wheat, *Aegilops tauschii,* has provided wheat with tolerance to drought, heat, salinity and water-logging, whilst another wild wheat relative, *Triticum dococcoides,* has improved nutritional qualities by increasing the protein content of durum wheat[17].

The dollar signs above are important and provide one reason why crop genetic diversity should be taken so seriously. The US Government estimates that just a one per cent gain in crop productivity means a US$1,000 million benefit to the American economy. Genes from CWR have been used in at least 23 non-timber crops in the US[18] and it has been estimated that between 1976 and 1980 wild species contributed US$340 million per year to the US farm economy in terms of yield increase and disease resistance[19]. Estimates of the global value associated with the use of plant genetic resources in food and agriculture vary from hundreds of millions to tens of billions of dollars per year[20]. One estimate, for example, puts the annual value of products derived from the exploitation of plant genetic resources at US$500–800 billion[21].

Wild tomato in Peru

Credit: © WWF-Canon / Hartmut Jungius

Breeders are however somewhat reluctant to use CWR in their programmes because when incorporating desirable traits into their crop they are likely to transfer associated less desirable traits (e.g. shattering rachis, bitter fruit or extended flowering) and several successive cycles of backcrossing may be necessary to eradicate these undesirable traits. This is less of a problem with landraces, which have already been domesticated and have fewer characters that the breeder would regard as undesirable. Crops have thus been improved even more by the use of landraces, but breeders use these so routinely that no quantative data exists on their level of use as economic value.

Overall, the estimated annual turnover of the commercial seed industry in OECD countries is US$13 billion[22] and the total commercial world seed market is assessed at approximately US$30 billion[23]. If just a fraction of this sum was used to protect the resources breeders rely on to improve commercial seeds, and small proportion of this went to the protected areas which conserve important crop genetic resources, many of the world's most under-resourced protected areas could receive a considerable boost to their budgets and thus their capacity for effective management.

Genetic diversity: a threatened resource

Our developing understanding of the importance of crop genetic diversity comes at a time when the threats to these resources have probably never been greater. Taxonomists have still only described a fraction of the world's plant species and threats have been assessed for only a small proportion of those described. IUCN's *Red List of Threatened Species* provides the most authoritative assessment of threat. The 2004 assessment included species from a broad range of taxonomic groups but is based on an assessment of less than three per cent of the world's 1.9 million described species. Of plants, only conifers and cycads have been completely assessed with 25 per cent and 52 per cent threatened respectively using the precise population parameters used in the latest IUCN *Red List* Criteria[24]. However, when the previous less precise criteria were applied for the whole world flora 12.5 per cent were considered threatened[25]. Whatever the exact figure we have enough information to know that many plants are at risk.

The IUCN *Red List* Criteria do not assess the loss of genetic diversity within species, which is equally being lost or eroded by the same factors, and gene pool shrinkage is largely taking place unrecognised or assessed. It is much more difficult to estimate precise levels of genetic diversity loss or so called 'genetic erosion', but the loss of genetic diversity must always be faster than the loss of species because there will be some genetic erosion from the species that remain extant. Loss of genetic diversity means that plants will not be able to adapt to changing conditions quite so readily, and that the breeder will have fewer options when a new pest or disease attacks the crop. Although genetic erosion cannot be quantified accurately, it seems likely that virtually all plant species are currently suffering loss of genetic variation to varying degrees and it was estimated that 25-35 per cent of plant genetic diversity would be lost between 1988 and the year 2000[26].

Most threatened species occur in the tropics: Central and South America, Africa south of the Sahara and tropical South and Southeast Asia. These areas contain the tropical and subtropical moist broadleaf forests that are believed to harbour the majority of the earth's living terrestrial and freshwater species. Habitat destruction and associated degradation and fragmentation are the greatest threats to assessed terrestrial species. Habitat loss appears to be by far the most pervasive threat, impacting 86 per cent of threatened birds, 86 per cent of threatened mammals and 88 per cent of threatened amphibians[27].

Habitat fragmentation, resulting in smaller and more isolated CWR populations, can pose a significant threat to genetic diversity and for cross-pollinating species, geographic isolation can increase inbreeding through mating among relatives, thus reducing diversity. The threat of genetic erosion will affect the ability of plants to adapt to changing conditions[28]. This is likely to increase the potential impact of threats such as climate change, as plants are unable to adapt quickly enough to change.

Gene flow between traditional varieties of crops and their wild relatives, leading to the establishment of 'crop-weed' complexes, has in the past been regarded as beneficial in terms of continued crop adaptation and this is almost certainly still the case for many economically important forest tree species. Gene flow from genetically modified (GM) crops may however pose a threat to crop genetic diversity. Large scale commercial planting of GM crops began in 1996, and awareness of the problem of genetic pollution has been raised through the steady increase in number of 'genetically modified organisms' (GMOs) under cultivation and the potential threat that GMOs could migrate to the crop's nearest relatives through intercrossing or even possibly transfer to some distant species via the food chain. To date, GMO contamination through cross-pollination has been found in landraces in Mexico and a herbicide tolerant gene from GM oilseed rape, *Brassica napus*, has been found in the first generation of wild turnip (*B. rapa*) hybrids in Canada[29]. In Mexico, indigenous and peasant communities and NGOs disclosed the results of their own studies on GMO contamination in nine states. They found GMOs in 24 per cent of 2,000 plants analysed (including contamination in corn landraces[30]) from 138 communities[31].

The possibility of GMO contamination in plants near their major centres of diversity poses the most serious threat. Thus reported unlicensed trials of GM plums in Romania and rice still in the process of experimental development being sold in China are particularly worrying[32]. As there is no global monitoring scheme for the impact of GMOs on food production or the environment, GeneWatch UK and Greenpeace started the GM Contamination Register to record publicly documented cases of contamination in June 2005. Their most recent report records 113 incidents: 88 cases of contamination, 17 illegal releases and eight reports of negative agricultural side-effects in a total of 39 countries on five continents. This is almost twice the number of countries that grow GM crops. Although the majority of contamination cases are not fully investigated, cross-pollination is thought to be the cause of the majority of seed contamination incidents.

Although GMOs pose one currently visible threat to natural diversity, traditionally bred varieties introduced into alien locations are also likely to have a negative impact on native diversity. For example, it is well established that within wild white clover populations in the UK there is as much genetic variation within populations as amongst populations and there is no correlation between the geographic distance of populations and their genetic distance. It was recently suggested that this might be explained by widespread introgression between modern widely distributed cultivated clover and wild populations leading to the homogenisation of all natural diversity. To test this hypothesis white clover samples were taken from the most remote corner of the UK where cultivated clover is unlikely to have reached, St Kilda in the Atlantic Ocean, and compared to mainland populations. The results indicated that there is more genetic variation on the largest island of St Kilda than in the mainland populations and further that the St Kilda populations are composed of genetically isolated unpolluted diversity, unlike all known mainland populations of white clover[33].

Reducing landrace diversity

By their act of sowing, harvesting and saving proportions of seed for subsequent sowing, farmers have over millennia enriched the genetic pool of crops[34]. The fact that such crop breeding has taken place on a local scale has enabled specific genetic adaptations to evolve over time in response to local selection pressures. Genetically uniform cultivars reliant on external inputs reduce the use of varieties that are suited to local climatic and soil conditions, and are resistant to local disease and pest attack. Yet the need for these characteristics remains, and may well increase under rapidly changing environmental conditions. Such adaptive characteristics are more likely to be found in the older native cultivars or landraces. For example, in Ethiopia, local varieties grown using animal manure as opposed to chemical fertilisers tolerated moisture stress and resisted disease and pest infestation better than the improved varieties[35]. Similarly, in Kenya, where the Sustainable Agriculture and Rural Development Project is working with communities in the Gilgil district to increase food security through a community indigenous seed conservation programme, local seeds perform better in harsh drought conditions and can thus increase food security[36]. Communities that lose locally-bred varieties (landraces) and knowledge of how to grow them, risk losing control of their farming systems and becoming dependent on outside sources of seeds and the inputs needed to grow and protect them. In turn, this can lead to the additional risk that during periods of economic downturn they may no longer be able to afford the chemical inputs that are essential to grow the new varieties. Loss of traditional varieties thus has important implications for social equity and for the ability of impoverished communities to survive periods of drought or other atypical conditions.

Several thousand plant species have been used as human food. However, a study of per capita food supply data from 146 countries published in 1990 found that only 103 species contribute 90 per cent of the world's plant food supply[37]. This decline in the sources of our food goes hand in hand with a decline in the gene pool at the level of individual crop species. The FAO estimates that about 75 per cent of the genetic diversity of agricultural crops has been lost in the last century[38]. This loss is clearly illustrated by a survey of 75 US crop species, carried out by the Rural Advancement Fund International (RAFI), which found that 97 per cent of the varieties listed in old United States Department of Agriculture catalogues are now extinct[39]. Equally dramatic losses have been recorded in Europe. In Germany, for example, about 90 per cent of historical diversity of crops has been lost, and in South Italy about 75 per cent of the crop varieties have disappeared[40].

The 'Green Revolution' of the 1950s addressed the challenge of feeding the human population explosion through the spread of new varieties across the developing world; by 1990 these varieties covered half of all wheat lands, and more than half of all rice lands – a total of some 115 million ha. This resulted in increases in yields, but large decreases in crop diversity[41]. Today, rice production provides an example of the extreme level of cultivar uniformity: 75 per cent of rice varieties grown in Sri Lanka are descended from one maternal parent, along with 62 per cent in Bangladesh, and 74 per cent in Indonesia[42]. In the Philippines, two rice varieties developed by the International Rice Research Institute (IRRI) occupied about 90 per cent of the entire rice-growing area during the 1984 dry season[43].

Control, ownership and access to plant genetic diversity

Although not dealt with in detail in this report, the issue of control, ownership and access to plant genetic diversity has assumed immense importance in the international policy arena over the past two decades. Historically, there has been free access to plant genetic diversity found in the farms, fields and forests of the South. Seeds found in tropical centres of diversity were freely collected by Northern scientists and later introduced in large plantations in their former colonies and also as the 'raw materials' for plant breeding in the industrialized world. In the process, seeds collected in the South were routinely transferred to Northern-based (or controlled) gene banks for safe-keeping.

Much of the collected diversity of tropical and sub-tropical origin thus came to be stored in the North, or in gene banks established by the International Research Centres under the aegis of the Consultative Group on International Agricultural Research (CGIAR).

Over the past 30 years, plant breeding in the industrialised world has become increasingly commercialised. In the marketplace today, plant breeding, agricultural biotechnology and commercial seed sales are now dominated by transnational seed and agrochemical corporations. Privatisation of plant breeding in the industrialised world led to the development of 'Plant Breeders' Rights', a system of patent-like protection that gives formal breeders private monopoly rights over the production, marketing and sale of their varieties for a period of up to 25 years. Many governments in the industrialised world adopted Plant Breeders' Rights as a mechanism to promote innovation in plant breeding and to allow seed companies to recoup their investment by collecting royalties on proprietary plant varieties. In recent years, intellectual property systems have been expanded and strengthened to afford the biotechnology industry greater control over seeds and germplasm. But intellectual property systems have evolved with little consideration for the impacts on farmers, food security and plant genetic resources. Intellectual property regimes increasingly deny farmers the right to save and propagate their seed, prohibit researchers from using proprietary germplasm (even for non-commercial purposes), and thus profoundly restrict access to and exchange of germplasm.

These inequalities have not gone unnoticed and many organisations have campaigned for more farmers and growers knowledge and rights to be recognised. The case study on the 'Potato Park' in Peru (see page 93) provides one particularly good example of how farmers' rights over genetic diversity can be successfully established.

Text source: FAO (1998); *Crop Genetic Resources***,** Special: Biodiversity for Food and Agriculture, Sustainable Development Department, FAO, Rome, http://www.fao.org/sd/EPdirect/EPre0040.htm

It is not just cereal crops which have shrinking gene pools. Brazil's 'typica' coffee originates from the progeny of one tree, introduced from East Africa via the Caribbean[44]. Such uniformity, and the susceptibility to disease which goes with it, means that landraces and the wild relatives of crops are likely to become even more important in the future. In the 1970s Latin American coffee plantations were under threat from rust disease. The plantations were saved because of information gained from a rust-resistant strain of coffee found in Ethiopia. However, despite their continuing importance as a genetic resource, the montane forests of Ethiopia and the *Coffea* species which grow in the forest under-storey are under serious threat: about four-fifths have already been destroyed[45].

Conservation of traditional genetic resources for nutritional security is crucial to many regions, such as Utría Sound, Colombia

Credit: © WWF-Canon / Diego M. Garces

Today, the bulk of genetic diversity in domesticated species is located in traditional varieties maintained by traditional agricultural systems. In the 1990's an estimated 60 per cent of the world's agricultural land was still farmed by traditional or subsistence farmers, mostly in marginal areas, although this is likely to have declined since[46]. For such areas in particular, crop genetic diversity is crucial to the production of crops under diverse and often adverse conditions, and therefore important for food security and sustainable agriculture. It is this diversity which enables farmers to select crop varieties best suited to their own ecological needs and cultural traditions. But even these traditional farming systems are threatened as the trend towards agriculture based on genetically uniform varieties continues apace.

Conserving CWR

Agricultural intensification not only threatens landraces, but also important CWR species. For example, an estimated 72 per cent of all known pear species are native to Asia where land development is posing a serious threat to indigenous species, and some like *Pyrus koehnei* are facing extinction[47]. Since the mid-1970s, as awareness of habitat and species declines increased, agricultural scientists have realised that CWR are no safer than other wild plants in natural settings and calls for *in situ* conservation have increased[48]. However, a major challenge to developing effective conservation strategies is still the lack of knowledge of CWR (see box).

CWR – creating a base-line for conservation action

Despite the steady increase in knowledge over the last thirty years about the location and status of wild species and which species should be categorised as CWR, global, national or even regional overviews of the conservation status of CWR remain rare. The first step in ensuring the effective conservation of CWR is an inventory (see page 58).

The first national inventories of CWR were probably those developed in the former Soviet Union, and the former Soviet republics of Armenia and Uzbekistan have maintained and updated these lists. Turkey has also recently completed a national CWR list, and similar efforts are underway in Germany, France and Italy[49]. At regional level, under the auspices of the EC-funded PGR Forum project (www.pgrforum.org), a catalogue of crops and CWR of Europe and the non-European countries of the Mediterranean Basin has been produced[50]. This is a significant step in our knowledge base within one region, and the methodology used to create the Catalogue can be applied within other regions or nationally. Regional data can also be used to form the basis of national inventories, as has been done for the UK[51], Ireland[52] and Portugal[53]. Projects mapping CWR are also taking place in the Middle East, Bolivia, Guatemala, Paraguay, and the USA[54]. There is also information on individual crop gene pools, such as rice, coffee and potatoes and numerous studies published by the International Plant Genetic Resources Institute (IPGRI)[55].

Many countries possess protected areas containing CWR, but in most cases species have either not been identified as such or are not being managed specifically to conserve CWR populations or their diversity[56]. Inventories and maps provide the critical baseline data for CWR conservation planning. Once a list of known crops and CWR taxa is available nationally or regionally, where data exists for protected areas, it is relatively simple to compare datasets and establish which taxa within the protected area are crops and CWR.

Within Europe for example, it has been possible to assess within the Natura 2000 network how many taxa are crops and their wild relatives. Preliminary analysis indicates that while only around four per cent of species in the European flora was listed in the Habitats Directive in 2005 (prior to the addition of data from the 10 additional European Union accession countries), about 63 per cent of these are crops and CWR species[57]. It is unlikely that the majority of these species are being targeted for their potential as gene donors, rather that they have been included as rare, threatened or possibly important habitat components. Highlighting their importance as wild relatives of crops is the next step and managers of data systems such as EUNIS[58] are being encouraged to add a CWR field in their databases to tag these taxa, thus providing greater weight to their conservation and potential for inclusion in existing protected area management plans.

In America, the USDA Agricultural Research Service is helping to establish lists and atlases of CWR in protected areas in several South and Central American countries. However this information is currently project led and not fed into a global database[59].

In Rome IPGRI is currently working on a UNEP-GEF-funded project to conserve CWR and ensure their increased availability for crop improvement in Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan. The project is assessing the conservation status of CWR in the participating countries and will then develop and test strategies for allowing countries to identify priority conservation actions. Benefit sharing issues relevant to CWR conservation are also being investigated and programmes are being developed to increase the involvement of country decision makers and the public in conservation of CWR[60].

International recognition of conservation need

Following Vavilov's early lead, in the 1970s the agricultural researchers, Frankel[61] and Jain[62] drew attention to the need for *in situ* conservation of CWR[63,64]. The development and endorsement of the Convention on Biological Diversity (CBD) in 1992[65], the FAO Global Plan of Action for Plant Genetic Resources in 1996[66] and the subsequent International Treaty on Plant Genetic Resources for Food and Agriculture[67] in 2001 helped move the conservation of CWR into the mainstream of international and national conservation concerns, particularly by re-focusing activities onto *in situ* conservation [68]. The International Treaty, for example, calls on contracting parties to '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' (5.1 (d)).

The CBD's 2010 Biodiversity Target specifically draws attention to promoting the conservation of genetic diversity, with Target 3.1 calling for "*Genetic diversity of crops, livestock, and of harvested species of trees, fish and wildlife and other valuable species conserved, and associated indigenous and local knowledge maintained"*[69]. In 2002, the CBD adopted the Global Strategy for Plant Conservation, which has the ultimate and long-term objective of halting the current and continuing loss of plant diversity. The Strategy also considers issues of sustainable use and benefit-sharing, and aims to contribute to poverty alleviation and sustainable development[70]. The European Plant Conservation Strategy notes that the *in situ* conservation of CWR is currently being neglected and that there is a critical need for genetic management plans for these species throughout Europe[71].

There is also a Global Strategy for Crop Wild Relative Conservation and Use which states in its Target 7, as a component of the development of an effective means of conserving and using CWR *in situ*, that (*7c*) there is a need to *'Identify internationally, and within each region and country, a small number of priority sites (e.g. international = 100, regional = 25, national = 5) for the establishment of active CWR genetic reserves'*[72]. These reserves which are being promoted by the newly established IUCN SSC Crop Wild Relative Specialist Group, should form an interrelated network of internationally, regionally and nationally important CWR genetic reserve sites for *in situ* conservation.

Taking Action

These calls for action, whether from International Fora or conservation bodies, are not new. In 1988, a joint publication by WWF, IUCN and the International Board for Plant Genetic Resources (IBPGR) on the conservation of CWR called for a range of *in situ* conservation actions including[73]:

1. Inventories of biosphere reserves and other protected areas to determine which wild relatives they already contain

2. Regular monitoring of known wild relatives in existing protected areas

3. Creation of specially managed genetic reserves where they are shown to be needed by ecogeographical surveys

Protected areas provide one obvious tool for conservation of crop genetic diversity and as the following analysis shows, many protected areas already play an important role in conserving economically and socially important food species. However, until recently there has been only a limited recognition of this function – even amongst the conservation community. Many protected area managers are unaware, or only dimly aware, that the land under their stewardship contains important crop genetic diversity.

One of the aims therefore of this report, and of the Specialist Group on crop genetic diversity set up under IUCN's Species Survival Commission, is to highlight the links between conserving biodiversity in general and conserving crop genetic diversity. By doing so we hope to encourage anyone with a stake in the long-term security of agriculture – governments, companies and farming organisations for instance – to consider how best to use the diversity inherent in natural areas for maintaining healthy genetic populations of crops.

Chapter 2: Conservation Strategies for Crop Genetic Diversity

Given our increasing knowledge of the threats to crop genetic diversity and the need for more effective conservation action, this chapter discusses some conservation consequent strategies that can be used to protect key crop genetic diversity. But first, given that it will be impossible to achieve such conservation objectives, or undertake an assessment of populations at risk, without at least a working definition of what constitutes a 'landrace' and a 'crop wild relative', the section starts with a discussion of definitions and prioritisations aimed at helping to guide conservation planning initiatives. The concept of protected areas is explained and a number of different management approaches within protected areas are summarised. The chapter then concludes with a survey of existing protected areas around the world that contain significant populations of important crop wild relatives.

Defining and prioritising crop genetic diversity

Crop genetic diversity is discussed here with respect to two distinct groups of plants: cultivated plants known as *landraces* and wild plant species that are closely related to crops known as *crop wild relatives* (CWR). Of course, not all CWR species need special conservation action. Many are common species whose populations are not particularly threatened and some are even problematic weeds[74]. For conservation efforts to be most effective and to be directed at the most important species there needs to be clear guidance on first *identifying* landraces and CWR, followed *prioritising* those species most under threat.

Landraces

Since the term landrace was first used in 1908, a number of definitions have been developed, which vary in their precision and applicability. Several terms have been associated with the concept of a landrace: including primitive cultivars, primitive varieties, primitive forms, farmers' varieties, traditional varieties, local varieties, folk varieties, ecotypes, heirlooms, heritage varieties, selections and conservation varieties. There has however been little consistency in the use of these terms and the use of phrases including 'variety' and 'cultivar' tends to be confusing as they refer more accurately to formally improved material[75]. The situation had become so confusing that in 1998 one author in a review of landrace definitions concluded that "as a landrace has a complex and indefinable nature an all-embracing definition cannot be given"[76].

Even if defining what constitutes a landrace is difficult, certain characteristics can be agreed by which landraces can be identified. A literature review carried out by Camacho Villa *et al* [77] found several defining characteristics associated with landraces:

- historical origin
- high genetic diversity
- local genetic adaptation
- recognisable identity
- lack of formal genetic improvement
- association with traditional farming systems

It has been suggested therefore, that while landraces are dynamic and hard-to-define entities, they may for practical purposes be defined by the presence of several of the characteristics listed above and by the absence of opposing characteristics, such as being highly bred by professional breeders or being the product of formal breeding programmes. Any one landrace need not fulfil all six characteristics to be considered a landrace.

A working definition of crop landraces is thus:

> "*A landrace is a dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems*."[78]

Prioritisation of landraces for conservation will mainly be determined by trends in area under cultivation, with those landraces that are gradually being lost to cultivation being the most important to conserve particularly if they are important economic species and if they have been subject to specific adaptations, such as to local climatic conditions.

Crop Wild Relatives

In the light of biotechnological advances in genetic modification, most if not all species (plant, animal and microbial) are potential gene donors to crops, which makes agreeing a definition of a CWR also somewhat problematic. Given the many threats associated with crop genetic diversity however, there is clearly a need, at least from the perspective of conservation, to define the relationship between a crop and its close wild relatives to allow the objective prioritisation of taxa for study[79]. A number of options exists for achieving this.

One widely applied definition draws on the 'Gene Pool concept' which suggests a definition based on the fact that within each crop there is a potential pool of genetic diversity available for utilisation and a gradation of that diversity dependent on the relative ease of crossing between the crop and the non-domesticated species. Three gene pools are distinguished using this concept:

- Gene Pool (GP) 1 within which GP-1A are the cultivated forms and GP-1B are the wild or weedy forms of the crop;
- GP-2 which includes less closely related species from which gene transfer to the crop is possible but difficult using conventional breeding techniques; and
- GP-3 which includes the species from which gene transfer to the crop is impossible, or if possible requires sophisticated techniques, such as genetic engineering[80].

The 'Gene Pool concept' however has limitations for practical conservation. Firstly, because the crossing ability and patterns of genetic diversity encompassing crops and their wild related taxa are unknown for all but the major crops and secondly, because conservation priorities are more likely to be established across an entire national flora covering numerous crop Gene Pools, rather than for a single crop[81].

This lack of gene pool data could be overcome by using the existing taxonomic hierarchy. Thus the degree of CWR relatedness can be defined when the gene pool concept is unknown as follows:

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

Using the Gene Pool concept together with the Taxon Group to determine whether a species is a CWR, Maxted *et al*[82] suggested a working definition of a CWR as follows:

> *A crop wild relative is a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to gene pools 1 or 2, or taxon groups 1 to 4 of the crop.*

This remains a very broad definition; if the Euro-Mediterranean data are taken as examples, around 80 per cent of the flora of the region comprises crop species and their wild relatives[83]. Nonetheless, this definition can broadly be used to estimate the degree of CWR-relatedness to assist in establishing conservation priorities and should be applied in conjunction with routine prioritisation of taxa for active conservation. Therefore, taxa which belong to GP1B or TG1b and TG2 may be considered close CWR of higher priority, and those in GP2 or TG3 and TG4 more remote CWR afforded lower priority from the perspective of maintaining agricultural stability. As such if only those taxa present in GP1B or TG1b and TG2, which are considered to be the close CWR, then it is estimated that crops (defined as all cultivated species) constitute approximately 10 per cent and close CWR constitute a further 20 per cent of the Euro-Mediterranean flora[84].

As well as prioritising conservation action by means of analysising how close CWR are related to a crop species, prioritisation can also be determined by many factors[85], but the relative socio-economic importance of the crop itself is the most widely applied. Thus clearly the close relations of major crops such as wheat and rice should have a higher conservation priority than distant relations of minor crops with little local or national value. The third important issue to consider when prioritising conservation is level of threat to a species; with those species subject to the most serious external threat, which are often also species found only in restricted areas, being of the most importance. Prioritisation for conservation is discussed more fully in chapter 4.

Conservation strategies: *ex situ* and *in situ*

There are two major strategies used in the conservation of plant genetic resources[86]:

- *Ex situ*: the conservation of components of biological diversity outside their natural habitats[87]. Basically this requires location, sampling, transfer and storage of samples of target taxa away from the target area[88]. Crop seeds can be stored in gene banks or in field gene banks as living collections. Examples of major *ex situ* collections include: the International Maize and Wheat Improvement Center (CIMMYT) gene bank with more than 160,000 accessions (i.e. crop variety samples collected at a specific location and time); the International Rice Research Institute (IRRI) which holds the world's largest collection of rice genetic resources; and the Chinese Academy of Agricultural Sciences (CAAS), holding the largest collection of cereals in Asia, totalling more than 160,000 accessions.

- *In situ*: 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 domesticates or cultivated species, in the surroundings where they have developed their distinctive properties[89]. *In situ* conservation involves the location, designation, management and monitoring of target taxa in the location where they are found[90].

The goal of plant genetic resource conservation is to maximise the proportion of the gene pool of the target taxon conserved, whether *in situ* or *ex situ*, which can be made available for potential or actual utilisation[91]. However, interest in the *in situ* approach to crop genetic diversity has been steadily growing since the 1990s, as a number of limitations of the *ex situ* approach have become apparent.

For example, the costs associated with the *ex situ* approach are often very high, particularly when trying to conserve genetic variation in species that are widely dispersed or small, have genetically distinct populations with poorly known genomes or low seed production and/ or viability. It has been estimated that the cost of collecting and incorporating the 6.1 million plant accessions currently held in the world's germplasm banks has already reached US$5.3 billion[92]. There are also high maintenance costs once collections have been made – which has been estimated at over US$30 million annually[93]. There can be problems in regenerating stored material, with genetic diversity being lost with each regeneration cycle and seed recalcitrancy – which sometimes actually makes conventional storage impractical[94].

Another important difference between the two approaches is that where the *ex situ* technique freezes adaptive evolutionary development, especially that which is related to pest and disease resistance[95], the *in situ* approach allows for natural genetic interactions between crops, their wild relatives and the local environment to take place[96]. It has to be acknowledged however, that under extreme conditions of environmental change (such as catastrophes, or rapid climate change) catastrophic loss of genetic diversity rather than adaptation is likely to occur *in situ*. Cost comparisons cannot be made, as *in situ* conservation is rarely carried out for just crop genetic diversity and many CWR species in particular may be conserved in protected areas where they receive little direct conservation attention.

This change of emphasis away from collecting cultivated material for *ex situ* conservation in gene banks towards the *in situ* conservation of locally adapted landraces and the wild relatives of crops within or outside existing protected areas has necessitated the research and development of new conservation methods[97]. Two distinct approaches to the *in situ* conservation of crop genetic diversity are being developed[98]:

- **Genetic Reserves** (synonymous terms include genetic reserve management units, gene management zones, gene or genetic sanctuaries, crop reservations): conserving wild species in their native habitats. This approach is the focus for CWR conservation, primarily due to the large numbers of species included and the difficulty of collecting and conserving their entire genetic diversity *ex situ* [99]. Conservation objectives in these reserves are defined as: *management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long-term conservation*[100]. The case study on *Vigna* (see page 85) discusses the establishment of genetic reserves within existing protected areas.

- **On-farm management** conserving landraces within traditional farming systems[101]. On-farm conservation is defined as: *the sustainable management of genetic diversity of locally developed landraces with associated wild and weedy species or forms by farmers within traditional agriculture, horticulture or agri-silviculture systems*[102]. Crop on-farm conservation may be divided into field crop conservation where the crop is grown at least partly for external sale and home garden conservation where several crops are grown as small populations and the produce is used primarily for home consumption. The case study on Vietnam (see page 88) looks at a project which is working with farmers to conserve landraces and CWR.

In situ protection can take place on private lands, in indigenous reserves and community conserved areas and in officially recognised protected areas. In this report, however, we focus specifically on the role of protected areas for *in situ* conservation of crop genetic diversity.

Protected areas as a tool for conserving agricultural biodiversity

Protected areas – such as national parks, nature reserves and wilderness areas – are places set aside from development pressures to act as reservoirs for wild nature. Most protected areas have been established to preserve exceptional geographical scenery or particular species or ecosystems, and are increasingly linked to global efforts at biodiversity conservation. In 2004, the Convention on Biological Diversity agreed a Programme of Work on Protected Areas, which aims to "complete" ecologically representative protected area networks: systems of protected areas that contain all species and ecosystems in sufficient numbers and sufficiently large area to ensure their long-term survival.

In practice, protected areas also perform other functions and provide wider benefits. Identifying and recognising these benefits is in itself a key step in building long term political and public support for protected area systems. Indeed, this is a major reason for developing the "arguments for protection" series, of which the current book is a volume. Wider benefits include, in no particular order: environmental services such as watershed protection; providing homeland for vulnerable human societies including indigenous peoples; maintaining places of importance to faith groups like sacred natural sites; acting as a buffer against climate change; and preserving socio-economicially or strategically important plants and animals including CWR.

It has been argued that CWR themselves are rarely associated with climax communities and so are less often associated with protected areas[103]. However, this implies the application of a narrow definition of both CWR and protected areas. While the close CWR and progenitors of the major crops are more often associated with disturbed habitats, this is not exclusively so and a broader definition of CWR will inevitably include species associated with the full range of habitats and successional stages. It is also mistaken to assume that protected areas are only established for climax communities. In particular, for those established near urban settlements it is unlikely that pure climax communities will remain; they will be highly modified and have an intrinsic habitat disturbance dynamic. Larger protected areas will undergo natural processes of change and renewal that maintain disturbed habitats. It therefore seems likely that many protected areas contain a wealth of plants of direct or indirect socio-economic importance.

Protected areas are not uniform entities with identical aims and management approaches; indeed the full extent of their variation may come as a surprise. IUCN - The World Conservation Union has divided protected areas into six different categories depending on management objectives, all falling under a central definition: *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*.

The CBD defines a protected area as a: *geographically defined area which is designated or regulated and managed to achieve specific conservation objectives*. The CBD also recognises the IUCN management categories, which are outlined in the box below.

The IUCN Protected Area Management Categories

IUCN – The World Conservation Union has developed a definition and a series of categories of protected areas: as outlined below[104].

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

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

Category VI: ***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.

Because protected areas are predominantly set up to protect habitats and species, by their nature they could be protecting many CWR. In theory, any of the IUCN management categories could be suitable, but in particular:

- Strictly protected reserves (often small) set aside and left untouched to protect particular species under threat (Category Ia)

- Large ecosystem-scale protected areas maintained to allow CWR to continue to flourish and evolve under natural conditions (Category II)

- Small reserves managed to maintain particular species, for example through controlled grazing or cutting to retain important grassland habitat, coppicing to maintain woodland ground flora, or sometimes even intervening to restore habitat of threatened CWR species (Category IV)

In any of the above cases, CWR could be incorporated as one of the aims of the management plan for the site. A more deliberate approach may be needed to maintain landraces, and the many CWR which are wild and weedy species associated with agriculture, inside protected areas. This usually involves the use of traditional agricultural practices, and a few reserves have been set up specifically to maintain such practices, for instance:

- Protecting traditional agricultural lands as part of a wider landscape-scale approach to protection (Category V)

- Maintaining the sustainable use of traditional CWR to ensure that these species remain valued by local communities and are thus protected (Category VI)

Sometimes a combination of approaches will be suitable, such as when a core area is strictly protected to preserve wild species and a buffer zone surrounding this is under a level of sustainable management involving the exploitation of the species, primarily by local people. The UNESCO Man and the Biosphere series of reserves is an example of mixing such sustainable use and strict protection strategies, but zoning can also be used in a wide variety of other protected area types to distinguish between different management approaches. In cases where conservation of landraces is an important focus of management, zoning might be used to allow greater intervention in some parts of the protected area, where traditional agriculture was being encouraged to maintain old varieties.

Just as protected areas encompass a range of different management types, so they can have a number of different governance regimes. IUCN recognises four broad groupings of governance type[105]:

1. **Government-managed protected areas**: Protected area managed by national or local government, occasionally through an officially appointed independent body: i.e. federal or national ministry or agency in charge; local / municipal ministry or agency in charge or government-delegated management (e.g. to an NGO)

2. **Co-managed protected areas**: protected areas which involve local communities in the management of government-designated protected areas through active consultation, consensus – seeking, negotiating, sharing responsibility and transferring management responsibility to communities or NGOs, i.e. transboundary management, collaborative management (various forms of pluralist influence) or joint management (pluralist management board)

3. **Private Protected Areas**: areas managed by private individuals, companies or trusts, i.e. declared and run by individual land-owner, non-profit organisation (e.g. NGO, university or cooperative or for-profit organisation (e.g. individual or corporate land-owners)

4. **Community Conserved Areas**: natural and/or modified ecosystems voluntarily conserved by indigenous, mobile and local communities. Some may be official protected areas, others compatible management systems suitable for buffer zones and corridors.

The conservation of crop genetic diversity, in particular diversity associated with traditional agricultural practices, may in some cases be most effectively achieved in areas managed by communities. Community Conserved Areas have been defined as: *natural and modified ecosystems, including significant biodiversity, ecological services and cultural values, voluntarily conserved by indigenous peoples and local and mobile communities through customary laws or other effective means*[106]. However, not all Community Conserved Areas are protected areas. At present there is very little literature to draw on to provide examples of where such areas have been formerly recognised as protected areas, for instance the Potato Park in Peru (see case study on page 93), has not been recognised by the Peruvian National Parks agency, INRENA, as part of Peru's protected area system.

WCPA published guidance on policy and practice for co-managed protected areas (defined by WCPA as: *government-designated protected areas where decision making power, responsibility and account ability are shared between governmental agencies and other stakeholders, in particular the indigenous peoples and local and mobile communities that depend on that area culturally and/or for their* *livelihoods)* and Community Conserved Areas. The publication discusses and describes the common features of Community Conserved Areas, gives examples of such areas and offers a series of options by which these areas' contribution to conservation can be "recognised" and supported"[107].

Examples of protected areas containing crop genetic diversity

Although it is clear that protected areas can help support the conservation of crop genetic diversity, this has in practice received little attention in actual protected area management planning. To provide a snapshot of the link between crop genetic diversity conservation and protected areas, we have drawn together data from over a hundred protected areas around the world that have links with crop genetic diversity. This list, which draws on and expands work by other authors particularly from the International Plant Genetic Resources Institute in Rome and a review of Man and Biosphere Reserves[108], is far from complete but it does provide a good indication of the importance of crop genetic diversity in protected areas worldwide.

Information on landraces and protected areas has proved much harder to find. Although as stated above it is likely that some of the protected areas set up to conserve traditional landscapes or for sustainable use could be rich reservoirs of landraces, in practice results of survey work available for these areas still tends to concentrate on wild species, leaving the breadth of cultivated species unrecorded.

Finally, it should be noted that the data on protected area size and IUCN category in the table is drawn from the UNEP World Conservation Monitoring Centre's World Database on Protected Areas. Although in some cases this may differ from national data it is the internationally accepted data source for protected area information and is used here for the sake of consistency of global data.

Table 1: Protected Areas with links to Crop Genetic Diversity

Country	Protected Area[i]	Link to CWR and landraces
Algeria	Tassili N'Ajjer National Park IUCN Category II 7,200,000 ha[109]	Relict Mediterranean fauna and flora survive in small areas of this National Park, World Heritage site and Biosphere Reserve, including the wild olive (*Olea laperrini*)[110].
	Djurdjura National Park IUCN Category II 35,660 ha (including Biosphere reserve)	This Park and Biosphere Reserve in the Djurdjura Mountains has an altitudinal range from 800 to 2,300 metres above sea level, resulting in rich species diversity and high numbers of endemic species. Wild Cherry (*Prunus avium*) is one of the dominant species[111].
Argentina	Nahuel Huapi National Park IUCN Category II 475,650 ha[112,113]	The oldest (established in 1934) national park in Patagonia, the reserve contains potato CWR (*Solanum brevidens* and *S. tuberosum*)[114].
Armenia	Erebuni State Reserve Category Ia 89 ha[115]	This area has long been known for its diversity of wild wheat (*Triticum* spp.). Species include *T. urartu,* which was discovered in the area in 1935, *T. boeoticum*, *T. araraticum* and *Aegilops* spp. This diversity led to protection of the area being recommended in 1951[116] and formal protection being achieved in 1981, making this one of the few protected areas worldwide specifically managed for crop genetic diversity[117]. Experts have recommended that the reserve, which covers less than 100 ha, is enlarged to about 400 ha, to include rare populations of other

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[i] Including name, IUCN protected Area Management Category and Area (ha) as given in the World Database on Protected Areas (http://sea.unep-wcmc.org/wdbpa/)

Country	Protected Area[i]	Link to CWR and landraces
		species growing on the periphery of the area. For example, *Amblyopyrum muticum*, which is considered to be taxonomically intermediate between *Aegilops* and *Agropyron*, has been found near the reserve[118].
	Khosrov State Reserve IUCN Category Ia 29,196 ha[119]	Dry scrub forests and semi-desert habitats with relict species of flora and fauna of Central Armenia. Some 1,800 plant species have been recorded in the reserve (representing more than 50 per cent of the Armenian flora) including wild relatives of cereals and fruit trees[120].
Australia	Border Ranges National Park IUCN Category II 31,683 ha[121]	Several species of economic importance are found in the Border Ranges, including macadamia nuts (*Macadamia integrifolia* and *M. tetraphylla*) and Finger Lime (*Microcitrus australasica)*, which has been used as a source of genetic material to improve disease resistance in commercial citrus fruit[122].
Austria	Lobau Reserve Man and Biosphere Reserve 1,037 ha[123]	A wild relative of pear (*Pyrus* sp.) has been documented in the reserve[124].
Azerbaijan	Fifteen sites 6,501 ha	*In situ* conservation of forest genetic resources of wild fruit trees and shrubs has been reported in fifteen protected areas, covering 6,501 ha[125].
	Arazboyu Nature Sanctuary or Partial Reserve IUCN Category IV 2,236 ha[126]	The Arazboyu protected area, along the borders of Iran, aims to conserve natural complexes of tugai forests, which includes plum (*Prunus* spp.) species[127].
Bolivia	Madidi National Park IUCN Category II 1,895,750 ha[128]	The Pampas del Heath in northern Bolivia and south-eastern Peru is the largest remaining undisturbed Amazonian grassland plain. Approximately two-thirds of the Bolivian Pampas is located within this Park[129]. A wild pineapple (*Ananas* sp.), which may be the ancestor of the cultivated pineapple, is common in the Pampas[130]. Bolivian National Parks have also been surveyed for *in situ* conservation of CWR, including potato and peanut (*Arachis* spp.) species[131].
Bulgaria	Ouzounboudjak Strict Nature Reserve IUCN Category Ib 2,530 ha[132]	Ouzounboudjak Nature Reserve and Biosphere Reserve (3,018ha) is situated in Strandzha Mountain on the left bank of the Rezvaya River on the Turkish border. The understorey includes Caucasian Whortleberry (*Vaccinium arctostaphylos*)[133].
Cameroon	Korup National Park IUCN Category II 129,481 ha[134]	Oil palm (*Elaeis guineensis*) is native in this park; as is its native and most effective pollinator, which was exported to South East Asia in 1981 resulting in an increase in production of 20 per cent within two years. Several species of Rubiaceae have been 'tentatively' identified as Coffea[135].
	Waza National Park IUCN Category II 140,707 ha[136]	The Yaéré floodplains, one of the five vegetation types in the park, are dominated by perennial grasses including wild rice (*Oryza barthii*)[137] and *Sorghum* sp.[138]
China	Hainan Island	The flora of Hainan Island has been identified as one of the centres of global plant diversity[139]. About 20 CWR species have been identified, including the wild rice (*O. meyeriana, O. granulate* and *O. officinalis*). Chinese researchers discovered a male sterile rice plant growing naturally within a population of wild rice (*O. sativa f . spontanea*) on the island in the 1970s. The plant was named "wild rice with abortive pollen" or WA for short. Scientists have crossed the plant with other rice varieties to determine whether this male sterility could be passed on to subsequent generations and thus be used in producing hybrid rice seeds[140].

Country	Protected Area[i]	Link to CWR and landraces
	Xishuangbanna Nature Reserve (and Biosphere Reserve) IUCN Category V 247,439 ha[141]	Xishuangbanna Nature Reserve lies in the Lancang (Mekong) River basin in the region of Yunnan; the terrain is mostly (95 per cent) mountainous[142]. The reserve is made up of five isolated protected areas (Mengyang, Mengla, Shangyong, Mengao and Menglun Nature Reserves). Thirty-eight species have been identified as having important germplasm resources. CWR include: rice, tea (*Camellia* spp.), litchi (*Litchi* spp.), citrus fruits (*Citrus* spp.), mango (*Mangifera* spp.), balsam pear (*Momordica subangulata*), cucumber (*Curcubita* spp.) and ginseng (*Panax zingiberensis*)[143].
	Shennongjia Biosphere Reserve 70,467 ha[144]	The Shennongjia Biosphere Reserve belongs to the east branch of the Dabashan Mountains which connect the Tibetan Plateau in West China with the Yangze plain in East China. Elevation ranges from the lowest valley at 420 metres to the highest peak at 3,106 metres above sea level and therefore offers a wide spectrum of vegetation zones. CWR recorded in the reserve include fruit species such as plum, apple (*Malus* sp.), currants (*Ribes* sp.), berries (*Rubus* sp.) and grapes (*Vitis* spp.), as well as grains (*Sorghum* sp. and *Avena* spp.), vegetables (*Brassica* sp. and *Allium* spp.) and ginseng[145].
Costa Rica	Corcovado National Park, IUCN Category II 47,563 ha[146]	This park in the south of the country is a genetic reserve for avocado (*Persea americana*), "nance" (*Byrsonima crassifolia*) and "sonzapote" (*Licania platypus*)[147].
	Volcán Irazú National Park IUCN Category II 2,309 ha[148]	Located in the central highlands of Cartago province, plant species include populations of wild avocados and avocado near relatives *P. schiedeana*[149].
Czech Republic	Sumava National Parks IUCN Category II 68,520 ha[150]	*In situ* conservation has been carried out in the Czech Republic within the framework of research projects focused on the collecting and maintenance of CWR, as part of this process many wild fruit trees were found in Sumava National Park[151],[152].
	Palava Protected Landscape Area IUCN Category V 12,526 ha[153]	Fruit (plum) and grain species (*Avena* sp.) have been ecorded in the area[154].
Ecuador	Galápagos Islands World Heritage Site 766,514 ha (terrestrial area)[155]	The Galápagos Islands are likely to contain important genetic resources, but in general these have yet to be investigated. One notable exception is the endemic tomato (*Lycopersicon cheesmanii*) which has contributed significantly to commercial tomato cultivation by improving the crop's survival during long-distance transport[156]. In a recent survey of tomato populations in the Galápagos Islands, several populations of *L. cheesmanii* reported 30–50 years earlier had disappeared, mostly as a consequence of human activity, highlighting the need for active conservation of CWR at this site[157].
	Sangay National Park IUCN Category II 517,725 ha[158]	This park in central Ecuador is considered "an enormous genetic reserve, and surely a source for wild relatives of crops and potentially valuable medicines"[159].
Ethiopia	Bale Mountains National Park IUCN Category II 247,100 ha[160]	Coffee (*Coffea Arabica*), is the dominant under storey shrub of the lower elevations of the Harenna forest, which once covered large parts of Ethiopia and possibly Yemen[161,162]. The protected area has however undergone severe degradation in recent years.

Country	**Protected Area**[i]	**Link to CWR and landraces**
Guatemala	Mario Dary Rivera Protected Biotope IUCN Category III 1,022 ha[163]	After more than 50 years, the rare pepper, *Capsicum lanceolatum*, was rediscovered in a virgin remnant of the Guatemala cloud forest, preserved as habitat for the Resplendent Quetzal (*Pharomachrus mocinmo*).[164]
	Sierra de las Minas Biosphere Reserve IUCN Category VI 94,796 ha[165]	This mountain range in eastern Guatemala contains several species of Solanaceae that "represent potential germplasm resources of food plants, including local varieties of tomatoes".[166]
Georgia	Algeti Nature Reserve IUCN Category Ia 6,822 ha[167]	The reserve is predominately forests (5,055 ha), with some meadows (372 ha) and gorges (289 ha). Important crop tree species in the forests include apple (*M. orientalis*) and pear (*P. caucasica*)[168].
Germany	Flusslandschaft Elbe Biosphere Reserve (includes the Steckby - Lödderitzer Forest Nature Reserve, IUCN Category IV, 3,850 ha[169]) 374,432 ha[170]	Germany is using its system of nature reserves as a basis for the *in situ* conservation of wild relatives of apples and pears[171]. In particular, the Flusslandschaft Elbe Biosphere Reserve, which represents one of the biggest contiguous floodplain forests in Central Europe[172], includes wild fruit tree species such as pear (*P. achras* and *P. pyraster*) and apple (*M. sylvestris*)[173]. The Steckby-Lödderitzer Forest, which is included in the reserve, is particularly important for *in situ* conservation of wild fruit crop genetic resources[174]. Other important CWR include perennial ryegrass (*Lolium perenne*) a pasture grass[175].
	Oberlausitzer Heide-Und Teichlandschaft Biosphere Reserve 30,102 ha[176]	This Biosphere Reserve is in Germany's largest pond region. The reserve is undertaking the *in situ* conservation of cereal landraces[177].
	Schorfheide-Chorin Biosphere reserve 129,161 ha[178]	This area of predominantly temperate broad-leaf forest mixed with agricultural areas has specific breeding programmes for ancient grain and vegetable species[179].
	Spreewald Biosphere Reserve 47,492 ha[180]	Spreewald is situated 100 km south-east of Berlin in an area of alder forests on wetlands and pine forests on sandy dry areas, interspersed with grassland areas and fields. The area is known for its traditional irrigation system which consists of 1,300 km of small channels (called 'Fliesse'). Research on the cultivation potato and cereal landraces and fruit trees is undertaken in the reserve[181].
India	Dandeli Sanctuary IUCN Category IV 47,502 ha[182]	The hill forests of the Western Ghats in South India are a biodiversity hot spot. Important species in terms of crop genetic diversity include an evergreen tree species related to nutmeg (*Myristica fatua*) and a wild pepper (*Piper hookeri*) which occur in the 'Myristica' swamps in the wet valleys. There are also species of wild yam (*Amorphophallus paeoniifolius*) and a berry (*Carissa congesta*) which occur in humid secondary scrub formations. Considerable areas of scrub are included within the Sanctuary and the best surviving area of *Myristica* swamp is protected as a research plot within a reserved forest area.
	Nokrek National Park IUCN Category II 4,748 ha[183]	This park, in the tropical Garo Hills of the Tura Range in the state of Meghalaya in North East India, supports broadleaved evergreen and semi-evergreen forest, with bamboo at lower altitudes. The reserve is one of the least disturbed forest areas of the sub-Himalayan ranges[184]. Varieties of mamang narang (*Citrus indica*), a wild relative of cultivated citrus plants, are present in large numbers[185].
	Silent Valley National Park	This is one of the least disturbed and extensive patches of tropical rain forest remaining in the Western Ghats. It contains many rare, endemic

Country	Protected Area[i]	Link to CWR and landraces
	IUCN category II 8,952 ha[186]	and economically valuable species, such as cardamom (*Ellettaria cardamomum*), pepper (*P. nigrum*), yams (*Dioscorea* spp.), beans (*Phaseolus* spp.), a pest-resistant strain of rice (species unknown) and plant species of importance in Ayurvedic medicine. Silent Valley is one of six protected areas that make up the 552,000 ha Nilgiri Biosphere Reserve (the others are Mudumalai and Wyanaad Wildlife Sanctuary's, Bandipur, Nagarhole and Mukurthi National Parks) 552,000 ha[187,188].
	Agastyamalai Hills (Three Sanctuaries, all IUCN Category IV): Mundanthurai, 56,738 ha[189]; Kalakad, 22,358 ha[190]; and Neyyar, 12,800 ha[191]	The Agastyamalai Hills are located at the southern end of the Western Ghats. The area contains a large number of CWR including species of rice, peppers, coffee, mango, bean (*Canavalia* sp.), yam (*Dioscorea* sp.), banana (*Musa* sp.) and spices such as Cardamom (*Amomum* sp. and *Elettaria* sp.), cinnamon (*Cinnamomum* sp.) and nutmeg (*Myristicia* sp.)[192].
	Namdapha National Park IUCN Category II 180,782 ha[193]	Namdapha lies in the Tirap District of eastern Arunachal Pradesh. It is a centre of diversity, supporting a large number of endemic species, many CWR and a variety of rare and threatened species[194]. CWR include: fruit tree relatives: *Artocarpus* spp., *Citrus medica*, and the mango (*M. sylvatica*); the banana relatives (*Ensete glaucum, M. rosacea* and *M. velutina*); tea relative (*C. caudate*) and coffee relatives (*C. benghalensis* and *C. khasiana*)[195].
Indonesia	Muara Kaman Sedulang Nature Reserve IUCN Category Ia 62,500 ha[196]	The aquatic vegetation in this East Kalimantan park includes a floating species of wild rice[197].
	Bukit Barisan Selatan National Park IUCN Category II 365,000 ha[198]	The flora of this park on the island of Sumatra includes relatives of durian (*Durio* spp.), a popular tropical fruit [199].
	Bukit Baka - Bukit Raya National Park IUCN Category II 181,090 ha[200]	The lowland forests of this park, which is part of the Schwaner mountain range in Central Borneo, contain wild fruit species, including: jackfruit (*Artocarpus* spp.); durians; Litchi (*L. chinensis*) and several species of mango[201].
	Gunung Palung National Park IUCN Category II 90,000 ha[202]	The forests of this park in West Kalimantan include many fruit tree families, including: durians, *Garcinia,* Mangosteen (*Mangostana* spp.*),* figs (*Ficus* spp.), rambutans *(Nephelium* spp.), jackfruit (*Artocarpus* spp.); keranji (*Dialium* spp.) and mata kucing (*Euphorbia malayana*)[203].
	Kerinci Seblat National Park IUCN Category II 1,375,000 ha[204]	Located in west-central Sumatra along the Bukit Barasan Range the park contains wild fruit tree relatives including banana, mango, durians, Langsat (*Lansium* spp.) and rambutan[205].
		Wild Banana in Kerinci Seblat National Park **Credit:** © WWF-Canon / Mauri Rautkari

Country	Protected Area[i]	Link to CWR and landraces
	Sungai Kayan Sungai Mentarang National Park IUCN Category VI 1,360,500 ha[206]	This large reserve in the interior of Borneo is considered to hold "a vast range of potentially useful and valuable genetic resources". The reserve contains many wild fruit relatives. A large number of landraces, including rice varieties and fruit trees, are cultivated by indigenous peoples living in the park[207].
	Gunung Leuser National Park IUCN Category II 1,094,692 ha[208]	This biosphere reserve, which covers a large area of tropical rain forest in northern Sumatra, protects a range of ecosystems. Several wild fruit tree species grow in the park, including the durians (*D. oxleyanus* and *D. zibethinus*), duku (*Lansium domesticum*) and rambutan (*N. lappaceum*)[209].
Iran	Touran Protected Area IUCN Category V 1,102,080 ha[210]	This area, which includes a national park (Category II, 118,000 ha) and biosphere reserve (1,470,640 ha) contains a CWR of barley (*Hordeum* sp.)[211].
Israel	Yehudiyya Nature Reserve IUCN Category not set 838 ha[212]	This forested reserve in the Golan Heights is characterised by stands of Mount Tabor oak, a large evergreen tree[213]. CWR of wheat are reported in the reserve[214].
Kyrgyzstan	Besh-Aral State Nature Reserve IUCN Category Ia 63,200 ha[215]	The walnut-fruit forests of this reserve contain a range of species including nuts such as walnut (*Juglans regia)*, pear and a number of wild plum (*P. sogdiana*).[216]
	Sary-Chelek Biosphere Reserve No category recorded 23,868 ha[217]	The Sary-Chelek Biosphere Reserve, which is situated in the western Tien Shan Mountains on the southern spurs of the Chatkal Range in the west of Kyrgyzstan, has been established to protect relict walnut-fruit forests[218]. The central and lower region is covered by nut-fruit forests with walnut, apple, pear and an understory of the plum (*P. divaricata*)[219]. Many of the fruits found in the forests have a high socio-economic value[220]. *In situ* conservation of forest genetic resources of wild fruit trees and shrubs is currently being carried out over 680 ha of the area[221].
Madagascar	Tsaratanana Strict Nature Reserve IUCN Category Ia 49,185 ha[222]	Wild populations of coffee (*C. tsaratananae*[223]) are found in the reserve[224], which includes Mont Maromokotra, the highest mountain in Madagascar, and consists of primary and secondary tropical evergreen forests of both high and low altitude.
Malaysia	Lambir Hills National Park IUCN Category II 8,307 ha[225]	Located in Sarawak, this park is rich in wild fruit trees. So far, over 70 tree species have been recorded, many of which may "prove to be valuable genetic resources for improving existing fruit tree crops, and developing new ones". Species represented include mangoes (*M. havilandii* and *M. pajang*), six species of durian and gingers (Zingiberaceae)[226].
Mauritius	Black River Gorges National Park IUCN Category II 6,574 ha (included in the Macchabee/Bel Ombre Biosphere Reserve)[227]	The park includes 'wild forms' of passion fruit (*Passiflora edulis f. flavicarpa)*, pineapple as well as 'semi-wild' coffee (*C. canephora*) and wild coffee (*C. macrocarpa*). The reserve covers 3.5 per cent of the island[228]. However, research has shown that key populations of coffee wild relatives remain outside the protected area network[229].
	Perrier Nature Reserve IUCN Category IV 2 ha[230]	Coffee (*C. macrocarpa*) grows in vegetation dominated by *Sideroxylon* spp, a subclimax to the high forest. This tiny reserve, which is surrounded by exotic forest plantations, is totally isolated from indigenous forests[231].

Country	Protected Area[i]	Link to CWR and landraces
Mexico	Sierra de Manantlan Biosphere Reserve Not categorised on WDPA, 139,577 ha [232]	See case study.
	Sierra Norte de Oaxaca Community Protected Natural Areas Not on WDPA	WWF has been helping create Community Protected Areas in the Mesoamerican Pine-Oak forest in Sierra Norte in the state of Oaxaca. The area is a known centre of potato diversity[233]. Ixtlán de Juárez protects 9,000 ha of pine-oak, cloud and tropical forests; Santa Catarina Ixtepeji protects 4,225 ha of pine-oak forest; Santa María Yavesía protects 7,000 ha of pine-oak forest and four communities of the Union of Zapotec and Chinantec Indigenous Communities (UZACHI) protect an area of 12,819 ha of pine-oak, cloud and tropical forests[234]. The area protected is expanding rapidly and during the past two years, an additional 18,970 ha of community protected areas in Sierra Norte have been established in: San Francisco La Reforma I (670 ha) Santa Sociedad Río Grande Teponaxtla (3200 ha), San Francisco la Reforma II (2500 ha) Cruz Tepetotutla (4600 ha) San Antonio del Barrio (2200 ha) San Pedro Tlatepusco (2300) and Nopalera del Rosario (3500 ha)[235].
	Montes Azules Biosphere Reserve IUCN Category VI 331,200 ha[236]	Montes Azules is located in the state of Chiapas in southeast Mexico. It is one of the largest areas of humid tropical forest in Mexico and Central America and contains some 500 species of trees[237], including wild avocados[238].
	Pico de Orizaba National Park IUCN Category II 19,750 ha[239]	Pico de Orizaba includes populations of the wild avocado (*P. americana*)[240].
Moldova	19,300 ha of reserves, names unknown	*In situ* conservation has been established in five reserves on over 19,300 ha (0.6 per cent of the total territory of the country), for fruit species (*Pyrus pyraster*, *Malus sylvestris*, *Cerasus frutescens*, etc.), vegetables (*Asparagus* sp. and *Portulaca* sp.), as well as some forage species[241].
Mongolia	Great Gobi Strict Protected Area IUCN Category Ia 5,311,730 ha[242]	Located in the south-west of Mongolia on the border with China, the Great Gobi supports rare desert and mountain steppe vegetation. CWR recorded in the reserve include onion and barley species[243]. The Gobi is one of the largest Biosphere Reserves in the world.
Niger	W du Niger National Park IUCN Category II 220,000 ha[244]	The wild flora includes herbaceous species such as millets (*Pennisetum* sp., *Digitaria* sp. and *Euleusine* sp.), rice and leguminous plants including beans (*Vigna* sp.), representing important genetic resources for biological conservation and research[245].
	Aïr and Ténéré National Nature Reserve IUCN Category IV 6,456,000 ha[246]	This, the largest protected area in Africa, includes the volcanic massif of the Aïr Mountains and the surrounding Saharan desert of Ténéré. It contains an outstanding variety of landscapes, plant species and wild animals. The site was inscribed on the World Heritage List in 1991[247].The reserve harbours crop genetic resources of several important species: wild olive (*O. europaea* subsp. *oleaster*), millet (*Pennisetum glaucum*), barley, wheat and sorghum (*S. aethiopicum*), which have been the subject of genetic studies by the French Institute for Scientific Research and Cooperative Development and the International Board for Plant Genetic Resources[248]. A number of traditional gardens are maintained to conserve crop material[249].

Country	Protected Area[i]	Link to CWR and landraces
North Korea	Mount Paekdu Natural Reserve IUCN Category IV 132,000 ha[250]	CWR species recorded in Mount Paekdu, which is also a biosphere reserve, include the fruit: *Ribes* spp., *Rubus* spp., *Prunus* sp. and *Vaccinium* sp., and onion species[251].
Paraguay	Mbaracayú Reserve IUCN Category IV 1,356 ha[252]	A USDA/Paraguay project is researching herbarium and museum records and other species inventories to determine geographical locations of CWR in Paraguay and especially in its protected areas. The objective is to use the data to create or revise management plans within existing protected areas and recommend sites for new protected areas in CWR 'hotspots'[253].
Peru	Bahuaja Sonene National Park IUCN Category II 1,091,416 ha[254]	Bahuaja Sonene protects the Peruvian area of Pampas del Heath (see Madidi National Park in Bolivia above). The park home to Peru's largest population of Brazil nut (*Bertholletia excelsa*) trees, over 30,000 ha, and protects a number of native fruits, including wild pineapple and guava (*Psidium* sp.)[255].
	Manú National Park IUCN Category II 1,716,295 ha[256]	The lowland floodplain forests of the Manú River harbour a number of commercially important or potentially important fruit-tree species including cacao (*Theobroma cacao)* and "sapote" (*Quararibea cordata).* It has been suggested that the forests of Manú "probably include a disproportionate number of the general region's economically important plants, and they are exceptionally important to maintain germplasm for future programmes of genetic improvement"[257].
Philippines	Rice Terraces of the Philippine Cordilleras	Although not officially recognised as a protected area, the rice terraces of the Philippine Cordilleras are recognised as a culturally important site by the World Heritage Centre and fit the criteria for an IUCN Category V protected area[258]. In contrast to lowland rice agriculture, the unique rice landrace grown on the terraces can tolerate the high-altitude conditions; in particular it germinates under freezing conditions, and grows chest-high stalks of non-shattering panicles, unlike lowland rice that grows to knee height with easily shattering panicles[259].
Senegal	Niokolo-Koba National Park IUCN Category II 913,000 ha[260]	Located along the banks of the Gambia river, the gallery forests and savannahs of Niokolo-Koba National Park, World Heritage site and Biosphere reserve have a rich biodiversity. Vegetation includes the wild rice (*O. brachiyantha*)[261].
Spain	Montseny Biosphere Reserve and National Park; IUCN Category unknown, 30,117 ha[262]	The Montseny Biosphere Reserve and National Park is in the highest part of the Catalan coastal range; vegetation includes oak woodlands dominated by holm oak (*Quercus ilex*)[263]. CWR have also been recorded in the reserve[264], including *Prunus* sp.[265].
Sri Lanka	Sinharaja Forest Reserve IUCN Category II 11,331 ha[266]	Sinharaja is the last extensive primary lowland tropical rain forest in Sri Lanka. It contains many endemic plants and animals, and species of known benefit to humans[267]. CWR species include: clove (*Syzgium* spp.); nutmeg; cinnamon; cardamom (*Elettaria* sp.); pepper; durian (*Cullenia* spp.), mango; breadfruit (*Artocarpus* sp.) and citrus (*Atalantia* sp.)[268].
Tajikistan	Dashtidzumsky State Nature Reserve IUCN Category Ia 53,400 ha[269]	This reserve on the southern slope of the Darvaz range protects juniper stands, mountain forests of pistachio, almonds, maple, pomegranate and wild figs[270].
Tanzania	Usambara Mountains East and West IUCN Category Unset 621,300 ha[271]	Two species of wild coffee have been identified[272].

Country	Protected Area[i]	Link to CWR and landraces
Thailand	Thungyai - Huai Kha Khaeng Wildlife Sanctuaries IUCN Category IV 577,464 ha[273]	Stretching over some 600,000 ha along the Myanmar border, the sanctuaries, which are relatively intact, contain examples of almost all the forest types of continental South-East Asia[274]. The sanctuaries support many CWR and have been identified as important sites for the conservation of genetic resources, including mango, rambutan, *Amorphophallus* spp., logan (*Dimocarpus* spp.) and *Xerospermum* spp.[275].
Tunisia	Parc national des Iles Zembra et Zembretta IUCN Category II 791 ha [276]	Two islands situated in the Gulf of Tunis make up this national park and biosphere reserve. Zembra Island is a mountainous island consisting mostly of a Mediterranean maquis including wild olive (*O. europaea*) and pistacio (*P. lentiscus*)[277].
Turkey	Beydaglari coast National Park IUCN Category II 34,425 ha[278]	Situated in Western Anatolia on the southern Mediterranean coast of Turkey, this park (also known as Olimpos-Beydaglari) contains the rare endemic relative of the faba bean (*Vicia eristalioides)*[279].
	Kazdagi National Park IUCN Category II 21,300 ha[280]	This national park is rich in fruit progenitor, nut, ornamental and forest species (see case study)[281].
	Munzur Vadisi (Valley) National Park IUCN Category II 42,000 ha[282]	Protecting the watershed of the Munzar river, this rugged park of high peaks and deep valleys, is located in the eastern region of east central Anatolia. Walnut (*Juglans* spp.) are found in the valleys[283].
Turkmenistan	Kopetdag State Nature Reserve IUCN Category Ia 49,793 ha[284]	Set up for the conservation and integrated study of the mountain forest ecosystems, Kopetdag incorporates two preserves established in 1976: Kalininsk (mountains), and Meana-Chaacha (piedmont)[285]. The area is important for many CWR including fruit trees, vines, cereals and nuts.
	Shirkent National Park IUCN Category II 30,000 ha[286]	The park includes ecosystem of sparse juniper forests, groves of maple, walnut, and wild apple[287].
Uganda	Kibale National Park IUCN Category IV 76,600 ha[288]	Wild robusta coffee (*C. canephora*) is found in the forest understorey of the Park[289].
	Itwara Forest Reserve No category recorded 8,680 ha[290]	This reserve of moist evergreen forest is along the eastern rim of rift valley escarpment. Non-timber trees of economic importance include wild robusta coffee and Shari coffee (*C. liberica*)[291].
	Mabira Forest Reserve No category recorded 31,032 ha[292]	The largest block of moist semi-deciduous forest remaining in the central region of Uganda contains wild robusta coffee[293].
USA	USDA has proposed expanded management attention for grape, onion and potato CWR in existing protected areas. CWR management has been investigated throughout the US, leading to recommendations for protected area management plans and increasing monitoring[294].	
	Wichita Mountains National Wildlife Refuge, IUCN Category IV, 23,884 ha[295]; Ouachita National Forest, IUCN Category VI (Two records on the WDPA: 103,523 ha[296] and 564,151 ha[297])	Since 1996, the USDA's National Plant Germplasm System (NPGS) has been working toward an *in situ* conservation policy for CWR native to the United States. Initally, work focussed on the rock grape (*V. rupestris*) due to the grape's economic importance and concerns that natural populations were being lost through habitat destruction. Rock grape has been used as a wine grape rootstock for nearly a hundred years, due to its resistance to *Phylloxera*, one of the grape's most destructive pests of wine grapes, and to its adaptability to harsh environmental conditions[298]. The species has, in particular, been widely and successfully used in France as grafting rootstock where deep roots were desired.

Country	Protected Area[i]	Link to CWR and landraces
	Clifty Creek Natural Area, not on WDPA	The grape has been recorded in three protected areas (listed in the left hand column) in the US[299].
	Organ Pipe Cactus National Monument IUCN Category II 133,925 ha[300]	Located in South-western Arizona, with a southern boundary shared with Mexico, this protected area contains small populations of wild chilli peppers (*Capsicum annuum*)[301].
	Big Bend National Park and Biosphere Reserve IUCN Category II 286,572 ha[302]	Big Bend National Park is located in the southern portion of the Trans-Pecos area of Texas and has an international border with Mexico. Small populations of wild chilli peppers are found in the park[303].
Uzbekistan	Mount Chatkal Biosphere Reserve No IUCN category 57,360 ha[304]	The Reserve, at the southwestern end of the Chatkal'skiy Range in the western Tien-Shan Mountains, conserves important wild relatives of walnuts, apples, pear and prunes. The juniper forests which cover much of the area include cherry plum (*P. sogdiana*) and the apple (*M. kirghisorum*); whilst groves of pistachio (*Pistacia vera*) can be found on the mountain steppe[305].
	Gissarskiy State Nature Reserve , IUCN Category Ia, 81,438 ha[306]	The park includes ecosystem of sparse juniper forests, groves of maple, walnut and wild apple[307].
Vietnam	Ba Vi National Park IUCN Category II 6,786 ha[308]	This national park is currently the focus of a GEF project to conserve landraces and CWR (see case study)
	Huu Lien Nature Reserve IUCN Category IV 10,640 ha[309]	This reserve is currently the focus of a GEF project to conserve landraces and CWR (see case study)

Chapter 3: Protection Status in the Centres of Crop Diversity

Prior to effective and efficient biodiversity assessment and conservation there is a need to establish the existence and status of biodiversity relevant to food security and production. This chapter reviews the areas of the world which have been identified as being the main sources of crop genetic diversity. The protection status of these areas is then assessed, helping to determine where conservation efforts should initially be directed.

Centres of Crop Diversity

Our major food crops (e.g. wheat, rice, maize, pulses, potatoes, millet) were domesticated between 5,000 and 12,000 years ago from wild relatives.

The domestication of plants that have become our major crops began in different parts of the world including the Fertile Crescent of the Near East (wheat, barley, pulses – see box), the Huang He (Yellow River) region of China (millet), southern Mexico (maize, pulses, peppers, squashes) and Latin America (tomato, potato, cocoa, sweet potato). This process was described in the work of the Russian botanist Nikolai Ivanovich Vavilov (1887–1943). He noted that the wild relatives and ancient forms of crop plants are not spread evenly across the land surface of the world, but are concentrated in relatively small, isolated and frequently mountainous regions that he referred to as their 'centres of origin or diversity'.

The "**Fertile Crescent**" is a semi-circle of land covering Palestine, Israel, the western part of Syria, south-eastern Turkey, eastern Iraq and western Iran. The phrase "Fertile Crescent" was coined by University of Chicago archaeologist James Henry Breasted in the early 20th century, to describe the area which saw the development of the first agricultural settlements, cities and states. These developments can be attributed to a combination of factors. Well sourced with water, the Fertile Crescent possessed four of the five species which have become the most important domesticated animals - cows, goats, sheep and pigs - and the fifth, the horse, was nearby. The climate encouraged the evolution of annual plants with traits amenable to domestication, and the area's varied elevation gave rise to a wide diversity of plants including several that have developed into major global crop plants such as wheat and barley.

Theories on the classification of centres of origin have been refined since Vavilov's work; for instance some crops, such as sorghum, sugarcane and peanuts, were probably domesticated over very broad areas rather than in a well defined centre[310]. Nonetheless, *in situ* conservation, as well as germplasm collection activities for *ex situ* conservation still tends to be focused in and around the centres of origin[311]. These centres thus provide a convenient focus for assessing the conservation status of crop genetic diversity. Slightly updated, these areas have been classified into eight loosely described centres of diversity, which are listed below[312].

I. East Asiatic Centre (central and West China, Korea, Japan, and Taiwan): 138 distinct species have been recognised in this centre, of which probably the earliest and most important were cereals, buckwheats and legumes

II. Tropical Centre (South China, India and South East Asia): some 55 species recognised, including Asian rice, millets, legumes, root crops (*Dioscorea* spp., *Tacca,* etc.), fruit crops, sugarcane, spices.

III. Central Asia and North West India (Uzbekistan, Kazakhstan, Kyrgyzstan and India): some 42 species identified, in particular wheat species, rye and many herbaceous legumes, as well as seed-sown root crops and fruits.

IV. South West Asiatic Centre (Turkey, Iran and Afghanistan): around 80 species, including wheat species, rye, oats, seed and forage legumes and fruits.

V. The Mediterranean Centre (countries bordering the Mediterranean Sea): includes over 80 identified species of wheat, barley, forage plants, vegetables and fruits, as well as spices and oil plants.

VI. The Abyssinian Centre (Ethiopian): again seen as being of lesser importance, but important as a refuge for crops from other regions, especially wheat and barley, as well as local grains and spices.

VII. Central American Centre (South Mexico and Central America): this centre is important for maize, *Phaseolus* and Cucurbitaceous species, with spices, fruits and fibre plants.

VIII. Andean Centre (Peru, Ecuador, Bolivia, and Chile): important for potatoes, other root crops, grain crops of the Andes, vegetables, spices and fruits.

Although these eight centres remain the standard framework for characterising crop centres of diversity, it should be noted that:

- *Centres of overall plant diversity are not necessarily the same as centres of crop diversity*. The 'fynbos' of South Africa is extremely diverse in species, but these have never been brought into cultivation. Similarly, none of the flora of southern Australia has been domesticated and in the tropical rainforests of South America, Africa and Asia plants have been used for millennia for food, medicine, clothing and building materials, but on the whole these species have not been domesticated but continue to be harvested from the wild[313].

- *Centres of diversity where crops were domesticated do not necessarily relate to the areas where crop wild relatives can be found today*. For instance, archaeobotanical evidence indicates that the Syrian and Jordanian steppes 10,000 years ago, where wild cereals were exploited together with a number of edible fruits and pulses, had much richer vegetation than at any other period since. Charcoal and fruit remains indicate these sites were situated within the forest/steppe where pistachio and almond (*Amygdalus* spp) were present in areas that today are arid steppe[314].

- *Centres of crop diversity are not necessarily centres of crop origin.* There is evidence that centres of diversity have migrated over time, so that current centres of diversity are unlikely to have been also centres of origin. For example, the current centres of floristic distribution in the Balkans, and South-west and South-east Asia may be in these areas due to climatic change and floristic movement from more northerly distributed floras[315].

- *There are gaps in the Vavilov analysis*. In particular, Vavilov did not investigate sub-Saharan Africa or the lowlands of South America where some important crops were domesticated[316]. Also, although Cuba has not been characterized as a gene centre, studies have shown that the island has a high diversity of crop plants; to date 1200 species of crop plants have been found – about 17 per cent of the world crop species[317].

Protection status of Centres of Diversity

Although some surveys have been carried out on the status of individual CWR and/or landraces, there have been no major global assessments of risk or protection status. For this report, therefore, we have attempted to assess the broadly-defined Vavilov centres of diversity against the 825 terrestrial ecoregions identified by WWF's Conservation Science Program[318].

For each centre of diversity those ecoregions which are known to be of particular importance for the conservation of crop genetic diversity have been assessed according primarily to their protection status (see table 2).

WWF's Conservation Science Programme has divided the world into 825 terrestrial ecoregions, which are defined as *a large area of land or water that contains a geographically distinct assemblage of natural communities that:*

- *share a large majority of their species and ecological dynamics*
- *share similar environmental conditions, and*
- *interact ecologically in ways that are critical for their long-term persistence.*

- **Identifying Ecoregions**

WWF's identification of ecoregions draws on the work of the Dasmann[319] system of 198 biotic provinces and Udvardy's[320] 193 units which are nested within seven biogeographic realms and 13 terrestrial and one freshwater biome. Neither system, however, is particularly suitable as a landscape conservation planning tool as many distinctive biotas may remain unrecognised[321]. WWF therefore developed, with the help of hundreds of experts, a regional analysis of biodiversity patterns across five continents by synthesising existing classifications from finer scales. The analysis resulted in the description of a series of terrestrial ecoregions, classified within biomes and realms, which can be mapped and used for priority-setting analyses and which provides a much more detailed picture of how species assemblages are distributed across the world than has been available previously[322]. Each ecoregion is defined by similarities in species and ecological interactions. Although terrestrial ecoregions are characterised by the dominant vegetation type[323], by virtue of their nature and scale, they also include all vegetation stages for a particular ecosystem, including the transitional and pioneer phases that occur after disturbance.

Ecoregions are humanly-defined and approximate divisions, but nonetheless they have proved to be useful units for conservation planning, assessment and analysis. They correspond to the major ecological and evolutionary processes that create and maintain biodiversity and encompass a logical set of biogeographically-related communities[324], including those of importance to agriculture.

What an ecoregion contains: "ecoregions" are spatial units developed by conservation biologists to help facilitate planning. They are determined mainly by dominant vegetation patterns. But because of their size, which can be hundreds of thousands or even millions of hectares, each ecoregion encompasses a range of ecosystems, all seral stages and in many cases also cultural landscapes. The names selected for the 825 terrestrial ecoregions relate to significant natural vegetation types and ecological features but they do not imply that other vegetation types found within their boundaries are unimportant or ignored. For instance, the *North East Spain and Southern France Mediterranean Forests* ecoregion, covering over 90,000 km^2, also includes important woodland, *maquis* and wetland habitats, along with cultural areas of high conservation value including traditional farming systems and cork oak forests. Ecoregions are social constructs and are therefore approximate, but have proved useful for planning conservation interventions at a broader scale than in the past. Good ecoregional conservation strategies will also include consideration of disturbed and marginal habitats if they contain rare and endangered species.

Table 2 on page 49 and figure 2, identifies those ecoregions that overlap with the Vavilov centres of diversity and which have been noted for their importance to the conservation of crop genetic diversity (i.e. the table does not list all the ecoregions overlapping with the centres of diversity, but a subset that contains habitats particularly important for crop genetic diversity conservation). The table also identifies the percentage of the area protected. Although the analysis could be further refined by more detailed mapping of the Vavilov Centres, this initial assessment indicates that many of the areas which are most important for the conservation of crop genetic diversity are generally not well protected.

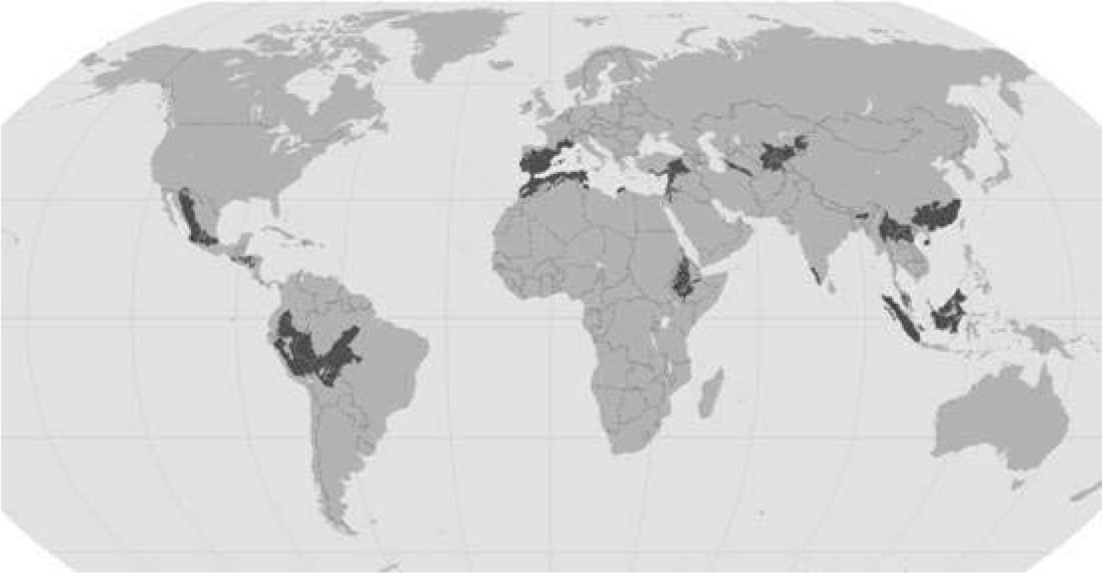

Figure 2: Terrestrial ecoregions (as listed in table 2) overlapping with centres of crop diversity

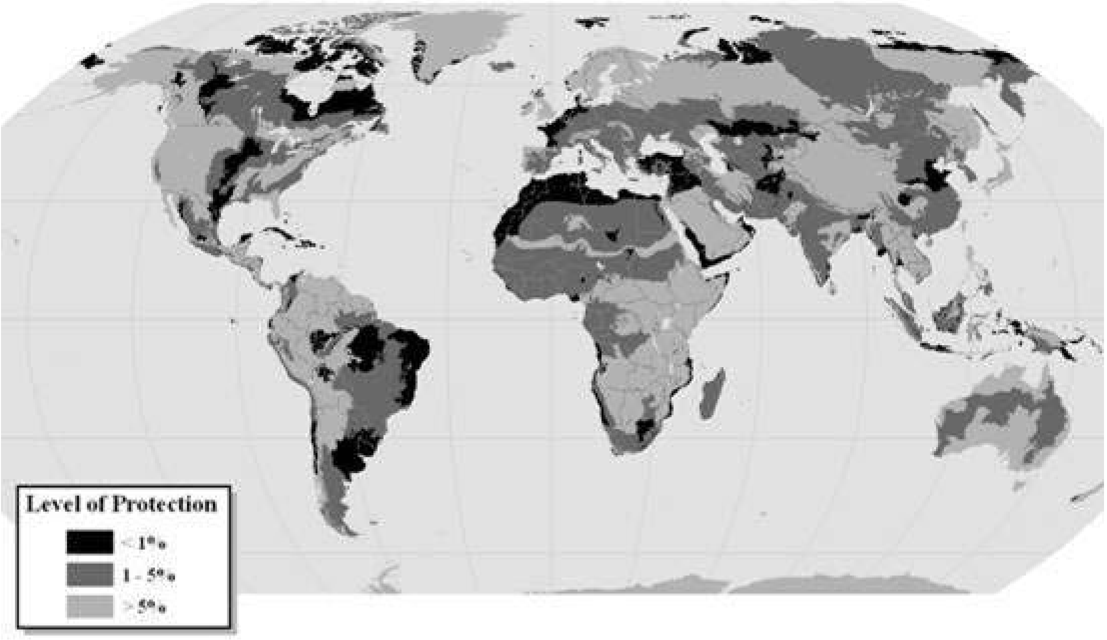

Figure 3: Level of protection (protected areas categorised as IUCN I-VI on the WDPA) of all terrestrial ecoregions

- **Protection status**

A global assessment of protection status in ecoregions has been carried out by The Nature Conservancy (TNC) and WWF[325]. The global extent and distribution of habitat protection were evaluated by summarising information in the 2004 edition of the World Database on Protected Areas (WDPA)[326] and using this to calculate the percentage of each biome and ecoregion covered by a designated protected area[ii] .

[ii] In calculating per cent area protected in each terrestrial biome and ecoregion, records from the WDPA were excluded if they were identified as marine protected areas, lacked location data or had non-permanent status. Protected areas with only point location and area data were mapped as circles with appropriate radii. Portions of protected areas that extended into marine environments were removed. Overlapping protected areas were combined to avoid double-counting errors.

Of those ecoregions identified as being important for crop genetic diversity, 29 (82 per cent) of the 34 ecoregions have under 10 per cent protection; indeed 6 areas (18 per cent) have protection levels of one per cent or less. In the global analysis of ecoregions, 19 per cent had more than 25 per cent of their land area protected (see figure 3); in the crop genetic diversity subset only six per cent (just two ecoregion) enjoys such levels of protection.

It should be noted when interpreting the results of this analysis that although the WDPA is the best data source available for global information on protected areas, the database is not 100 per cent accurate and inconsistencies with national data are known to exist. The WDPA is however the source of information used for global reporting of protected areas to the UN, Convention on Biological Diversity etc. We have thus used the WDPA as the primary data source for information on protected areas throughout this report (as TNC did for the study on protection levels quoted here), as mixing globally available data with other reported, and not always verified data, would be unlikely to make the analysis any clearer. Thus although some data may not be totally accurate we are confident that overall trends can be drawn from analysis using this source.

- **Habitat loss**

The study on levels of protection also looked at the global extent and distribution of habitat loss (see table 3). The level of habitat loss was estimated using a modified version of the Global Land Cover (GLC) 2000 dataset to calculate the level of habitat conversion in each ecoregion. The area converted was calculated as the per cent of land area classified as being cultivated, managed or covered by artificial surfaces in the modified GLC, assuming that historically the per cent area converted in each ecoregion was zero[327].

Globally in all 825 ecoregions, 21.8 per cent of land area has been converted to human dominated uses. Regionally, habitat loss has been most extensive in tropical dry forests in South East Asia, where 69 per cent has been converted. Two biomes stand out as being at greatest conservation risk because of extensive habitat loss and under-protection: temperate grasslands and savannas and Mediterranean forests, woodlands and scrub.

Of course, many CWR species are found in and sometimes confined to disturbed habitats and early seral stages and a proportion can also adapt well to agricultural landscapes, maintaining themselves in field edges and other managed lands. For example, the most closely related species of the major cereal crops and pulses are largely annual weedy species associated with human disturbance. In fact it is their feral nature, short life cycle and adaptation to marginal conditions that helped make them suitable for domestication as crops; they were able to thrive in disturbed conditions where their pioneer characteristics provided them with an advantage over more stable species. Other plants which were either never, or only temporarily domesticated, sometimes hybridized with the cultivated crop enhancing diversity[328].

“Habitat loss” in this context therefore does not automatically mean that all CWR species have been lost from the areas – in some cases they may paradoxically have been provided with increased opportunities to grow. However, experience suggests that as development progresses and agriculture become more intensive, many CWR and landraces become threatened: hence the number appearing in Red Lists and the need for conservation strategies including *in situ* conservation. That is, as development reduces opportunities for CWR and landraces in the broader landscape, protected areas gain an increasingly important role in maintaining agricultural biodiversity. (This also implies that protected area management strategies may occasionally need to address these issues quite specifically, e.g., by including management to maintain disturbed land and by maintaining traditional agricultural practices).

- **Status: Conclusions for Crop Genetic Diversity**
  The analysis by TNC and WWF focused on all biodiversity. No specific analysis has been attempted for crop genetic diversity; the following is thus a preliminary attempt to draw together information relating to the main centres of crop diversity and levels of protection. Of the 34 ecoregions identified in table 2, 951 protected areas, or parts of these protected areas[iii], (see Appendix 1) have been identified by TNC researchers as being within the ecoregions[329]. Although here we have provided evidence that only a few of these areas are known to contain crop genetic diversity (see table 1), many more are likely to contain important resources and further research is clearly needed.

  I. East Asiatic Centre (Central and West China, Korea, Japan, and Taiwan). Only one ecoregion was identified which overlaps with this centre of diversity: the Southern Korean evergreen forest. This however clearly only represents a small part of this centre of diversity. The ecoregion identified is severely under threat: over 70 per cent of the area's natural habitat has been converted and only 2.4 per cent is protected. As with many parts of East Asia, low-lying plains have been converted to agricultural land, with natural vegetation being mostly confined to the mountains and hills. There are six protected areas listed in the WDPA for this ecoregion: three mountain sites and three marine sites.

  II. Tropical Centre (South China, India and South East Asia). Eleven ecoregions were identified as being broadly within this centre of diversity. Generally, protection status is low – five of the ecoregions have less than five per cent of their area protected.

  An area of particular importance to crop genetic diversity conservation is the Jian Nan subtropical evergreen forests ecoregion in China. The level of protection is low, only 5.2 per cent of the ecoregion, and the management of existing protected areas is considered inadequate[330]. There are over 100 protected areas all designated as Category V nature reserves within the 663,600 km^2 ecoregion. One which may be of particular importance to crop genetic diversity is the Wuyishan Biosphere reserve in the north-western part of Fujian Province in south-east China[331]. The reserve includes Mount Wuyi World Heritage site, which is considered the most outstanding area for biodiversity conservation in south-east China and a refuge for a large number of ancient, relict species, many of them endemic to China[332]. The area, which has been inhabited for thousands of years, includes the extensive remains of an ancient city of the Min Yue people which dates back over 2300 years. The World Heritage site is considered to have probably the largest and best-preserved area of humid subtropical native forest in the world. Since 1873 zoologists and botanists have collected nearly 1,000 new specimens of animals and plants, including 780 specimens of insects, 100 of vertebrates and 60 plants[333]. Guizhou Plateau broadleaf and mixed forests ecoregion, also in China, includes important CWR. There are 36 nature reserves recorded in this area protecting the last remnants of original forest types[334]. The Fanjingshan Biosphere Reserve, which includes the main peak of the Wuling Mountain Range, is recorded as having wild relatives of *Vaccinium* spp[335].

  Although forests in the hills of southern Yunnan, in the Northern Indochina subtropical forests ecoregion, are very degraded – over 60 per cent of the ecoregion has been converted mainly into agricultural land – large tracts of monsoon forest are protected in the Xishuangbanna Biosphere Reserve (see table 1), making this protected area extremely important for the protection of crop genetic diversity. Just over 50 fairly small protected areas are recorded in this ecoregion which covers China, Vietnam, Lao PDR, Thailand and China. One, the Ba Vi National Park (see case study on Vietnam), is being studied for tea CWR. There are 13 protected areas in the Hainan Island monsoon rain forests ecoregion. As noted in table 1 above, the flora of Hainan Island has been identified as one of the centres of global plant diversity[336], with some 20 CWR species being identified there.

[iii] Note: some protected areas, such as those in Sumatra with large altitudinal ranges, have areas within more than one ecoregion.

The 16 protected areas in the South Western Ghats montane rain forests ecoregion may all be of importance to crop genetic diversity conservation. Three reserves found in the Agastyamalai Hills (see table 1) all contain a large number of CWR[337] as do those in the Nilgiri Biosphere Reserve (see reference to Silent Valley in table 1). The 10 protected areas in the Meghalaya subtropical forests ecoregion protect a mere 154 km^2 – less than one per cent of the ecoregion's land area[338]. Nokrek (see table 1) is recorded as containing a citrus wild relative in large numbers[339]. Other sites likely to contain CWR include Balphakram National Park (IUCN Category II).

Peninsular Malaysia, Sumatra and Borneo are all important areas for crop genetic diversity conservation. For landraces, the over 3,500 varieties of rice found in Thailand alone, indicate the enormous genetic wealth which can be found in the region. Malaysia is also known for its diversity in tropical fruit genetic resources. The majority of the fruit species currently being cultivated in the country are indigenous and have wild relatives in the rain forest, particularly those from the genera *Durio*, *Nephelium*, *Baccaurea*, *Citrus*, *Mangifera*, *Musa*, *Salacca*, and others[340]. Two ecoregions associated with this genetic diversity are thus highlighted here; the Peninsular Malaysian montane rain forests and the Peninsular Malaysian rain forests ecoregions. There are only four protected areas in the Peninsular Malaysian Montane Rain Forests ecoregion. Of these, there is apparently some *in situ* conservation of citrus species being carried out in the only national park, Taman Negara (IUCN Category II)[341], and the park has also been surveyed for Pulasan (*Nephelium ramboutan-ake*) which is closely related to rambutan (*Nephelium lappaceum*)[342]. There are further 22 protected areas recorded within the Peninsular Malaysian rain forests ecoregion.

There are 32 protected areas in the Sumatran lowland rain forests ecoregion of Indonesia, several of which contain important crop genetic resources. National parks already known to be of importance in this regard are described in Table 1 above (including Bukit Barisan Selatan National Park, Bukit Baka - Bukit Raya National Park, Sungai Kayan Sungai Mentarang National Park, Kerinci Seblat National Park and Gunung Leuser National Park). There are however several other reserves and "protection forests" listed in Appendix 1 which may also contain CWR. Many of the protected areas in the region have large altitudinal ranges and are thus also part of the Sumatran montane rain forests ecoregion (i.e. Bukit Barisan Selatan National Park and Kerinci Seblat National Park). There are however an additional six "protection forests" in the montane rain forests ecoregion which may harbour important resources of crop genetic diversity.

In the Borneo lowland rain forests ecoregion, the Lambir Hills are known to be particularly rich in wild fruit trees (see table 1). There are another 49 protected areas in the ecoregion which may also be important reservoirs of crop genetic diversity. For example, the Tabin Wildlife Reserve (IUCN Category IV) conserves the last sizeable tract of lowland forest remaining in Sabah[343] and Kinabalu National Park (IUCN Category II) has high levels of endemism[344].

III. Central Asia and North West India (Uzbekistan, Kazakhstan, Kyrgyzstan and India). Three ecoregions were identified in this area, all three are in the temperate grasslands and savannas biome, which over the whole ecoregion network has one of the highest levels of habitat conversion and the lowest levels of protection[345].

The Gissaro-Alai open woodlands of Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan, are a mix of steppe with important CWR of Brassicaceae, Poaceae, Lamiaceae and *Allium* species along with wild fruit and nut forests [346]. Twenty-nine protected areas overlap with this ecoregion protecting some seven per cent of the land area. Five of these are listed in table 1 in Kyrgyzstan, Tajikistan and Uzbekistan, and it is likely that some of the remaining 24 protected areas also contain CWR. The Tian Shan foothill arid steppe ecoregion overlaps slightly with the Gissaro-Alai open woodlands. The area contains 18 protected areas listed in Appendix 1.

Only 0.6 per cent of the Alai-Western Tian Shan Steppe ecoregion is protected. Three protected areas, Nuratinskiy and Zeravshanskiy in Uzbekistan and Zeravshansky (Sarezmsky) reserves in Tajikistan, are recorded for this ecoregion. The region is known to be rich in CWR species.

IV. South West Asiatic Centre (Turkey, Iran and Afghanistan). Three ecoregions represent the most important areas for crop genetic diversity in this centre: the Eastern Anatolian deciduous forests, the Eastern Anatolian montane steppe and Kopet Dag woodlands and forest steppe. Only 0.5 per cent of the deciduous forest ecoregion is protected by just one national park, the 42,800 ha Muzur Vadisi Park (IUCN II) and two forest reserves: Mendo and Zafran Forest. In the Eastern Anatolian montane steppe ecoregion the situation is equally critical. The protected areas in this ecoregion are in Armenia (three protected areas, including the Khosrov State Reserve listed in table 1), Azerbaijan (three areas, including Arazboyu National Park, see table 1), Iran (five areas) and Georgia (the Algeti Nature Reserve listed in table 1). In Armenia the growth of the agricultural, industrial, construction and energy sectors has led to extensive habitat change across all landscape types. Urban and industrial areas have grown, while forests have been logged and over 20,000 ha of marshes and wetlands have been drained. To date, 35 plant species of economic importance are known to have become extinct and a further 386 species (12 per cent of the flora) are listed in the 1998 Armenian Red Data Book[347].

Although conversion rates are lower and protection levels are higher in Kopet Dag there are only seven protected areas in this ecoregion, five in Turkmenistan (including Kopet Dag State Nature Reserve, see table 1) and two in Iran. Overgrazing in the mountains of this ecoregion has led to the destruction of grasslands and to mudflows, disturbing woodlands on the lower slopes. Recently, dry summers have dried out vegetation resulting in unusually hot fires destroying the unique wild-fruit communities, which are characterised by long and difficult regeneration cycles. Although the existing nature reserves are contributing to the overall protection of Kopet Dag's most diverse woodlands, they often lack effective management. As a result, this important ecosystem could be altered irreversibly[348].

Wild pear in the walnut fruit forest of Eidere Valley, Kopetdag.

Credit: © WWF-Canon / Hartmut Jungius

V. The Mediterranean Centre (countries bordering the Mediterranean Sea). Five ecoregions represent this centre of diversity. Mediterranean forests, woodlands and scrub stood out in the analysis carried out by TNC and WWF as being at greatest risk because of extensive habitat loss and under-protection[349]. Forests originally represented 82 per cent of the total Mediterranean land cover. Today, only about 17 per cent remains[350]. All five ecoregions of importance to crop genetic diversity have inadequate levels of protection; for instance only 0.8 per cent in the Mediterranean woodlands and forest ecoregion, and all have high levels of conversion; over 70 per cent in the Iberian sclerophyllous and semi-deciduous forests ecoregion.

The Mediterranean woodlands and forests ecoregion includes 12 protected areas in Algeria, Morocco and Tunisia, several of which are recognised as Biosphere Reserves. Three forest sites are protected in Algeria, including the Djurdjura Biosphere Reserve (see table 1) and El Kala National Park and Biosphere Reserve, which may also contain species of crop genetic diversity importance. The Parc National des Iles Zembra et Zembretta (also a Biosphere Reserve) in Tunisia is also noted in table 1.

Appendix 1 listed 17 protected areas in the Eastern Mediterranean conifer-sclerophyllous-broadleaf forests ecoregion; 15 are in Israel, the others are in Jordan and Turkey. Israel is a well known centre of diversity for both CWR and landraces, and has well established *ex situ* and *in situ* conservation programmes. In the late 1990s, a European Union funded project was established to study the conservation of crop plant germplasm in Israel's nature reserves[351].

Although only one of the 177 protected areas recorded in the Northeastern Spain and Southern France Mediterranean forests ecoregion (Montseny National Park and Biosphere Reserve) is listed in table 1, it is likely that several other reserves in this region will contain tree species important to crop genetic diversity. Similarly, wild olive (*Olea europaea*) and carob (*Ceratonia siliqua*) are features of the Iberian sclerophyllous and semi-deciduous forests and the Southwest Iberian Mediterranean sclerophyllous and mixed forests ecoregions in Spain and Portugal. These ecoregions contain 53 and 33 protected areas respectively.

VI. The Abyssinian Centre (Ethiopian). The one ecoregion in this centre, the Ethiopian montane grasslands and woodlands, is under severe threat. By the early twentieth century, only five per cent of the Ethiopian Highlands were forested, although it is believed that at one time forest was extensive[352]. The natural vegetation has been altered by intensive human use over millennia, and today only fragments remain. The ecoregion has nine protected areas reported on the WDPA. The Bale Mountains National Park (see table 1) is known to contain a CWR and the Simien Mountains (IUCN Category II), have high, but unquantified, levels of endemism[353]. The proposed Termaber-Wufwasha-Ankober conservation area in the western Highlands would protect much of the ecoregions' biodiversity[354].

VII. Central American Centre (South Mexico and Central America). Four ecoregions are identified. The Central American montane forests of El Salvador, Guatemala, Honduras and Nicaragua have relatively high level of protection, with 40 protected areas covering 27.6 per cent of the ecoregion. However, protected area enforcement and infrastructure is in most cases poor and the protected areas are small and unlikely to conserve biodiversity unless significantly expanded[355].The protected areas include the Sierra de las Minas biosphere reserve and Mario Dary Rivera Protected Biotope in Guatemala (see table 1), both noted for their CWR.

The other ecoregions identified in this centre of diversity are far less well conserved, and habitat conversion is a major issue, in particular in the Istmian-Pacific moist forests of southern Nicaragua, northern Costa Rica and Panama where only a quarter of the original land cover remains and only 9.1 per cent of the land is protected in 33 protected areas. The Corcovado National Park is known for its crop genetic diversity importance (see table 1). Other protected areas of possible importance are within the 207,000 ha Talamanca Range-La Amistad Reserves (which includes the Barbilla National Park, Chirripo National Park, Hitoy Cerere Biological Reserve, La Amistad (Talamanca) National Park, Las Tablas Protected Area, Rio Macho Forest Reserve and Tapanti National Park) which protects the foothills and mountains of Cordillera de Talamanca on the Panamanian/Costa Rican border. The reserve, which includes a wide range of biomes, has extraordinary species diversity due to the convergence of the floras of North and South America. Some 9,000 flowering plant have been recorded across the reserve, which also has levels of endemism estimated at between 30-40 per cent. The area also seems to have a long, but mainly unresearched, history of human habitation[356].

The Sierra Madre region of Mexico and the USA is the richest area for CWR north of the Tropic of Cancer[357]. The Sierra Madre Occidental pine-oak forests ecoregion is however critically endangered with only 0.61 per cent of its original vegetation remaining[358]. There are 29 protected areas listed in Appendix 1 protecting 5.4 per cent of the ecoregion. Wild capsicums are an important CWR in this area and have been given 'special plant' status in the Coronado National Forest which is within this ecoregion[359].

The 29 protected areas of the Trans-Mexican Volcanic Belt pine-oak forests ecoregion includes the Sierra de Manantlan reserve (see case study), one of the few protected areas in the world specifically designed to conserve CWR, and Pico de Orizaba National Park (see table 1).

VIII. Andean Centre (Peru, Ecuador, Bolivia, and Chile). Six ecoregions which include areas of importance to crop genetic diversity were identified as overlapping with the large Andean centre of diversity.

The Beni savanna ecoregion is represented by only one protected area in Peru, the Bahuaja Sonene National Park (see table 1) and two in Bolivia, including the Estación Biológica Beni Biosphere reserve. There are eight protected areas in the Central Andean wet puna ecoregion, in Bolivia and Peru. Overall this area is particularly important for tubers, in particular potato species.
Eight protected areas overlap with the Madeira-Tapajós moist forests ecoregion in Bolivia and Brazil and nine in the Napo moist forests ecoregion in Colombia, Ecuador and Peru. As noted below, the western Amazonian is an important centre for the domestication of crop plants and for the development of landraces, and contains some of the most species-rich forests in the world.

In the Napo moist forests ecoregion two Ecuadorian biosphere reserves may be of particular importance for crop genetic diversity conservation: the Yasuní Biosphere Reserve and National Park and Sumaco Biosphere Reserve. The objectives of the 1,682,000ha Yasuní Reserve, for example, are to conserve both the natural ecosystems and the lifestyles of the indigenous communities, such as the Huaorani, Aucas and Quichuas. Some 10,000 people in the reserve are occupied in agriculture (coffee, bananas, yuca, paw paw, citrus fruit, maize and achiote), fishing, hunting and gathering forest products[360]. The 931,215ha Sumaco Biosphere Reserve is located 100 km south-east of Quito in western Napo province. The reserve covers a large variety of ecosystems from the tropical highlands-Andean paramour to the tropical Amazon plains. There are about 100,000 (2001) people living in the area, including indigenous communities[361].

Wild potato, Peru

Credit: © WWF-Canon / Hartmut Jungius

There are 16 protected areas in the Peruvian Yungas ecoregion, including the incredibly biodiverse Manú National Park (see table 1). Some botanists claim that Manú, which is located in the upper Amazon of southern Peru, has more plant species than any other protected area on the earth[362]. For example, a study of a single one hectare plot near the Cocha Cashu research station recorded 1,200 lowland vascular plant species and more than 200 tree species[363]. The ecoregion also includes Andean cloud forest characterised by *Polylepis*. There are only 93,700 ha of *Polylepis* forests left in highland Peru, mostly in patches which are typically less than 30 ha each. The understorey of *Polylepis* forest is associated with wild relatives of Andean food crops, including wild relatives of potatoes and other Andean tubers[364]. Indeed, the area is said to contain 40 percent of the world's wild potato species[365]. Manú National Park also overlaps the Southwest Amazon moist forests ecoregion. There are in total six protected areas in Bolivia, nine in Brazil and four in Peru recorded on the WDPA which overlap with this ecoregion.

Conclusion

This analysis is necessarily preliminary but it does gives an indication that the degree of protection in places with the highest levels of crop genetic diversity is significantly lower than the global average. Coupled with evidence of high levels of habitat conversion, which although not always associated with threats to crop genetic diversity does often indicate conversion to land uses which are not associated with high levels of diversity, such as industrial agriculture, suggests that governments and the international community should be giving far higher priority to crop biodiversity in deciding the location of protected areas. A new emphasis on targeting protected areas for their food benefits would fit well with the aims of the Convention on Biological Diversity, with its mixture of social and conservation aims. Those areas which stand out as requiring urgent conservation action include:

- ✓ The East Asiatic Centre of Diversity (central and West China, Korea, Japan, and Taiwan). Only one ecoregion was identified as overlapping with this area, the Southern Korea evergreen forests. However the fact that this area has seen over 70 per cent habitat conversion and has only 2.4 per cent protection highlights the challenge of undertaking effective conservation in the region.

- ✓ It is well known that the Sumatran lowland rain forests are under great risk, with high levels of habitat conversion (66 per cent) and low levels of protection (4.9 per cent). There are however several national parks in Indonesia already known as being important for crop genetic diversity (see table 1). This relationship should be built upon with more focus on crop genetic diversity conservation strategies in the region.

- ✓ Turkey's importance as a reservoir of crop genetic diversity is highlighted in the case study (see page 74), as is the need for higher levels of protection in the country. The Eastern Anatolian deciduous forests ecoregion, for example, has levels of habitat conversion of over 65 per cent, but the lowest protection level of all the ecoregions identified in table 2 – only 0.5 per cent.

- ✓ Turkey is part of the South West Asiatic centre of diversity, one of the most important centres for cereal crops and fruits and part of the Fertile Crescent. Two other ecoregions overlap with this centre. Although the Kopet Dag woodlands and forest steppe ecoregion has low levels of conversion, protection is also low and, as reported above, overgrazing and dry summers pose a considerable threat to the area's ecological integrity. The Eastern Anatolian montane steppe ecoregion has a wealth of crop genetic diversity, but only three per cent of the ecoregion is protected and many plant species are threatened. 12 per cent of Armenia's flora was listed in the 1998 Red Data Book for the country, includes several species of economic importance[366]. If this is an indication of current threat, then conservation measures need to be put in place as a matter of urgency if *in situ* conservation of crop genetic diversity is to be achieved.

- ✓ Protection levels are also notably low in the Central Asia and North West India centre of diversity. All three ecoregions overlapping with this centre are in the much threatened temperate grassland and savannas biome. Two have protection levels at around seven per cent and habitat conversion levels around 40 per cent; indicating a need for greater protection as conversion levels are likely to rise and are unlikely to be associated with activities conducive to crop genetic diversity conservation. The Alai-Western Tian Shan steppe is recorded as having only three protected areas (just 0.60 per cent protection). Desertification is a major threat to the steppe zone of the lower mountain belt due to overgrazing and the subsequent degradation of vegetation[367].

- ✓ The Andes are well known for their importance as reservoirs of root crops and grains. Protection levels are low, less than one per cent in Beni savanna and just over five per cent in the Central Andean wet puna. Protection is however being increased and initiatives such as the community-led Potato Park (see case study) not only provide excellent examples of practical crop genetic diversity conservation but also of a new type of protected area managed by local communities who directly benefit from the conservation activity.

- ✓ Several other ecoregions identified in table 2 are also clearly under threat, and although they are not as rich in the range and variety of crop genetic resources as those areas highlighted above, the resources they contain should be conserved. These include the Ethiopian montane grasslands and woodlands, which have only 8.4 per cent protection and over 82 per cent habitat conversion and the Meghalaya subtropical forests, in the eastern Indian states of Meghalaya and Assam, with less than one per cent protection and over 60 per cent habitat conversion.

- ✓ Although the Mediterranean Centre of crop diversity is not as rich as some of the other centres identified by Vavilov, the high levels of habitat conversion and low levels of protection in the region have warranted considerable conservation concern in recent years. The importance of the area for crop genetic diversity adds another important argument for the protection of the region.

Table 2: Vavilov Centres Of Diversity overlapping with WWF's Terrestrial Ecoregions

'Centre of Origin' of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
East Asiatic Centre (central and West China, Korea, Japan, and Taiwan)	Southern Korea evergreen forests (PA0439)	Temperate Broadleaf and Mixed Forests	The evergreen forests at the southern tip of the Korean Peninsula are important for their genetic resources of the tea family, i.e. *C. japonica*[368].	2.4
Tropical Centre (South China, India and South East Asia)	Jian Nan subtropical evergreen forests (IM0118)	Tropical and Subtropical Moist Broadleaf Forests	This ecoregion includes the extensive hill country to the south of the lower Yangtze River Basin and north of the tropical coastal plains of southeastern China; extending from China's southeast coast westward to the Guizhou and Yunnan Plateaus. The area provides native habitat for a number of commercially important food plants including tea, citrus and lychee, which may have first come into cultivation in this area[369]. So far, in the Yunnan tropics about 120 species of CWR have been recorded[370].	5.2
	Guizhou Plateau broadleaf and mixed forests (PA0101)	Tropical and Subtropical Moist Broadleaf Forests	The Guizhou Plateau lies to the east of the higher Yunnan Plateau and to the south of the Yangtze River. The original forest of this ecoregion was dominated by trees in the oak (*Castanopsis, Quercus, Cyclobalanopsis*), laurel (*Phoebe, Eugenia*) and tea (*Schima, Camellia*) families. Today, original forest types exist within the protected areas, but are almost completely gone elsewhere[371].	10.6
	Northern Indochina subtropical forests (IM0137)	Tropical and Subtropical Moist Broadleaf Forests	This large ecoregion extends across the highlands of northern Myanmar, Laos and Vietnam and also includes most of southern Yunnan Province. Parts of this ecoregion, in particular the Xishuangbanna Region of Yunnan, include important crop germplasm resources[372].	6.1
	Hainan Island monsoon rain forests (IM0169)	Tropical and Subtropical Moist Broadleaf Forests	Hainan is the second largest island off the coast of China. Many endemic taxa have evolved here. The flora of Hainan Island has been identified as one of the centres of global plant diversity, and about 20 CWR species have so far been identified[373].	9.1

'Centre of Origin' of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
	South Western Ghats montane rain forests (IM0151)	Tropical and Subtropical Moist Broadleaf Forests	This ecoregion runs up the Western boundary of India. More than 80 per cent of the flowering plants in these mountain ranges are in the forests of the south. In particular, the Agasthyamalai and Nilgiri hills are recognised as centres of plant diversity. The ecoregion also contains high levels of endemism – some 35 per cent of the plants[374, 375.]	13.3
	Meghalaya subtropical forests (IM0126)	Tropical and Subtropical Moist Broadleaf Forests	The Meghalaya subtropical forests, in the eastern Indian states of Meghalaya and Assam, are one of the wettest ecoregions in the Indo-Pacific region. Varieties of wild citrus are found in the ecoregion[376].	0.7
	Peninsular Malaysian rain forests (IM0146)	Tropical and Subtropical Moist Broadleaf Forests	The area includes the lowland moist forests of peninsular Malaysia and the extreme southern part of Thailand[377]. Peninsular Malaysia, Sumatra, Borneo, Java, Bali and Palawan (of the Philippines) form a distinct floristic region, called West Malesia: a centre for diversity for many important crops most notably banana, ginger and tropical fruits, in particular mango species[378]. An inventory of 50 ha of primary lowland rain forest in Peninsular Malaysia found about 340,000 trees, out of 820 species, 76 were found to bear edible fruits. Wild species of mango (12 spp.), mangosteen (*Garcinia*, 13 spp.), breadfruit (10 spp.) and rambutan (5 spp.) were found to be particularly diverse. 24 species are cultivated, 38 edible species are congeneric with cultivated species and at least 10 other species bear non-edible fruits but are related to cultivated ones. The forest is thus rich in fruit trees gene pools which are of potential economic value and useful for crop improvement[379].	3.3
	Borneo lowland rain forests (IM0102)	Tropical and Subtropical Moist Broadleaf Forests	This ecoregion is dominated by the lowland dipterocarp forests of Borneo. These forests are globally outstanding for both bird and plant richness, with an estimated 10,000 plant species found within their boundaries. The forests contain wild fruit species, such as jackfruit, durians, litchi (*L. chinensis*) and numerous species of mango[380].	
	Peninsular Malaysian Montane Rain Forests (IM0144)	Tropical and Subtropical Moist Broadleaf Forests	This ecoregion is made up of the montane, areas above 1,000 m, moist forests of Peninsular Malaysia and southernmost Thailand. The forest provides connectivity between fragmented forest patches, and thus many of the species found in the Peninsular Malaysian Lowland Rain Forests are also found in this ecoregion[381].	14.7

'Centre of Origin' of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
Central Asia and North West India (Uzbekistan, Kazakstan, Kyrgyzstan and India)	Sumatran lowland rain forests (IM0158)	Tropical and Subtropical Moist Broadleaf Forests	The Sumatran lowland rain forests of Indonesia are extremely diverse but extremely threatened. The forests contain several species of wild fruit tree[382].	4.9
	Sumatran montane rain forests (IM0159)	Tropical and Subtropical Moist Broadleaf Forests	This ecoregion represents the montane forests (above 1,000 m) along the Barisan Mountain Range of Sumatra. The ranges flora includes wild fruit tree relatives including mango, durians, Langsat (*Lansium* spp) and rambutan[383].	31.1
	Tian Shan foothill arid steppe (PA0818)	Temperate Grasslands, Savannas, and Shrublands	Deciduous forests grow in this Central Asian ecoregion (Kazahkstan, Uzbekistan and Tajikistan) at elevations ranging from 1,200-1,700m (representing the remnants of broad-leaved temperate forests that once flourished in this area, but were nearly extirpated during the glaciations of the past two million years). One notable tree that grows along river valleys at these elevations in the Yili region of the Tian Shan is Sievers' apple (*M. sieversii*) a major progenitor of the domestic apple[384]. The US Department of Agriculture has evaluated this species to identify the genes responsible for apple scab resistance[385].	7.3
South West Asiatic Centre (Turkey, Iran and Afghanistan)	Eastern Anatolian deciduous forests (PA0420)	Temperate Broadleaf and Mixed Forests	More than 30 species of wild wheat (*Triticum* and *Aegilops* spp.) are found in this much modified area of Turkey along with barley (*H. vulgare*), chickpeas (*Cicer arientinum*), lentils (*Lens culinaris*), apricots (*P. armeniaca*), figs (*Ficus carica*), cherries (*Prunus* spp.) and many types of nuts[386].	0.5
	Eastern Anatolian montane steppe (PA0805)	Temperate Grasslands, Savannas, and Shrublands	The ancestors of wheat (*Triticum* and *Aegilops* spp.), barley, rye (*Secale* spp.) and oats (*Avena* spp.), and several fruit trees, such as grape and wild pear (*P. pyrifolia*), are found in this ecoregion which includes part of Iran, Turkey and Armenia. The almonds (*Amygdalus kotschyi, A. cardauchorum*) and pears (*P. hakiarica* and *P. salicifolia* var. *serrulatal*) are also endemic taxa from the ecoregion[387].	3.0
	Kopet Dag woodlands and forest steppe (PA1008)	Montane Grasslands and Shrublands	Mountainous shrub-like Mediterranean xeric woodlands grow in the Kopet Dag mountains – the northernmost range of the Turkmeno-Khorassan system of southern Turkmenistan and northern Iran. They are the centre of origin and genetic diversity for CWR of grapes (*V. sylvestris* and *V. vinifera*), pomegranates (*Punica granatum*), figs (*F. carica*), almonds	4.3

'Centre of Origin' of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
			(*A. communis* and *A. scoparia*), walnuts, wheat, barley and many others[388]. Kopetdag woodlands include wild apple (*M. turkmenorum*), wild pear (*P. boisiieri*), wild cherries (*Cerasus microcarpa*, *C. erythrocarpa*, *C. blinovskii*), wild prune (*P. divaricata*), almonds and hawthorns (*Crataegus* spp.). Several important plants from the perspective of crop genetic diversity are listed in the *Red Book of Turkmenistan* (2000), including Walnut *(J. regia);* Pomegranate *(Punica granatum);* Turkmen Pear (*P. turcomanica);* Boissier Pear (*P. boissieriana) and* Apple (*M. sieversii (=M. turkmenorum)* [389].	
Mediterranean Centre (countries bordering the Mediterranean sea)	Mediterranean woodlands and forests (PA1214)	Mediterranean Forests, Woodlands, and Scrub	Wild olive (*O. europaea* subsp. *cuspidata*) and carob (*Ceratonia siliqua*) forests once covered 50,000 km^2 of the dry coastal and inland plains of this Mediterranean ecoregion, which extends over Morocco, Algeria and Tunisia. Today in Algeria, only 1,000 km^2 of the original 10,000 km^2 of wild olive and carob forests remain, whilst in Morocco, only 5,000 km^2 of the estimated 36,240 km^2 of these forests survive[390].	0.8
	Eastern Mediterranean conifer-sclerophyllous-broadleaf forests (PA1207)	Mediterranean Forests, Woodlands, and Scrub	Human settlement and agriculture in this ecoregion date back to the early Holocene, a key factor underlying the enormous genetic diversity among the area's crop species. Some of the wild relatives of agricultural plants that occur here include species in genera such as wheat (*Triticum* spp.), lentil (*Lens* spp.), grasspea (*Lathyrus* spp.), garden pea (*Pisum* spp.), sainfoin (*Onobrychis* spp.) and clover (*Trifolium* spp.). Four species of *Triticum* (*T. baeoticum, T. dicoccoioes, T. durum,* and *T. aestivum*), for example, have been recorded in the ecoregion[391].	1.0
	Northeastern Spain and Southern France Mediterranean forests (PA1215)	Mediterranean Forests, Woodlands, and Scrub	Wild olive and carob (*C. siliqua*) woodlands and maquis can be found in the southern portion of this ecoregion (Valencia region and Balearic Islands) [392].	5.7
	Iberian sclerophyllous and semi-deciduous forests (PA1209)	Mediterranean Forests, Woodlands, and Scrub	Wild olive and carob woodlands and maquis are mainly distributed in the southern part of this ecoregion and in river canyons of the Duero and Tajo basins[393].	4.0

‘Centre of Origin’ of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
	Southwest Iberian Mediterranean sclerophyllous and mixed forests (PA1221)	Mediterranean Forests, Woodlands, and Scrub	Wild olive (*O. europaea* and *O. maroccana*) and carob woodlands and maquis were once widespread in this region (which includes parts of Portugal, Spain, France, Italy and Morocco), however agricultural expansion has left only a few remnants of natural forest[394].	8.8
Abyssinian Centre (Ethiopia)	Ethiopian montane grasslands and woodlands (AT1007)	Montane Grasslands and Shrublands	*Coffee arabica* is the dominant understorey shrub of the Afromontane forests of the Harenna forest, which once covered a large part of Ethiopia. This area is also home to the wild garden pea relative (*Pisum abyssinicum*). Only five per cent of Ethiopian Highland forest remains today, some of which is protected in the Bale Mountains National Park[395].	8.4
Central American Centre (South Mexico and Central America)	Trans-Mexican Volcanic Belt pine-oak forests (NT0310)	Tropical and Subtropical Coniferous Forests	The Sierra de Manantlan Mountains (see case study), in the western zone of this ecoregion, are famous for their genetic resources of maize (*Zea spp*.). The area has a long history of human habitation, which has had a major influence on the area’s biodiversity. Today almost half of the Mexican population lives in the states that are part of the Trans-Volcanic belt[396].	5.9
	Sierra Madre Occidental pine-oak forests (NA0302)	Tropical and Subtropical Coniferous Forests	More than 250 species of CWR have been recorded in the Sierra Madre region[397]. Landrace diversity of native crops is also richer than in any other American region north of the tropics[398].	5.4
	Central American montane forests (NT0112)	Tropical and Subtropical Moist Broadleaf Forests	The montane ecoregion of northern Central America covers as more than 40 relatively small habitat islands extending from southern Mexico to the southeast through Guatemala and into El Salvador and Honduras[399]. The mountains, specifically those in eastern Guatemala, contain several species of Cucurbitaceae and Solanaceae that “represent potential germplasm resources of food plants”.[400] Much of the higher elevations remain relatively intact and are reasonably well protected (e.g. Sierra de las Minas biosphere reserve); however, there is little management or enforcement[401].	27.6
	Isthmian-Pacific moist forests (NT0130)	Tropical and Subtropical Moist Broadleaf Forests	Covering the lowland Atlantic slopes of southern Nicaragua, northern Costa Rica and Panama, this forest ecoregion combines North American and South American flora and fauna following the joining of the two continents three million years ago[402]. The area is an important genetic reserve for fruit species. [403].	9.1

‘Centre of Origin’ of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
Andean Centre (Peru, Ecuador, Bolivia, and Chile).	Peruvian Yungas (NT0153)	Tropical and Subtropical Moist Broadleaf Forests	This region maintains one of the richest montane forest ecosystems in the Neotropics; species include relatives of papaya (*Carica* spp)[404].	7.9
	Madeira-Tapajós moist forests (NT0135)	Tropical and Subtropical Moist Broadleaf Forests	The Madeira-Tapajós moist forest ecoregion lies in central Amazonia, encompassing three Brazilian states (Amazonas, Rondônia and Mato Grosso) and part of the Bolivian Department of Beni. The ecoregion is the eastern limit for naturally occurring cacao (*Theobroma cacao*) [405].	9.9
	Southwest Amazon moist forests (NT0166)	Tropical and Subtropical Moist Broadleaf Forests	This ecoregion is located in the Upper Amazon Basin of Peru, Brazil and Bolivia. The area is well known as an important reservoir of plant genetic diversity[406].	8.5
	Napo moist forests (NT0142)	Tropical and Subtropical Moist Broadleaf	The Gran Sumaco and Upper Napo River region of Peru contains a wealth of plant species used traditionally by the native Quichua inhabitants for medicine, food, construction, crafts and clothing. Western Amazonia in general has been cited as an important centre for the domestication of crop plants[407]. Domesticated and semi-domesticated landraces of fruit-bearing trees such as *Bactris gasipaes*, *Rollinia mucosa* and *Gustavia macarenensis*, and *Chrysophyllum venezuelanense* and *Pouteria caimito*, are commonly grown in Quichua house-gardens. These selected landraces are an important genetic resource, and some of the edible fruit trees could merit consideration for cultivation in other tropical regions[408].	8.1
	Beni savanna (NT0702)	Tropical and Subtropical Grasslands, Savannas, and Shrublands	The Beni savannas are in the lowlands of the southwestern Amazon basin, within Bolivia, the Brazilian State of Rondonia and in the Pampas del Heath of Peru. This area has been identified as a centre of plant diversity and endemism[409]. A wild pineapple (*Ananas* sp.), possibly the ancestor of the cultivated pineapple, is common in the Pampas[410].	0.8

'Centre of Origin' of Crop Plants	Related Terrestrial Ecoregions (no.)	Dominant Biome	Important CWR and/or Landraces found in the Ecoregion	Protection Status (%)
	Central Andean wet puna (NT1003)	Montane Grasslands and Shrublands	The Central Andean wet puna ecoregion is located in the Andean Mountains of Peru and eastern Bolivia[411] The lower elevations of puna are often used for growing native and introduced crops. Native Andean crops include tubers, represented by several kinds of potatoes (*S. acaule*, *S. andigenum*, *S. curtilobum*, *S. juzepczukii*, *S. tuberosum*), "ollucos" (*Ullucus tuberosus*), "oca" (*Oxalis tuberosa*); and pseudo-cereals (*Amaranthus caudatus*, *Chenopodium quinoa*, *C. pallidicaule*). Other Andean species are planted in mixed fields with tubers and cereals. These species, such as *Lupinus* spp., *Phaseolus* spp. and *Vicia* spp., may represent a potential source for new commercial crops[412].	5.2

Table 3: Centres of diversity, terrestrial ecoregions and level of habitat loss

'Centre of Origin' of Crop Plants	Related Terrestrial Ecoregions (no)	% of habitat lost
East Asiatic Centre	Southern Korea evergreen forests (PA0439)	70.90
Tropical Centre	Jian Nan subtropical evergreen forests (IM0118)	16.90
	Guizhou Plateau broadleaf and mixed forests (PA0101)	30.20
	Northern Indochina subtropical forests (IM0137)	60.50
	Hainan Island monsoon rain forests (IM0169)	5.69
	South Western Ghats montane rain forests (IM0151)	7.46
	Meghalaya subtropical forests (IM0126)	60.90
	Borneo lowland rain forests (IM0102)	42.90
	Peninsular Malaysian rain forests (IM0146)	60.60
	Peninsular Malaysian Montane Rain Forests (IM0144)	8.38
	Sumatran lowland rain forests (IM0158)	66.40
	Sumatran montane rain forests (IM0159)	25.70
Central Asia and North West India	Gissaro-Alai open woodlands (PA0808)	40.10
	Alai-Western Tian Shan steppe (PA0801)	16.30
	Tian Shan foothill arid steppe (PA0818)	45.90
South West Asiatic Centre	Eastern Anatolian deciduous forests (PA0420)	65.60
	Eastern Anatolian montane steppe (PA0805)	55.60
	Kopet Dag woodlands and forest steppe (PA1008)	1.06
Mediterranean Centre	Mediterranean woodlands and forests (PA1214)	29.90
	Eastern Mediterranean conifer-sclerophyllous-broadleaf forests (PA1207)	50.20
	Northeastern Spain and Southern France Mediterranean forests (PA1215)	47.30
	Iberian sclerophyllous and semi-deciduous forests (PA1209)	73.80
	Southwest Iberian Mediterranean sclerophyllous and mixed forests (PA1221)	54.20
Abyssinian Centre	Ethiopian montane grasslands and woodlands (AT1007)	82.50
Central American Centre	Trans-Mexican Volcanic Belt pine-oak forests (NT0310)	29.10
	Sierra Madre Occidental pine-oak forests (NA0302)	3.20[iv]
	Central American montane forests (NT0112)	36.70
	Isthmian-Pacific moist forests (NT0130)	76.60
Andean Centre	Peruvian Yungas (NT0153)	12.80
	Madeira-Tapajós moist forests (NT0135)	11.90
	Southwest Amazon moist forests (NT0166)	3.65
	Napo moist forests (NT0142)	11.50
	Beni savanna (NT0702)	0.52
	Central Andean wet puna (NT1003)	17.70

[iv] Research authors note that this figure looks inaccurate, as sources state that this area has suffered massive deforestation

Chapter 4: Developing a National Crop Wild Relative Conservation Strategy

Given the importance of conserving crop genetic diversity and the urgency of the threats that they face, their inclusion in national conservation strategies needs to be carefully planned and implemented. Time and resource constraints also mean that in most cases only the most important sites will be able to be protected, making it imperative that priorities are identified carefully, using as much information as possible and drawing on the latest planning techniques. The following section outlines a methodology that has been developed for identifying conservation priorities with respect to crop wild relatives. Although at present no similar methodological development has been carried out for landraces, the methodology presented here could be further developed to cover landraces as well.

As discussed above until recently the major effort and the majority of the funds devoted to conserving crop genetic diversity have been directed towards the collection of material for *ex situ* storage. Very few CWR or landraces are intentionally managed, or even monitored, for conservation in their natural habitat[413]. It is likely that many existing protected areas contain a wealth of crop genetic diversity; the summary table in the last chapter has done no more than scratch the surface of information about crop genetic material within the world's protected area system. One urgent task is to carry out more rigorous surveys and inventory individual protected areas to find out what is already protected. It is also likely that many existing protected areas, particularly those in IUCN categories V and VI, will be associated with landrace cultivation. However most, but not all, existing protected areas have been established to conserve habitats or mega-fauna rather than crop genetic diversity: thus the presence of CWR is a matter of coincidence and landraces in most cases are unlikely to have been recognised as being of conservation value.

Unless CWR species are coincidentally keystone or indicator species, they are unlikely to be actively managed. Instead, the management of crop genetic diversity is usually passive and individual populations may possibly even decline or be lost without changes to the management plan being triggered.

This lack of information on the status of CWR in particular has led to the development of methodologies for both national CWR strategies and of CWR strategies for individual protected areas; as such these represent the first steps in ensuring the effective *in situ* conservation of CWR within protected area networks. Although both strategies are interconnected they can also be distinct activities with quite separate goals:

- A national CWR strategy developed for an individual country will aim to ensure the conservation of the maximum taxonomic and genetic diversity of the country's CWR both within and outside protected areas (see figure 4).

- In an individual CWR protected area strategy, the aim will generally be to ensure the conservation of the maximum CWR taxonomic and genetic diversity within the protected area – this is addressed in the next chapter.

A national strategy is clearly more extensive and will have policy implications for national conservation and management agencies, and if properly carried out and implemented will lead to the conservation of priority CWR taxa in key protected area sites. Strategies for individual protected areas may be seen as more focused and practical in terms of conserving CWR, and may involve the identification of CWR found in a single, existing protected area and possible adaptation of the protected area conservation management plan to include CWR.

Thus, the national phase is composed of various steps that lead to the selection of key protected area sites, but must also be linked to multiple applications of individual protected area CWR strategies to ensure the maximum taxonomic and genetic diversity of the country's CWR are conserved. All protected areas are likely to contain CWR but some will be regarded as Important CWR Areas where CWR diversity of national importance is concentrated. Other protected areas may not be considered of national importance but in some cases it may be important to highlight the CWR found within them to raise the public profile of those reserves.

In many countries development of the national CWR strategy is likely to be a priority for the Ministries dealing with agriculture or agriculture research centres. However, the implementation of strategies is likely to involve several partners, such as the Ministries responsible for the Environment, or Protected Area Agencies and possibly Ministries dealing with forestry if they have responsibility for protected area management. Implementing a national CWR strategy may therefore involve several Ministries working together to ensure success. Experience has shown this in itself is a challenge when developing a national CWR strategy, however where these strategies have been implemented successfully cross-sectoral collaboration has been shown to be key.

National CWR strategy

There is no one method of developing a National CWR Strategy; each is likely to be unique because of questions over the conservation resources available, the amount and availability of baseline biodiversity data and which agency is responsible for developing the strategy (e.g. agricultural or environmental, formal or NGO sector). However, the process can be seen as a series of steps that do not necessarily always have to follow the same predefined order (see figure 4 below). However, this path was followed for both the generating of the UK CWR Inventory[414] and highlighting where in the UK genetic reserves should be established in existing protected areas[415].

- **Step 1: Identify national botanical diversity**

The first step is to draw together information on existing botanical diversity by identifying a national botanical checklist. Most countries will have some form of floristic checklist, even if relatively old or incomplete. The useful information on floristic checklists for any target area can be identified using two country-based lists of the world's floras: Davis *et al.*[416] and Frodin[417]. Prendergast[418] also lists other published sources of information on wild species. For areas where there is no adequate flora or the flora is written in an unfamiliar language, it may be possible to make use of that of a neighbouring region. Thus, for example, the Flora of Turkey lists many of the species found in Syria but it has to be recognised that this may lead to confusion as there will be taxa present in neighbouring countries that are absent in the target country and vice versa. Details of status, including rarity, will also sometimes be available on global or national red lists.

- **Step 2: Carry out a national inventory of Crop Wild Relatives**

Having established the national botanical checklist, the CWR included in the national list can be extracted after applying a definition of a CWR. Maxted *et al*[419] has proposed a precise definition of a CWR (see page 22), but its application requires detailed knowledge of the taxonomy and / or genetic diversity of each CWR taxon, and therefore presents difficulties when applied to an entire country's flora. Broadly speaking, those taxa found in the same genus as a crop are necessarily CWR taxa by virtue of their close relationship with the crop, so the process of identifying CWR at national level is one of identifying which crop genera have representatives present in a country and then extracting these genera from the national botanical checklist. For agricultural and horticultural crop genera (including cultivated medicinal and aromatic plants, but excluding forestry and ornamental species), Mansfeld's World Database of Agricultural and Horticultural Crops can be utilised, along with other crop genus data sources for forestry and ornamental crops if required[420],and this crop genus list can be used to match against a regional or national botanical checklist[421]. In addition, many countries have studies of uses of wild harvested crops, which can provide valuable information in refining the inventory.

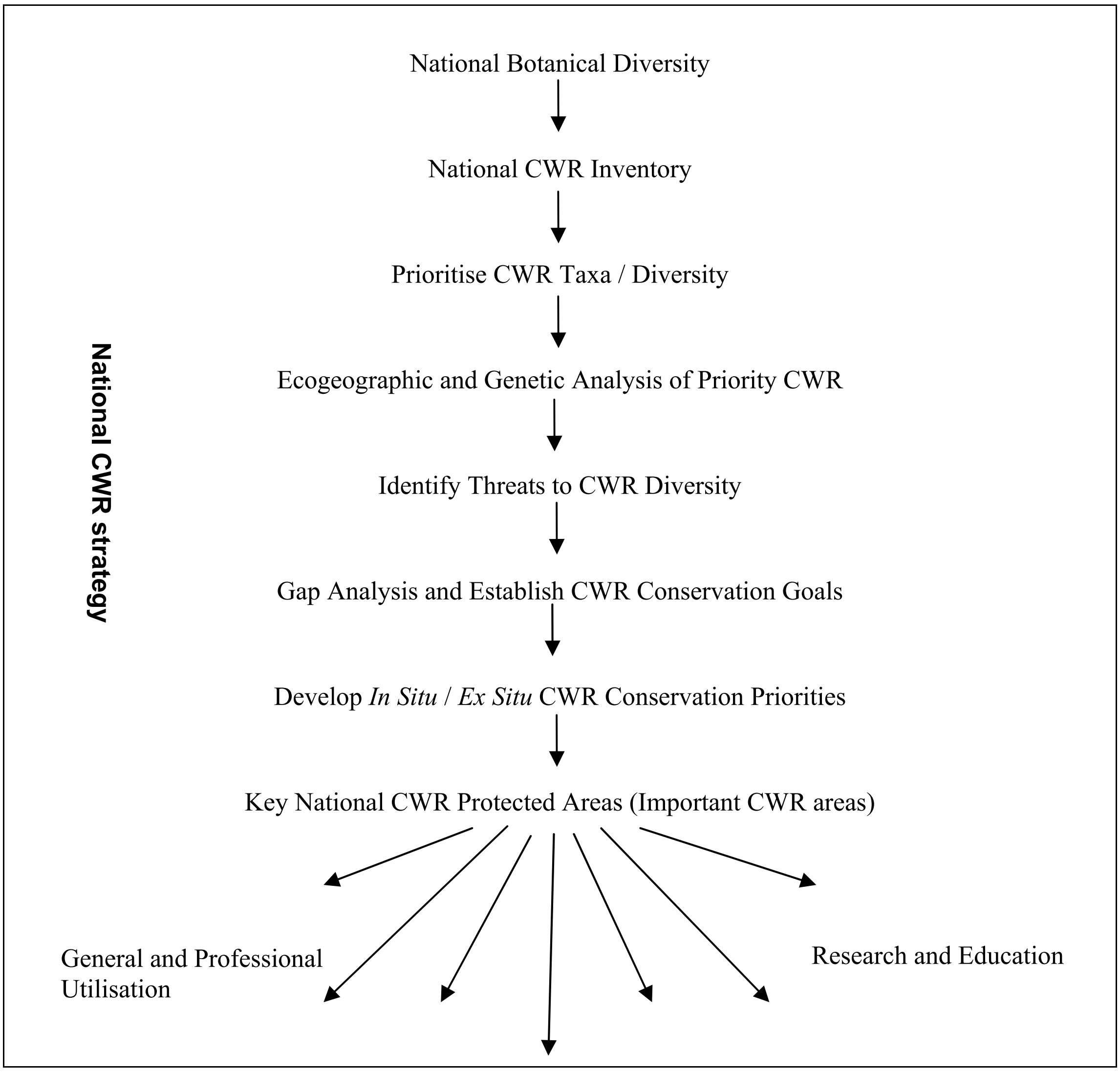

Figure 4: Development of National CWR Strategies

- **Step 3: Prioritise CWR taxa / diversity**

Applying such a broad definition of a CWR will inevitably result in a National CWR Inventory containing a relatively large number of taxa, even for a country like the UK that is regarded internationally as floristically poor. Therefore, further analysis is needed to prioritise those taxa that are the most important and / or that require the most immediate conservation action; in other words a strategy for how best to utilise the available conservation resources. Opinions vary as to how this prioritisation should be undertaken, and it is inevitable that prioritisation will differ according to needs within a region as a whole, an individual country or specific organisation within a country. Biodiversity conservationists may, for example, have different views to plant breeders or to foresters or horticulturists. The various factors that can be used to ascribe 'value' and thus prioritise taxa for conservation, include:

– current conservation status
– socio-economic use
– threat of genetic erosion
– genetic distinctiveness

- ecogeographic distribution
- biological importance
- cultural importance
- cost, feasibility and sustainability of conservation
- effectiveness of conservation legislation
- ethical and aesthetic considerations
- priorities of the conservation agency[422]

Out of this extensive array of factors there is some consensus for prioritisation on the basis of two key issues: economic value and relative threat[423,424]. To assess economic value would at first appear simple but there are various ways of estimating comparative economic value by, for example, using crop product market value, area harvested, yield or whether the crop is native to a particular country. Perhaps surprisingly it is sometimes difficult to obtain this information but a country's Ministry of Agriculture may have such statistics. However economic value is assessed, those CWR species with more value will be awarded high conservation priority. The threat assessment used in prioritisation is likely to be based entirely on existing threat assessments. However, once broad CWR priorities have been established it will be useful to undertake the threat assessment of all prioritised taxa to provide a clearer picture of overall threat assessment for each CWR species. Step 5 below also considers threat in the context of areas prioritised for CWR conservation.

- **Step 4: Ecogeographic and genetic analysis of priority CWR**

Once a priority list of CWR species has been identified there is a need to collate the ecogeographic and genetic diversity information that is available to assist in the formulation of the CWR conservation strategy, i.e. to identify the most important places in the country or region for CWR and where their conservation can be sustainably assured. This will involve the collation and analysis of all available ecological, geographic, genetic and taxonomic data sets obtained from the literature and from the passport data associated with herbarium specimens and germplasm accessions, and also possibly from novel studies. These data are ecologically and geographically predictive in that they aid the location of the CWR taxonomic (inter-taxa) and genetic (intra-taxon) diversity to be conserved.

The final outcome of an ecogeographic and genetic diversity analysis should be a set of areas with high concentrations of the priority CWR species, possibly identified using GIS analysis of ecological, geographic, genetic and taxonomic data sets. These areas might be considered akin to the broader taxonomic 'important plant areas' (Target 5 of the CBD Global Strategy for Plant Conservation[425]) and could be referred to as 'Important CWR Areas'. (See Case Study on the African *Vigna* on page 85).

- **Step 5: Identify threats to CWR diversity**

As well as assessing threat in relation to prioritising CWR taxa, there will also be a need to assess threat in terms of its impact on the important CWR areas identified. In developing a strategy for a region or country's important CWR areas there will be a twofold requirement:

- To focus conservation effort in areas most suitable for CWR conservation, i.e. those which are least threatened by such factors as the introduction of new varieties of crops, civil strife, habitat fragmentation, over-exploitation, over-grazing, competition from exotic invasive species, climate change and urbanization

- To eliminate or minimise threats to CWR taxa in places where there is a real prospect of genetic erosion or extinction. This will involve some form of comparative assessment of the various putative causative factors amongst important CWR areas.

In other words as an insurance policy conservation effort should be divided between areas where there is the greatest chance of success and areas where immediate threats make a conservation response imperative. Such an approach is particularly important when considering the impacts of climate change. If climate changes as some models predict, there is a possibility that current reserve selection methods might not prove adequate to ensure species' long term persistence[426]. IPGRI, for example, is currently undertaking a modelling study on the impact of climate change on the wild relatives of rice, peanut, *Vigna* and potato. Preliminary analysis shows that climate change will have impacts on all taxa within the next 50 years.

Various methodologies exist for identifying both immediate and underlying threats at national, regional and local scale, including threats to individual protected areas. For example, The Nature Conservancy's Conservation Action Planning[427] includes detailed methodologies to identify and rank threats, WWF's Root Causes assessment method proposes a framework for assessing underlying causes of pressure[428] and the WWF RAPPAM methodology for assessing status of protected area systems includes an innovative threat assessment technique[429].

- **Step 6: Carry out a gap analysis and use this to establish CWR conservation goals**

Conservation planners use the term "gap analysis" to describe methods of identifying biodiversity (*i.e., species, ecosystems and ecological processes*) not adequately conserved within a protected area network or through other effective and long-term conservation measures[430]. Gap analysis has developed in response to recognition that protected area systems of all types and in all parts of the world currently do not fully protect biodiversity[431].

Gap analysis in this traditional sense is usually applied to fairly large areas. In an ideal situation it would be applied across the whole of an ecologically defined region (such as an ecoregion), because this allows decisions about conservation to be made with the best available information and on the basis of ecological rather than political boundaries in order to ensure that the needs of biodiversity conservation are met. In practice however gap analyses are also frequently carried out for countries or even smaller areas such as states or provinces. The Convention on Biological Diversity requires, in its Programme of Work on Protected Areas, that signatory states carry out national gap analyses as part of their efforts to develop ecologically representative protected area networks. However simple or complicated, cheap or expensive, all gap analyses should follow a number steps (see figure)[432].

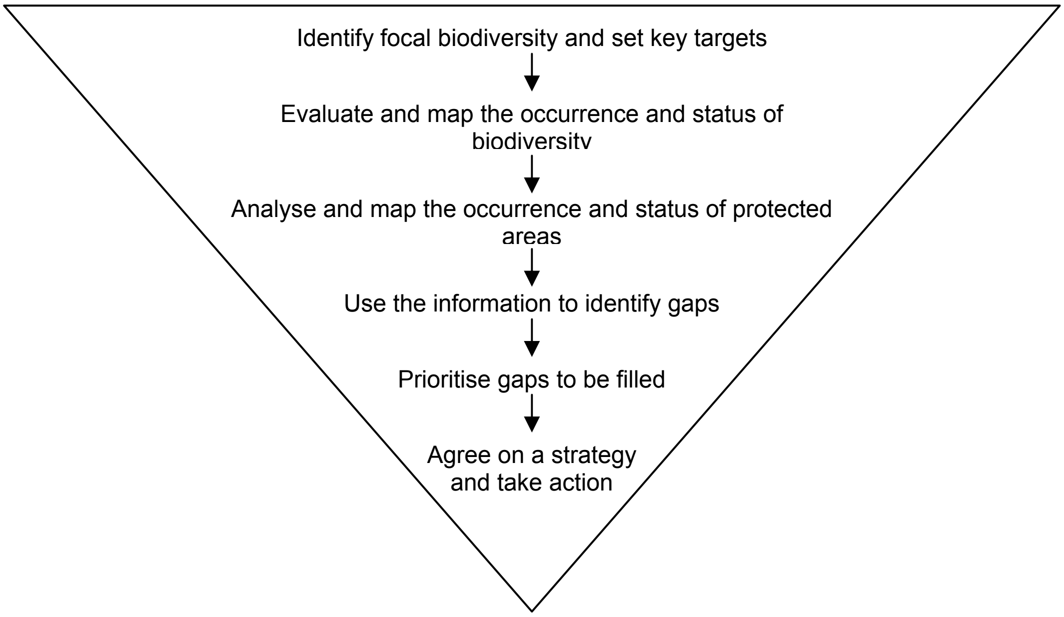

Figure 5: Key steps in a protected area gap analysis

Most of these steps have already been included above for developing the CWR strategy. The next stage is to use the available information to identify conservation gaps. Gap analysis in relation to CWR involves a comparison of natural *in situ* CWR diversity with the diversity that has been sampled and/or conserved either *in situ* or *ex situ*[433]. This involves a three step process:

- reviewing the natural ecogeographic distribution and genetic diversity inherent within and between the target taxa
- reviewing ecogeographic distribution and genetic diversity currently conserved either *in situ* or *ex situ* by current conservation actions
- comparison of inherent and conserved ecogeographic distribution and genetic diversity of target taxa to highlight component(s) of inherent diversity not currently adequately conserved, i.e. remaining protection gaps, where important species or genera are not sufficiently represented in protected areas or adequately sampled *ex situ*.

The review of genetic representation is an ideal that may only rarely be possible because of insufficient knowledge of genetic diversity within particular species or genera; often there will not be enough time or money to collect this for the analysis. Therefore in the absence of 'real' genetic diversity information it will be necessary to employ the proxy of ecogeographic diversity. In other words, if a priority CWR species is distributed throughout a country then it is assumed unless there is evidence to the contrary that genetic diversity is partitioned in relation to ecogeographic diversity and sampling from the maximum diversity of locations will result in the most genetically diverse sample. Therefore, if no diversity is conserved in the West of the country, for example, then this is identified as a gap which requires further conservation action.

- **Step 7: Develop *in situ* / *ex situ* CWR conservation priorities**

A CWR gap analysis would take the full list of important CWR areas known to contain significant CWR species and identify which combination of these contains the maximum or 'best' sample of CWR species in the minimum number or size of protected areas. The first protected area chosen is likely to be the site that contains the highest concentration of actual or predicted species richness. The second protected area chosen is not necessarily the site with the second highest species richness because the species present in the second site may simply duplicate those in the first site selected, so the second site selected is the protected area with the highest concentration of actual and predicted species richness *not present* in the first selected protected area, and so on. There is however likely to be some duplication of species between protected areas because of the widespread distribution of common species, so it is also advisable to select protected areas located in diverse locations, for example in the extreme North and South of the country, at sea level and on high land, etc.

- **Step 8: Draw up a list of key national CWR protected areas**

At the end of this process, the last stage is to draw up a list of critical protected areas for CWR conservation, including both existing protected areas and new target sites for protection. For the UK the five key sites where genetic reserves should be established are shown in Figure 6.

At this stage, the strategy needs to consider the costs and benefits of different options, for example creation of new protected areas as opposed to improving existing reserves. The location and establishment of specific CWR genetic reserves *within* existing protected areas is one option that may also help to avoid resource expenditure on purchasing new sites for protection. However, the creation of new protected areas for CWR conservation should not be excluded from consideration, especially as many CWR species are located in disturbed habitats that may not previously have been considered appropriate for the establishment of protected areas. Although the actual number of specific CWR genetic reserves will ultimately be dictated by the financial resources available for CWR *in situ* conservation, it is important to appreciate that protection of any species within just one protected area is extremely unlikely to conserve an adequate or representative amount of the total genetic diversity for that species. The number of protected areas required to achieve this will very much depend upon the species in question as different species have their genetic diversity apportioned within and amongst populations in very different ways.

Figure 6: The numbers of priority CWR species found at each of the five best Sites for CWR in the UK[434]

Once established, the key national CWR protected areas provide an opportunity to monitor and assess short and longer term changes in CWR diversity, and adapt management strategies as required. A national CWR strategy should be augmented and supported by individual strategies for priority protected areas. As mentioned above, many protected areas are protecting crop genetic diversity at best by accident and therefore often not affording protection as effectively as possible. Protected area specific strategies may include surveys to identify CWR and a series of tailored responses for their conservation.

Managers of other protected areas may also wish to consider CWR conservation as part of their management activities. When deciding management objectives a first step could be to consult the National CWR Inventory and match this against the species list for the protected area, generating a list of which CWR species are found at the site. This list can also be compared with any national priorities for CWR conservation and an assessment of importance of CWR conservation against other conservation objectives can be made, and appropriate management resources allocated. Managers can then if necessary adapt the management of a site or sites to facilitate CWR conservation, if the management objectives do not already include these taxa.

- **Step 9: General and professional utilisation**

The establishment and management of key national CWR protected areas is not an end in itself. There needs to be an explicit link, especially for socio-economically important species like CWR, between genetic conservation and utilisation; genetic conservation must facilitate utilisation, either now or in the future. This point is highlighted in the Convention on Biological Diversity and in this context any utilisation should be ‘sustainable’ and “meet the needs and aspirations of present and future generations”.

The national utilisation of the material conserved in the protected area may be divided among general and professional users. The general users of a protected area are the population at large, and whether local, national or international, their support may be essential for the long-term political and financial viability of the protected area. The ethical and aesthetic justification for species conservation is of increasing importance to professional conservationists, and in many cases the general public will ultimately finance the establishment and continuation of the protected area through taxation; it is important that the reasons for, and benefits of, such reserves are carefully explained. In other cases, protected areas that prioritise CWR may be under private ownership or operated through some kind of community management. Many smaller reserves are already operated by private individuals or NGOs and the opportunities for interest groups supporting food security have to date scarcely been addressed. In time, commercial agricultural interests may also be prepared to support such forms of *in situ* conservation. Lastly but not least, many indigenous peoples and local communities traditionally ‘conserve’ important plant species for their own uses and the importance of such community conservation areas (CCAs) is increasingly recognised; some of these groups will be interested in the potential advantage of having such areas included in official protected area networks, but others may not.

In the case of state-run protected areas, some members of the general public may wish to visit and this should be clearly encouraged as an educational exercise. When this is likely, the protected area design should take into account the needs of visitors, by way of visitor centres, nature trails, lectures, etc. Visitors may also bring additional income to the protected area itself by paying for guided tours and information packs. If the reasons for protection and the importance of CWR are carefully explained, such visitors can in turn become important proponents of *in situ* conservation.

Professional utilisation of CWR species conserved in a protected area will be similar to professional utilisation of *ex situ* conserved germplasm. One of the main disadvantages of *in situ* as opposed to *ex situ* conservation of CWR is that it is more difficult for the professional user to gain access to the CWR material; seed is only available for a proportion of the year for instance[435]. To avoid or lessen this problem those managing the protected area should attempt to characterise, evaluate and publicise the germplasm held in the protected area, possibly in collaboration with those likely to use the material. Protected area agencies and individual managers have an incentive, in the same way as gene bank managers, to promote utilisation of the material in their care.

- **Step 10: Research and education**

Protected areas can also act as a general research platform for field experimentation. There is a real need for a better understanding of species dynamics within protected areas to help to improve the sustainable management of the specific taxa that they include, but protected areas can also serve as a more general experimental tool for ecological and genetic studies of *in situ* conserved species. However, caution is needed to ensure that experiment does not lead to increased threat to taxa. Notwithstanding, research activities should be encouraged as they provide another use for the material conserved and another justification for establishing the protected area.

Specifically in terms of research priorities, the establishment of the key national CWR protected areas will clearly facilitate national monitoring of CWR species. The Conference of the Parties to the CBD adopted a strategic plan (decision VI/26), committing the parties to a more effective and coherent implementation of the three CBD objectives, specifically to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth. Subsequently in decision VII/30 the Conference of the Parties adopted a framework to facilitate the assessment of progress towards the 2010 targets by identifying indicators of biodiversity change, one area of which will focus on “trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance”. This requirement would be met by the use of key national CWR protected areas as part of the international and national monitoring process. Protocols for managing individual CWR protected areas will necessarily involve routine monitoring of taxonomic, population demographic and genetic diversity changes. Analysing subsequent monitoring data sets at a national scale will provide information necessary for the assessment of taxonomic, population demographic and genetic diversity changes; if this were linked to the identification of drivers of change, it would mean that action could be taken to reduce current rate of CWR loss, and enable modelling and prediction of future changes associated with future habitat management scenarios.

In many cases, the work of professional users, the general public and local people can be linked through partnership within Non Governmental Organisations, especially those involved in sustainable rural development, conservation volunteers or use of resources in accordance with traditional cultural practices. Raising public and professional education and awareness of the need to conserve CWR will help to facilitate the creation and management of specific protected areas as well as more general support for conservation sustainability. All partners will therefore share the goals of sustainable use of biological resources, taking into account social, economic, environmental and scientific factors, which form a cornerstone to the nations' proposals to implement Agenda 21.

Chapter 5: Implementing Crop Genetic Diversity Conservation in Individual Protected Areas

A national strategy to conserve crop genetic diversity will help to identify where conservation effort should be focused and eventually to suggest a network of new and existing protected areas that will together help to protect agriculturally important biodiversity. A second element in a conservation strategy, identified at the start of chapter 4, is developing plans aimed at specific protected areas. Some of the approaches and tools to achieve this are described below.

It is worth recalling that protected areas can have a variety of management approaches and that within a protected area system a series of quite different types of reserves may be appropriate. A broad typology is presented below:

Type of protected area	Details
Strictly protected areas	Usually quite small area, strictly protected from human interference to preserve important species, either as a separate reserve or as a zoned area within a larger protected area
Sustainable resource use protected areas	Larger area, managed for a variety of values (e.g. wildlife, recreation, ecosystem services) with important CWR existing inside and subject to particular management attention
Intensively managed area	Protected area, frequently small, where management is needed to maintain crop genetic diversity, either through interventions by protected area staff or by maintaining traditional agricultural systems as part of the protection regime
Extensively managed area	Protected area under some form of low intensity, extensive management, such as a Community Conserved Area or an area with landscape designation for protection

Table 4: A typology of protection types for protected areas conserving crop genetic diversity

Although a proportion of agricultural genetic material can be conserved as one part of broader protected area management, in many cases efforts need to be augmented by some reserves set up specifically to maintain crop genetic diversity. Protection strategies include protection via active management; the traditional concept of a protected area managed so that human intervention at a site is kept to a minimum, is not always appropriate for crop genetic diversity conservation. Many CWR species are found in pre-climax communities and anthropogenic habitats, meaning that human intervention may be essential to the maintenance of a healthy CWR population. Such protected areas can be under a range of governance types: state, private, NGO or Community Conserved Areas and some may profit from co-management.

In situ conservation of landraces usually takes place on-farm, within indigenous land territories, community-owned lands, or in home gardens. Often these will be outside protected areas. However, there are examples (see case studies on Mexico, Vietnam and Peru) were the goals of protected area management overlap with the conservation needs for landrace conservation. The International Plant Genetic Resources Institute (IPGRI) has developed *A Training Guide for* In Situ *Conservation On-farm*[v], which provides national programmes basic technical skills and tools to build institutional capacity and partnerships for an on-farm conservation programme.

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[v] The report can be downloaded at: http://www.ipgri.cgiar.org/publications/pubfile.asp?ID_PUB=611

Although not written with protected areas specifically in mind the guide discusses the information necessary and the practical steps for the implementation of on-farm conservation, as well as the importance of such an initiative[436]. The guide's chapter on preparation, site selection and participatory approaches include guidance on:

1. Identification of key crops for conservation
2. Review of existing information sources
3. Training local research teams in participatory methods
4. Defining criteria for site selection
5. Diagnostic surveying to generate information for site selection
6. Site selection
7. Community sensitization
8. Selecting a sampling regime for data collection.

Relic stand of wild sorghum North Aïr, Niger

CREDIT: © WWF-Canon / John E. Newby

Conservation of landraces is likely to be commonest in IUCN management Categories IV-VI, with Category V, protected landscapes, being particularly suitable. Indeed, one of the objectives of Category V protected areas is "to encourage the understanding and conservation of the genetic material contained in domesticated crops and livestock"[437]. For some communities the establishment of a protected area can help to protect indigenous or traditional lifestyles and farming practices, including the protection of landraces. Initiatives such as those highlighted in the case studies from Mexico and Peru provide examples of how conserving the diversity found in local landraces requires the maintenance of both the cultural techniques used by farmers and of the broader social context within which they are farming[438].

It is likely that protected areas important for CWR will be sited in existing protected areas, or created through cooperative schemes with private land owners, indigenous peoples, or on community owned lands. The reason for this assumption is that there are generally limited financial or land resources available for setting aside public lands for this purpose or for purchasing new protected area sites. Secondly, some areas prioritised within crop genetic diversity conservation prioritisation exercises are likely to overlap with the existing network of protected areas within a country and the establishment of a parallel network of CWR reserves would not be economically justifiable or practically advisable.

If an existing protected area is selected as a national CWR protected area then the management plan could be adapted to improve genetic conservation of CWR, possibly in part of the wider reserve, therefore saving some of the costs of protected area establishment and maintenance. Although these assumptions will normally hold true there are likely to be circumstances when the areas identified as key for the conservation of crop genetic diversity will not overlap with existing protected areas and there will be a necessity to establish new sites. Guidelines for these more specialised protected areas already exist[439], and thus the following discussion looks solely at crop genetic diversity, and specifically again at CWR, within existing protected areas.

The following steps outline an approach to implementing such protection in existing areas; they are described in greater detail below.

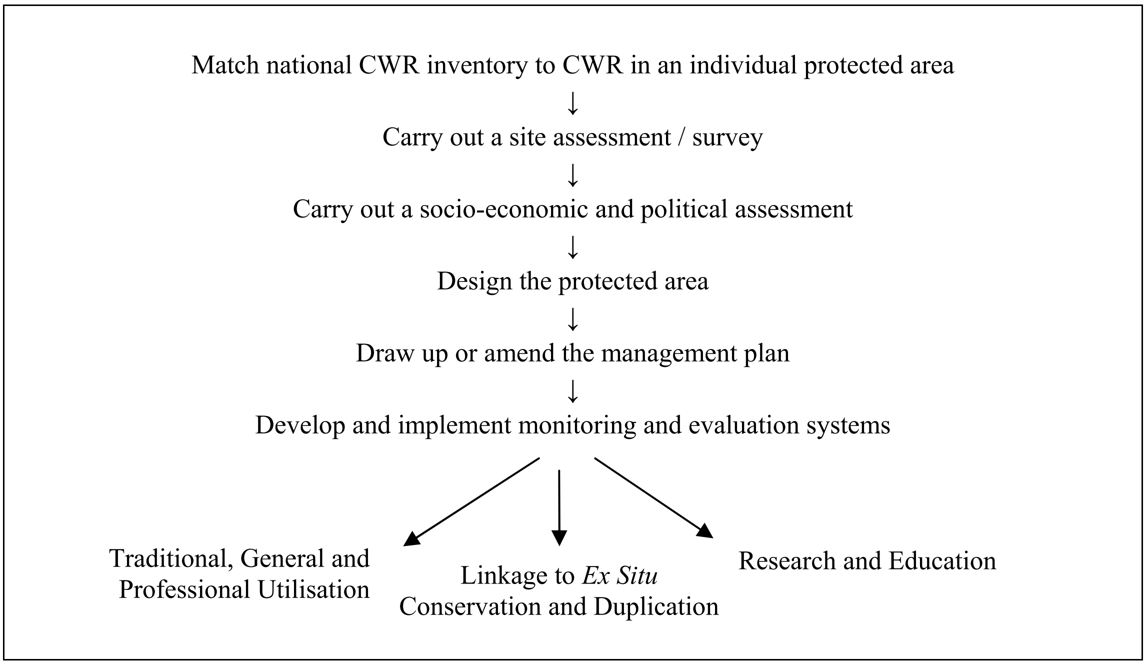

Figure 7: Steps in implementing CWR conservation within protected areas

- **Step 1: Match the national CWR inventory to CWR in protected areas**

Managers of ‘broad-spectrum’ protected areas may wish to address CWR conservation in the protected area they manage; indeed they will increasingly be encouraged to consider this as part of their commitment under international conventions. A first step could be to consult the National CWR Inventory, where one exists, and match this against the species list for the protected area, thus generating a list of which CWR species are found at the site. This was done for the UK by prioritising the initial list of 1955 UK CWR on the basis of threat, socio-economic importance and current conservation status to generate a priority UK CWR list, then matching this priority list of 250 CWR against the species lists for existing UK protected areas[440]. Individual protected area managers could just as easily match their own reserve species list with the national CWR inventory to establish which CWR species are present in their reserve. Then once this is established they could adapt the management of the site to facilitate CWR conservation if the current management objectives do not directly include management goals which ensure CWR conservation. The manager may also wish to publicise the presence of CWR species in the protected area to the general public as a means of emphasising the protected area’s role in wealth creation and food security. For example, Sri Lanka has created a list of wild *Oryza* (rice) species in its protected areas in order to sensitize their managers to CWR conservation needs[441].

- **Step 2: Carry out site assessments / surveys**

In most cases, some further assessment will be needed to refine decisions about the location of protected areas. Although the ecogeographic techniques described in the last chapter can predict broad areas of potential genetic diversity where CWR protected areas could be sited, especially when used in conjunction with geographical information systems, they will not provide the precise location for national CWR protected areas. To establish which of the existing protected areas is most appropriate, surveys of taxonomic diversity are needed (including numbers of taxa and variation within taxa) and this work will increasingly involve assessment of genetic diversity using molecular techniques, comparing the relative diversity in different sites. The ecogeographic survey should conclude with a clear statement of the habitat requirements of the target taxa, which will need to be reviewed in the light of the potential sites being considered, to match habitats with species of particular concern and thus choose the best areas. The overriding criterion is to maximise the conserved genetic diversity of the various taxa by maximising their actual population sizes, as it will rarely prove possible to determine the effective population size and hence the minimum viable population size necessary for effective conservation.

The relative management cost of CWR reserve establishment also affects selection of alternative sites. If faced with a choice of equally suitable sites and differing establishment costs, it makes sense to choose the least expensive. The same logic would also apply to the running costs of the reserve once established. This may necessitate the application of some form of cost-benefit analysis prior to actual reserve selection.

To facilitate sustainability of CWR conservation it is strongly advisable that more than one protected area is designated for any target taxon and that the protected areas should be selected to complement each other. This will permit the conservation of diverse ecotypes within the conservation of the gene pool. Where possible, sites should be selected to encompass the widest possible range of ecogeographic conditions in which the target taxon is located. Also, each protected area selected should be sustainable for the foreseeable future and not under threat of developments, such as roads, urbanisation, dams, etc. The reserve must be accessible to the manager and have clear rules for potential germplasm use, while being secure from deleterious changes caused by human or natural intervention (e.g. increased or decreased levels of fires, wild grazing animals or roads).

- **Step 3: Assessment of local socio-economic and political factors**

The establishment of key national CWR protected areas, even in existing protected areas, or publicising of CWR species at existing sites, is likely to result in additional costs, and the next stage in assessment is thus to identify likely costs and ways of meeting these. At its simplest there will be costs associated with additional monitoring to ensure that the management regime is actually benefiting CWR populations, but there may also be costs associated with specific management interventions required. If the protected area is designated as a key national CWR protected area then the impetus to designate the site has by definition been made at a national level and therefore may come with some governmental funding support. However, individual protected area managers wishing to promote CWR species may have to bear additional costs that might be offset by increased use and greater public appreciation of the protected area.

Many protected area networks are established on a voluntary basis, but the establishment of key national CWR protected areas is likely to be more sustainable if there is a legal obligation for their establishment and legal protection once established. Even though moral and legal obligations may have been recognised, government policies often need adjustment because many such policies provide incentives to mismanage the environment, especially in the agriculture and forestry sectors.

There is a requirement under the Global Strategy for CWR Conservation and Use (available at http://www.pgrforum.org) to establish a network of key international, regional and national CWR protected areas where important CWR are to be systematically conserved and sustainable development is to be promoted. At present the Strategy is under international review but in due course it is expected that it will be adopted by the SBSTTA of CBD as means of promoting global CWR conservation.

International or national donors need to be found to sponsor the establishment of key national CWR protected area networks. There is also a need to build on the existing scientific knowledge base to develop standard CWR conservation protocols, summaries of organisational needs and to train staff so that CWR conservation can be applied in diverse developed and developing countries. Ideally, in time the national CWR conservation strategy will form a routine element in the national biodiversity action plan. Appropriately qualified and experienced staff remain in short supply or unavailable in many countries, and without them the availability, utilisation and flow of benefits resulting from CWR conservation may be constrained.

Assessment should look beyond costs to include potential beneficiaries, particularly amongst local communities. In cases where there are clearly accepted and understood benefits in maintaining agricultural biodiversity, local people can sometimes offset a substantial amount of the costs through voluntary conservation and monitoring efforts.

- **Step 4: Protected area design**

Although there are many protected areas without fully up-to-date and well implemented management plans, most areas are managed in accordance with some form of planning document and many include a variety of zones in which different management objectives are followed[442]. There are often core areas with a stable habitat, surrounded by zones allowing a wider variety of uses and thus differing management needs. Many protected areas also have buffer zones, sometimes outside the legally protected area, where uses are complementary to the conservation objectives of the site. If a CWR is to be prioritised within an existing protected area, changes in zoning may be needed along with the creation of additional highly protected sites within the overall protected area boundaries.

It has been suggested that for CWR conservation the core area should be sufficiently large to accommodate as many as 5,000 potentially inter-breeding individuals of the CWR species to ensure the long term viability of the population[443]. This figure however is severely influenced by various factors which can alter the figure by orders of magnitude either way. The actual design of the CWR conservation area involves consideration of various factors, such as structure, size, whether a single large or multiple smaller sites are best for the target taxon, the use of corridors, reserve shape, environmental heterogeneity and potential user communities[444].

Individual species have specific design requirements. Practical experience of collecting CWR for *ex situ* conservation has shown that CWR often exist in small isolated populations and, therefore, the site with the largest population should be selected and efforts taken in the management plan to encourage maintenance of a large CWR population. Alternatively, rather than designating a single reserve site it may be possible to nominate a network of smaller reserves, each sited in a distinct environment that would better enable conservation of different ecotypes, and which would facilitate gene flow and migration between the component reserves via pollen or seed dispersal. In this way, a network of small reserves can act as a meta-population.

The concept of environmental heterogeneity and disturbance should be built into the CWR protected area design. Genetic diversity in CWR is often associated with ecogeographic diversity so that when selecting sites for establishing a key national CWR protected area, heterogeneous sites should be given priority over more homogeneous areas, both relating to spatial variation and temporal variation (e.g. taxa contained in the reserve with different flowering times). As noted in previous chapters, CWR are also often associated with more disturbed habitats than plant species associated with climax vegetation. Therefore the management regime may necessitate conserving the habitat disturbance, which results in the desired patchwork of diverse habitat types (see case study from Mexico, page 82). The minimum dynamic area for CWR conservation has been defined as the smallest area with a complete, natural disturbance regime[445]. This area would maintain sufficient internal colonisation to balance natural extinctions. As the majority of species are not exclusive to one habitat, the maintenance of reserve heterogeneity will promote the health (genetic diversity) of the full gene pool as represented in multiple populations or metapopulation.

The need for continued habitat heterogeneity is a factor that should be considered when formulating the reserve management plan. If fire, for example, was a natural causal agent of habitat disturbance and was seen to benefit the CWR species, then the reserve design should permit continued use of fire, though often controlled by the manager to ensure that the effects were beneficial. Controlled burning is a management tool in many protected areas and techniques are long established and understood.

As mentioned earlier, the ultimate rationale behind CWR conservation is potential human utilisation; therefore the user communities must be considered when designing the reserve, whether in terms of permitting or safeguarding sustainable exploitation by traditional farmers, access to plant breeders where appropriate or building facilities for eco-tourists or scientific visitors. User will have different view of the reserve and a different set of priorities. The requirements of each group should be surveyed before the reserve is established and their needs considered when establishing the management regime.

Step 5: Amendment of the protected area management plan

The original protected area designation is likely to have been based on a charismatic fauna, rare or threatened taxa, or a beautiful landscape; few protected areas have been established because they contain priority CWR taxa. So when designating key national CWR protected areas, the sites are likely to have been selected because they contain abundant and hopefully genetically diverse CWR populations, but the management of these populations may possibly conflict with the management required for the species that the protected area was originally designated to conserve. Therefore, amendment to the protected area management plan (or operational plans) to accommodate the new CWR priority need to be careful implemented[446] to avoid any detrimental effects on other species. (In cases where no management plan has been prepared – which are by no means uncommon – then the needs of CWR still have to be balanced with those of other factors whenever a plan is prepared.)

The first step in formulating the revised management plan is to observe the biotic and abiotic dynamics of the site for both CWR and non-CWR species. Species present in the ecosystem need to be surveyed to help understand the ecological interactions within the reserve. A clear conservation goal should be decided and a means of implementation agreed that may involve some compromise between the priorities for CWR and non-CWR species conservation.

Changes in population levels and density are a natural component of community dynamics but in the majority of places today humans have the most dramatic effect on communities, for example, through urbanisation and pollution, or changes in agricultural and forestry practice. Therefore the management plan must be flexible enough to accommodate superficial anthropogenic factors, but recognise those factors that could seriously threaten the levels of the target CWR and non-CWR populations.

The management of any protected area involves an element of experimentation, and it is unlikely that the ideal management regime will be known when initially establishing the reserve. For example, how can the appropriate level of grazing in the protected area be estimated prior to initiating the management plan? Knowledge of the area and the current and historic grazing levels are important, but the actual level of grazing recommended once the reserve is established can only be known through scrupulous experimentation. Thus, the initiation of the amended management plan requires careful introduction combined with evaluation, revision and refinement in the light of its practical application. An increasing number of protected areas are now rejecting the old model of a fixed plan that was followed for many years and instead choosing to have flexible plans that are regularly assessed and amended as necessary.

- **Step 6: Develop and implement monitoring and evaluation systems**

The monitoring of selected taxa in key national CWR protected areas is likely to be the same as for other forms of protected areas. It involves identification of changes in the structure or size of populations of the target species within the reserve via transects or quadrats where selected taxa population characteristics are periodically assessed and where statistical analyses will indicate if any changes are needed to the management plan[447].

It is impossible to record and monitor every species or individual plant within a reserve, so managers are forced to select a sample of key indicator CWR and non-CWR species that, if effectively selected, will reflect an overall picture of the status of biodiversity in the protected area. The key indicator taxa are likely to include the most important CWR and non-CWR species, but may also include other selected plant and animal species, including keystone species without which the population of target taxa would decline, such as primary herbivores or necessary pollinators.

As the goal of CWR conservation is to retain the breadth of genetic diversity, monitoring of key national CWR protected areas may, where resources permit, require the use of molecular population genetic methods to measure genetic diversity. The technologies involved in the use of these markers and the acquisition of data derived from such markers for protected area applications may be criticised for being time-consuming and expensive, but this is rapidly becoming much less so. Consequently, if not now, then soon, we can expect that not only will data be collected *vis a vis* species lists, and density and range of individual species, but target populations within any reserve will also be assessed in terms of their true genetic diversity. Whether genetic markers will prove practical for repeated monitoring of populations within reserves is currently unknown. Their immediate value lies in accurately establishing the levels of genetic diversity between and within the potential populations and aiding the initial selection of populations to be conserved in a genetic reserve. Following the establishment of the reserve, loss of diversity could be directly deduced if the extent is known to which population numbers vary in sequential monitoring operations.

- **Step 7: Traditional, general and professional utilisation**

As discussed above, the establishment and management of key national CWR protected areas is not an end in itself. Because CWR conservation focuses explicitly on socio-economically important species there is a direct link from genetic conservation to utilisation. As a result, at both the level of the national CWR strategy and with strategies aimed at individual protected areas there is a requirement to address the two user communities, the general public and professional users. For many individual protected areas, there is an additional need to address a third community - the local, traditional users of the site. Protected areas are very rarely established in a vacuum, and instead there are likely to be local farmers, land-owners and other members of the community who may wish to utilise the proposed protected area site and who are likely to remain as neighbours. Their traditional use may be disrupted by the establishment of the protected area or CWR conservation area, unless this is carried out in cooperation with these communities. These local people may have historically harvested or collected from, hunted over or may simply have enjoyed visiting the site on which the protected area has been established. It is unlikely that any *in situ* conservation project could succeed in the absence of local support and it will definitely fail if the local population opposes the establishment of the protected area. Therefore, where traditional utilisation is compatible with conservation objectives, sustainable exploitation of resources by local, traditional user communities should be encouraged. However, to avoid negation of the conservation objectives, their access and harvesting, hunting, etc. may need to be regulated. There may be a need to compromise between traditional utilisation and conservation objectives to ensure the long-term success of the protected area[448]. Some level of trade-off and compromise is often required.

Considerable experience has been developed in approaches to collaborative management of protected areas over the last decade[449] and detailed guidance is available[450]. There are no simple formulaic methods of achieving agreement about natural resource use however, and each protected area and each community needs to be approached individually.

- **Step 8: Research and education**

The establishment of any protected area should be associated with research; the ideal management prescription is unlikely to be known from the first day the reserve is established and will be developed as a result of knowledge gained. Education is also a vital component, particularly when protected areas are being used for something that has immediate human benefits. Protected area managers should promote public awareness of the need for CWR conservation at their sites. It is a fact that the more protected area managers raise awareness of the need for conservation, the more sustainable their protected areas are likely to be[451]. Local people can become the most vociferous supporters of protected areas as long as they see the relevance of the conservation action to their lives. They may experience direct financial benefits to their community resulting from eco-tourists, schools and other visitors. This is likely to require the protected area manager to meet the needs of visitors, by way of visitors' centres, information boards, nature trails, lectures and various media information packs.

- **Step 9: Linkage to *ex situ* conservation and duplication**

It would be foolish to implement a national CWR strategy and establish key national CWR protected areas without a safety back-up to ensure the conservation of the germplasm in the protected area, particularly in light of projected climatic changes and their potential impact on the protected area networks; therefore this germplasm should also be sampled and deposited in appropriate *ex situ* collections. Although both *ex situ* and *in situ* techniques have their advantages and disadvantages they should not be seen as alternatives or in opposition to one another. The two strategies are complementary and just as a good gene bank manager will duplicate his or her collection in another gene bank, a good protected area manager should also duplicate his or her collection of CWR in appropriate *ex situ* collections.

By definition it is not possible to duplicate material from one reserve to another without the material being taken *ex situ*. But it is worth repeating here that it would again be unwise to entirely focus *in situ* conservation effort on a single reserve. Multiple reserves should be established, where possible, not to duplicate the conservation of the material *in situ,* but to maximise the genetic diversity that is being conserved. In this context, if the germplasm user does not have a specific requirement for material from a reserve, the gene bank may be seen to act as a staging post for those wishing to utilise the germplasm originally conserved *in situ*.

Chapter 6: Case Studies

Turkey: Increasing Protection for a Major Centre of Diversity of Cereals Crops

In some ways Turkey leads the world in its attempts to protect in situ *plant genetic diversity. It was the site of the world's first* in situ *gene conservation project, has a national plan for* in situ *conservation of plant genetic diversity and was the first country to identify its Important Plant Areas (IPAs) and Key Biodiversity Areas (KBAs). The reason for this predominance is the country's extraordinarily rich flora and its position within the so-called "Fertile Crescent" – one of the birthplaces of agriculture.*

Unfortunately, Turkey's biodiversity is also under threat and its protected areas do not provide an ecologically representative network for the conservation of biodiversity.

This case study considers Turkey's unique geographical position, which has made it a major centre of plant genetic diversity. In particular, it provides an overview of the conservation status of the crop wild relatives of cereals found in the country, and of the forests to which some species are closely aligned. Finally, it provides some suggestions, based on a series of projects to prioritise conservation efforts, on protection needs.

Introduction

Turkey has the richest flora in the temperate zone. 8,998 plant species were recorded in the *Flora of Turkey and the East Aegean Islands* in 1991[452], but the species count is increasing rapidly, with estimates putting the total species at 10-12,000. Indeed, according to Andrew Byfield, who helped identify Turkey's Important Plant Areas (see below), a new species is found in Turkey on average every 8 days and 20 hours[453]!

Four factors illustrate this diversity[454]:

I) Turkey contains three distinct plant geographic (or phytogeographic) regions which are broadly defined below:
Euro-Siberian: a narrow strip in the European part of Turkey, extending along most of North Anatolia[vi] (Colchic Provence and Euxin). The area is mainly forested and has the highest rainfall in the country.
Mediterranean: covers all areas bordering the Mediterranean and the Aegean Seas. Typically, Mediterranean vegetation is dense and composed of broad-leaved evergreen shrubs, bushes and small trees. This vegetation type dominates much of the area, although there are considerable differences in flora due to altitudinal change.
Irano-Turanian: the largest region, extending from Central Anatolia to Mongolia in the east. The climate is continental and generally steppe vegetation dominates[455].

II) Turkey has two Vavilovian centres of cultivated crop diversity 'the Mediterranean' and 'South West Asiatic Centre'.

III) Turkey has extremely high levels of endemism, about one third of all plant species, the highest numbers of which are found in the Irano-Turanian and Mediterranean regions.

[vi] Anatolia, is the Asiatic portion of contemporary Turkey extending from the Bosphorus and Aegean coast eastward to the borders of Georgia, Armenia, Iran and Iraq.

IV) Turkey is the gateway between Europe and Asia. Anatolia has been a major agricultural centre since the Neolithic Period and an important trading centre for thousands of years.

It is therefore not surprising that Turkey has a long history of agriculture and horticulture; archaeological evidence traces the earliest agriculture back to Anatolia almost 10,000 years ago[456] and this area is generally acknowledged as being where wheat and barley were first domesticated[457]. Turkey is thus a major centre of origin for cereals, with 25 CWR of wheat (*Triticum* and *Aegilops*), eight of barley (*Hordeum*), five of rye (*Secale*) and eight of oats (*Avena*)[458].

Turkey is also home to a number of wild relatives of vegetable species including many brassicas, wild celery (*Apium graveolens*), wild beet (*Beta vulgaris* ssp. *maritima*), wild carrots (*Daucus* spp.) and wild lettuce *Lactuca* spp) and legumes such as wild lentil species, peas and several chickpea species (*Cicer* spp.)[459]. Turkey is also described as a microcentre for other important foods including the almond, melon (*Cucumis melo),* cucumber *(C. sativus),* squash, pumpkin, marrow and courgette species, apple, pistachio, plums, pears and grapes[460].

Conservation status of cereal CWR

Cereals such as wheat and barley seem to have originated in or near woodlands and their wild progenitors can still be found in the oak forest belt of Southeastern Anatolia[461] and the pine, beech and Cilician fur forests of the southern Anatolia[462]. Forests once covered large parts of Turkey, but centuries of use and exploitation have reduced the area of large *intact* forest to some 12 per cent of the land area (forests and other wooded land cover some 27 per cent of the area), mainly in the major mountain ranges in the north and south[463]. These remaining forests receive little protection.

Turkey has at least 12 categories of protected areas, with a combined area of approximately 3.6 million ha, representing 4.6 per cent of the national landmass. However, the protected areas designated and managed according to the National Parks Law (No. 2873) with a primary objective of biodiversity conservation – Nature Reserves, National Parks, Nature Parks and Nature Monuments, corresponding to IUCN I-IV – cover a mere one per cent of the national territory[464].

Where areas are protected, the traditional focus of management is recreational, often to the detriment of its ecological integrity. Protection is however in great need, as unfortunately the list of threats to Turkey's floral biodiversity is long – over 4,500 nationally rare plant species are listed in the two national Red Data Books[465]. Threats include:

- overgrazing and other unsustainable agricultural practices
- unsustainable use of forests
- conversion of wetlands and other critical natural habitats (steppes) mainly to agriculture
- interference with the hydrological regime of wetlands for agriculture and other water use
- pollution
- hunting
- unsustainable harvesting of wild plants and tubers

The international importance of conserving CWR in Turkey provides a compelling argument for increasing protection in the country. Below, we examine the status of cereal relatives as just one example of the need and options for protection.

- **Types of protection**

Four types of protected areas are administered by the Ministry of Environment and Forestry's (MOEF) General Directorate of Nature Conservation and National Parks: National Parks (there are currently 36 parks in Turkey), Nature Reserves, also known as Nature Conservation Areas (34 areas), Nature Parks

(18) and Nature Monuments (102). Seven Biogenetic reserves have also been established and over 3,000 ha of Gene Conservation Forests, which have been set aside for producing trees of high quality timber value, are also managed by MOEF. Nature Conservation Areas are considered by some commentators to be the most suitable for *in situ* gene conservation programmes[466].

Most recently, protected areas with specific management requirements adapted to individual plant species and environmental conditions, known as Genetic Reserves, have been introduced as a result of the *In Situ* Gene Conservation Project (see box). These serve as reserves for one or more endangered or economically important plant species ("target species")[467]. They are natural or semi-natural areas with the primary objective of protecting genetic resources, whilst still allowing other economic activities, such as grazing and timber harvesting, as long as these do not threaten the primary objective. The aim of such areas is that they should be managed to maximize maintenance of broad genetic diversity while allowing for continued adaptation to changing environmental conditions and thus should be large enough to encompass considerable genetic variation within populations[468].

Genetic Reserves

The *In Situ* Gene Conservation Project, funded by the Global Environment Facility (GEF), started in 1993 and ran for five years. The Ministry of Agriculture (MARA), Ministry of Forestry (MOF) and Ministry of Environment (MOE) were the principle partners of the project and the main species prioritised for conservation were:

- wheat (*Aegilops speltoides* ssp. *speltoides, A. speltoides* spp. *ligustica, A. squarrosa, Triticum boeoticum* and *T. dicoccoides*), barley (*Hordeum vulgare*), chickpea (*Cicer arientinum*) and lentils (*Lens culinaris*)
- wild species of plum (*Prunus divaricata*)
- sweet chestnut (*Castanea sativa*)
- tree species such as *Abies equi-trojani, Pinus brutia* and *P. nigra*[469].

The project undertook five main activities:

- site survey and inventories
- designation of Genetic Reserves
- data management (GIS data management and monitoring system)
- development of a national plan for *in situ* conservation of plant genetic diversity
- development of institutional capacity within and between relevant ministries [470].

Three sites were selected on state-owned land with the aim of establishing Genetic Reserves:

- *Southeast Anatolia*: Ceylanpınar State Farm (175,650 ha) for its wild wheat, barley, lentil and chickpea germplasm
- *Northwestern Aegean Region*: Kazdagi National Park (21,300 ha, Category II[471]) which is rich in fruit progenitor, nut, ornamental and forest species
- *Central Southern Anatolia*: the Anatolian Diagonal (Amanus, Bolkar and Aladağ mountains) which lie at the extreme geographical limits of several species[472]

Repeated surveys provided the information base necessary for the selection of Genetic Reserves:

- Initial surveys sampled target species populations and documented: their locations within the survey area, abundance, and density; surrounding associated species; soil type; topography; and morphological variation between and within populations of the target species. Also noted were grazing pressure, distance to human settlements, and suitability for *in situ* conservation.
- Follow-up surveys were conducted in different seasons, and later surveys documented changes in population density, variation at each site from year to year, and habitat factors that could explain the variation in population density within and between sites[473].

Twenty-two Genetic Reserves were established: Seven were designated at Ceylanpınar State Farm, containing five species of wild wheat relatives. A further 10 were designated in Kazdagi National Park covering five target species, including wild plum, and five in the Bolkar Mountains[474].

Table 5: Genetic Reserves designated at Ceylanpınar State Farm[475]

Name	Size (ha)	Target Species
Beyazkule	30	*Aegilops speltoides* var. *speltoides, A. speltoides* var. *ligustica*
Cavani	10	*A. speltoides* var. *speltoides, A. speltoides* var. *ligustica, Aegilops tauschii*
Gokcayi	9	*A. tauschii*
Gurgurbaba	35	*Triticum dicoccoides, A. speltoides* var. *speltoides, A. speltoides* var. *ligustica, A. tauschii*
Horozmiran	30	*A. tauschii*
Saraccesme	NA	*A. speltoides* var. *speltoides, A. speltoides* var. *ligustica*
Saraccestic	30	*T. monococcum*

Management plans were developed for each Genetic Reserve, with the objective of maintaining as much genetic variation as possible in a given area. Much discussion centred on optimal management practices– such as whether managers should intervene to promote colonisation of annuals (e.g. many wild relatives of grains) in a given area or instead allow the natural succession of biennial and perennial vegetation. A case in point is the easternmost population of *Aegilops tauschii* that was observed in the early years of the project. This population became extinct in 1996, probably due to the cessation of grazing in the area. Similarly, *Lens orientalis* populations varied greatly over the three years of surveying[476]. Local community participation was very important in the development of the management plans, to ensure local people retained access to the Genetic Reserve and practiced traditional activities important to local livelihoods. For instance, in most cases grazing can continue in the area with some modifications. During some parts of the year, grazing animals actually enhance a Genetic Reserve's desired vegetation pattern by shattering the seed and trampling it into the soil for germination the following year ("natural seeding"). One less expected outcome from the project was the discovery of two or possibly three new species of wheat wild relatives during the course of the project. These are now being evaluated for their potential to provide useful attributes to modern varieties of cultivated wheat[477].

- **CWR: habitat and conservation status**

Table 6 summarises the most important field CWR in Turkey; the table lists only species targeted in the National Plan for *In Situ* Conservation of Plant Genetic Diversity in Turkey (see below), reviews information on the area where they are known to exist and their preferred habitat type and finally summarizes information on their status and any suggested conservation options. These options are drawn from a number of projects discussed in this case study, which have surveyed the status of CWR and undertaken exercises to prioritise their protection.

Table 6: Status of key CWR of field crops in Turkey

Species	Area and habitat	Conservation status
Triticum boeoticum (wild einkorn)	Southeastern, Northwestern and Inner Anatolia. In high densities in the Karacadağ Mountain between 900 and 1500m[478]. Primary habitat is oak forests, deciduous steppe, dwarf shrub formations and pastures where it is found on rocky slopes between 500 and 2000 m[479].	Archaeological evidence suggests that *T. boeoticum* was first domesticated in the Karacadağ Mountain close to Diyarbakir[480]. Karacadağ East is suggested as both a strict reserve (IUCN Category Ia) and a National Park (Category II)[481].
T. urartu (wild einkorn)	Southern Turkey. Found in undisturbed habitats in Southeastern Anatolia[482].	
T. dicoccoides (wild emmer wheat)	From the Eastern Anatolian diagonal to Southeastern Anatolia, but more restricted in range than *T. boeoticum*. It is found in relatively undisturbed natural grasslands, in pastures, oak forests and dwarf shrub formations at ranges between 200 and 1600 m[483].	Included in the 35 ha Gurgurbaba Genetic Reserve designated at Ceylanpınar State Farm[484]. WWF suggest the farms becomes a Category V protected area and possibly a Biosphere Reserve[485].
T. araraticum (wild tetraploid wheat)	Southeast and Northeast Turkey, where it shows close affinity with oak park forest belts. Altitude ranges from 300 to 1600m[486].	
Aegilops speltoides (wild wheat) also known as *T. speltoides*	*Speltoides* wheats are found in Southeast Anatolia, the central Anatolian Plateau and Thrace (in European Turkey – the area that borders Greece and Bulgaria). Wide ranging habitats include openings in deciduous oak forest, slope maquis, other steppe like areas and disturbed habitats, at ranges between 50 and 1500m[487].	Included in the 30 ha Beyazkule, 10 ha Cavani, 35 ha Gurgurbaba and Saraccesme Genetic Reserves designated at Ceylanpınar State Farm[488,489]. Possible Genetic Reserves in the Amanos (Nur) Mountains (pine and beech forests) in Southern Anatolian Diagonal[490]. Five candidate reserves surveyed in the Bolkar and Aladağ Mountains in Southern Anatolian Diagonal[491].
A. squarrosa (T. taushii)	Found in East and Southeast Anatolia in open areas of deciduous steppe maquis, dwarf shrubs, other steppe like areas and in disturbed habitats, at a range between 150 and 1400m[492].	
Hordeum spontaneum (barley)	West, South, East and Southeast Anatolia. It is found on low-fertility soils in rocky limestone area, such as oak forests and in man-made habitats such as roadsides. It ranges from 30 to 1650 m[493].	
Lens orientalis (lentil)	Central and Southeastern Anatolia. Adapted to mountainous regions and found in oak and pine forests, disturbed steppe, vineyards and fallow fields, at between 450 and 1300m[494].	Possible Genetic Reserves in the Amanos (Nur) Mountains (pine and beech forests) in Southern Anatolian Diagonal[495].

Species	Area and habitat	Conservation status
L. nigricans	Found in West, South and Central Turkey, predominately on limestone hills up to 900m, and is frequently associated with oak and pine forests[496].	
L. ervoides	West, North and South Turkey. Found on coastal limestone rock and associated with mature mixed pine and oak woodland[497].	Seen as being particularly threatened by genetic erosion[498]. Possible Genetic Reserves in the Amanos (Nur) Mountains (pine and beech forests) in Southern Anatolian Diagonal[499]. Eight candidate Genetic Reserves surveyed in the Bolkar and Aladağ Mountains in Southern Anatolian Diagonal[500].
L. odemensis	A restricted distribution, in North, West and South Turkey, where it is found in pine groves[501].	Also seen as being particularly threatened by genetic erosion[502].

National Plan for *In Situ* Conservation of Plant Genetic Diversity in Turkey

A national plan for *in situ* gene conservation was prepared as part of the GEF project. A draft strategy was completed in January 1995 and revised based on input from a series of stakeholder workshops. The final draft was presented at a November 1996 international scientific symposium[503]. The Ministry of Environment drafted legislation to adopt the strategy, and hoped for approval by the end of 1999. However, the legislation was stalled due to disputes among the three project agencies concerning their respective responsibilities under the draft statute[504]. By March 2006, the plan had still not been approved and thus had not become an official document. The plan was, however, already being used by the Ministry of Environment and Forestry and the Ministry of Agriculture and Rural Affairs for planning purposes. The priorities in the national plan will form the basis for "the biodiversity national plan", prepared during 2006[505].

The overall objective of the *National Plan for* In Situ *Conservation of Plant Genetic Diversity in Turkey* is: "to determine the priorities and strategies for effective management and conservation, sustainable utilisation and monitoring of genetic diversity of target species". The target species in the plan include 57 agricultural plants (including field crops and fruit, vegetable, medicinal and aromatic species), 13 landraces and 25 forest tree species[506].

When the Plan was presented at the International Symposium on *In situ* Conservation of Plant Genetic Diversity, in 1997, the authors offered their views on its implementation[507] which included: Building on the experiences from the *In Situ* Gene Conservation Project and the pilot studies at Ceylanpınar, Kazdagi and Anatolian Diagonal-Bolkar - they hoped to see *in situ* conservation studies for target species of CWR carried out over 21.7 million ha of pasture lands nationwide: Areas with important plant genetic resources should be identified and set aside as NCAs [Nature Conservation Areas] … as soon as possible." In particular, they stressed the "great need to establish new Genetic Reserves for wild relatives of agricultural plants that should also aim to conserve plant genetic resources in pasture lands, especially in highland pastures".

- **Protection in Eastern and Northern Anatolia**

Most of the species listed in table 6, can be found in the deciduous forests of mountainous Eastern Anatolia (for example more than 30 species of wild wheat, along with barley, chickpeas, lentils, apricots, figs, cherries, and many types of nuts, can be found here). In total, about 3,200 vascular plant species, at least 725 of which are endemic are found in the *Quercus* spp. (oak) dominated forests, including Turkey oak (*Q. cerris*) and Lebanon oak (*Q. libani*), with steppe vegetation increasing to the east. The forests are situated in an area known as the Anatolian Diagonal – a floristic line crossing inner Anatolia running from the southern foothills of the Black Sea Mountains around Bayburt, through the Munzur Mountains and the Anti Taurus range, which then splits into two branches; one branch reaches the Mediterranean via the Amanos Mountains and the other via the Bolkar Mountains[508]. Approximately 390 plant species have distributions largely confined to the Anatolian Diagonal[509]. The area is however seriously under-protected with only one National Park, Munzur Valley (48,000 ha, IUCN Category II). The lower slopes of the park are covered in oak forests of *Quercus frainetto* and *Q. aegilops*, whilst the upper slopes are covered by alpine vegetation[510]. As in the rest of Turkey, the area's forest cover has been dramatically reduced. In Southeast Anatolia, for example, the region's dominant vegetation was once steppe grassland in the lowlands and oak woodland in the uplands. Today, agriculture is dominant; over 40 per cent of the land area is suitable for cultivation, 30 per cent is pasture and rangeland and 17 per cent is forest[511].

The other important area for cereal wild relatives is the conifer and deciduous forests of the Northern Anatolian strip. This mountain range is particularly important for its intact forest cover and the diversity of flora and fauna that it supports. Situated south of the Black Sea coastal zone, the western areas support a high diversity of woody species, and the eastern areas host intact stands of old growth forests. The northern, more humid slopes of the coastal mountains support broadleaf deciduous humid forests, the southern slopes support drier needle-leaf coniferous forests[512]. The Ilgaz, Kaçkar and Gümüşhane Mountains and the Çankırı area are known as centres of plant endemism[513]. There are five national parks and five nature reserves in the ecoregion. National parks protect the old-growth forest of Kackar Mountain National Park (Category II, 51,550 ha): Montane *Picea orientalis* forest of Maçka-Altındere Valley National Park (Category II, 4,800 ha) and Black Sea Deciduous forests of Yedigöller National Park (Category II, 1,636 ha). Two smaller parks, which have been suggested as suitable for enlargement are the Ilgaz Mountain National Park (Category II, 1,088 ha), recommended for enlargement specifically to cover more of the centre of endemism that occurs in the area, and Soğuksu (Category II, 1,050 ha), which is important in terms of natural history as it is situated in the transition zone between the Central Anatolia Steppe and Black Sea Forest[514].

The five nature reserves are all classified as IUCN Category Ia. Old-growth forest is protected at the Örümcek Nature Reserve in the Gümüşhane province and the Kökez Reserve in the Bolu province. The Akdoğan-Rüzgarlı Reserve, in the Bolu province, protects a specific variety of Anatolian Black Pine, while the Sülüklügöl Reserve, also in Bolu, protects a wide range of tree species. The Kale Hazelnut Reserve in Bolu was created to protect old hazelnut individuals, but there is also considerable habitat diversity in the reserve[515]. One of the forest hotspots, Yenice Forests, hosts two nature reserves; one – Kavaklı Reserve – also includes hazelnut (*Corylus colurna)* as well as many other important tree species and ancient trees.

- **Priorities**

Table 6, includes information from a number of projects, i.e. the *in situ* gene conservation project, National Plan for *In Situ* Conservation of Plant Genetic Diversity and the WWF Turkey SE Anatolia Biodiversity Research Project (see box below), which have included consideration of areas that should be protected to conserve plant genetic resources. From these prioritisation exercises and considering the protection status of the important primary habitats of cereal wild relatives some clear priorities for protection emerge:

- The designation of protected areas in Southeastern Anatolia, including a national park in the Karacadağ Mountain
- Increased protection of forested areas, in particular oak forests in Eastern Anatolia
- The continued surveying and designation of Genetic Reserves in Anatolia

WWF Turkey SE Anatolia Biodiversity Research Project

In 2004, WWF Turkey published the results of a two year project (SE Anatolia Biodiversity Research Project) to identify biodiversity hot-spots in the region[516]. Although the region supports a rich and varied biodiversity, it was one of the least known areas of Turkey prior to the project. Two years of mapping, studies on selected species and field data collection resulted in a proposed list of 30 Priority Areas for conservation and recommendations for further research and conservation action in each area.

Changes in agricultural practices are a major threat to the region's natural resources. Traditional cropping and cultivation practices are being abandoned as agricultural practices are intensified, cultivation is being expanded into marginal areas and natural pastures and grazing lands are being over-exploited. Without appropriate management and conservation, serious biodiversity losses are going to take place in the agricultural and grassland areas in the region. The SE Anatolia Biodiversity Research Project thus suggested not only areas for strict protection in the region, but also for the management of sensitive areas over the whole landscape in a much broader approach to achieve the objectives of biodiversity conservation.

The Priority Areas were selected by assessing the biodiversity of the region through using data on large mammals, birds, threatened plant species, herpetofauna species, butterflies and best ecological communities.

Two of the 30 Priority Areas proposed, have specific relevance for the conservation of CWR:
- Ceylanpınar East
- Karacadağ East

Ceylanpınar East is a state (owned and managed) farm covering 175,650 ha, just over 40 per cent of which is semi-natural steppe vegetation. The area is identified as an important bird area (IBA), a key biodiversity area (KBA) and an important plant area (IPA 122). It currently has Gene Conservation and Management Area status. The WWF project recommends that it becomes an IUCN Category V protected areas or a UNESCO Biosphere Reserve. The area has unique vegetation communities associated with the volcanic steppe. 482 plant taxa have been recorded; 55 of them nationally rare and there is notable concentration of CWR.

The Karacadağ Mountain was selected in part due to its role in the domestication of grain crops and its archaeological importance. *Triticum boeoticum* (wild einkorn) was domesticated in southeast Turkey in the Karacadag Mountains close to Diyarbakir[517]. Karacadağ East is recommended to be a strict reserve (IUCN Category Ia) and a National Park (Category II). The site is also an IPA (122), KBA and an IBA.

Mexico: Sierra de Manantlan
"from a one-species project to an ecosystem project"[518]

The 're-discovery' of a maize crop wild relative in the Mexico's Sierra Madre del Sur in the 1970s resulted in the creation of the Sierra de Manantlán Biosphere Reserve in 1988. The reserve, which contains a mix of indigenous, community and privately owned land, is leading the way in promoting the conservation of both crop wild relatives and landraces in an area of diverse cultures and traditions.

Discovery of a new species

In 1976, Professor of Botany, Dr Hugh Iltis, at the University of Wisconsin-Madison in the United States of America, sent a New Year's card in the form of a poster to botanists around the world with a picture of *Zea perennis* against which he wrote "extinct in the wild". Wild populations of *Z. perennis* had last been seen in 1921 in Western Mexico, by two U.S. Department of Agriculture botanists, who introduced the species to university greenhouses in the USA. Since then several other botanists had tried, and failed, to relocate the wild population.

One poster was placed on a bulletin board at the University of Guadalajara by a local taxonomist, who urged her students: "*Go and find this teosinte, and prove that gringo Iltis wrong*". One undergraduate student took the challenge and went back to the plant's last known location in Western Mexico and found the long-lost *Zea perennis*.

This one find led to another even more important discovery. On being told that *Z. perennis* was growing in another location the student, Rafael Guzman, collected more seed. This teosinte (known locally as 'milpilla') however turned out to be a new species – *Z. diploperennis* (see picture overleaf from the S.M. Tracy Herbarium, Texas A&M University[519]). Unlike *Z. perennis*, this species freely interbreeds with corn, which raised the possibility that the crop could be grown for several years from one rootstock and, perhaps more importantly, it appeared to be tolerant of seven corn viruses and the only member of *Zea* that is immune to three of them.

Teosinte is a group of large, Central and South American grasses of the genus *Zea*. There are five recognized species of teosinte: *Zea diploperennis*, *Z. luxurians*, *Z. mays*, *Z. nicaraguensis* and *Z. perennis*. The maize gene pool consists mainly of cultivated *Z. mays* and several related wild species (*Z. diploperennis* and *Tripsacum* spp.). *Z. diploperennis* and *Z. perennis* are perennial, while all other taxa are annual. Virtually all populations of teosinte are either threatened or endangered

Maize is one of the major crops of the world. Figures from 1995 estimate that globally maize is cultivated on an area of 130 million hectares; the largest producer is the United States (38 per cent of global production), followed by China (21 per cent), Brazil (7 per cent), Mexico (3 per cent) and France (2 per cent).

Source: FAO (1997); *The State of the World's Plant Genetic Resources for Food and Agriculture*, FAO, Rome, Italy

Protection

From this discovery followed years of negotiations which eventually resulted in the creation of the Sierra de Manantlan Reserve, under the direction of the University of Guadalajara - the first protected area established principally for the preservation of a wild crop relative, as well as traditional agricultural systems and cultivars[520]. *Z. diploperennis* is found on some 375 ha of the reserve. Steps towards protection began in 1984, when the State of Jalisco purchased land at Las Joyas, which included a large population of *Z. diploperennis.* The following year this area became the Laboratorio Natural Las Joyas de la Sierra de Manantlán run by the Universidad de Guadalajara.

The 139,577 ha IUCN Category VI[521] protected area, Reserva de la Biósfera de la Sierra de Manantlán (Sierra de Manantlán Biosphere Reserve), was established in 1988 by Presidential decree, under the auspices of the Jalisco government, with support from the Consejo Nacional de Ciencia y Tecnología (CONACYT). It was also recognised by UNESCO's Man and the Biosphere Programme in 1988[522].

Apart from the Laboratorio Natural Las Joyas de la Sierra de Manantlán, none of the land in the Biosphere Reserve has been purchased by governmental authorities – rather 20 per cent is owned by indigenous communities, 40 per cent is community-owned ("ejido") lands and 40 per cent privately owned[523].

The Universidad de Guadalajara's Instituto Manantlán de Ecología y Conservación de la Biodiversidad (IMECBIO), has estimated that around 33,000 people who live in agricultural communities in the area have rights over some of the land in the Reserve. There are also 400,000 people who rely on the Sierra's water catchment for industry, agriculture and other purposes[524].

Research and conservation

The discovery of *Z. diploperennis* and the subsequent declaration of a biosphere reserve has led to intensive research into the biodiversity, and specifically the flora of the reserve. Over 2,700 plant species have been recorded in the area, of which 40 per cent are endemic to Mexico. Agricultural fields and associated secondary vegetation in hillsides and small valleys in the reserve and surrounding area have been found to contain CWR of beans (*Phaseolus coccineus* and *P. vulgaris)* as well as maize[525].

Protection strategies for *Z. diploperennis,* began with gathering baseline information on the species' habitat requirements. Surveys revealed that all known *Z. diploperennis* populations were found near highland farming villages, and that the plants invariably occur in clearings surrounded by pines, oaks and broadleaf cloud forest. *Z. diploperennis* was found in areas created by small-scale clearance for maize cultivation and abandoned or in actively cultivated fields.[526]

The **Sierra de Manantlán region** is located between the states of Jalisco and Colima in West-Central Mexico in the north-western Sierra Madre del Sur, some 50 km inland from the Pacific Ocean. The region's altitude ranges from 400 m to 2860 m, and temperature ranges from 27°-12°C depending on elevation. The area is considered one of the richest biodiversity regions in Mexico, as it lies within the Nearctic-Neotropical transition zone. Most of the area is under forest cover. Eight distinct forest types are found in the reserve, where lowland tropical forest is followed by temperate forest (oak and oak-pine), and finally cloud forest at the highest elevations. The area has a long history of human inhabitation which has had considerable influence over the whole landscape.

Source: Cuevas-Guzmán, R; B F Benz; E J. Jardel-Peláez; O Herrera-MacBryde (undated); *Fact Sheet, Sierra de Manantlan Region*; Smithsonian Institution, SI/MAB Program, Washington, DC, USA (accessed from: www.nmnh.si.edu/botany/projects/cpd/ma/ma6.htm)

Further research found that *Z. diploperennis* cover and stem abundance appeared to be highest in sites that had not been cultivated for at least 15-years. However, these sites also showed the first incursion of young woody trees that could eventually shade out the plant, suggesting that long-term conservation of the species will depend upon regular small-scale forest openings like those produced by shifting agriculture[527].

The Sierra de Manantlán is also an important refuge for animals, including threatened species such as the jaguar (*Panthera onca*). So far, 108 species of mammals have been recorded in the region – at least 12 of which are endemic to montane areas of western Mexico and 2 subspecies to the reserve. Thirty per cent of Mexico's bird species have also been found in the area (336 species). Lists are also being compiled for other species: to date 60 species of reptiles, 20 amphibians, 16 fish species, a high proportion of which are endemics, and more than 180 families of insects have been recorded[528].

Conclusions

The reason why the Sierra de Manantlan was first considered for protection and its subsequent success as a protected area, which at least in part is specifically aimed at CWR conservation, is not just due to the work carried out by scientists and conservationists. Mexicans call teosinte the ‘grain of the gods’ and the crop is of great importance to food security in the region. The reverence the species is held in has clearly helped preserve its diversity.

The local rural communities in the region have considerable knowledge of the area’s diversity and their agricultural practices have helped to retain this diversity. Interviews with the local inhabitants have found that over 500 species are utilised – although only 179 are used in more than one of the ten communities studied[529]. Landraces are also diverse and under threat; for example, the region’s cultivated maize (*Zea mays* subsp. *mays*) includes two of the most primitive traditional varieties in Mexico, one of which is only found in small isolated towns, so this landrace could be eroding.

The existence of *Z. diploperennis* and other CWR is likely to be due to the traditional agricultural practices of slash-and-burn cultivation (‘coamil’) and cattle-ranching. The management practices and objectives of the reserve thus stress the necessity to conserve traditional agricultural systems and it is planned to continue the coamil system in areas within the reserve so that the *Z. diploperennis* populations can survive[530].

Can just one protected area meet the challenge of conserving these long held agricultural practices and the landraces and their wild relatives found in the region? Research in the buffers zones and areas surrounding the Manantlan Reserve has been fundamental in showing that the agricultural system is not closed and that local farmers are constantly experimenting and modifying the genetic composition of the local maize varieties through seed exchanges. This element of natural evolution though local selection is an additional aspect that must be taken into account in conservation projects if they are going to be effective. It is a conservation challenge that must be addressed inter-sectorially by various government agencies acting in unison with a common goal and with the participation of the main stakeholders in the design and implementation of dynamic conservation projects[531].

Africa: *Vigna*, a crop worthy of protection[vii]

Ongoing work in Africa is identifying a group of existing protected areas suitable for helping to protect Vigna*, a bean widely used in subsistence agriculture in the tropics. When suitable reserves have been located, specific protection strategies for the bean will need to be developed.*

Cultivation of beans, predominantly from the closely related genera of *Phaseolus* L. and *Vigna* Savi (cowpea and Bambara groundnut), is increasing and contributes widely to subsistence agriculture in the Americas, sub-Saharan African and Asia. Although plant breeders have striven to enhance and improve production (for example cowpea production has increased 10-fold in the last 20 years), exploitation has been hampered by a lack of:

- Taxonomic, genetic and ecogeographic knowledge
- *In situ* and *ex situ* conserved material that is easily exploitable by breeders
- Characterisation and evaluation of existing conserved germplasm
- Coordination of national, regional or international conservation strategies for *Phaseolus* and *Vigna* diversity.

The ecogeographic study reported here was commissioned by the International Board for Plant Genetic Resources (now the International Plant Genetic Resources Institute). It aimed add to information available for wild African *Vigna* by reviewing *Vigna* diversity and conservation status and discussing how the *Vigna* gene pool might be more efficiently sustained and exploited to benefit African agriculture. The excerpt here deals only with the recommendations in relation to protected areas, but the final report is far more wide ranging and offers a strategy for the *Vigna* throughout sub-Saharan Africa.

Vigna protection

There are currently no reserves specifically established to conserve African *Vigna* species or where they are priority taxa identified within the management plan and monitoring objectives. Having made this point, the majority of the species are widely distributed in grassland, along roadsides, field margins and open primary forest, and therefore existing national parks and other protected areas networks will contain many of them.

A comparison of the location data for herbarium specimens or gene bank accessions with the boundaries of existing African protected areas found that 54 per cent of wild *Vigna* species have populations present in at least one protected area. The real figure for populations present in protected areas is likely to be higher because the dataset only refers to those populations that have been sampled for herbarium specimens or germplasm and obviously not all populations would have been sampled.

Bearing in mind the genetic erosion from habitat destruction and degradation that is current in many parts of Africa, as well as the fact that most protected areas in Africa were established to conserve animals or ecosystems, the size and well-being of populations of *Vigna* they contain is uncertain.

[vii] This case study has been edited from a longer document of the same name authored by: Maxted, N., Mabuza-Dlamini, P., Moss, H., Padulosi, S., Jarvis, A. & Guarino, L., (2004). An Ecogeographic Survey: African *Vigna*. *Systematic and Ecogeographic Studies of Crop Genepools* 10. pp. 1-468. IPGRI, Rome.

Any management or monitoring of the reserve will be targeted at the animals or ecosystems the reserve has been set up to conserve, not generally taking CWR such as *Vigna* into account.

This "passive" conservation of *Vigna* populations in existing protected areas is better than nothing, but there is a need for active *in situ* genetic reserve conservation of priority *Vigna* taxa.

Bwindi Impenetrable Forest National Park in Uganda has been highlighted as potential site for the establishment of genetic reserves for priority Vigna taxa

Marc Hockings

The sheer number of African *Vigna* taxa, and their genetic and ecogeographic diversity, makes *in situ* conservation the only practical conservation option for adequately maintaining the broadest gene pool of these socio-economically important species. This study has identified where the hotspots of *Vigna* taxonomic diversity are located in Africa. Existing protected areas in these regions need to be identified and the possibility of establishing genetic reserves in them assessed. Existing protected areas where management can be amended to permit the establishment and monitoring of a *Vigna* genetic reserve are prime targets for any *Vigna* conservation strategy. These nearby protected areas are listed in table 7 below. Surveys are now needed to identify the most appropriate areas for the establishment of genetic reserves. One genetic reserve within each priority area would be appropriate to conserve a significant proportion of *Vigna* genetic diversity.

Table 7: Locations suggested for potential establishment of genetic reserves.

Country	**PA name**	**Type of PA**	**IUCN PA Category**	**Location**	**Area (km^2)**
Southern tip of Lake Tanganyika					
Zambia	Lusenga Plain	National Park	II	9°23'S/ 29°13'E	88,000
	Mweru-Wantipa	National Park	II	8°44'S/ 29°38'E	313,400
	Nsumbu	National Park	II	8°47'S/ 30°30'E	206,300
Tanzania	Uwanda	Game Reserve	IV	8°32'S/ 32°08'E	500,000
	Katavi	National Park	II	6°53'S/ 31°10'E	225,300
	Mahale Mountain	National Park	II	6°10'S/ 29°50'E	157,700
Coastal area of Sierra Leone					
Sierra Leone	Outamba-Kilimi	National Park	IV	9°45'N/ 12°13'E	80,813
Between Lake Victoria and the other Great Lakes					
Uganda	Bwindi Impenetrable Forest	National Park	II	1°02'S/ 29°42'E	32,092

Country	PA name	Type of PA	IUCN PA Category	Location	Area (km^2)
	Gorilla (Mgahinga)	National Park	II	1°22'S/ 29°38'E	2,899
	Lake Mburo	National Park	II	0°35'S/ 31°00'E	25,594
	Queen Elizabeth	National Park	II	0°04'S/ 30°00'E	197,752
	Rwenzoris	National Park	II	0°15'N/ 29°57'E	99,576
Tanzania	Biharamulo	Game Reserve	IV	2°30'S/ 31°30'E	500,000
	Burigi	Game Reserve	IV	2°05'S/ 31°20'E	130,000
	Ibanda	Game Reserve	IV	1°09'S/ 30°35'E	20,000
	Kigosi	Game Reserve	IV	3°42'S/ 31°34'E	700,000
	Moyowosi	Game Reserve	IV	4°08'S/ 31°00'E	600,000
	Ugalla River	Game Reserve	IV	5°53'S/ 31°50'E	500,000
	Gombe	National Park	II	4°40'S/ 29°35'E	5,200
	Katavi	National Park	II	6°53'S/ 31°10'E	225,300
	Mahale	National Park	II	6°10'S/ 29°50'E	157,700
	Rubondo	National Park	II	2°25'S/ 31°50'E	45,700
Burundi	Kibira	National Park	V	3°00'S / 29°22'E	40,000
	Rusizi	National Park	V	3°15'S / 29°15'E	5,235
	Ruvubu	National Park	V	3°00'S / 30°23'E	43,630
Rwanda	Akagera	National Park	II	1°32'S/ 30°38'E	312,000
	Volcans	National Park	II	1°28'S/ 29°33'E	15,000
DR Congo	Garamba	National Park	II	4°13'N/ 29°24'E	492,000
	Kahuzi-Biega	National Park	II	2°31'S/ 28°45'E	600,000
	Kundelungu	National Park	II	10°35'S/ 28°56'E	760,000
	Virunga	National Park	II	0°20'S/ 29°35'E	780,000

It is rare that such an explicit set of conservation recommendations exist for a CWR group, particularly for an African genus where the flora is perhaps least well understood compared to the other continents. The case study illustrates that even for a widely distributed and comparatively poorly known genus, use of established ecogeographic, gap analysis and GIS protocols can provide a key to the establishment of specific conservation priorities. In this particular case, once the recommendations have been implemented by national governments, the study will have underpinned the species diversity and genetic diversity within species that secures continued cowpea (*V. unguiculata*) and Bambara groundnut (*V. subterranea*) cultivation, so providing additional food security for a significant proportion of subsistence farmers in Sub-Saharan Africa.

Vigna adenantha, a wild relative of cowpea, found on a lakeside in Cameroon.

Stefano Padulosi

Vietnam: Supporting farmers to protect crop genetic diversity[viii]

In North Vietnam, the conservation of agricultural genetic diversity (plants, animals and microbes) is being developed through on-farm conservation. A GEF-funded project is working with local communities, helping them to be recognised as the "curators" of genetic diversity, with incentives and programmes designed to support this role. Working in eight sites the project aims to develop a wide range of experiences that can be replicated elsewhere in Vietnam. The project is working in two protected areas, and buffer zones around these areas.

The conservation of agricultural biodiversity was identified as a national priority in the 1995 Vietnam Biodiversity Action Plan[532]. The Plan places emphasis on enhancing measures for:

- protecting agricultural biodiversity through on-farm management, giving particular attention to the conservation of popular traditional varieties which have long been adapted to the local geography and climatic conditions in different regions of the country; and
- encouraging farmers to participate in the protection strategies[533].

Vietnam is within one of Vavilov's 'Centres of Origin' of domesticated plants. The frequent migration and exchanges of people and plants from one region to another within Vietnam has enriched its plant genetic resources and diversified crop species.

Threats to agro-biodiversity

Thirty per cent of Vietnam is under forest and woodland (9,650,000 ha), whilst arable land and permanent crop plants cover a further 21 per cent (6,985,000 ha). The total number of native plant species found in Vietnam is estimated at 4,800. Of these, 1,900 are food plants (cultivated plants and their wild relatives). But, just as in the rest of the world, agro-biodiversity is fast disappearing.

Table 8: Reduction in Area and Loss of Landraces for Key Crops in Vietnam since 1970[534]

Crop	Reduction in Area	Loss of Landraces
Rice	50%	80%
Maize, Legumes	75%	50%
Roots/tubers	75%	20%
Tea and Jute	20%	90%
Fruit Trees	50%	70%

Threats to cultivated varieties include:

- replacement of native landraces by modern varieties as a result of:
  - a lack of incentives for the cultivation and conservation of native landraces
  - a loss of traditional knowledge about the cultivation of native landraces
  - growing urbanisation and reduction of agro-ecosystems

Threats to CWR include:

- encroachment of agriculture into natural habitats. This is exacerbated by the lack of personnel for the maintenance of protected areas, which limits the capacity to control encroachment; and
- genetic erosion as a result of fragmentation and isolation of habitats containing the wild relatives of cross-pollinating crops.

[viii] This case study draws on material posted on the *In situ conservation of native landraces and their wild relatives in Vietnam* project web site, at: http://www.undp.org.vn/projects/vie01g35/index.htm

Supporting on-farm conservation

One of the primary reasons for the declining abundance and variety of native landraces is a loss of traditional knowledge needed for growing these crops among farmers. A lack of information and effective information management results in a rising perception among farmers and consumers that landraces are somehow inferior. These factors contribute to a low market demand for landraces, thus creating an added disincentive to cultivate them. There is therefore a pressing need to redress current perceptions which make it less likely that farmers will grow native crop varieties. *In situ* strategies to address these threats include:

- Increasing awareness of the advantages of native landraces among farmers and local communities, and providing incentives to use them

- Promoting marketing of products derived from cultivation of native landraces

- Forums for training, exchanging techniques and experiences, and disseminating traditional knowledge on the cultivation of native landraces

- Reviewing the environmental policy on master planning of urban areas and other areas in cooperation with related organisations to make the plans more supportive of agrobiodiversity

- Strengthening and developing buffer zones surrounding protected areas

- Developing Genetic Reserves based on the agrobiodiversity encompassed by a particular area

GEF Project

A medium sized GEF project "*In situ* Conservation of Native Landraces and their Wild Relatives in Vietnam" ran from 2002 until 2005.

Although Vietnam has developed some *ex situ* collections of crop genetic diversity (there are 61,276 accessions of 104 domesticated species in *ex situ* collections held at different institutions), there has until now been little in the way of *in situ* conservation. The project therefore targeted the conservation of six native landraces and CWR in three areas (the Northern Mountains, Northern Midlands, and Northwest Mountains) and provided technical support to help farmers in effective conservation, development, sustainable management and use of their native landraces and wild relatives.

Overall, the project objectives were:
- Native landraces and wild relatives to be conserved in dynamic agriculture/forest landscapes
- Replicable models to be established of community-based genetic reserves
- An enabling environment to be established to support conservation of agrobiodiversity

Targeted species included:
- *Rice:* The centre of genetic diversity for cultivated rice (*Oryza sativa* L.) is situated from Nepal to northern Vietnam. Many local varieties have been modified and more than 100 varieties of rice are known from Vietnam.

- *Taro*: Tuber plants of the family Araceae have a tropical origin and high diversity. In Vietnam, there are 30 genera with 100 species. Presently, taro is grown mainly in small areas of mid-Vietnam or in valleys under limestone mountains where other valuable plants cannot grow.

- *Tea*: Species used for tea production originate mainly from two genera: *Camellia* and *Ilex*. It is estimated that 40 species of *Camellia* are found in Vietnam, which represents almost half of the total number for the genus. *Ilex* is a much larger genus, with an estimated 800 species, of which about 40 are found in Vietnam. Many landraces of *Camellia sinensis* are found throughout northern Vietnam, such as *C. sinensis* var. *Shan*, or "*yellow tea*".

- *Mung Bean*: The mung bean (or rice bean) originated in Southeast Asia and is a popular crop in East Asia and Southeast Asia. The rice bean has many varieties, varying in seed colour and size and time taken to maturity. It is a crop of high economic importance to the ethnic minority people of the northern mountain and western highland regions of Vietnam.

- *Citrus* spp*:* The north of Vietnam is one of the centres of diversity for citrus fruit, with 23 species and some 185 local varieties cultivated.

- *Litchi* and *Longan:* The origin and geographical distribution of both litchi and longan occurs in the area between southern China and northern Vietnam. Cultivated varieties of native litchi and longan species have been grown for at least 400 years in Hai Duong, Hung Yen, Vinh Phu and Ha Tay provinces. Some areas of surviving forest in these provinces are home to species of wild litchi trees such as Guoc litchi (*Nephelium lappaceum* L.) and forest litchi (*N. cuspidatum* Blume var.). Wild litchi are also found in southern Chinese forests and also in Lao Cai, Ha Giang, Lang Son and Cao Bang provinces.

Eight Genetic Reserves have been selected (table 9). In two (see numbers 3 and 8 in table below) there is more than one project site (in a cultivated ecosystem and an associated site in an adjoining protected area). The six remaining reserves consist only of cultivated ecosystems.

Table 9: Project Sites

Site	**Location**	**Area (ha)**	**Crops**
1 Hong Nam-Hong Chau (Hung Yen)	N: 20° 38.353' E: 106° 03.614'	200	Longan, Taro, Citrus
2 Thanh Son-Hoang Hoa Tham (Hai Duong)	N: 20° 52.206' E: 106° 26.861'	160	Litchi, Taro, Citrus
3 (a) Ba Vi National Park (Ha Tay)	N: 21° 01' E: 105° 18'-105° 25' Alt: 1000m	120	Tea
3 (b) Ba Vi National Park (Ha Tay)	N: 21° 05.409' E: 105° 22.745' Alt: 400m	150	Litchi, Taro
3 (c) Ba Trai buffer zone of Ba Vi National Park (HaTay)	N: 21° 06.962' E: 105° 22.733' Alt: 40m	145	Taro, Litchi, Longan, Citrus
4 Thanh Cong-Nguyen Binh (Cao Bang)	N: 22° 35' E: 105° 50' Alt: 654-965m	600	Rice, Litchi, Taro, Citrus, Rice, Bean
5 Cao Bo (Ha Giang)	N: 22° 44.950' E: 104° 54.703' Alt: 320m	200	Tea
6 Viet Vinh (Ha Giang)	N: 22° 26.331' E: 104° 51.167' Alt: 70m	200	Citrus, Rice

Site	Location	Area (ha)	Crops
7 Ngoc Hoi (Tuyen Quang)	N: 22 ° 28.316' E: 105 ° 22.703' Alt: 72m	150	Citrus, Rice, Taro
8 (a) Huu Lien Nature Reserve (Lang Son)	N: 21 ° 39.809' E: 106 ° 21.927' Alt: 208m	160	Taro, Rice, Litchi, Longan, Citrus, Bean
8 (b) Yen Thinh buffer zone of Huu Lien Nature Reserve (Lang Son)	N: 21 ° 39.012' E: 106 ° 21.622' Alt: 208m		

✓ **Site selection**

The selection of project sites proceeded in two steps. The first step was to identify genetically important areas based on the following criteria:

- presence and genetic diversity of target species
- presence of endemic species
- overall floristic species richness
- presence of high numbers of other economic species
- presence of natural and/or semi-natural ecosystems
- presence of traditional agricultural systems
- protection status and/or existence of conservation-oriented farmers or communities that manage a number of species and varieties.

The second step was to select specific sites and communities within the larger Genetic Reserves where socio-economic conditions indicate good feasibility for on-farm agrobiodiversity conservation activities. Several workshops, stakeholder consultations, and numerous meetings between IAG, NGOs working in the Genetic Reserves, local institutes, and farmer groups aided this process. Visits were made to each site to assess community receptivity to sharing traditional knowledge and practices that promote *in situ* conservation.

The selected sites also represent both high species and variety diversity of the target crops. They encompass a range of topographic, climatic and socio-economic conditions (e.g., proximity to markets and community-level associations), species and landraces. The selected sites range in size from 120 to 600 hectares. This variety allowed the project to develop a range of experiences to reflect these varying conditions, thus increasing the opportunities for replication elsewhere.

The stakeholder consultations recommended that, where possible and consistent with the principles of agrobiodiversity conservation, protected areas with natural ecosystems containing wild relatives of crop species should be included. Two of the Genetic Reserves, numbers 3 and 8, include protected areas - Ba Vi National Park and Huu Lien Nature Reserve. The six remaining reserves consist only of cultivated ecosystems. For those reserves in natural ecosystems, the designation process will involve incorporation of the special status and management protocols into the protected area management plans within which the Genetic Reserves are located.

Involving farmers and improving livelihoods

One of the main criteria for selecting the target sites was the presence of conservation-oriented farmers, as they can become leading actors and partners in consolidating and disseminating this knowledge base. Traditional practices of agrobiodiversity conservation are being identified and documented and the exchange and dissemination of this information is being encouraged. Particular attention was given to women in consolidating and documenting traditional knowledge as they play an important role in the management, selection and propagation of native crops and varieties, especially in family gardens.

Activities focus on threats affecting traditional on-farm management of agrobiodiversity and on enhancing farmers' access to genetic resources of native crops. Due to increased food demands and low productivity, farmers are faced with the need to expand production onto uncleared lands. Grazing pressure is steadily increasing with a serious effect on habitats of different landraces and wild relatives. By working with local government to improve land use and pasture management in ways that maintain species and genetic diversity, farmers can be empowered to adapt their management strategy to the growing food demand.

In situ conservation programmes also have significant potential to improve the livelihoods of farmers at the local level. On-farm conservation programmes can be combined with local infrastructure development or the increased access by farmers to useful germplasm held in national gene banks. Local crop resources can be the basis for initiatives to increase crop production or secure new marketing opportunities. Building development efforts on local resources and including empowerment of farming communities, can lead to sustainable livelihood improvement. Resource-poor farmers, in particular, may benefit if development initiatives are not based on external inputs that may be costly or inappropriate for marginal agro-ecosystems.

On-farm conservation also serves to empower farmers to control the genetic resources in their fields. On-farm conservation recognizes farmers and communities as the curators of local genetic diversity and the indigenous knowledge to which it is linked. In turn, farmers are more likely to reap any benefits that arise from the genetic material they have conserved.

Enabling environment

One of the most important requirements for establishing Genetic Reserves is an enabling institutional and policy environment. This enabling environment not only makes it possible to designate reserves, but establishes mechanisms by which Genetic Reserves will be financially sustainable through, for example, the development of new or increased markets for traditional varieties, processes for benefit sharing from commercialization of agrobiodiversity, etc. Economic policies and programmes, agricultural input subsidies, agricultural pricing and other issues have a direct impact on the cropping decisions of farmers and communities. These government programmes are driven by the need to enhance food production and availability and, as such, reflect national priorities. The result in Vietnam is an increasing emphasis on subsidising cultivation in fertile, well-irrigated land areas (through subsidised inputs and secure markets), with local landraces being relegated to marginal fields on steep slope with poorer soils. In order for these "islands of agrobiodiversity" not to disappear completely, it is important that the areas where the "biodiversity pay-off" is much higher, also receive economic support through targeted programmes. IAG, the executing agency of the project, is part of the Ministry of Agriculture and Rural Development, and it is the latter which will take the lead in supporting decisions relating to agricultural policies that provide incentives for the cultivation of native landraces.

Peru: Protecting rights, conserving diversity

An agreement between six indigenous communities of Quechua Indians in Peru and the International Potato Centre in Cusco has recognised the right of communities over the unique potato strains that they have grown and bred for thousands of years.

Potato varieties in Peru

Credit: © WWF-Canon / Udo Hirsch

The cultivated potato traces its origin to landraces developed by pre-Columbian farmers, and recent archaeological evidence puts the earliest signs of cultivation at around 7000 years ago in the Lake Titicaca region of southern Peru[535]. Today, potatoes are one of the world's most important food crops. According to the Lima-based International Potato Centre (CIP, in its Spanish acronym), annual production approaches 300 million tonnes worldwide, with more than one-third being grown in developing countries[536].

Protecting rights and diversity

Quechua communities in the Pisac Cusco area of Peru (an area characterised by rain-fed high altitude agriculture systems) have been working for several years to establish a 'Parque de la Papa' (Potato Park), a community-based, agrobiodiversity focused conservation area[537]. The initiative has bought together 8,000 villagers from six communities (Pisaq, Cusco, Saccaca, Cuyo Grande, Amaru, Paru-Paru, Pampallacta and Chawaytire), who have agreed to manage jointly their 8,661 ha of communal land for their collective benefit. Their aim is to conserve their landscape, livelihoods and way of life, and to revitalise their customary laws and institutions[538].

The parks objectives are to ensure the survival of the genetic heritage of the Andes. The area is a centre of diversity for a wide range of crops including Quinoa (*Chenopodium quinoa*), Kiwicha (*Amaranthus caudatus*), Tarwi (*Lupinus mutabalisis*), Oca (*Oxalis tuberosa*) and Mashua (*Tropaeolum tuberosum*)[539], and most importantly the potato (*S. tuberosum*). Indeed, the wealth of the area is based on the 1,200 different traditional varieties or landraces of potato that are named, known and managed by the local people (a typical farm plot may contain 250-300 varieties). The area's economy is largely dependent on the potato; both in terms of local consumption and the regional barter trade. This trade has important nutritional, as well as economic value, allowing the highlanders to exchange the carbohydrates and meat that they produce (in the form of potatoes, guinea pigs, llama and alpaca), for vegetable protein from the grains produced at middle altitudes and for vitamins and essential fatty acids from the fruits and vegetables grown in subtropical gardens at lower altitudes towards the Amazon. Vertical trade of this kind has been an integral part of the economy of the region since pre-Inca times[540].

Regaining control

The development of the Potato Park took a major step forward in December 2004 with the *Agreement on the repatriation, restoration and monitoring of agrobiodiversity of native potatoes and associated community knowledge systems*[541] made between the Association of Communities in the Potato Park, represented by the Association for Nature and Sustainable Development (ANDES, in its Spanish acronym), and CIP is legal under Peruvian law[542]. CIP is one of the 15 research centres of the Consultative Group on International Agricultural Research (CGIAR).

The agreement, in the words of Alejandro Argumedo, Associate Director of ANDES, was the "first legal sign of the restoration of rights that indigenous people once had"[543]. He continued, "this does not mean that these communities will now procure patents over these varieties of potato. These indigenous people are against patents. They represent a model of property that does not fit into their worldview. Indigenous people are used to exchanging and sharing information in open ways. But this means a legal agreement that no one else can claim intellectual property rights over their knowledge".

Under the scheme, CIP scientists and local farmers are 'repatriating' potato varieties from CIP's collection of specimens (the agreement initially covers 206 varieties). CIP has agreed to pay for the cost of reintroduction as an acknowledgment of the benefits the organisation has derived from the indigenous knowledge of the region[544]. The repatriated varieties have been distributed in the Potato Park and replanted in the area, where they are used for local food security, medicines and ceremonies.

Management

The Potato Park is a locally managed community conserved area using the model, developed by ANDES, of an Indigenous Biocultural Heritage Area (IBCHA). The IBCHA model describes a community-led and rights-based approach to conservation based on indigenous traditions and philosophies of sustainability, and the use of local knowledge systems, skills and strategies related to the holistic and adaptive management of landscapes, ecosystems and biological and cultural assets. An IBCHA incorporates the best of contemporary science and conservation models and rights-based governance approaches, including the IUCN's Category V Protected Areas[545] and Community Conserved Areas (CCA's)[546], as well as positive and defensive protection mechanisms for safeguarding the Collective Biocultural Heritage (CBCH) of indigenous peoples. (CBCH includes the cultural heritage, i.e. both the tangible and intangible including customary law, folklore, spiritual values, knowledge, innovations and practices and local livelihood and economic strategies, and the biological heritage, i.e. diversity of genes, varieties, species and ecosystem provisioning and regulating, of indigenous communities which are often inextricably linked through the interaction between local peoples and nature over time and shaped by their socio-ecological context).

IBCHA are based on deeply-rooted Andean traditions of biodiversity and landscape management. Therefore the approach uses context-specific indigenous knowledge, practices and innovation systems, customary laws principles, norms and institutions, and traditional organisations of collective action. IBCHA aims to ensuring the sustainable livelihoods of indigenous cultures and their future generations by:

- ✓ relying on local resources to create alternative economies;
- ✓ reinforcing indigenous cultural and spiritual values (such as gratitude and respect for Pachamama (Mother Earth) and the Apus (Mountain Gods)) in order to achieve sustainable resource exploitation; and
- ✓ using Customary Laws and Institutions to develop an effective management, conservation and sustainable use of biodiversity and ecosystems outside formal protected areas.

Though IBCHAs are voluntarily established, these community conserved areas are obliged to have a management plan, a five year master plan, yearly reports and a monitoring and auditing system. Authority for the Park is shared between the villages, each of which elects one Chairperson to coordinate the work of the Association and concerted efforts are made to integrate traditional religious beliefs and understanding into the management[547].

Sustaining development

The repatriation of native potatoes is helping support the work of the Association of Communities of the Potato Park to develop alternative economic activities. Examples of local projects which are managed by economic collectives include:

- ✓ the Sipaswarmi Medicinal Plants Womens' Collective, which develops and sells natural medicine and natural soaps in the six communities of the Potato Park;
- ✓ a landscape-based agroecoturism venture which includes a network of walking trials, a potato-oriented restaurant and workshops and stores for the production and sale of local handicraft;
- ✓ the Arariwa, a native potato repatriation and seed development collective; and
- ✓ the Tijillay T'ika Women´s Audio-visual Collective, where members of a women's cooperative are being trained in making and digitally editing videos in order to record and share knowledge of potato varieties and how to manage them, using the local language.

A database of traditional medicinal knowledge is also being established to protect against biopiracy and a network of barefoot technician, who are elected by their communities because of their expertise in traditional knowledge, are developing a dynamic process of horizontal learning and knowledge exchange. These barefoot technicians, for example, have been supporting other communities by providing information, support exchange of experiences and cross-community visits, offering participatory planning and evaluation methods at community level, organising training courses and help advocate for the needs, visions and rights of indigenous peoples and their knowledge systems. Organisations of collective action such as Local Learning Groups and experts in traditional knowledge spearhead community training as well as processes to gather, organise and apply traditional knowledge. Local Learning Groups have been trained as community facilitators and leaders to enhance indigenous knowledge and to strengthen the institutional capacity of communities to manage local knowledge and innovations in the Park's conservation and development programmes.

As well as ensuring the conservation of potatoes, the communities plan to regenerate native forests, most of which were cut down in the 18th century to provide timber for Spanish silver mines. Currently the main tree species on the hillsides are alien *Eucalyptus*, planted in the 1940s and 1950s, which, though it is valued for being fast growing and currently the main source of fuelwood, is otherwise of limited use. Nurseries for growing thousands of seedlings of native species have been set up. By regenerating native forests, the villagers hope to promote greater biodiversity, which will also help fulfil the objective of encouraging 'agro-ecotourism'.

The Park is developing an autonomous programme for managing tourism and ensuring local people benefit equitably. A new research and visitor's centre is being established to help with administration, marketing and coordination. The Potato Park is also in discussions with the National Institute of Culture to agree a system for co-management of archaeological sites and sacred sites in the area[548].

The new sense of unity that has been established between the communities has brought other ancillary benefits. A history of (occasionally violent) land conflicts between the communities has been largely overcome, in part through the revival of the customary village boundary festival, in which each village's links with the land are celebrated each year by walking the boundaries. As Association Chairman Wilbert Quispe has remarked, "Before this project we were divided and were losing our diversity, native potatoes, wildlife and many other things....we were also forgetting how to manage this variety. Our aim is to reunite our villages in order to restore our traditional ways of managing our landscape" [549].

Support and recognition

International support for the project has come from a number of NGOs, including the Sustaining Local Food Systems Agrobiodiversity and Livelihoods Programme of IIED and the Rockefeller Foundation. The initiative is also backed by an International Support Committee which includes Hamdallah Zedan, the Executive Secretary of the CBD at the time, Juan Mayr Maldonado, ex-Minister for the Environment in Colombia among others, including movie artists and human rights activists. However, support has not been universal, as the Peruvian National Parks agency, INRENA, has yet to recognise the park as part of Peru's protected area system[550].

Conclusion

The Potato Park has demonstrated that successful biodiversity and ecosystem management depends on largely on the recognition of property rights, the dynamics of ecosystems and indigenous knowledge. This ensures the conservation and sustainable use of biodiversity at all levels, contributing to the equity, opportunity, security and empowerment of local and indigenous communities, as well as to the sustainability of the biological resources and landscapes. The Potato Park is an excellent example of biocultural restoration, which has resulted in a wide range of biodiversity, agricultural and cultural benefits to the local communities, as well as safeguarding an important global resource for future generations. The scheme is planned as a pilot for an even larger initiative in landscape conservation in the Andean region[551] and a long term goal of the Association is to re-establish all the world's 4,000 known potato varieties in the valley[552].

India: Prioritising conservation[ix]

The Biodiversity Conservation Prioritisation Project of WWF-India has researched the status of the known CWR in India and identified in situ *conservation priorities.*

India is one of the world's most important regions of crop genetic diversity. Notable contributions to the world's crops include species of rice, beans, onions, mango, yam, okra, pepper, nutmeg, ginger, sugar cane and cinnamon.

The National Bureau of Plant Genetic Resources (NBPGR) has listed more than 320 species of CWR known to occur in India. These species are vulnerable to the same kinds of threats as other wild species, including habitat degradation and loss, over-exploitation and competition from introduced species. Many of the CWR are endemic and restricted to a limited geographical area, and thus more likely to become extinct from their natural habitats where these threats occur. The distribution of CWR in seven phytogeographic zones in India has been estimated (see table 10).

Table 10: Phytogeographic Zones and CWR of India

Phytogeographic Zone	No. of CWR species
Western Himalaya	125
Eastern Himalaya	82
North Eastern Region	132
Gangetic Plains	66
Indus Plains	45
Malabar / Western Peninsular Region	145
Deccan / Eastern Peninsular Region	91

The need to understand the current status of CWR and identify urgent *in situ* conservation requirements has been studied by the Biodiversity Conservation Prioritisation Project of WWF-India. The project's objectives were:

1. To update the list of wild relatives of crop plants and domesticated animals of India, to assess their conservation status and to prioritise them for conservation.

2. To identify relevant institutions/organisations/NGOs who may contribute towards conservation of these wild plants and animals.

3. To collate information on distribution of wild relatives of cultivated plants and domesticated animals with distribution of tribal communities in India and study ethnobotanical relationships.

4. To prepare distribution maps of the prioritised species of wild relatives of crop plants and domesticated animals and identify suitable areas for *in situ* conservation.

[ix] This case study is based on the paper by Rana R.S. and Sudipto Chatterjee (2000); Prioritization of Wild Relatives of Crop Plants of India and domesticated animals. In: In Singh et al (eds), *Setting Biodiversity Conservation Priorities for India*, WWF-India, New Delhi, India, 707 pp

Methodology

A strict definition of CWR was not available; therefore, a species was considered a wild relative of a crop plant if it was within a genus reported to be under cultivation.

All available information was categorised for CWR concerning their distributional range, consumptive usage and any other aspect which would aid prioritisation of the species. Those wild relatives which were identified to be closest to their domesticated counterparts morphologically and genetically, have a limited distributional range, are rare and/or endemic, are reported to be threatened due to overexploitation, are species of high socio-economic significance and those species for which adequate information could not be obtained, were initially shortlisted. Final prioritisation was made on the basis of criteria given below:

1. Species endemic to a particular region. Endemism was afforded highest priority.
2. Species having restricted distribution in one to two biogeographic zones
3. Species categorized as Critically Endangered due to overexploitation or habitat destruction.
4. Species that have contributed genes of resistances to present day cultivars and facing threats due to anthropogenic factors
5. Species having a potential of conferring useful traits
6. Species of high socio-economic significance, such as those used for medicinal purposes, as substitutes for food crops during stress periods like drought and famine, and in religious ceremonies etc.

Since the existing information on wild relatives of crop plants is scattered, research effort was targeted primarily on the collection of information. Distribution maps of the prioritised species were prepared on the basis of available information on the species from the herbarium of NBPGR in New Delhi.

Results

Over 100 species were prioritised following the methodology above (see table below). More specifically, NBPGR has recorded a rich diversity of 26 species of wild *Allium* in the Western Himalaya. Thus as most of the species of *Allium* in India are distributed in the temperate and alpine zones of Himalaya, WWF suggested that a suitable site in West Himalaya could thus be considered as a probable site for a Gene Sanctuary for *Allium*.

Table 11: CWR conservation priorities in India

No. of species	Crop related to	Reason for Prioritisation
7	Rice	Three species were endemic to specific regions (*Oryza malabarensis; O. jeyporeniis; O. inadamanica)*; one species was of socio-economic significance as it is used in religious ceremonies, has decreasing habitat and has already contributed a gene for resistance to blast and grassy stunt virus (*O. nivara)*; two species were seen as difficult to conserve *ex-situ* – and one also had very specific habitat requirements (*O. rufipogon*; *O. meyeriana* ssp. *granulata*); and one is a monotypic genus and species of significance for transfer of the trait for salt tolerance (*Porteresia coarctata*).
2	Maize	Two primitive forms of maize (*Zea* spp) (Sikkim primitive1 and Sikkim primitive 2) which were discovered in the 1960s in the foothills of North Eastern Himalaya[553].
3	Millets	Three species with limited distribution: *Panicum hippothrix; Setaria glauca; Chionachne semiteres* (the latter is only found in Tamil Nadu in moist deciduous forest openings).

No. of species	Crop related to	Reason for Prioritisation
1	Cucumber	*Cucumis hardwickii*, the likely progenitor of cultivated cucumber, which has recently been reported in peninsular India.
1	Loofah	*Luffa umbellata* was prioritised as its distribution is confined to the Eastern cost/ Coromandal belt.
4	Gourd	Three species have been categorized as endemic/rare and overexploited (*Trichosanthes majuscule; T. ovata; T. tomentosa*) and one species with restricted distribution (*T. nervifolia*).
2	Yam	*Dioscorea deltoidae* and *D. prazeri* were prioritised as they both have been exploited due to their higher percentage of diosgenin (which provides about 50 per cent of the raw material for steroid synthesis; wild yam root has been used for hundreds of years to treat rheumatism and arthritis-like ailments).
3	Okra	All have limited distribution (*Abelmoschus angulosus; A. crinitus; A. manihot* ssp. *manihot*).
4	Brinjal (Aubergine)	The species which is the closest relative of cultivated brinjal *S .melongena* (*Solanum melongena* var. *incanum*); two species have been identified as rare (*S. straminfolium*; *S. vagum*)[554]; and one species categorized under endemic, rare and over-exploited (*S. potangi)*.
10	Pigeon pea	Nine have limited distribution (*Cajanus trinervius*; *C. goensis; C. grandiflorus; C. kulensis; C. lineatus; C. nivea; Dunbaria glandulosa; C. rugosus; C. trinervius*); and one is endemic (*A. cajanifolius)*.
6	Bean	Five species with restricted distribution (*Vigna grandis; V. khandalensis; V. mungo* var. *sylvestris; V. vexillata; V. dalzelliana*); also *Canavalia microphyllum* which is restricted to the temperate and alpine regions of Western Himalaya and reported to be at risk.
4	Onion	Restricted ranges. *Allium rubellum*, *A. tuberosum* and *A. schoenoprasum* are found in Western Himalaya and *A. jacquemontii* is distributed in Western Ghats.
1	Mulberry	*Morus serrata* is indigenous to India and is restricted to forests in the North Eastern States to an elevation of 1000-1400 m.
12	Banana	It is believed that Musa originates from the humid tropical regions, somewhere in the mountainous regions of Assam, Burma and Indo-China. All species prioritised have a restricted distribution (*M. acuminata, M. balbisiana, M. cheesmanii, M. flaviflora, M. itinerans, M. manii, M. nagensium, M. sikkimensis, M. superba* and *M. velutina, M. kattuvazhana, M. rosaceae*).
2	Jackfruit	*Artocarpus heterophyllus* and *A. integer* are both indigenous to India and reported to occur in the Western Ghats region.
4	Plum/Cherry	*Prunus cerasoides*, *P. cornuta* var. *vilosa*, *P. napaulensis* and *P. jenkinsii* are recommended for prioritisation due to their restricted distribution in the North East of India.
3	Pear/peach	*Pyrus kumaoni* (endemic to Western Himalaya - Kashmir to Kumaon), *P. pashia* (endemic, distributed in subtemperate to temperate Himalayas, used as rootstocks for peach), *P. pyrifolia* (found semi - wild in Nilgiris, used as rootstock) are recommended for prioritisation.
1	Black currant	*Ribes nigrum,* which has restricted distribution in Temperate Western Himalaya.
5	Berry	Varieties with limited distribution (*Rubus fruticosus* var. *discolour; R. lineatus; R. nutans; R. paniculatus* and *R. rosafolius)*.

No. of species	**Crop related to**	**Reason for Prioritisation**
3	Jujuba	*Zizyphus mauritiana* var. *fruticosa* (rarely found in rain shadow areas at lower elevations in Western Ghats), *Z. xylopyrus* (occurs rarely in semi – deciduous forests in Western Ghats) and *Z. trinervia* (confined to Western Ghats) are being recommended for prioritisation.
7	Citrus fruit	Restricted ranges (*Citrus inchangensis, C. assamensis, C. macroptera, C. laltipes, C. media, C. jambhiri)*. *Citrus indica,* the most primitive and perhaps the progenitor type, is highly endangered. The species was prioritised despite a Citrus Gene Sanctuary being established in the Tura range and its foothills (see entry on Nokrek National Park), the species is also still found in the Garo hills in Meghalaya, the foothills in Nagaland and Kajiranga forest in Assam.
2	Quince	*Docynia indica* and *D. hookeriana* are confined to the Evergreen and Semi Evergreen forests of the North Eastern Hills.
2	Loquat	*Eriobotrya angustissima* and *E. dubia* which are endemic to central and Eastern Himalaya.
1	Strawberry	*Fragaria nilgerrensis* which has restricted distribution in Nilgiris and in the Aka and Khasi Hills of Meghalaya.
17	Mangosteen	Restricted rages and some species which are rare and endemic to Andaman & Nicobar Islands (*Garcinia andamanica, G. andamanica* var. *pubesens, G. atroviridis, G. breviastris (=G. euginefolia), G. cadolliana, G. calcyna, G. cambogia, G. cowa, G. dulcis, G. hombroniana, G. jilineki, G. kingi, G. kurzi, G. microstigma, G. nervosa, G pedunculata, G. spicata (=G. ovalifolia)*)
1	Apple	*Malus sikkimensis*, which is endemic to high altitudes in Central and North Eastern region and also used as a rootstock.
3	Mangoes	*Mangifera andamanica* (restricted to Andamans), *M. gedebe* (restricted to Andaman and Nicobar), *M. khasiana* (restricted to khasi hills) are recommended for prioritisation.

Chapter 7: Recommendations

African rice from Udzungwa Mountains, Tanzania

Credit: © WWF-Canon / Sandra Mbanefo Obiago

In situ conservation of CWR and landraces is fundamental to global food security and protected areas can play a key role in achieving the conservation of crop genetic diversity. It is understood that there is routinely a need to integrate the conservation of agro-biodiversity into protected area management. However at present the current global protected areas network is largely inadequate for this task, not only in terms of the under-representation of areas most suitable for CWR and landraces within existing protected areas but also in terms of the neglect they suffer on the part of management in the protected areas where they are indeed represented. If the desired goal of combining protected areas with agro-biodiversity conservation is to be achieved, there is a need for a global collaborative approach to increasing, systematic levels of protection. The increasing loss of agro-biodiversity threatens all humankind as this diversity forms the basis of plant breeders' options for new varieties. Loss of diversity in one country can affect crop stability in remote countries on the other side of the world and potentially the profits of companies based far away. Agro-biodiversity conservation requires a concerted local, national and global effort to halt this thoughtless waste of our natural resources. Protected areas can provide effective protection for agro-biodiversity when they are prioritised, effectively managed and their conservation exists within an adequate policy and governance environment that can ensure their long-term sustainability. The following outlines a recommended approach for implementation at the local, national and international levels to facilitate agro-biodiversity conservation in protected areas and address the important issues outlined.

Recommendations for Local Fora

- **Protected area / Agro-biodiversity**: Protected area managers should promote the conservation of crop wild relatives and landraces within their protected area. A detailed methodology to assist protected area managers to enact this requirement is provided in Chapter 5, but initial steps will involve the identification of priority national CWR and landrace diversity, producing an inventory of CWR and landrace diversity within the protected area, actively conserving that diversity and then promoting that diversity with the user stakeholder whether they be the general public or agri-business.

- **Protected area inventories**: It is recognised that many protected areas lack complete floristic inventories. This is necessary to highlight which CWR are present and should be extended, where applicable, to cover the landrace varieties traditionally grown in the protected area.

- ***Ex situ* duplication**: Once CWR and landrace diversity is identified in protected areas it should be routinely sampled and duplicated in *ex situ* collections as a safety back-up for its *in situ* conservation, and also as a means of promoting diversity utilisation. The routine duplication should be linked to a broader *in situ* and *ex situ* gap analysis of CWR and landrace diversity, as is discussed in Chapter 4 above.

- **Use of agro-biodiversity from protected areas**: It is widely recognized that conservation of agro-biodiversity is not an end in itself. To be effective and sustainable, conservation of agro-biodiversity needs to be linked to use. Therefore, it is vital to ensure that agro-biodiversity conserved in protected areas is made available to the user community.

- **Private industry**: The agri-business industry is the sector that most directly reaps the economic benefits from the genetic potential maintained in CWR and landraces. A thorough calculation of how much the main international corporations dealing with agribusiness invest in support to *in situ* CWR conservation is still to be done, but it would certainly reveal that it is infinitely smaller than the benefits that they reap from the use of the genetic material conserved in protected areas. Therefore they should be actively encouraged to take a partnership role in supporting protected areas, where this role does not clash with international treaties and conventions such as the CBD, International Treaty on Plant Genetic Resources for Food and Agriculture or CITES.

- **Non-governmental organisations**: Conservation organisations, particularly those that own or manage land for conservation, should include the conservation needs of agricultural biodiversity within their planning systems as well as methodologies for identification and management of protected areas. This could involve the establishment of community seed banks for locally unique landraces and wild harvested CWR to help ensure their continued availability and use.

- **Communities**: Protection is not necessarily confined to government-owned protected areas. Community Conserved Areas can play a fundamental role in protecting agricultural biodiversity and they should be supported in their efforts.

- **Benefit sharing**: many landraces and CWR exist on the lands of indigenous peoples and other ethnic minority groups. There is a need to ensure that their fundamental role in conserving this type of diversity is fully acknowledged, and their efforts supported. Current international legislation aims at ensuring that this will take place, but its actual implementation at the local level needs careful monitoring. The benefits that indigenous and local people could accrue from the use of 'their' genetic material for commercial purposes is so far ill defined, and the positive and real advantages for local people and their important biodiversity remain to be seen

Recommendations for National Fora

- **Protected area / plant genetic resources collaboration:** Traditionally the protected areas and plant genetic resources communities have tended to work in isolation as two independent conservation communities; this lack of communication and collaboration has undoubtedly been to the detriment of both communities and the elements of biodiversity they wish to conserve. This new initiative to bring to two communities closer together and engender cross-community collaboration will benefit both and should be actioned through closer institutional ties and joint fora.

- **Prepare national CWR strategic action plans**: Each country needs to nominate two national focal points one for CWR and one for landrace conservation, to prepare a national inventory for CWR and landrace diversity, prioritise taxa and traditional varieties, and write a national action plan for their conservation (highlighting the role of protected areas and *ex situ* collections), and sustainable use. A methodological approach to these issues is discussed in Chapter 4 above.

- **National governments in centres of crop diversity**: One of the findings of this report is that there are still some fundamental gaps in the representation of CWR under the current system of protected areas, and this gap is particularly prevalent in the centres of crop diversity. Countries should be encouraged to develop national strategies for CWR and landraces as outlined in this report, including assessing the potential of existing protected area networks for conserving crop genetic diversity and if necessary expanding and strengthening these networks.

- **National governments capable of providing support**: Donor countries could consider the role of support for protected areas in maintaining agricultural diversity in light of efforts to promote sustainable development, reduce the vulnerability of the poor and improve livelihoods. Further support is required, possibly through GEF or bilateral agencies, to develop protected area projects in those parts of the world where important CWR and landraces are currently under-protected. There is also a need to further disseminate the results of projects which are already underway to do this.

- **Market or economically-based actions**: There is a need to establish market or economically-based actions that will promote CWR and landrace maintenance, and identify and counter perverse incentives that result in the erosion of genetic diversity, particularly in relation to crop landraces.

- **Genetic pollution**: Urgent action is required to ensure that CWR and landraces are not contaminated by either genetically modified or modern crop varieties, as this can undermine the very concept of maintaining their unique genetic diversity. The planting of GMOs or modern cultivars near priority sites where CWR or landrace are being actively conserved should be avoided. National legislation and regulation regarding GMOs must account for this important priority.

- **Biopiracy**: Many governments are understandably concerned about the risks of losing genetic material through theft. Management of protected areas to protect genetic material should include effective means of ensuring that control of this material remains in the state in which it occurs naturally. However, this should be consistent with the application of the International Treaty on Plant Genetic Resources for Food and Agriculture which promotes the utilization of genetic resources for the good of humankind.

Recommendations for International Fora

- **Greater international, regional and national collaboration**: If CWR and landraces are to be more effectively conserved in protected areas there is need for increased collaboration and coordination to prioritise agro-biodiversity conservation in key protected areas. The ‘Global Strategy for Crop Wild Relative Conservation and Use’ recommends the identification at the national, regional and global level a small number of priority sites (global = 100, regional = 25 and national = 5) for the establishment of active CWR genetic reserves. These reserves should form an interrelated network of internationally, regionally and nationally important CWR genetic reserve sites for *in situ* conservation. Although the Global Strategy is focused on CWR conservation the principle could be equally applied to landraces conservation.

- **Additional Protected Areas**: there is an urgent need to increase the level of protection in centres of crop genetic diversity with inadequate levels of protection and / or rapid habitat destruction to uses incompatible with biodiversity conservation. Our initial research has identified the following examples of ecoregions where additional protected areas should be established in areas of particular agro-biodiversity importance:
    - Southern Korea evergreen forests (South Korea)
    - Sumatran lowland rain forests (Indonesia)
    - Eastern Anatolian deciduous forests (Iran, Turkey and Armenia)
    - Kopet Dag woodlands and forest steppe (Southern Turkmenistan and northern Iran)
    - Eastern Anatolian montane steppe (Iran, Turkey and Armenia)
    - Alai-Western Tian Shan steppe (Kazakhstan, Uzbekistan, and into Tajikistan)
    - Gissaro-Alai open woodlands (Kyrgyzstan, Tajikistan, and Uzbekistan)
    - Tian Shan foothill arid steppe (China, Kazakhstan, and Kyrgyzstan)
    - Beni savanna (Northern Bolivia)
    - Central Andean wet puna (Peru and Bolivia)

  Each country needs to assess whether the existing network of protected areas adequately represents the full range of national CWR diversity, and suggest additional reserve locations where required.

- **International direction**: The CBD could consider developing additional guidance to its *Programme of Work on Protected Areas*, in collaboration with the Food and Agriculture Organization of the UN and the International Plant Genetic Resources Institute, encouraging Parties to include CWR and landraces within their ecologically-representative protected area networks.

- **Technical support**: The conservation of agro-biodiversity in protected areas is a relatively novel concept and clear methodological guidelines need to be developed and made widely available to protected area managers. Specifically the guidelines need to focus on managing protected areas for CWR and landraces, the integration of agro-biodiversity conservation with broader biodiversity conservation and also how best to enhance the benefits for local community from conserved areas that could provide useful resources, including sacred sites and other areas set aside from development. Certain regions of the world with experience in these applications should be encouraged to share their expertise by means of active programmes of technology transfer between countries and regions.

- **Legislation**: The CBD encourages individual countries to establish national biodiversity conservation, but there is a more specific need to develop and strengthen national and international wildlife protection legislation to promote the conservation of agro-biodiversity in protected areas**.** There is a need to review which CWR species are included in existing national, regional and global policy and legislative instruments, and where necessary initiate legislative protection for priority CWR taxa and landraces not already covered.

- **Professional and public awareness**: Encouragement of greater professional and public awareness of the vital role agro-biodiversity plays in global, national and local food security, and the pivotal role that protected areas can play in the long-term sustainability of agro-biodiversity.

- **Education**: General public awareness of the vital role agro-biodiversity in food security and wealth creation could be enhanced by the promotion of greater general environmental and specific agro-biodiversity and protected area conservation in education at primary, intermediate and higher levels.

- **IUCN**: Within IUCN, the World Commission on Protected Areas and the Species Survival Commission could help to provide leadership on these issues by setting up a joint task force on CWR and protected areas. It should also take the lead in red listing of CWR taxa.

- **Conservation outside of protected areas**: Finally is should be recognised that as many CWR favour disturbed habitats, their conservation outside the formal network of protected areas should also be encouraged, for example along roadsides and field margins. However, protected area managers may still play a role in advising those who manage these habitats on how best to promote the maintenance of the CWR diversity within these habitats.

Research requirements

- An expanded survey of global CWR occurrence in protected areas, particularly in centres of crop diversity, and identification of priority sites for the establishment of novel protected areas.

- Survey the landraces being grown in protected areas, possibly concentrating initially on IUCN Category V and VI protected areas, as these areas include overall management objectives to conserve traditional landscapes or areas of sustainable use.

- Survey community conservation areas outside of formal protected areas that play a major role in maintaining genetic material of agricultural value.

- Conduct population level research on selected CWR to aid IUCN Red List Category threat and conservation assessment.

- Examine the level of genetic erosion and genetic pollution threatening CWR and landrace diversity and its possible consequences on future food security.

- Establish and publish protocols for the complete genetic reserve location, establishment and routine maintenance process to act as templates for subsequent projects.

- Establish and publish protocols for the integration of CWR and landrace into established protected area management and how to promote the routine use of *in situ* conserved CWR and landrace diversity.

Appendix 1: Protected Areas in Ecoregions Important to Crop Genetic Diversity

Alai-Western Tian Shan Steppe
Uzbekistan
Nuratinskiy
Zeravshanskiy
Tajikistan
Zeravshansky (Sarezmsky)
Beni Savanna
Peru
Bahuaja-Sonene
Bolivia
Estación Biológica Beni
Isiboro Securé
Borneo Lowland Rain Forests
Brunei Darussalam
Anduki (Conservation)
Andulau (Conservation)
Arboretum (Conservation)
Berakas (Recreation)
Bukit Biang (Conservation)
Bukit Shahbandar (Recreation)
Keluyoh (Conservation)
Labi Hills (Sungai Ingei Conservation)
Ladan Hills (Bentuan Catchment Protection)
Peradayan (Recreation)
Pulau Siarau Nature Reserve
Subok Hills (Recreation)
Sungai Liang (Recreation)
Tasek Merimbun Nature Park
Ulu Temburong
Indonesia
Bukit Baka - Bukit Raya
Bukit Batutenobang
Bukit Perai
Bukit Rongga
Gunung Bentuang
Gunung Niut Penrisen
Gunung Palung
Gunung Raya Pasi
Gunung Sebatang
Gunung Tunggal
Kepulauan Karimata
Kutai
Pararawen I, II
Sultan Adam
Sungai Kayan Sungai Mentarang
Tanjung Puting
Teluk Kelumpang/Selat Laut/Selat Sebuku
Malaysia
Batang Ai
Bukit Tawau
Crocker Range
Gunung Gading
Gunung Mulu
Kinabalu
Kubah
Kulamba
Lambir Hills
Lanjak-Entimau
Loagan Bunut
Niah
Pulau Tiga
Samunsam
Similajau
Tabin
Tunku Abdul Rahman
Central American Montane Forests
El Salvador
El Imposible
Montecristo
Guatemala
El Espino
K'ante Shul
Laguna El Pino
Los Altos de San Miguel Totonicapán
Mario Dary Rivera
Pachuj
Quetzaltenango SAQBE
Sierra de las Minas
Volcán Atitlan
Volcán Acatenango
Volcán Agua
Volcán Chicabal
Volcán Lacandón
Volcán San Antonio o Saquibutz
Volcán Tacaná
Volcán Tajumulco
Volcán Tecuamburro
Honduras
Celaque
Cerro Azul de Copán
Cusuco
El Uyuca
La Tigra
Pico Bonito
Pico Pijol
Nicaragua
Bosawas
Cerro El Arenal
Cerro Kilambé
Cerro Quiabuc (Las Brisas)
Cerro Tisey - Estanzuela
Cordillera Dipilto y Jalapa
Fila Cerro Frío - La Cumplida
Macizo de Peñas Blancas
Mesa de Moropotente
Ramal de Datanli - Cerro El Diablo
Saslaya
Tepesomoto / Pataste
Volcán Yalí
Central Andean Wet Puna
Bolivia
Cotapata
Ulla Ulla
Peru
Chacamarca
Huascarán
Huayllay
Junín
Machupicchu
Titicaca
Eastern Anatolian Deciduous Forest
Turkey
Muzur Vadisi
Mendo Forest
Zafran Forest
Eastern Anatolian Montane Steppe
Armenia
Dilijan
Khosrov
Sevan
Azerbaijan
Arazboyu
Basutchay
Ordubad
Georgia
Algeti
Iran, Islamic Republic of
Angoran
Arasbaran
Kiamaky
Marakan
Urumieh Lake
Eastern Mediterranean conifer-sclerophyllous-broadleaf forests
Israel
Allone Abba
Ashqelon
En Afeq
Gan Hashlosha
HaGilboa
Hahula
Har Meron (Mount Meron)
Me'arat HaNetifim
Mount Carmel
Nahal Hermon
Nehalim Gdolim U-Qtura
Sela Akhbara
Tel Dan
Tel Qeriyyot
Yarkon
Jordan
Ajloun
Turkey
Karatepe-Aslantas
Ethiopian Montane Grasslands and Woodlands
Eritrea
Yob

Ethiopia
Arsi
Bale Mountains
Borana
Eastern Hararghe (Harar-Wabi Shebelle)
Maze
Mizan-Teferi
Nechisar
Simien Mountains

Gissaro-Alai Open Woodlands
Kazakhstan
Aksu-Dzhabagly
Kyrgyzstan
Akbuurin
Besh-Aral
Chandalash
Chychkan
Gulchin
Kara-Shoro
Kyrgyz-Ata NP
Manass
Sary-Chelekskiy
South Kyrgyz
Yassin
Tajikistan
Aktashsky
Chil'dukhtaronsky
Dashtidzumsky
Dashtimaidonsky
Iskanderkul'sky
Komarou
Ramit
Saivatinsky
Sarykhosorsky
Shirkent
Tigrovaya Balka
Uzbekistan
Chatkalskiy
Gissarskiy
Kitab Geological NR
Ugam-Chatkal
Zaamin
Zaaminskiy

Gizhou Plateau Broadleaf and Mixed Forests
China
Badagongshan
Baiqing
Caohai
Changningzuhai
Chishuisuoluo
Chishuiyuanshenglin
Daozhendashahe
Duyunluosike
Fanjingshan (Guizhou)
Fodingshan
Haiziping
Houhe
Huagaoxi
Huoyan
Jinfoshan
Leigongshan
Lenshuihe
Liangtouyang (Fenghuang)
Mayangheheiyehou
Mulinzi
Qizimeishan
Sanjiangkou (Yunnan)
Shimenhupingshan
Simianshan
Suoxiyu
Tianmenshan
Tianzishan
Tongluoba
Tuodabaiguanchangweizhi
Wangcaokuankuoshui
Xiaohe
Xiaonanhai
Xiaoxi
Xingdoushan
Xishuizhongyaredaisenlin
Zhangjiajiedani

Hainan Island Monsoon Rain Forests
China
Bangxipolu
Bawangling
Datian (Hainan)
Fanjia
Huishan
Jianfengling
Jiaxi
Nanlin
Shahe shuiziyuan
Songtao shuiyuanlin
Wenquan
Wuzhishan
Xihau kuangquanshui

Iberian Sclerophyllous and Semi-Deciduous Forests
Portugal
Serra de Sao Mamede
Spain
Balsa de Agua Salada
Balsa de Purguer
Cañón del Río Lobos
Cabañeros
Cabo Cope y Puntas de Calnegre
Carrascal de la Font Roja
Caídas de la Negra
Cornalvo
Cuenca Alta del Manzanares
Cursos Bajos de los rios Manzanares y Jarama
Cursos Bajos de los rios Manzanares y Jarama
Despeñaperros
El Carrizal de Villamejor
El Fondo
Hoces del Río Duratón
Laguna Amarga
Laguna de Fuentedepiedra
Laguna de los Jarales
Laguna de Tiscar
Laguna del Rincon
Lagunas de la Mata y Torrevieja
Lagunas de Ruidera
Las Tablas de Daimiel
Mas de Melons
Monfragüe
Montes de Malaga
Montserrat
Noguera Ribagorтana-Montrebei
Rincon del Bu
Salinas de Santa Pola
Salinas y Arenales de San Pedro del Pinatar
Sant Lloren del Munt I L'obac
Sierra de Andujar
Sierra de Aracena y Picos de Aroche
Sierra de Baza
Sierra de Cardena y Montoro
Sierra de Cazorla, Segura y las Villas
Sierra de Grazalema
Sierra de Hornachuelos
Sierra de Huétor
Sierra de La Pila
Sierra de las Nieves
Sierra Espuña
Sierra Mágina
Sierra Nevada
Sierra Norte
Sierra y cañones de Guara
Sierras Subbéticas de Córdoba
Vedado de Eguaras

Isthmian-Pacific Moist Forests
Costa Rica
Aguabuena
Cacyra
Carara
Cataratas de Cerro Redondo
Cerro de La Cangreja
Cerro Nara
Cerros de Turrubares
Chirripó
Corcovado
Donald Peter Hayes
Fernando Castro Cervantes
Finca Barú del Pacífico
Forestal Golfito S.A.
Golfito
Golfo Dulce
Hacienda Copano
Internacional La Amistad
Las Tablas
Manuel Antonio
Marino Ballena
Piedras Blancas
Portalón

Punta Río Claro
Rancho La Merced
RHR Bancas
Transilvania
Panama
Altos de Campana
Cerro Hoya
Coiba
General Omar Torrijos
La Amistad
Playa de Boca Vieja
Volcan Baru
Jian Nan Subtropical Evergreen Forests
China
Baidongheshuiyuanlin
Bamianshan
Bantang
Buliuheshuiyuanlin
Cenwanglaoshanshuiyuanlin
Changle haibang
Chebaling
Chengbiheshuiyuanlin
Chuandonghe
Dahongjiangshuiyuanlin
Daiyunshan
Dapingshanshuiyuanlin
Dingliao
Donganshunhuangshan
Duyi
Fanjingshan (Guizhou)
Fengxi
Fengyangshan-baishanzu (Zhejiang)
Geshikao
Guangningtuo
Guanjingyangdahuangyu
Guanshan
Guposhanshuiyuanlin
Gutian
Guxiuniaolei
Haiyangshanshuiyuanlin
Haiyangzhenxiwuzhong
Heishidingkuoyelin
Huangsang
Huangyoubi
Huaping
Huashuichongshuiyuanlin
Huifengling
Jiangshi
Jianxinniaolei
Jiaqiaolingshuiyuanlin
Jinggangshan
Jinpenshan (Longnan)
Jiugongshan
Jiulianshan
Jiulongjianghongshulin
Jiulongshan (Zhejiang)
Jiuwanshanshuiyuanlin
Jiuyishan
Lagouniaolei
Leigongshan
Liangyeshan
Linghuashan
Liuyangdaweishan
Longmenxidani
Luobuyannanmu
Luofushan
Mangdangshan
Mangshan
Maoershan
Maolan
Meihuashan
Miliangdongziranbaohuqu
Mulun
Nankunshankuoyelin
Nanling
Nanling
Ningdoulianhuashan
Niumulin
Qianjiadongshuiyuanlin
Qingshitanshuiyuanlin
Quanzhouwanhekou
Sanbaishan
Sanpihushuiyuanlin
Sansuoniaolei
Shajiaodongyingshan
Shimentai
Shouchengshuiyuanlin
Shuijiang
Taoyuandong
Tianbaoyan
Wufubaodingshuiyuanlin
Wugangyunshan
Wuhua qirifeng
Wuyanling
Wuyishan
Xiangtoushan
Xilinshan shuiyuanlin
Xingangzhenguidongwu
Xinningshunhuangshan
Yangchunbaiyong
Yangling
Yangmingshan
Yanquan
Yihuanghuananhu
Yindingshanshuiyuanlin
Yinzhulaoshanlengshan
Yongzhoudupangling
Yuanbaoshanshuiyuanlin
Yuanyangmihou
Yuebeihuananhu
Yukeng
Yunjishan
Zhangjiangkouhongshulin
Ziyunwanfengshan
Kopet Dag Woodlands and Forest Steppe
Iran, Islamic Republic of
Sarany
Tandoureh
Turkmenistan
Guryhowdan
Kopetdag
Meana-Chaacha
Pulihatum
Sunt-Khasardag
Madeira-Tapajós Moist Forests
Bolivia
Federico Roman
Noel Kempff Mercado
Brazil
Amazônia
Cuniá
Guaporé
Iquê
Jarú
Pacaás Novos
Mediterranean Woodlands and Forests
Algeria
Belezma
Djurdjura
El Kala
Morocco
Ifrane
Merja Zerga
Talassantane
Toubkal
Tunisia
Bou-Hedma
Boukornine
Chambi
Ichkeul
Zembra and Zembretta
Meghalaya Subtropical Forests
India
Baghmara Pitcher Plant
Balphakram
Garampani
Intanki
Kaziranga
Nokrek
Nongkhyllem
Pobitora
Rangapahar
Siju Wildlife
Napo Moist Forests
Colombia
Alto Fragua - Indi Wasi
La Paya
Ecuador
Cayambe-Coca
Cuyabeno
Limoncocha
Napo-Galeras
Sumaco Napo Galeras
Yasuní
Peru
Pacaya Samiria
Northeastern Spain and Southern France Mediterranean Forests
France
Affluent de la Bléone, adou de Féraud
Anse des Galères

Bac de l'Alvèze
Bagnas
Barre des Dourbes et hêtraie du défend des Dourbes
Biotope de la doradille laineuse
Bois de Courbebaisse
Bois de Tourtoulen
Bois du Boucanet
Briande
Cadéraou
Camargue
Cap Camarat
Cap Lardier
Cap Taillat
Caroux-Espinouse
Castéou dou Souléou
Cerbère-Banyuls
Cirque de Mourèze
Collet de Sen
Combe chaude
Combe de Montelier
Conat
Coussoul de Gingine
Coussoul de la Jasse
Coussoul du Mas de gravier
Coussoul du Mas du Moulin
Coussoul du Mas du village
Cédraie du mont Ventoux
Cévennes
Domaine de Bonporteau
Domaine de Buisson gros et de la Fromagère
Domaine de Calissane
Domaine de Frescati
Domaine de Vaufrèges
Domaine des arbousiers
Domaine des Courmettes
Domaine du château de la Barben
Domaine du Rayol
Ecrins
Escampo - Bariou
Etang de Bolmon
Etang de l'Estagnet
Etang de l'Estagnol
Etang de l'Or - Cote de Plagnol
Etang de Méjean
Etang de Vendres
Etang de Vic
Etang du Grec
Etangs de Villepey
Falaises du mont Caume
Figuerolles
Fondurane
Font Brun
Forêt de la Massane
Gaou Bénat
Gorges de la Nesque
Gorges de l'Ardèche
Gorges de l'Hérault
Gorges du Gardon
Grotte des Sadoux
Grotte du Boundoulaou
Grotte du T.M. 71
Haras Saint- Estève
Hauts Plateaux du Vercors
Hêtraie du mont Ventoux
Ile de la Platière
Ile de l'Aute
Ile de Planasse
Ile du Beurre
Ile Sainte Lucie
Jujols
La Bastide du couvent
La Côte Bleue
La Caume
La Clapière
La Fontasse
La Gaillarde
La Lieude
La Palissade
La Peyroutarié, le Fourcat d'Héric et le Mascar
La Poitevine
La Ribère
Lac de Montoison
Le Bagnas
Le Coulomp et ses affluents
Le Doul, La Saline
Le Défend
Le grand Abondoux
Le Grand Castélou
Le Grand Travers
Le Jas de Rhodes
Le Lido
Le Luberon
Le Mazet
Le Petit Cogul
Le Petit Travers
Les Aresquiers
Les Auzils
Les Concluses
Les Eouvières
Les Grads de Naves
Les Orpellières
L'Hortus
Lit de la Durance : secteur de la Bastide neuve
Lit de la Durance : secteur de Restegat
Lit de la Durance : secteur de Tombadou
Lit de la Durance : secteur du Font du pin
Lit de la Durance : secteur du Mulet
L'Oustalet
Luberon
Marais de la Castillone
Marais de Manteyer et de la roche des Arnauds
Mas Atché
Mas de la Cure
Mas de l'Isle
Mas Larrieu
Massif de la dent de Rez
Mercantour
Montdenier
Montredon
Muraille de Chine
Nohèdes
Négreiron
Pla de les Forques
Plage de Vendres
Plateau de Dormillouse
Plateau du mont Serein
Pointe du Dattier
Port Cros
Presqu'ile de Port Miou – Plaine du Ris
Pré de Baugé
Puech des Mourgues
Ramières du Val-de-Drôme
Ravin des Arcs
Ripisylve de Chonas-l'Amballan
Rivière Ardèche
Rivière Asse
Rivières la Carança,la Tet et de Maureillas
Robiac
Roque-Haute
Saint Jean de Minervois
Sainte-Victoire
Saint-Martin de Bromes
Salines de Villeneuve
Salins de Frontignan
Sauve Plane
Secteur nord du massif du Bouquet
Serrat de la Narède
Site fossilifère Saturnin Garimond
Site paléontologique d'Aumelas
Sommet du mont Ventoux
Terre de Méjanes
Terre Neuve
Tour du Valat
Tournebelle
Tête de l'Emine
Vallon de la Goutine
Vallon du Fenouillet
Vallon et rocher de Roquebillière
Vallée de l'Avène
Spain
Aiguamolls de l'Empordà
Albufera de Valencia
Archipiélago de Cabrera
Delta del Ebro
Delta del Llobregat
El Montgo
Font Groga
Illa de Caramany
Isla de Sapinya

La Muga-Albanya
Marjal de Pego-Oliva
Massis del Montseny
Mondragó
Montserrat
Penyal d'Ifac
Prat de Cabanes-Torreblanca
Punta de la Banya
Riera d'arbucies
Riera de Merles
Riu Algars
Sa Dragonera
S'Albúfera des Grao
S'albufera
Sant Lloren del Munt I L'obac
Serres de Cadi- Moixeró
Zona Volcánica de la Garrotxa

Northern Indochina Subtropical Forests

China
Ailaoshan
Amushan
Caiyanghe
Daweishan
Dazhongshan
Dedanghoushan shuiyuanlin
Gancha
Gaoligongshan (Yunnan)
Guanyinshan (Yunnan)
Gulinqing
Huanglianshan
Huoshaoliangzi
Jiezihe (Mofanghe)
Jinpingfenshuiling (Yunnan)
Laojunshan (Maguan)
Longshanguishan
Nangunhe
Nanxi
Niuluohe
Ruilijiangliuyu
Tongbiguan
Weiyuanjiang
Wuliangshan
Xiaoqiaogou
Xintian (Dabanbi)
Xishuangbanna
Xishuangbanna nabanhe
Yongde daxueshan
Yuanjiangshuixiqudao
Zhangba
Lao PDR
Nam Et
Nam Ha (West)
Nam Xam
Phou Dene Din
Phou Loey
Thailand
Doi Pha Chang
Vietnam
Ba Vi
Ben En
Cuc Phuong
Dao Ho Song Da
Den Hung HCR
Hoang Lien Son-Sa Pa
Lam Son
Muong Nhe
Muong Phang
Nam Don
Ngoc Trao HCR
Pa Co Hang Kia
Phong Quang
Pu Huong
Sop Cop
Thac Ba
Thuong Tien
Xuan Nha
Xuan Son

Peninsular Malaysian montane rain forests

Malaysia
Cameron Highlands
Taman Negara
Templer
Krau

Peninsular Malaysian rain forests

Malaysia
Gunung Jerai (or G. Jerai)
Bukit Larut
Cameron Highlands
Bukit Fraser (Selangor)
Bukit Kutu
Klang Gate
Bukit Sungai Puteh
Berembun
Endau Rompin (Johor)
Gunung Ledang (or G. Ledang)
Port Dickson
Singapore
Singapore Botanic Gardens
Bukit Timah
Central Catchment
Thailand
Khao Nam Khang
Namtok Sai Khao
Budo-Sungai Padi
Sun Gala Khiri
Chalerm Prakiat Somdej
Prathep Ratsuda
Namtok Sipo
Budo-Sungai Padi
Bang Lang
Hala - Bala

Peruvian Yungas

Peru
Alto Mayo
Ampay
Bahuaja-Sonene
Cutervo
Huascarán
Machupicchu
Manu
Pagaibamba
Pampa de Ayacucho
Pui Pui
Río Abiseo
San Matias San Carlos
Sunchubamba
Tingo María
Yanachaga-Chemillen
Yanesha

Sierra Madre Occidental Pine-Oak Forests

Mexico
Campo Verde
Cascada de Bassaseachic
Cumbres de Majalca
La Michilia
Papigochic
Sierra de Alamos-Rio
Cuchujaqui
Sierra de Organos
Tutuaca
United States of America
Aravaipa Canyon
Baboquivari Peak
Chiricahua
Chiricahua NaM Wilderness
Coronado
Coyote Mountains
Dos Cabezas Mountains
Fort Bowie
Galiuro
Gila
Miller Peak
Mount Wrightson
North Santa Teresa
Pajarita
Peloncillo Mountains
Pusch Ridge
Redfield Canyon
Rincon Mountain
Saguaro
Santa Teresa

South Western Ghats Montane Rain Forests

India
Anamalai
Aralam
Eravikulam
Idukki
Kalakad
Mudumalai
Mundanthurai
Nagarahole (Rajiv Gandhi)
Neyyar
Parambikulam
Peppara
Periyar
Pushpagiri
Shenduruny
Silent Valley
Talakaveri

Southern Korea Evergreen Forests

Korea, Republic of
Chiri Mountain
Halla Mountain
Hallyo-Haesang Sea
Nakdong River Mouth
Tadohae-Haesang Sea
Wolchul Mountain

Southwest Amazon Moist Forests

Bolivia
Carrasco
Estación Biológica Beni
Federico Roman
Isiboro- Securé
Manuripi
Parque Nacional Pilón-Lajas
Brazil
Alto Juruá
Figueira
Macauá
Porto Dias
Remanso
Rio Acre
Riozinho
Santa Quiteria
Serra do Divisor
Peru
Bahuaja-Sonene
Manu
Pacaya Samiria
San Matias San Carlos

Southwest Iberian Mediterranean Sclerophyllous and Mixed Forests

Portugal
Arrábida
Arriba Fossil de Costa de Caparica
Açude da Agolada
Açude do Monte da Barca
Campo de Lapias da Granja dos Serroes
Campo de Lapias de Negrais
Estuario do Sado
Estuario do Tejo
Fonte Benemola
Gruta do Zambujal
Mata Nacional dos Medos
Monte S. Bartolomeu
Montes de Santa Olaia e Ferestelo
Paul de Arzila
Paul do Boquilobo
Ria Formosa
Rocha da Pena
Sapal de Castro Marim e Vila Real de S. Antonio
Serra de Sao Mamede
Serras de Aires e Candeeiros
Sintra-Cascais
Sudoeste Alentejano e Costa Vicentica
Spain
Bahía de Cadiz
Doñana
Entorno de Doñana
Isla de Enmedio
Laguna de Zóñar
Los Alcornocales
Montes de Malaga
Sierra de Aracena y Picos de Aroche
Sierra de Grazalema
Sierra de Hornachuelos
Sierra de las Nieves
Sierra Norte

Sumatran Lowland Rain Forests

Indonesia
Aceh Rafflesia I/II Serbojadi
Bentayan
Bukit Balai Rejang
Bukit Balal
Bukit Barisan Selatan
Bukit Dingin/Gunung Dempo
Bukit Hitam (Sebag)
Bukit Nantiogan Hulu/Nanti
Komerung Hulu
Bukit Raja Mandara
Bukit Sebelah & Batang
Pangean
Dangku
Dolok Sibual-bual
Dolok Sipirok
Dolok Surungan
Gumai Pasemah
Gunung Betung
Gunung Leuser
Gunung Raya
Gunung Singgalang
Hutan Pinus/Janthoi
Isau-Isau Pasemah
Kepulauan Banyak
Kerinci Seblat
Lembah Harau
Lingga Isaq
Paraduan Gistana &
Surroundings
Pulau Anak Krakatau
Pulau Sangiang
Semidang Butik Kabu
Ujung Kulon
Way Kambas
Way Waya

Sumatran Montane Rain Forests

Indonesia
Bukit Balai Rejang
Bukit Balal
Bukit Barisan Selatan
Bukit Dingin/Gunung Dempo
Bukit Hitam (Sebag)
Bukit Nantiogan Hulu/Nanti
Komerung Hulu
Bukit Raja Mandara
Bukit Sebelah & Batang
Pangean
Dolok Sibual-bual
Dolok Sipirok
Dolok Surungan
Gumai Pasemah
Gunung Betung
Gunung Leuser
Gunung Merapi
Gunung
Patah/Bepagut/Muara
Duakisim
Gunung Raya
Gunung
Sago/Malintang/Karas
Gunung Singgalang
Hutan Pinus/Janthoi
Isau-Isau Pasemah
Kerinci Seblat
Lembah Harau
Lingga Isaq
Maninjau (North and South)
Paraduan Gistana &
Surroundings
Punguk Bingin
Semidang Butik Kabu
Tanggamus
Way Waya

Tian Shan Foothill Arid Steppe

China
Huochengsizhualugui
Yiningxiaoyebaila
Kazakhstan
Altun Emel
Ele Alatau
Lepsinskiy
Toktinskiy
Verkhnekoksyiskiy
Kyrgyzstan
Aksuiski
Beshtash
Dzhardy-Kaindin
Issyk-Kul
Karatal-Zhapyrk NR
Kochkor
Manass
Naryn
Sonkul
Teploklyuchinski
Toguz-Torouss

Trans-Mexican Volcanic Belt Pine-Oak Forests

Mexico
Barranca de Metztitlan
Bosencheve
Canon del Rio Blanco
Cerro de Garnica
Cienegas del Lerma
Cobio Chichinautzin
Cofre de Perote
Cuenca Hidrografica del Rio Necaxa

Cumbres del Ajusco
Desierto de los Leones
Desierto del Carmen O de Nixcongo
El Jabali
El Tepozteco
Gogorron
Insurgente Jose Maria
Morelos
Insurgente Miguel Hidalgo y Costilla
Iztaccihuatl-Popocatepetl
La Primavera
Lagunas de Zempoala
Malinche O Matlalcueyatl
Mariposa Monarca
Nevado de Colima
Nevado de Toluca
Pico de Orizaba
Pico de Tancitaro
Sierra de Huautla
Sierra de Manantlan
Sierra de Quila

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References

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[1] Prescott-Allen, Robert and Christine (1984); Park your genes: protected areas as *in situ* gene banks for the maintenance of wild genetic resources. pp 634-638 in McNeely, Jeffrey A. and Kenton R. Miller (eds.) *National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society*, Smithsonian Institution Press, Washington D.C.

[2] de Klemm, Cyril (1984); Protecting wild genetic resources for the future: the need for a world treaty. pp. 661-666 in McNeely, Jeffrey A. and Kenton R. Miller (eds.) *National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society*, Smithsonian Institution Press, Washington D.C.

[3] Prance, G T (1997); *The conservation of botanical diversity*, in N Maxted, B V Ford-Lloyd and J G Hawkes (Eds) Plant Genetic Diversity, Chapman and Hall, UK

[4] Groombridge, B (1992); *Global Biodiversity: Status of the Earth's Living Resources*, WCMC with Chapman and Hall, London

[5] Prance, G T (1997); *op cit*

[6] Baillie, J E M, C Hilton-Taylor and S N Stuart (Editors) (2004); *2004 IUCN Red List of Threatened Species. A Global Species Assessment*. IUCN, Gland, Switzerland and Cambridge, UK

[7] FAO (1998); Crop Genetic Resource, in *Special: Biodiversity for Food and Agriculture*, FAO, Rome, at: http://www.fao.org/sd/EPdirect/EPre0039.htm (accessed 29/6/05)

[8] Shand, H (1993); *Harvesting Nature's Diversity*. Food and Agriculture Organization of the United Nations, Rome

[9] IPGRI (1993); *Diversity for development*, International Plant Genetic Resources Institute, Rome

[10] Maxted, N (2003); Conserving the genetic resources of crop wild relatives in European Protected Areas, *Biological Conservation*, 113, Elsevier Science Ltd, The Netherlands

[11] Meilleur, B A and T Hodgkin (2004); *In situ* conservation of crop wild relatives: status and trends, *Biodiversity and Conservation* **13:** 663–684

[12] Hijmans, R J, K A Garrett, Z Huaman, D P Zhang, M Schreuder and M Bonierbale (2000); Assessing the geographic representativeness of genebank collections: the case of Bolivian wild potatoes, *Conservation Biology*, 14:6, 1755-1765

[13] Shand, H (1993); *op cit*

[14] ibid

[15] Prance, G T (1997); *op cit*

[16] IPGRI (undated); *Conserving crop wild relatives*: Information Sheet, International Plant Genetic Resources Institute, Rome, Italy

[17] ibid

[18] Tewksbury, J J, G P Nabhan, D Norman, H Suzan, J Tuxill and J Donovan (1999); *In Situ* Conservation of Wild Chiles and their Biotic Associates, *Conservation Biology*, 13:1, 98-107

[19] Shand, H (1993); *op cit*

[20] FAO (1998); *The State of the World's Plant Genetic Resources for Food and Agriculture*, FAO, Rome and University Press, Cambridge, UK

[21] ten Kate, K and S A Laird (1999); *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*, Earthscan, London

[22] FAO (1998); *op cit*

[23] http://www.worldseed.org/statistics.htm#TABLE%201 (accessed 4/11/2005)

---

[24] IUCN, (2001). *IUCN Red List Categories Version 3.1*. Prepared by the IUCN Species Survival Commission, Gland, Switzerland.

[25] Walters, K S and H J Gillett (1998); *1997 IUCN Red List of Threatened Plants*. Compiled by the World Conservation Monitoring Centre. pp. 1-862. IUCN, Gland, Switzerland.

[26] Maxted, N, J G Hawkes, L Guarino and M Sawkins (1997);The selection of taxa for plant genetic conservation. *Genetic Resources and Crop Evolution*, 44: 337-348.

[27] Baillie, J E M, C Hilton-Taylor and S N Stuart (Editors) (2004); *op cit*

[28] Maxted, N (2003); Conserving the genetic resources of crop wild relatives in European Protected Areas, *Biological Conservation*, 113

[29] Warwick, S I *et al* (2003); Hybridisation between transgenic *Brassica napus* L. and its wild relatives: *Brassica rapa L., Rahanus raphanistrum L., Sinapsis arvensis L.,* and *Erucastrum gallicum* (Willd.) O.E. Schulz. *Theoretical and Applied Genetics*, **107**:528

[30] Quist, D and Chapela, I H (2001); Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. *Nature* **414**: 541-543

[31] RAFI (2003); Press Release: Contamination by genetically modified maize in Mexico much worse than feared, October 9, 2003, Mexico City, Mexico

[32] GeneWatch UK and Greenpeace (2006); *GM Contamination Report 2005: A review of cases of contamination, illegal planting and negative side effects of genetically modified organisms*, GeneWatch UK, Greenpeace International, Amsterdam, The Netherlands

[33] Hirano, R, M Abbertton and N Maxted (2005); Genetic comparison of *Trifolium repens* L. population samples from St Kilda and mainland UK. Unpublished thesis, University of Birmingham.

[34] Frankel, O H, A H D Brown and J J Burdon (1998); *The Conservation of Plant Biodiversity*. Cambridge University Press, Second edition, pp. 56-78

[35] Teshome, T (2000); Resource conserving technologies for Ethiopian poor farmers, in Alföldi, T, W Lockeretz and U Niggli, *Proceedings 13th International IFOAM Scientific Conference,* IFOAM, Germany

[36] Wairegi, F (2000); Biodiversity conservation of indigenous food crops to improve household food security and poverty alleviation, in Alföldi, T, W Lockeretz and U Niggli, *Proceedings 13th International IFOAM Scientific Conference,* IFOAM, Germany

[37] Prescott-Allen, R and C Prescott-Allen (1990); How Many Plants Feed the World?, *Conservation Biology*, Vol. **4**:4, p365-374

[38] FAO (1998); Crop Genetic Resource, in *Special: Biodiversity for Food and Agriculture*, FAO, Rome, at: http://www.fao.org/sd/EPdirect/EPre0039.htm (accessed 29/6/05)

[39] Fowler, C and P Mooney (1990); *The Threatened Gene - Food, Politics, and the Loss of Genetic Diversity*, The Lutworth Press, Cambridge, UK

[40] K. Hammer, Th Gladis and A Diederichsen (2002); In situ and on-farm management of plant genetic resources, *Europ. J. Agronomy* **19**, 509-517, www.elsevier.com/locate/eja

[41] FAO (1998); *op cit*

[42] Groombridge, B (Ed) (WCMC) (1992); *op cit*

[43] US National Research Council Board on Agriculture (1993); *Managing Global Genetic Resources: Agricultural Crop Issues and Policies*, National Academy Press, Washington, USA

[44] Huxley, A (1984); *Green Inheritance*, Collins-Harvill, London

[45] Lewington, A (1990); *Plants for People*, The National History Museum

---

[46] Cooper, D (1993); *Plant Genetic Diversity and Small Farmers: Issues and Options for IFAD*, Staff Working Paper 13, International Fund for Agricultural Development, Italy

[47] Nee, C.-C., C.-H. Tsai, D.D. Anstine (2002); Asian Pear Germplasm - Future Trends And Current Research In The Industry, in S. Iwahori, H. Gemma, K. Tanabe, A.D. Webster, A.G. White (editors); International Symposium on Asian Pears, Commemorating the 100th Anniversary of Nijisseiki Pear, *ISHS Acta Horticulturae 587*

[48] Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); Complementary Conservation Strategies*,* in Maxted, N, B V Ford-Lloyd and J G Hawkes , *Plant genetic conservation: the* in situ *approach* (eds.), Chapman & Hall, London, UK

[49] Meilleur, B A and T Hodgkin (2004); *In situ* conservation of crop wild relatives: status and trends, *Biodiversity and Conservation* **13:** 663–684

[50] Kell, S P, N Maxted and B V Ford-Lloyd (2005); *PGR Forum Crop Wild Relative Catalogue for Europe and the Mediterranean*, Published online: http//:cwris.ecpgr.org, University of Birmingham, UK

[51] Scholten, M, N Maxted, S P Kell and B V Ford-Lloyd (in press); Creation of a national crop wild relative strategy: a case study for the United Kingdom. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, *Crop Wild Relative Conservation and Use*, CAB International

[52] Markkola, H (2005); Regional Red List assessment and Biodiversity Action Plans for crop wild relatives in Ireland, thesis presented to the Faculty of Science of the University of Birmingham in partial fulfilment of the requirements for the degree of Master of Science in Conservation and Utilisation of Plant Genetic Resources

[53] Magos Brehm, J, N Maxted, B V Ford-Lloyd and M A Martins-Loução (in prep.); Portuguese Crop Wild Relatives and Wild Harvested Plants Inventory

[54] Meilleur, B A and T Hodgkin (2004); *op cit*

[55] ibid

[56] Maxted, N, J G Hawkes, B V Ford-Lloyd and J T Williams (1997); A practical model for *in situ* genetic conservation, in Maxted, N., Ford-Lloyd, B.V., Hawkes, J.G. (Eds.), *Plant Genetic Conservation: the In Situ Approach,* Chapman and Hall, London

[57] Kell, S P, H Knüpffer, S L Jury, B V Ford-Lloyd and N Maxted (in press); Creation and application of the Crop Wild Relative Catalogue for Europe and the Mediterranean. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, *Crop Wild Relative Conservation and Use*, CAB International

[58] EEA - European Topic Centre on Biological Diversity (2005) *European Nature Information System (EUNIS)*. http://eunis.eea.eu.int (Accessed 13 March 2006)

[59] Meilleur, B A and T Hodgkin (2004); *op cit*

[60] http://www.ipgri.cgiar.org/system/page.asp?frame=themes/in_situ_project/home/insituhome.htm (accessed 29/6/05)

[61] Frankel, O (1970); Genetic conservation of plants useful to man, *Botanical Conservation* **2**: 162–169

[62] Jain, S (1975); *Genetic reserves*, in Frankel, O and J Hawkes (eds), Crop Genetic Resources for Today and Tomorrow, Cambridge University Press, Cambridge, UK

[63] Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); Complementary Conservation Strategies*,* in Maxted, N, B V Ford-Lloyd and J G Hawkes , *Plant genetic conservation: the* in situ *approach* (eds.), Chapman & Hall, London, UK

[64] Meilleur, B A and T Hodgkin (2004); *op cit*

[65] Convention on Biological Diversity (1992); *Convention on Biological Diversity: Text and Annexes*. pp. 1-34. Secretariat of the Convention on Biological Diversity, Montreal

[66] FAO (1996); Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture and the Leipzig Declaration (http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPS/Pgrfa/Pdf/GPAENG.PDF, accessed 6/6/05)

---

[67] FAO (2001); *International Treaty on Plant Genetic Resources for Food and Agriculture*. FAO, Rome

[68] Meilleur, B A and T Hodgkin (2004); *op cit*

[69] http://www.biodiv.org/2010-target/goals-targets.aspx (accessed 1/5/06)

[70] http://www.biodiv.org/programmes/cross-cutting/plant/default.shtml (accessed 1/5/06)

[71] Council of Europe and Planta Europa (2001); *European Plant Conservation Strategy*, unpublished submission to the SBBSTA of the CBD, Planta Europa, London, available on: http://www.plantlife.org.uk/downloads/ipa/European_Plant_Conservation_Strategy.pdf (accessed 1/11/2005)

[72] Heywood, V H, N Maxted and S P Kell (in press); Towards a global strategy for the conservation and use of crop wild relatives. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, *Crop Wild Relative Conservation and Use*, CAB International

[73] Hoyt, E (1998); *Conserving the Wild Relatives of Crops*, WWF, IUCN and the International Board for Plant Genetic Resources (IBPGR), Switzerland

[74] Hodgkin, T (1997); Managing the populations – some general considerations, *Bocconea* **7**: 197–205

[75] Camacho Villa, T C, N Maxted, M A Scholten and B V Ford-Lloyd (2005); *op cit*

[76] Zeven, A C (1998); Landraces: A review of definitions and classifications. *Euphytica* **104**:127–139.

[77] Camacho Villa, T.C., Maxted, N., Scholten, M.A. & Ford-Lloyd, B.V., (2005). Defining and identifying crop landraces. *Plant Genetic Resource: Characterization and Utilization*, 3(3): 373-384.

[78] ibid

[79] Kell, S and N Maxted (compilers) (2003); Report of Workshop 1. European Crop Wild Relative Diversity Assessment and Conservation Forum - PGR Forum, (www.prgforum.org) and Meilleur, B A and T Hodgkin (2004); *In situ* conservation of crop wild relatives: status and trends, *Biodiversity and Conservation* **13:** 663–684

[80] Harlan, J and J de Wet (1971); Towards a rational classification of cultivated plants, *Taxon* **20**, 509-517

[81] Maxted, N, J Hawkes, L Guarino and M Sawkins (1997); The selection of taxa for plant genetic conservation, *Genetic Resources and Crop Evolution* **44**:337-348

[82] Maxted, N, B V Ford-Lloyd, S L Jury, S P Kell and M A Scholten (2005); Towards a definition of a crop wild relative. *Biodiversity and Conservation*, 14: 1-13

[83] Kell, S P, H Knüpffer, S L Jury, B V Ford-Lloyd and N Maxted (in press); *op cit*

[84] ibid

[85] Maxted, N, J G Hawkes, L Guarino and M Sawkins (1997); The selection of taxa for plant genetic conservation. *Genetic Resources and Crop Evolution*, 44: 337-348

[86] Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); Complementary Conservation Strategies, in Maxted, N, B V Ford-Lloyd and J G Hawkes , *Plant genetic conservation: the* in situ *approach* (eds.), Chapman & Hall, London, UK

[87] UNCED (1992); *Convention on Biological Diversity*, United Nations Conference on Environment and Development, Geneva, Switzerland

[88] Maxted, N, M Dullo and A Eastwood (1999); A model for genetic reserve conservation: A case study for *coffea* in the Mascarene Islands, *Botanica Lithuanica*, Suppl. 2: 61-78

[89] UNCED (1992); *op cit*

[90] Maxted, N, M Dullo and A Eastwood (1999); *op cit*

---

[91] Maxted, N, J Iriondo, E Dulloo and B Ford-Lloyd (In Prep.); Gap Analysis: a tool for effective genetic conservation assessment.

[92] FAO (1998); *op cit*

[93] Maxted, N (2003); Conserving the genetic resources of crop wild relatives in European Protected Areas, *Biological Conservation*, 113, Elsevier Science Ltd, The Netherlands

[94] Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); *op cit*

[95] ibid

[96] Meilleur, B A and T Hodgkin (2004); *op cit*

[97] Hawkes, J (1991); International workshop on dynamic *in situ* conservation of wild relatives of major cultivated plants: summary of final discussion and recommendations. *Israel Journal of Botany* **40**, 529-536 and Maxted, N, B V Ford-Lloyd and J Hawkes (1997a); *Plant genetic conservation: the* in situ *approach*. pp. 1-451. Chapman & Hall, London

[98] Maxted, N, M Dullo and A Eastwood (1999); A model for genetic reserve conservation: A case study for *coffea* in the Mascarene Islands, *Botanica Lithuanica*, Suppl. 2: 61-78

[99] Maxted, N., Ford-Lloyd, B.V., Jury, S.L., Kell, S.P. & Scholten, M.A., (2005). Towards a definition of a crop wild relative. *Biodiversity and Conservation*, 14: 1-13.

[100] Maxted, N, J G Hawkes, B V Ford-Lloyd and J T Williams (1997); A practical model for *in situ* genetic conservation, in Maxted, N., Ford-Lloyd, B.V., Hawkes, J.G. (Eds.), *Plant Genetic Conservation: the In Situ Approach,* Chapman and Hall, London

[101] K. Hammer, Th Gladis and A Diederichsen (2002); In situ and on-farm management of plant genetic resources, *Europ. J. Agronomy* **19**, 509-517, www.elsevier.com/locate/eja

[102] Maxted, N, J G Hawkes, B V Ford-Lloyd and J T Williams (1997); op cit

[103] Jain, S.K. (1975) Genetic reserves, in *Crop genetic resources for today and tomorrow* (O.H. Frankel and J.G. Hawkes), Cambridge University Press. Cambridge, pp. 379-396.

[104] IUCN Commission on National Parks and Protected Areas with the World Conservation Monitoring Centre (1995); *Guidelines for Protected Area Management Categories*, IUCN, Gland, Switzerland

[105] Adapted from Borrini-Feyerabend, G, Kothari, A and Oviedo, G (2004); *Indigenous and Local Communities and Protected Areas: Towards Equity and Enhanced Conservation.* IUCN, Gland, Switzerland and Cambridge, UK

[106] Borrini-Feyerabend, G, Kothari, A and Oviedo, G (2004); *op cit*

[107] ibid

[108] Groombridge, B. (ed.) (1992); *op cit*. 550-551

[109] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=12352&level=nat (accessed 27/2/06)

[110] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=ALG%2001 (accessed 27/2/06)

[111] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=ALG%2003 (accessed 27/2/06)

[112] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=2497&level=nat (accessed 19/6/05)

[113] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=97490&level=nat (accessed 19/6/05)

[114] Maxted, N, B V Ford-Lloyd and J G Hawkes (Eds.) (1997); *op cit*

[115] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=62677&level=nat (accessed 19/6/05)

---

[116] Vavilov, N.I (1951); Phytogeographic basis of plant breeding, in The origin, variation, immunity and breeding of cultivated plants. (K.S. Chester, trans.) *Chronica Botanica* **13**: 14-54

[117] http://enrin.grida.no/biodiv/index_en.htm (accessed 24/5/05)

[118] Damania, Ardeshir B. (undated); Domestication and in situ conservation of cereal wild progenitors in the Near East, paper downloaded from Consortium for the Sustainable Development of Andean Ecoregion (CONDESAN), www.condesan.org/download/insitu/damania.doc (accessed 28/6/04) and Damania, A (1996); Biodiversity conservation: a review of options complementary to standard *ex situ* methods. *Plant Genetic Resources Newsletter* 107: 1–18

[119] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1631&level=nat (accessed 20/6/05)

[120] The Ministry of Nature Protection (1999); *First National Report to The Convention on Biological Diversity incorporating A Country Study on the Biodiversity of Armenia*, The Ministry of Nature Protection, Yerevan, Republic of Armenia

[121] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=9464&level=nat (accessed 28/8/05)

[122] Davis, S D, V H Heywood and A C Hamilton (1994); *Centres of plant diversity. A guide and strategy for their conservation*, 3 volumes, IUCN, Cambridge, UK and WWF, Gland, Switzerland; Vol 2: 465

[123] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=900001&level=int (accessed 27/2/06)

[124] Groombridge, B. (ed.) (1992); *op cit*, 594

[125] FAO (1997); *The State of the World's Plant Genetic Resources for Food and Agriculture***,** Food and Agriculture Organization of the United Nations, Rome, Italy

[126] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=101830&level=nat (accessed 29/8/05)

[127] http://www.gateway.az/cgi-bin/cl2_gw/browse.cgi?lang=en&topic=000c0510 (accessed 29/8/05)

[128] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=98183&level=nat (accessed 29/8/05)

[129] Anon (2004); Amazon Conservation Association Newsletter, September 2004, available at: http://www.amazonconservation.org/home/newsletter.htm (accessed 29/8/05)

[130] Davis, S D, V H Heywood and A C Hamilton (1994); *Centres of plant diversity. A guide and strategy for their conservation*, 3 volumes, IUCN, Cambridge, UK and WWF, Gland, Switzerland, Vol 3: 358

[131] Meilleur B A and T Hodgkin (2004); *op cit*

[132] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1229&level=nat (accessed 27/2/06)

[133] http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/pa/0345v.htm~main (accessed 27/2/06)

[134] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=20058&level=nat (accessed 28/8/05)

[135] Davis, S D, V H Heywood and A C Hamilton (1994); *Centres of plant diversity. A guide and strategy for their conservation*, 3 volumes, IUCN, Cambridge, UK and WWF, Gland, Switzerland, Vol 1: 187-188

[136] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=608&level=nat (accessed 27/2/06)

[137] http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/pa/0033p.htm~main (accessed 27/2/06)

[138] Groombridge, B (1992); *op cit*, 550

[139] Davis, S D, V H Heywood and A C Hamilton (1994); *Centres of plant diversity. A guide and strategy for their conservation*, IUCN, Cambridge, UK and WWF, Gland, Switzerland, Vol 2: 160

[140] http://www.grain.org/research/hybridrice.cfm?id=57 (accessed 28/8/05)

[141] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=96141&level=nat (accessed 29/8/05)

[142] http://sea.unep-wcmc.org/sites/pa/1811v.htm (accessed 29/8/05)

---

[143] WWF and IUCN (1994); *Centres of plant diversity. A guide and strategy for their conservation*, 3 volumes, IUCN Publications Unit, Cambridge, UK; Vol 2: 190

[144] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=27158&level=int (accessed 27/2/06)

[145] Groombridge, B (1992); *op cit* 550

[146] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=164&level=nat (accessed 29/8/05)

[147] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 217

[148] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=171&level=nat (accessed 8/9/05)

[149] Tuxill, J and G P Nabhan (1998); *Plants and Protected Areas: A guide to* in situ *management*, Stanley Thornes, UK

[150] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=26059&level=nat (accessed 20/6/05)

[151] Alexanian, S M. (2001); Management, conservation and utilization of plant genetic diversity in CEEC, CIS and other Countries in Transition, in *Seed policy and programmes for the Central and Eastern European Countries, Commonwealth of Independent States and other Countries in Transition,* Proceedings of the Regional Technical Meeting on Seed Policy and Programmes for the Central and Eastern European Countries, Commonwealth of Independent States and other Countries in Transition, Budapest, Hungary, 6 - 10 March 2001, FAO Plant Production and Protection Papers: 168, FAO, Rome

[152] Roudná, Milena (undated); Conservation of Genetic Resources in the Czech Republic with Special Reference to Fruit Trees, Ministry of the Environment of the Czech Republic, http://www.biosphaerenreservat-rhoen.de (accessed 28/6/04)

[153] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=142700&level=nat (accessed 27/2/06)

[154] Groombridge, B (1992), *op cit*, 550

[155] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=191&level=int (accessed 28/8/05)

[156] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 558

[157] Nuez, F, J Prohens and J M Blanca (2004); Relationships, origin, and diversity of Galápagos tomatoes: implications for the conservation of natural populations, *American Journal of Botany,* **91**:86-99

[158] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=188&level=nat (accessed 29/8/05)

[159] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 461

[160] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=2281&level=nat (accessed 26/8/05)

[161] Burgess, N, J D'Amico Hales, E Underwood, E Dinerstein, D Olson, I Itoua, J Schipper, T Ricketts and K Newman (2004); *Terrestrial ecoregions of Africa and Madagascar: a continental assessment*, Island Press, Washington DC, p 262

[162] http://www.unep-wcmc.org/sites/pa/0048p.htm (accessed 29/8/05)

[163] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=2551&level=nat (accessed 17/6/05)

[164] Bosland, P W and M M Gonzalez (2000); The rediscovery of Capsicum lanceolatum (Solanaceae), and the importance of nature reserves in preserving cryptic biodiversity. *Biodiversity and Conservation* 9:10, 1391-1397

[165] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=102944&level=nat (29/8/05)

[166] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 196

[167] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1658&level=nat (accessed 28/8/05)

[168] http://enrin.grida.no/htmls/georgia/soegeor/english/biodiv/reserves/algeti.htm (accessed 28/8/05)

---

[169] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=14448&level=nat (accessed 19/6/05)

[170] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=3022&level=int (accessed 19/6/05)

[171] Schlosser, S (1985); The Use of Nature Reserves for *in situ* Conservation. *IBPGR Plant Genetic Resources Newsletter*, p23-24

[172] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=GER%2001 (accessed 19/6/05)

[173] Seidel, E (1983); Biosphere Reserve Steckby-Loedderitzer Forest, German Democratic Republic, GDR National Committee of the UNESCO Programme on Man and the Biosphere

[174] Schlosser, S (1985); *op cit*

[175] ibid

[176] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=134939&level=int (accessed 29/6/05)

[177] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=res&code=GER+12 (accessed 29/6/05)

[178] http://sea.unep-wcmc.org/wdbpa/site.cfm?siteid=26647&level=int (accessed 29/6/05)

[179] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=res&code=GER+06 (accessed 29/6/05)

[180] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=29769&level=int (accessed 29/6/05)

[181] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=res&code=GER+07 (accessed 29/6/05)

[182] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1779&level=nat (accessed 20/6/05)

[183] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=14174&level=nat (accessed 19/6/05)

[184] http://www.indiawildliferesorts.com/national-parks/nokrek-national-park.html (accessed 19/6/05)

[185] Gogoi, P C (1981); Tura Ridge Biosphere Reserve (Citrus Gene Sanctuary), Department of Forests, Government of Meghalaya, Shillong, India

[186] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=9216&level=nat (accessed 17/6/05)

[187] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=900551&level=int (accessed 17/6/05)

[188] http://cpreec.org/04_articles/nilgiri_bio_reser/nilgiri_bio_reser.html (accessed 10/2/05)

[189] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1798&level=nat (accessed 28/8/05)

[190] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1826&level=nat (accessed 28/8/05)

[191] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1840&level=nat (accessed 28/8/05)

[192] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 112

[193] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=4527&level=nat (accessed 28/8/05)

[194] http://www.unep-wcmc.org/sites/pa/1039v.htm (accessed 28/8/05)

[195] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 102

[196] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1917&level=nat (accessed 28/8/05)

[197] http://sea.unep-wcmc.org/sites/pa/1844v.htm (accessed 28/8/05)

[198] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1252&level=nat (accessed 28/8/05)

[199] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 265

[200] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=62496&level=nat (accessed 28/8/05)

---

[201] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 326

[202] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=20378&level=nat (accessed 28/8/05)

[203] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 330

[204] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=4994&level=nat (accessed 28/8/05)

[205] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 369

[206] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1899&level=nat (accessed 28/8/05)

[207] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 338

[208] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1251&level=nat (accessed 28/8/05)

[209] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 366

[210] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=17177&level=nat (accessed 27/2/06)

[211] Groombridge, B (1992); *op cit*, 551

[212] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=14915&level=nat (accessed 19/6/05)

[213] http://www.parks.org.il/ParksENG/company_card.php3?NewNameMade=0&from=116&CNumber=422683 (accessed 19/6/05)

[214] Damania, A (1996); Biodiversity conservation: a review of options complementary to standard *ex situ* methods. *Plant Genetic Resources Newsletter* 107: 1–18 and Maxted, N., Ford-Lloyd, B.V., Hawkes, J.G. (Eds.), (1997); *Plant Genetic Conservation: the In Situ Approach,* Chapman and Hall, London

[215] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1675&level=nat (accessed 6/9/05)

[216] Musuraliev, T M (1998); Forest management and policy for the walnut-fruit forests of the Kyrgyz Republic, in Blaser, J, J Carter and D Gilmour (Eds); *Biodiversity and sustainable use of Kyrgyzstan's walnut-fruit forests*, IUCN Gland, Switzerland and Cambridge, UK and INTERCOOPERATION, Bern, Switzerland

[217] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=220030&level=int (accessed 19/6/05)

[218] Krever, V, O Pereladova, M Williams and H Jungius (1998); *Biodiversity Conservation in Central Asia: An analysis of biodiversity and current threats and initial investment portfolio*, WWF, Gland

[219] Blaser, J, J Carter and D Gilmour (Eds) (1998); *Biodiversity and sustainable use of Kyrgyzstan's walnut-fruit forests*, IUCN Gland, Switzerland and Cambridge, UK and INTERCOOPERATION, Bern, Switzerland

[220] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=KIZ%2001 (accessed 10/6/05)

[221] FAO (1997); *The State of the World's Plant Genetic Resources for Food and Agriculture***,** Food and Agriculture Organization of the United Nations, Rome, Italy

[222] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=2306&level=nat (accessed 19/6/05)

[223] http://sea.unep-wcmc.org/sites/pa/0492p.htm (accessed 19/6/05)

[224] Dulloo, M E, L Guarino, F Engelmann, N Maxted, H J Newbury, A F Attere and B V Ford-Lloyd (1998); *op cit*

[225] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=4056&level=nat (accessed 28/8/05)

[226] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 338

[227] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=39872&level=nat (accessed 17/6/05)

[228] Damania, A B (1996); Biodiversity conservation: a review of options complementary to standard *ex situ* methods, *Plant Genetic Resources Newsletter*, 107:1-18

---

[229] Dulloo, M E, L Guarino, F Engelmann, N Maxted, H J Newbury, A F Attere and B V Ford-Lloyd (1998); *op cit*

[230] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=5042&level=nat (accessed 7/9/05)

[231] Dulloo, M E, N Maxted, L Guarino, D Florens, H J Newbury and B V Ford-Lloyd (1999); Ecogeographic survey of the genus *Coffea* in the Mascarene Islands, *Botanical Journal of the Linnean Society*, **131**:263-284

[232] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=13695&level=int (accessed 19/6/05)

[233] Maxted, N, B V Ford-Lloyd, and J G Hawkes (Eds.) (1997); *op cit*

[234] See: www.wwf.org.mx/oaxaca_areas_comunitarias.php (accessed 17/8/04)

[235] *pers com* Vanessa Perez-Cirera

[236] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=14305&level=nat (accessed 17/8/04)

[237] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=MEX%2003 (accessed 17/8/04)

[238] Groombridge, B (1992); *op cit*, 551

[239] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=214&level=nat (accessed 8/9/05)

[240] Tuxill, J and G P Nabhan (1998); *op cit*

[241] Alexanian, Sergey M (2001); Management, conservation and utilization of plant genetic diversity in CEEC, CIS and other Countries in Transition, in *Seed policy and programmes for the Central and Eastern European Countries, Commonwealth of Independent States and other Countries in Transition,* Proceedings of the Regional Technical Meeting on Seed Policy and Programmes for the Central and Eastern European Countries, Commonwealth of Independent States and other Countries in Transition, Budapest, Hungary, 6 - 10 March 2001, FAO Plant Production and Protection Papers: 168, FAO, Rome

[242] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=798&level=nat (29/8/05)

[243] Groombridge, B (1992); *op cit*, 551

[244] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=818&level=nat (accessed 29/8/05)

[245] http://sea.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/wh/'w'-np.htm~main (accessed 28/8/05)

[246] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=9024&level=nat (accessed 29/8/05)

[247] http://www.unep-wcmc.org/index.html?http://www.unep-wcmc.org/sites/wh/atnnr.html~main (accessed 29/8/05)

[248] Ingram, G. (1990); Multi-gene pool surveys in areas with rapid genetic erosion: An example from the Aïr mountains, northern Niger. *Conservation Biology* **4**: 78-90

[249] Groombridge, B (1992); *op cit*, 594

[250] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=17908&level=nat (accessed 5/9/05)

[251] Groombridge, B. (1992); *op cit*, 551

[252] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=20991&level=nat (accessed 5/9/05)

[253] Meilleur B A and T Hodgkin (2004); *op cit*

[254] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=127825&level=nat (accessed 5/9/05)

[255] http://parksinperil.org/wherewework/southamerica/peru/protectedarea/bahuaja.html (accessed 5/9/05)

[256] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=257&level=nat (accessed 29/8/05)

[257] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 362

---

[258] Phillips, Adrian, (2002). *Management Guidelines for IUCN Category V Protected Areas: Protected Landscapes/Seascapes.* IUCN Gland, Switzerland and Cambridge, UK

[259] Villalón, A (2004); World Heritage inscription and challenges to the survival of community life in Philippine cultural landscapes, in Brown, Jessica, Mitchell, Nora and Beresford, Michael (Eds.) (2004). *The Protected Landscape Approach: Linking Nature, Culture and Community*, IUCN, Gland, Switzerland and Cambridge, UK

[260] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=865&level=nat (accessed 29/8/05)

[261] http://sea.unep-wcmc.org/sites/wh/niokolo.html (accessed 28/8/05)

[262] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=2099&level=int (accessed 5/9/05)

[263] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=SPA%2003 (accessed 5/9/05)

[264] Bonet, MA and J Valles (2002); Use of non-crop food vascular plants in Montseny biosphere reserve (Catalonia, Iberian Peninsula), *Int J Food Sci Nutr*, **53**(3):225-48

[265] Groombridge, B. (ed.). *op cit*, 551

[266] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=16791&level=int (accessed 28/8/05)

[267] http://www.unep-wcmc.org/sites/wh/sinharaj.html (accessed 28/8/05)

[268] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 133

[269] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=167080&level=nat (accessed 7/9/05)

[270] Krever, V, O Pereladova, M Williams and H Jungius (1998); *op cit*

[271] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=9042&level=nat (accessed 28/8/05)

[272] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 1: 250

[273] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=67729&level=int (accessed 28/8/05)

[274] http://whc.unesco.org/pg.cfm?cid=31&id_site=591 (accessed 28/8/05)

[275] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 217

[276] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=TUN+04 (accessed 18/12/05)

[277] ibid

[278] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=3377&level=nat (accessed 5/9/05)

[279] Maxted, N, B V Ford-Lloyd and J G Hawkes (Eds.) (1997); *op cit*

[280] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=61944&level=nat (accessed 5/9/05)

[281] Tan, A (1998); *Current status of plant genetic resources conservation in Turkey*, in N. Zencirci, Z. Kaya, Y. Anikster and W. T. Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[282] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=944&level=nat (accessed 19/9/05)

[283] http://sea.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/pa/0072v.htm~main (accessed 19/9/05)

[284] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=167106&level=nat (accessed 19/6/05)

[285] http://enrin.grida.no/biodiv/biodiv/national/turkmen/htmfiles/reserve.htm (accessed 19/6/05)

[286] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=167121&level=nat (accessed 8/9/05)

[287] Krever, V, O Pereladova, M Williams and H Jungius (1998); *Biodiversity Conservation in Central Asia: An analysis of biodiversity and current threats and initial investment portfolio*, WWF, Gland

---

[288] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=40002&level=nat (accessed 20/6/05)

[289] Oryem-Origa, H, J. M. Kasenene and M. J. S. Magambo (2004); Some aspects of wild robusta coffee seedling growth in Kibale National Park, Uganda, *African Journal of Ecology*, 42:s1, 34-39(6)

[290] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=33147&level=nat (accessed 20/6/05)

[291] http://sea.unep-wcmc.org/sites/pa/0727p.htm (accessed 20/6/05)

[292] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=34808&level=nat (accessed 20/6/05)

[293] http://www.natureuganda.org/html/Mabira.htm (accessed 20/6/05)

[294] Meilleur B A and T Hodgkin (2004); *op cit*

[295] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=13891&level=nat (accessed 20/6/05)

[296] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=101003&level=nat (accessed 20/6/05)

[297] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=100894&level=nat (accessed 20/6/05)

[298] Anon (1998); Agreements between NPGS and public landholders establish first *in*-situ conservation sites in US, *Diversity,*14:3&4, available at: http://www.mobot.org/MOBOT/research/diversity/journal/vol14_2.pdf (accessed 20/6/05)

[299] Pavek D, W Lamboy and E Garvey (2000); Ecogeographic Study of *Vitis* Species: Final Report for Rock Grape (*Vitis rupestris*). USDA, Beltsville, Maryland, US

[300] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=1020&level=nat (accessed 6/9/05)

[301] Tewksbury J, G Nabhan, D Norman, H Suzan, J Tuxill and J Donovan (1999); *In situ* conservation of wild Chiles and their biotic associates. *Conservation Biology* **13**: 1 98–107

[302] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=976&level=nat (accessed 7/9/05)

[303] Tewksbury J, G Nabhan, D Norman, H Suzan, J Tuxill and J Donovan (1999); *op cit*

[304] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=134942&level=int (accessed 20/6/05)

[305] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?code=UZB+01&mode=all (accessed 20/6/05)

[306] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=11829&level=nat (accessed 7/9/05)

[307] Krever, V, O Pereladova, M Williams and H Jungius (1998); *Biodiversity Conservation in Central Asia: An analysis of biodiversity and current threats and initial investment portfolio*, WWF, Gland

[308] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=10113&level=nat (accessed 5/9/05)

[309] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=10361&level=nat (accessed 5/9/05)

[310] Harlan, J R (1992: *Crops and Man*, 2ed. American Society of Agronomy, Inc.; Madison, WI and Harlan, J R (1971); Agricultural origins: Centers and Noncenters. *Science* 174:468-474.

[311] Rubenstein, K D, P Heisey, R Shoemaker, J Sullivan and G Frisvold (2005); *Crop Genetic Resources: An Economic Appraisal*, Economic Information Bulletin No. (EIB2) 47 pp, United States Department of Agriculture

[312] Vavilov, N I (1951); *The origin, variation, immunity and breeding of cultivated plants. Selected writings Ronald Press New York*; Amended by Hawkes, J G (1993); *The Diversity of Crop Plants*, Harvard University Press and Hawkes, J G (1998); Back to Vavilov: Why Were Plants Domesticated in Some Areas and Not in Others?, in Damania, A.B., J. Valkoun, G. Willcox and C.O. Qualset (Eds.) *The Origins of Agriculture and Crop Domestication*, ICARDA, Aleppo, Syria

[313] Hawkes, J G (1998); *Back to Vavilov: Why Were Plants Domesticated in Some Areas and Not in Others*?, in Damania, A.B., J. Valkoun, G. Willcox and C.O. Qualset (Eds.) The Origins of Agriculture and Crop Domestication. ICARDA, Aleppo, Syria

---

[314] Willcox, G (1998); *Archaeobotanical Evidence for the Beginnings of Agriculture in Southwest Asia,* in Damania, A.B., J. Valkoun, G. Willcox and C.O. Qualset (Eds.) The Origins of Agriculture and Crop Domestication. ICARDA, Aleppo, Syria

[315] Takhtadjan, A., (1969). Flowering plants: origin and dispersal. Oliver & Boyd, Edinburgh and London.

[316] Harlan, J R (1998): *Distribution of Agricultural Origins: A Global Perspective*, in Damania, A.B., J. Valkoun, G. Willcox and C.O. Qualset (Eds.) The Origins of Agriculture and Crop Domestication. ICARDA, Aleppo, Syria

[317] Hammer, K, Th Gladis and A Diederichsen (2002); In situ and on-farm management of plant genetic resources, *Europ. J. Agronomy* **19**, 509-517, www.elsevier.com/locate/eja

[318] http://www.worldwildlife.org/science/ecoregions.cfm (accessed 19/6/05)

[319] Dasmann, R F (1974); *Biotic Provinces of the World: Further Development of a System for Defining and Classifying Natural Regions for Purposes of Conservation*. IUCN Occasional Paper No. 9. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland

[320] Udvardy, M D F (1975); *World Biogeographic Provinces*. IUCN Occasional Paper No. 18. Gland, Switzerland

[321] Olsen, D M and E Dinerstein (2002); The Global 200: Priority Ecoregions for Global Conservation, *Annals of the Missouri Botanical Gardens*, **89**:199-224

[322] ibid

[323] Dinerstein, E, G Powell, D Olson, E Wikramanayake, R Abell, C Loucks, E Underwood, T Allnutt, W Wettengel, T Ricketts, H Strand, S O'Connor and N Burgess (2000); *A workbook for conducting biological assessments and developing biodiversity visions for ecoregion-based conservation: Part I: Terrestrial Ecoregions*, World Wildlife Fund, Washington DC

[324] Abell, R, M Thieme, E Dinerstein and D Olson (2002); *A Sourcebook for Conducting Biological Assessments and Developing Biodiversity Visions for Ecoregion Conservation. Volume II: Freshwater Ecoregions,* World Wildlife Fund, Washington DC

[325] Hoekstra, J M, T M Boucher, T H Ricketts and C Roberts (2005); Confronting a biome crisis: global disparities of habitat loss and protection, *Ecology Letters*, **8**: 23–29

[326] WDPA Consortium (2004) *2004 World Database on Protected Areas*. Available at: http://maps.geog.umd.edu/WDPA/index.html.

[327] Hoekstra, J M, T M Boucher, T H Ricketts and C Roberts (2005); *op cit*

[328] Hawkes, J G (1998); *op cit*

[329] Hoekstra, J M, T M Boucher, T H Ricketts and C Roberts (2005); *op cit*

[330] http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0118_full.html (accessed 19/6/05)

[331] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=CPR%2006 (accessed 15/2/06)

[332] http://whc.unesco.org/pg.cfm?cid=31&id_site=911 (accessed 15/2/05)

[333] http://www.wcmc.org.uk/protected_areas/data/wh/mt_wuyi.html (accessed 15/2/05)

[334] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0101_full.html (accessed 6/6/05)

[335] Groombridge, B (1992); *op cit*, 550

[336] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 160

[337] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 112

[338] http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0126_full.html (accessed 5/9/05)

[339] Gogoi, P C (1981); *op cit*

---

[340] Ministry of Science, Technology and the Environment (1998); First national report to the Conference of the Parties of the Convention on Biological Diversity, Malaysia, http://www.biodiv.org/doc/world/my/my-nr-01-en.pdf (accessed 5/5/06)

[341] USDA (2004); Citrus & Date Germplasm: Crop Vulnerability, Germplasm Activities, Germplasm Needs, Citrus & Date Crop Germplasm Committee, Agricultural Research Service, USDA, Washington DC

[342] Idris S and R Mat Lin (2002); Status Report on Genetic Resources of Pulasan [*Nephelium ramboutan-ake* (Labill.) Leech] in Southeast Asia, IPGRI Office for South Asia, New Delhi, India

[343] http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/pa/0885v.htm~main (accessed 15/2/2006)

[344] http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/pa/0440v.htm~main (accessed 15/2/2006)

[345] Hoekstra, J M, T M Boucher, T H Ricketts and C Roberts (2005); *op cit*

[346] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1220_full.html (accessed 6/6/05)

[347] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0805_full.html (accessed 9/9/05)

[348] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1008_full.html (accessed 9/9/05)

[349] Hoekstra, J M, T M Boucher, T H Ricketts and C Roberts (2005); *op cit*

[350] http://www.panda.org/about_wwf/where_we_work/mediterranean/forests/index.cfm (accessed 9/9/05)

[351] Israel Genebank (1995); *Israel: Country report to the FAO international technical conference on plant genetic resources (Leipzig 1996)*, Israel Genebank, Tel Aviv

[352] Friis, I (1992); *Forests and Forest Trees of Northeast Tropical Africa*. HMSO, Kew Bulletin Additional Series XV.

[353] http://www.wcmc.org.uk/protected_areas/data/wh/simen.html (accessed 15/2/06)

[354] http://www.worldwildlife.org/wildworld/profiles/terrestrial/at/at1007_full.html (accessed 6/6/05)

[355] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0112_full.html (accessed 9/9/05)

[356] http://www.wcmc.org.uk/protected_areas/data/wh/talamanc.html (accessed 9/9/05)

[357] Nabhan, G P (1991); Genetic resources of the U.S.- Mexican borderlands: wild relatives of crops, their uses and conservation, In Ganster, P. and Walter, H. (eds), *Environmental hazards and bioresource management in the United States-Mexico borderlands*. U.C.L.A. Latin American Center Publications, University California, Los Angeles. Pp. 345-360.

[358] Lammertink, J.M., Rojas-Tomé, J.A., Casillas-Orona, F.M. & Otto, R.L. (1997); *Situación y conservación de los bosques antiguos de pino-encino de la Sierra Madre Occidental y sus aves endémicas*. Consejo Internacional para la preservación de las aves, Sección Mexicana, D.F. México

[359] Tewksbury J, G Nabhan, D Norman, H Suzan, J Tuxill and J Donovan (1999); *op cit*

[360] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=ECU%2002 (accessed 27/8/05)

[361] http://www2.unesco.org/mab/br/brdir/directory/biores.asp?mode=all&code=ECU%2003 (accessed 27/8/05)

[362] http://www.wcmc.org.uk/protected_areas/data/wh/manu.html (accessed 29/8/05)

[363] Saavedra, C (1989); Manu - two decades later. *WWF Report* June/July. WWF, Gland, Switzerland, 6-9.

[364] Bubb, P, I May, L Miles and J Sayer (2004); *Cloud Forest Agenda*, UNEP-WCMC, Cambridge, UK, http://www.unep-wcmc.org/resources/publications/UNEP_WCMC_bio_series/20.htm

[365] http://www.cipotato.org/market/ARs/AR2003/pdf/ar2003_08.pdf (accessed 27/8/05)

---

[366] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0805_full.html (accessed 9/9/05)

[367] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0801_full.html (accessed 6/6/05)

[368] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0439_full.html (accessed 6/6/05)

[369] http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0118_full.html (accessed 19/6/05)

[370] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*

[371] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0101_full.html (accessed 6/6/05)

[372] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 190

[373] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 160

[374] http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0151_full.html (accessed 6/6/05)

[375] WWF and IUCN (1994); *op cit,*: 112

[376] Gogoi, P C (1981); *op cit*

[377] http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0146_full.html (accessed 5/5/06)

[378] Kostermans, A J H and S M Bompard (1993); *The mangoes: their botany, nomenclature, horticulture and utilisation*, IBPGR and Linnean Society of London, Academic Press, London

[379] Osman, M B, Z A Mohamed, S Idris and R Aman (1995); Tropical fruit production and genetic resources in Southeast Asia: Identifying the priority fruit species. Pp. 61-84 in: Arora, R.K. and V. Ramanatha Rao (eds.).1995. *Proc. Expert Consultation on Tropical Fruit Species of Asia. Kuala Lumpur*, Malaysia, 17-19 May 1994

[380] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 326

[381] http://www.worldwildlife.org/wildworld/profiles/terrestrial/im/im0144_full.html (accessed 2/5/06)

[382] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 366

[383] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 2: 369

[384] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0818_full.html (accessed 6/6/05)

[385] http://www.ars.usda.gov/research/projects/projects.htm?accn_no=407600 (accessed 6/6/05)

[386] http://www.nationalgeographic.com/wildworld/profiles/terrestrial/pa/pa0420.html (accessed 6/6/05)

[387] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0805_full.html (accessed 6/6/05)

[388] Lunyova, N and T Ulyanova (1997); Central Asian *in situ* conservation of wild relatives of cultivated plants, in N Maxted, B V Ford-Lloyd and J G Hawkes (Eds) *Plant Genetic Conservation*, Chapman and Hall, London

[389] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1008_full.html (accessed 10/6/05)

[390] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1214_full.html (accessed 6/6/05)

[391] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1207_full.html (accessed 19/6/05)

[392] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1215_full.html (accessed 19/6/05)

[393] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1209_full.html (accessed 19/6/05)

[394] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1221_full.html (accessed 19/6/05)

[395] Burgess, N, J D'Amico Hales, E Underwood, E Dinerstein, D Olson, I Itoua, J Schipper, T Ricketts and K Newman (2004); *op cit*

---

[396] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0310_full.html (accessed 24/5/05)

[397] Felger, R S and Wilson, M F (eds) (1995); Northern Sierra Madre Occidental and its Apachian outliers: a neglected center of biodiversity. In DeBano, L F, P F Ffolliott and R H Hamre (eds), *Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and northwestern Mexico*. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Pp. 36-59.

[398] http://www.nmnh.si.edu/botany/projects/cpd/ma/ma11.htm (accessed 26/8/05)

[399] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0112_full.html (accessed 5/9/05)

[400] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 196

[401] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0112_full.html (accessed 5/9/05)

[402] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0130_full.html (accessed 5/9/05)

[403] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 217

[404] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0153_full.html (accessed 26/8/05)

[405] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0135_full.html (accessed 24/5/05)

[406] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 362

[407] Clements, C R (1990); A center of crop genetic diversity in western Amazonia. *BioScience* **39**: 624-631

[408] http://www.nmnh.si.edu/botany/projects/cpd/sa/sa38.htm (accessed 27/8/05)

[409] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0702_full.html (accessed 5/9/05)

[410] Davis, S D, V H Heywood and A C Hamilton (1994); *op cit*; Vol 3: 358

[411] http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt1003_full.html (accessed 27/8/05)

[412] http://www.nmnh.si.edu/botany/projects/cpd/sa/sa33.htm (accessed 27/8/05)

[413] Tewksbury, J J, G P Nabhan, D Norman, H Suzan, J Tuxill and J Donovan (1999); *op cit*

[414] Scholten, M, N Maxted, S P Kell and B V Ford-Lloyd (in press); Creation of a national crop wild relative strategy: a case study for the United Kingdom. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, *Crop Wild Relative Conservation and Use*, CAB International

[415] Codd, R B, M Scholten, S P Kell, B V Ford-Lloyd and N Maxted (in prep); *Conservation action planning for UK crop wild relatives.*

[416] Davis, S D, S J M Droop, P Gregerson, L Henson, C J Leon, J Lamlein Villa-Lobos, H Synge and J Zantovska (1986); *Plants in danger: what do we know?* IUCN, Gland, Switzerland

[417] Frodin, D.G., (2001); *Guide to the standard floras of the world*; Second edition. Cambridge University Press, Cambridge

[418] Prendergast, H D V (1995); Published sources of information on wild species, pp. 255-28. In Guarino, L, V R Ramanatha Rao and R Reid (eds) *Collecting plant genetic diversity: technical guidelines*. CAB International, Wallingford

[419] Maxted, N, B V Ford-Lloyd, S L Jury, S P Kell and M A Scholten (2005); *op cit*

[420] See: http://mansfeld.ipk-gatersleben.de and/or Hanelt, P. and Institut für Pflanzengenetik und Kulturpflanzenforschung Gatersleben (eds.), (2001); *Mansfeld's encyclopaedia of agricultural and horticultural crops. 6 vols.* 1st Engl. ed. Springer, Berlin, Heidelberg, New York, etc

---

[421] Kell, S P, H. Knüpffer, S L Jury, B V Ford-Lloyd and N Maxted; (in press) Creation and application of the Crop Wild Relative Catalogue for Europe and the Mediterranean. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, Crop Wild Relative Conservation and Use. CAB International, Wallingford

[422] Maxted, N., Hawkes, J.G., Guarino, L. and Sawkins, M., (1997); The selection of taxa for plant genetic conservation. *Genetic Resources and Crop Evolution*, **44**: 337-348.

[423] Ford-Lloyd, B V, N Maxted and S P Kell (in press); Establishing conservation priorities for crop wild relatives. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, Crop Wild Relative Conservation and Use. CAB International, Wallingford

[424] Magos Brehm, J., Mitchell, M., Maxted, N., Ford-Lloyd, B.V. and Martins-Loução, M.A., (in press); National approach for Crop Wild Relatives Red Listing. In Maxted, N, B V Ford-Lloyd, S P Kell, J M Iriondo, E Dulloo and J Turok, Crop Wild Relative Conservation and Use. CAB International, Wallingford

[425] See: www.biodiv.org/programmes/cross-cutting/plant/

[426] Araújo, M, M Cabeza, H L Thuiller and P Williams (2004); Would climate change drive species out of reserves? An assessment of existing reserve-selection methods; *Global Change Biology* 10: 1618-1626.

[427] Anon (2000); *The Five-S Framework for Site Conservation*, The Nature Conservancy, Arlington Virginia

[428] Stedman-Edwards, P (1998); *Assessing Root Causes: A User's Guide*, WWF US, Washington DC

[429] Ervin, J (2003); *WWF Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) Methodology*, WWF International, Gland, Switzerland

[430] Scott, M J, F W Davis, R G McGhie, R G Wright, C Groves and J Estes (2000); Nature reserves: do they capture the full range of America's biological diversity? *Ecological Applications* **11**(4): 999-1007

[431] Scott, M J, F W Davis, B Cusuti, R Noss, B Butterfield, C Groves, H Anderson, S Caicco, F D'Erchia, T C Edwards, J Ulliman, and R G Wright (1993); GAP Analysis: A Geographic Approach to Protection of Biological Diversity, *Wildlife Monographs* **123**:1-41

[432] Dudley, N and J Parrish (2005); *Closing the Gap: Creating ecologically representative protected area systems*, Convention on Biological Diversity, Montreal, Canada

[433] Maxted, N, J Iriondo, E Dulloo and B Ford-Lloyd (In Prep.); Gap Analysis: a tool for effective genetic conservation assessment.

[434] Codd, R B, M Scholten, S P Kell, B V Ford-Lloyd and N Maxted (in prep); *op cit*

[435] Hawkes, J G (1991); International workshop on dynamic *in situ* conservation of wild relatives of major cultivated plants: summary of final discussion and recommendations. *Israel Journal of Botany*, 40: 529-536

[436] Jarvis, D I, L Meyer, H Klemick, L Guarino, M Smale, A H D Brown, M Sadiki, B Sthapit and T Hodgkin (2000); *A Training Guide for In Situ Conservation On-farm: Version 1*, International Plant Genetic Resources Institute, Rome.

[437] Phillips, A (2002); *op cit*

[438] Louette, D and M Smale (1996); *Genetic Diversity and Maize Seed Management in a Traditional Mexican Community: Implications for* In Situ *Conservation of Maize,* NRG Paper 96-03. Mexico, D.F., CIMMYT

[439] Iriondo, J, E Dulloo, S P Kell and N Maxted (2005); *Genetic reserve management guidelines*. ECP/GR Technical Bulletin No. 10. IPGRI, Rome and Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); *op cit*

[440] Codd, R B, M Scholten, S P Kell, B V Ford-Lloyd and N Maxted (in prep); *op cit*

[441] Meilleur B A and T Hodgkin (2004); *op cit*

[442] Iriondo, J M, L De Hond and N Maxted (2006); Genetic Reserve Management Guidelines. IPGRI Technical Bulletin No. 12. IPGRI, Rome

---

[443] Lawrence, M J and D F Marshall (1997); Plant population genetics, In: Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); *op cit.* pp. 99-113

[444] See Hawkes, J G, N Maxted and D Zohary (1997); Reserve design. In: Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); *op cit.* pp. 210-230

[445] Pickett, S T A and J N Thompson (1978); Patch dynamics and nature reserves. *Biological Conservation*, **13**, 27-37

[446] Maxted, N, J M Iriondo, L De Hond, E Dulloo, F Lefèvre, A Asdal, S P Kell and L Guarino (2006); Genetic Reserve Management. In: Genetic Reserve Management Guidelines (Eds. Iriondo, J.M., De Hond, L and Maxted, N.). IPGRI Technical Bulletin No. 12. IPGRI, Rome.

[447] Maxted, N, L Guarino and M E Dulloo (1997); Management and monitoring. In: Maxted, N, B V Ford-Lloyd and J G Hawkes, *op cit*

[448] Shands, H L (1991); Complementarity of *in situ* and *ex situ* germplasm conservation from the standpoint of the future user. *Israel Journal of Botany*, **40**: 521-528

[449] Borrini-Feyerabend, G (1996); *Collaborative Management of Protected Areas: Tailoring the approach to the context*, IUCN, Gland, Switzerland

[450] Borrini-Feyerabend, G, A Kothari and G Oviedo (2004); *op cit*

[451] Maxted, N, J G Hawkes, B V Ford-Lloyd and J T Williams (1997); A practical model for *in situ* genetic conservation, In: Maxted, N, B V Ford-Lloyd and J G Hawkes (1997); *op cit.*

[452] Güner, A, N Özhatay; T Ekim and K Hüsnü, C Baser, with the assistance of I Hedge (eds) (2001); *Flora of Turkey and the East Aegean Islands, 11* (Supplement 2). Edinburgh University Press, Scotland

[453] Plant Talk (2003); Important Plant Areas of Turkey Documented, *Plant Talk*, November 2003 (http://www.plant-talk.org/Pages/lead2.html, accessed 22/3/05)

[454] Tan, A (1998); *Current status of plant genetic resources conservation in Turkey*, In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[455] Karagöz, A (2003); *Plant Genetic Resources Conservation in Turkey*, In: Düzyaman, E and Y Tüzel (eds) International Symposium on Sustainable Use of Plant Biodiversity to Promote New Opportunities for Horticultural Production Development, ISHS Acta Horticulturae 598, Antalya, Turkey

[456] Harlan, J R (1992);*Crops and Man*., American Society of Agronomy, Crop Sci. Soc. of America, Madison, Wisconsin, USA

[457] Karagöz, A (2003); *op cit*

[458] Davis, P H (1985); Juncaceae, Cyperaceae and Graminae, in Flora of Turkey, Vol. 9: 1-724. Edinburgh University Press, Edinburgh.

[459] Açõkgöz, N, C O Sabancõ and A S Cinsoym (1998); Ecogeography and distribution of wild legumes in Turkey. In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[460] Tan, A (1998); *op cit*

[461] Damania, A B (1998); Domestication of Cereal Crop Plants and In situ Conservation of their Genetic Resources in the Fertile Crescent, In: Damania, A B, J Valkoun, G Willcox and C O Qualset (Eds.) *The Origins of Agriculture and Crop Domestication*. ICARDA, Aleppo, Syria

[462] Kıtıkı, A and A Tan (1998); Vegetation survey in the southern part of the Anatolian diagonal and possible gene management zones for wild crop relatives, In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

---

[463] UNECE and FAO (2000); Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand: Main report, Geneva Timber and Forest Study Papers number 17, United Nations, New York and Geneva, page 62

[464] Figures from WWF Turkey

[465] Ekim, T, M Koyuncu, S Erik and R Ýlarslan (1989); List of rare, threatened and endemic plants in Turkey according to IUCN Red Data Book Categories, Turkish Association for Conservation of Nature and Natural Resources, No: 18. Ankara. Ekim, T, M Koyuncu, M Vural, H Duman, Z Aytaç and N Adigüzel (2000); Red Data book of Turkish Plants, Türkiye Tabiatini Koruma Derneği – Van Yüzüncü Yil Üniversitesi, Banşcan Ofset, Ankara, Turkey

[466] Kaya, Z, E Kün and Güner (1998); *National plan for* in situ *conservation of plant genetic diversity in Turkey,* in N. Zencirci, Z. Kaya, Y. Anikster and W. T. Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[467] Anon (2000); *C*utting-Edge Conservation Techniques Are Tested in the Cradle of Ancient Agriculture: GEF Turkish Project Is a Global Model for in Situ Conservation of Wild Crop Relatives; *Diversity*, Vol.**16**:4, Missouri Botanical Garden, USA

[468] ibid

[469] Karagöz, A (2003); *op cit*

[470] ibid

[471] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=61944&level=nat (accessed 5/9/05)

[472] Anon (2000); *op cit*

[473] ibid

[474] Brylski, P (2003); *Biodiversity Strategy For The Europe And Central Asia Region*, Discussion Draft – dated March 2003, presented at the Closing Plenary of the 1st Regional Session of the Global Biodiversity Forum for Europe, Chisinau, Moldova, April 2003 (www.gbf.ch/Session_Administration/ upload/paper%20Phillip%20Brylski,%20World%20Bank.doc, accessed 30/3/05) and Anon (2000); *C*utting-Edge Conservation Techniques Are Tested in the Cradle of Ancient Agriculture: GEF Turkish Project Is a Global Model for in Situ Conservation of Wild Crop Relatives; *Diversity*, Vol.**16**:4, Missouri Botanical Garden, USA

[475] Anon (2000); *op cit*

[476] Karagöz, A (1998); *In-situ* conservation of plant genetic resource in the Ceylanpınar State Farm, In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[477] Anon (2000); *op cit*

[478] Willcox, G H (1992); Archaeobotanical significance of growing Near Eastern progenitors of domestic plants at Jalés (France), P C Anderson (Eds) *Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques*, Monographie du CRA No. 6, Centre de Recherches Archéologiques (CNRS, Paris, France

[479] Fırat, A E and A Tan (1998); Ecogeography and distribution of wild cereals in Turkey, In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[480] Heun, M, R Schäfer-Pregl, D Klawan, R Castagna, M Accerbi, B Borghi and F Salamini (1997); Site of einkorn wheat domestication identified by DNA fingerprinting, *Science* **278**:1312-1314

[481] Welch, H J (ed) (2004); *GAP Biodiversity Project 2001 – 2003 – final report*, DHKD (Turkish Society for the Conservation of Nature), Istanbul, Turkey

[482] Fırat, A E and A Tan (1998); *op cit*

[483] ibid

[484] Brylski, P (2003); *op cit*

---

[485] Welch, H J (ed) (2004); *GAP Biodiversity Project 2001 – 2003 – final report*, DHKD (Turkish Society for the Conservation of Nature), Istanbul, Turkey

[486] Fırat, A E and A Tan (1998); *op cit*

[487] ibid

[488] Anon (2000); *op cit*

[489] Karagöz, A (1998); *op cit*

[490] Kıtıkı, A and A Tan (1998); *op cit*

[491] ibid

[492] Fırat, A E and A Tan (1998); *op cit*

[493] ibid

[494] Açıkgöz, N, C O Sabancı and A S Cinsoy (1998); *Ecogeography and distribution of wild legumes in Turkey*; In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[495] Kıtıkı, A and A Tan (1998); *op cit*

[496] Açıkgöz, N, C O Sabancı and A S Cinsoy (1998); *op cit*

[497] ibid

[498] ibid

[499] Kıtıkı, A and A Tan (1998); *op cit*

[500] ibid

[501] Açıkgöz, N, C O Sabancı and A S Cinsoy (1998); *op cit*

[502] ibid

[503] Anon (2000); *op cit*

[504] ibid

[505] Yildiray Lise (2006); per com, Information from the Ministry of Environment and Forestry

[506] Kaya, Z, E Kün and Güner (1998); *National plan for* in situ *conservation of plant genetic diversity in Turkey,* In: Zencirci, N, Z Kaya, Y Anikster and W T Adams (eds); The Proceedings of International Symposium on *In Situ* Conservation of Plant Genetic Diversity, Central Research Institute for Field Crops, Turkey

[507] ibid

[508] Davis, P (1971); *Distribution patterns in Anatolia with particular reference to endemism*, in Davis P, P C Harper and I C Hedge (eds); Plant life of South-West Asia. Botanical Society of Edinburgh, Scotland

[509] http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0420_full.html (accessed 30/3/05)

[510] http://www.unep-wcmc.org/protected_areas/data/sample/0072v.htm (accessed 30/3/05)

[511] Welch, H J (ed) (2004); *GAP Biodiversity Project 2001 – 2003 – final report*, DHKD (Turkish Society for the Conservation of Nature), Istanbul, Turkey

[512] http://worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0515_full.html (accessed 30/3/05)

[513] Davis, P H (ed) (1965-1985); *Flora of Turkey and the east Aegean islands*. Vol.1-9, Edinburgh University Press, Edinburgh, Scotland

---

[514] http://worldwildlife.org/wildworld/profiles/terrestrial/pa/pa0515_full.html (accessed 30/3/05)

[515] ibid

[516] Welch, H J (ed) (2004); *op cit*

[517] Heun, M., R. Schäfer-Pregl, D. Klawan, R. Castagna, M. Accerbi, B. Borghi and F. Salamini (1997); Site of einkorn wheat domestication identified by DNA fingerprinting, *Science* **278**:1312-1314

[518] E Santana, of the Manantlán Institute of Ecology and Conservation Biology, Text from article on: The Biodiversity Leadership Awards of The Bay Foundation and the Josephine Bay Paul and C. Michael Paul Foundation and award recipients: Eduardo Santana Castellon and Enrique Jardel Pelaez at: http://www.bayandpaulfoundations.org/manant.htm (accessed 59/6/05)

[519] http://www.csdl.tamu.edu/FLORA/taes/tracy/typeimgs/Zeadiploperennis.html (accessed 7/7/2004)

[520] Iltis, H (1994); New Year's Card Leads to Newly Discovered Species of Enormous Economic Potential, *R&D Innovator,* 3:6, June 1994 at: http://www.winstonbrill.com/bril001/html/article_index/articles/101-150/article103_body.html (accessed 7/7/04)

[521] http://sea.unep-wcmc.org/wdbpa/sitedetails.cfm?siteid=301929&level=nat (accessed 19/6/05)

[522] Cuevas-Guzmán, R, B F Benz, E J Jardel-Peláez and O Herrera-MacBryde (undated); *Fact Sheet, Sierra de Manantlan Region*; Smithsonian Institution, SI/MAB Program, Washington, DC, USA, at: http://www.nmnh.si.edu/botany/projects/cpd/ma/ma6.htm (accessed 29/6/05)

[523] Sheean-Stone, O (1989); Mexico's wonder weed, *WWF Reports,* Gland, Switzerland, Aug.Sept.: 9-12

[524] Eduardo Santana, of the Manantlán Institute of Ecology and Conservation Biology, Text from article on: The Biodiversity Leadership Awards of The Bay Foundation and the Josephine Bay Paul and C. Michael Paul Foundation and award recipients: Eduardo Santana Castellon and Enrique Jardel Pelaez at: http://www.bayandpaulfoundations.org/manant.htm (accessed 59/6/05)

[525] ibid

[526] Benz, B F *et al* (undated); Case study: drawing on the results of preliminary investigations of the ecology and ethnobotany of *Zea diploperennis;* in J. Tuxill and G.P. Nabhan (undated) *People and Plants conservation manual on Plants and Protected Areas*, (accessed from: www.unesco.org/mab/sustainable/chap2/2boxZea.htm, 7/7/04)

[527] ibid

[528] Cuevas-Guzmán, R; B F Benz; E J. Jardel-Peláez; O Herrera-MacBryde (undated); op cit

[529] ibid

[530] ibid

[531] E Santana pers com and Louette, D and M Smale (1996); *Genetic Diversity and Maize Seed Management in a Traditional Mexican Community: Implications for* In Situ *Conservation of Maize,* NRG Paper 96-03, Mexico, D.F.: CIMMYT

[532] *Vietnam Biodiversity Action Plan* (1995), at: http://www.biodiv.org/doc/world/vn/vn-nbsap-01-p6-en.pdf (accessed 29/6/05)

[533] From the Resolution of the Prime Minister No. 845-TTg, December 22, 1995, on the ratification of BAP, in Vietnamese

[534] GEF (2002); Medium-Sized Project Document (VIE/01/G35); *In situ* Conservation of Native Landraces and their Wild Relatives in Vietnam, available at: http://www.undp.org.vn/projects/vie01g35/docs/vie01g35.pdf (accessed 6/4/2005)

[535] Spooner, D S, K McLean, G Ramsay, R Waugh and G J Bryan (2005); A single domestication for potato based on multilocus amplified fragment length polymorphism genotyping, *Proceedings of the National Academy of Sciences of the United States of America*, **102**:41,14694-14699, October 11, 2005

---

[536] Leighton, P (2004); *Latin American potato network to help Africa and Asia*, SciDev.Net, 9 November 2004, www.scidev.net/News/index.cfm?fuseaction=readNews&itemid=1727&language=1 (accessed 21/4/05)

[537] IUCN (2003); 'Potato park' aims to help save genetic resources in Peru, Feature Story PR, Gland, Switzerland, 10 April 2003

[538] Colchester, M and A Argumedo (2003); *Peru: Visit to a 'Potato Park'*, document prepared for the IUCN World Parks Congress, http://www.tilcepa.org/themes/themes.asp?ID=3#titles (accessed 21/4/05)

[539] National Research Council (1989); *Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation*, Ad Hoc Panel of the Advisory Committee on Technology Innovation, Board on Science and Technology for International Development, Office of International Affairs, Washington DC

[540] Colchester, M and A Argumedo (2003); *ibid*

[541] Grain (2005);ANDES-Potato Park-CIP agreement, BIO-IPR Docserver, 20 January 2005, www.grain.org/bio-ipr/?id=429#_eng (accessed 21/4/05)

[542] Suri, S (2005); *Potato Capital of the World Offers Up New Recipe*, Inter Press Service News Agency, 18 January 2005, www.ipsnews.net/interna.asp?idnews=27069 (accessed 21/4/05)

[543] ibid

[544] Shetty, P (2005); *Peruvian 'potato park' to protect indigenous rights*, SciDev.Net, 19 January 2005, www.scidev.net/news/index.cfm?fuseaction=readnews&itemid=1859&language=1 (accessed 21/4/05)

[545] Phillips, A, (2002); *op cit*

[546] Borrini-Feyerabend, G, Kothari, A and Oviedo, G (2004); *op cit*

[547] ibid

[548] ibid

[549] ibid

[550] ibid

[551] Phillips, A, (2002); *op cit*

[552] Colchester, M and A Argumedo (2003); *op cit*

[553] Dhawan, N L (1964); Primitive Maize in Sikkim, *Maize Genet. Coop. Newsletter*, **60**:104

[554] Velayudhan, K C *et. al.* (1996); Collecting Genetic Diversity of Egg Plant and its wild relative from South India; *Indian J. Pl. Genet. Resources,* **9**:1; 89-95

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