

SUMMARY

Crop wild relatives and landraces are key components of plant genetic resources for food and agriculture (PGRFA) and of overall agricultural biodiversity (or agrobiodiversity). Both of these plant groups are genetically diverse, locally adapted and represent a potential source of traits for adapting crops to changing environmental conditions and human needs, particularly in the face of the increasing negative impacts of climate change. If efficiently preserved and sustainably used, they can contribute significantly to an increase in food security, alleviation of human poverty and improvement of ecosystem stability. However, the diversity of both crop wild relatives and landraces is severely threatened by environmental mismanagement and socio-political pressures and is quickly being eroded or lost.

The need to effectively conserve and manage PGRFA is enshrined in a number of international agreements, including in the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture. FAO's Member Countries have long been calling for greater attention to the genetic conservation of crop and crop related diversity that is essential for food security, as well as improved collaboration and coordination of actions at national, regional and global levels. Recognizing the need to support a systematic and coordinated approach at global level to conserve diverse crops and crop wild relatives *in situ* (i.e., in their native environments), the Commission on Genetic Resources for Food and Agriculture is currently exploring options for establishing a global network for their *in situ* conservation and on-farm management.

Despite the increased political, scientific and public interest in conserving PGRFA, many countries still lack effective actions to systematically and effectively protect crop wild relative and landrace diversity *in situ* with adequate complementary back-up in *ex situ* facilities. *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* identified a number of gaps at national level, including the need to develop specific strategies for *in situ* conservation and on-farm management. This resource book aims to help guide national governments in developing a systematic approach to conservation and use of crop wild relatives and landraces. The focus is on *in situ* and on-farm conservation techniques, but methods for identifying *ex situ* conservation needs are also provided since a complementary approach is fundamental to ensure that genetic material is adequately conserved and available for utilization. The book is primarily intended for staff associated with National Plant Genetic Resources Programmes, but may also be valuable for universities and research organizations, NGOs and other institutions involved in conservation planning.

The resource book is divided into two parts: Part 1 focuses on the political and economic context of conservation and use of agrobiodiversity, and aims to provide national decision-makers with an overview of the key elements influencing this sector. Part 2 focuses on the technical aspects of planning genetic conservation and provides detailed protocols for planning and implementing complementary conservation activities. Particular importance is placed on: (a) the creation of national inventories; (b) prioritizing taxa for active conservation; (c) collation of

taxonomic, ecogeographic, genetic and threat data; (d) *in situ* and *ex situ* gap analysis; (e) development and implementation of complementary *in situ* and *ex situ* conservation recommendations, (f) monitoring conserved diversity; and (g) making the critical link between conservation and use to ensure the conserved resources are sustainably exploited. The protocols are illustrated with real-life examples and an extensive list of additional materials is provided to help the user in their work.

Both parts are designed to facilitate the development and implementation of a national plan for conservation and management of crop wild relatives and landraces. The preparation of a strategic plan will depend heavily on the local context, including the availability of baseline biodiversity data, the existing policy framework, the focal area and remit of the agencies which are responsible for formulating and implementing the plan, as well as on the resources available for its implementation. Nevertheless, the process of developing a strategic plan requires a series of decisions and actions that essentially follow the same pattern in all countries, including developing an effective consultation process, establishing a knowledge base, analysing conservation gaps, identifying priorities, and planning and implementing specific conservation actions. The resource book therefore provides a framework and guide to assist in the preparation of national plans, bearing in mind that the suggested steps do not necessarily have to be followed in the same predefined order.

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CONTEXT

1.1 Importance of agrobiodiversity for food security

A country's crop wild relatives (CWR) and landraces (LR) diversity constitute an important component of a nation's natural resources, as plant genetic resources for food and agriculture (PGRFA) they are available for utilisation by national, regional and international stakeholders; and form the basis of food and livelihood security (Maxted *et al.*, 2011).

CWR are species closely related to crops and are defined by their potential ability to contribute beneficial traits for crop improvement (Maxted *et al.*, 2006). They have been used increasingly in plant breeding since the early 20th century and have provided vital genetic diversity for crop improvement—for example, to confer resistance to pests and diseases, improve tolerance to environmental conditions such as extreme temperatures, drought and flooding and to improve nutrition, flavour, colour, texture and handling qualities (Hajjar and Hodgkin 2007, Maxted and Kell 2009). Almost all modern varieties of crops contain some genes derived from a CWR and in monetary terms, CWR have contributed significantly to the agricultural and horticultural industries, and to the world economy (Maxted *et al.* 2008a, Maxted and Kell 2009). Furthermore, as CWR are components of natural and semi-natural ecosystems, they also play a role in ecosystem functioning and thus in broader environmental sustainability and maintenance of ecosystem services.

The particular food security value of CWR has been recognized at least since Darwin discussed their study and conservation (1868), but it was Vavilov (1926) who was the first to promote their systematic conservation in practical terms. However, CWR conservation had remained widely neglected because the responsibility for their conservation has neither been adopted by agricultural agencies (whose remit is not wild species conservation) nor environment agencies (whose focus is not on PGRFA conservation). It is only relatively recently that their systematic conservation has been addressed due to the growing interest in their use as gene donors (e.g., Maxted *et al.*, 1997a; Meilleur and Hodgkin, 2004; Heywood and Dulloo, 2005; Stolton *et al.*, 2006; Maxted *et al.*, 2008a), even though their value as gene donors has been extensively documented since the 1970s (e.g., Frankel, 1970; Jain, 1975; Prescott-Allen and Prescott Allen, 1986; Hoyt, 1988). Their economic value is now understood; for example, one recent estimate is that approximately 30% of modern crop production increase is due to the use of CWR genetic diversity and that this has an annual value of approximately US \$115 billion worldwide (Pimentel *et al.*, 1997).



Wild wheat CWR, *Aegilops triuncialis* growing near Meghri Armenia. Photo: N. Maxted



Wild cowpea CWR, *Vigna comosa*. Photo: S. Padulosi

LR are dynamic population(s) of traditional crop varieties that have some, if not all, of the following characteristics: historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with cultural practices and associated with traditional farming systems. The importance of LR is two-fold: they are of direct use in small-scale subsistence and commercial agriculture and constitute a potential source of novel genetic diversity for crop improvement. It can also be argued that LR diversity is more likely to be of use to plant breeders, because if a breeder cross their elite lines with a CWR then the progeny are likely to quite distinct from the elite line and the breeder will need several generations to get back to the semblance of the original elite line plus the desired CWR trait, whereas with a cross with a LR is less disruptive as the cross is with the species and obtaining the elite line plus the desired LR trait will be faster. Further, LR can be used directly by farmers, particularly in subsistence or marginal agriculture either as agricultural varieties in themselves or via crossing with locally adapted LR without suffering the potential yield loss that crossing with a CWR is likely to incur.



Cucurbit landrace 'Santorini'. Photo: N. Maxted



Paul Watkins with wheat landrace 'Squareheads Master' Photo: N. Maxted

The increasing human population, periodic food shortages and current and expected effects of climate change have all led to raised awareness of the need for more attention to be paid to global and national food security. Globally, agriculture is being practiced in more adverse or marginal environments, whether due to human degradation of habitats, the demand for food forcing the expansion of agricultural lands or the effects of climate change. As a consequence, there is growing demand for the development of new varieties that can be adapted to these marginal environments and to the changing environmental conditions that have been rapidly evolving in recent years (Heywood *et al.*, 2007), as well as those expected in the coming decades due to the effects of climate change. This has stimulated the search for genetic material that can be used to confer pest and disease resistance and tolerance to various environmental conditions—in particular, resistance to drought, flooding and heat stress—in turn enhancing productivity, for which CWR and LR are potential sources (Heywood, 2007; Negri *et al.*, 2009). Additionally, inter- and intra-species crossing techniques have rapidly developed, facilitating the use of LR and CWR diversity in the improvement and creation of new varieties. Some examples include the use of: *Oryza rufipogon* to confer cold tolerance and other abiotic stress resistance in rice (*O. sativa*) in China (Song *et al.*, 2005), *Thinopyrum intermedium* and *Th. ponticum* to improve wheat (*Triticum aestivum*) for barley yellow dwarf virus immunity which was released all across the World (Ayala *et al.*, 2001), *Arachis batizocoi*, *A. cardenasii*, *A. duranensis*, *A. stenosperma* and *A. villosa* for rust and late leaf spot resistant to peanut (*A. hypogaea*) in India (Singh *et al.*, 2003), amongst many others (see Maxted and Kell, 2009 for reviews).

Box 1. Can current crop varieties cope with changing environments?

The increasing human population and periodic food shortages have led to raised awareness of the need for global and sub-global food security. In turn, this has stimulated the search for genetic material that can be used to enhance productivity, disease resistance, and tolerance to various environmental conditions, for which CWR and LR are potential sources (Heywood 1997, Negri *et al.* 2009). As a consequence, there is a growing demand for the development of

novel varieties adapted to the new environmental conditions that have rapidly 'evolved' in recent years, as well as to meet the short-term adaptation goal of breeding new varieties that address changing consumer demands (Heywood *et al.* 2007). Additionally, inter and intra-species crossing techniques have rapidly developed facilitating the use of CWR and LR diversity in the improvement and creation of new varieties.

While climate change will directly impact CWR diversity, it will also undoubtedly alter the agro-environmental conditions under which our crops grow and thus impact agricultural production. It is likely that many current crop varieties will need replacement to enable them to better suit the new and changing agro-environments (e.g. Jones *et al.* 2003, Duveiller *et al.* 2007, Deryng *et al.* 2011, Li *et al.* 2011, Luck *et al.* 2011). Failure to meet this challenge could have a devastating impact on the global economy and social well-being. Genetic diversity offers an insurance against the harmful impacts of climate change and CWR are particularly likely to contain the breadth of genetic diversity necessary to combat these impacts because of the diversity of habitats in which they grow and wide range of conditions to which they are adapted (FAO 2008). Changes in climate are also expected to augment the risk of pest and disease spread and to affect precipitation regimes and cropping patterns in cultivated species, thus also affecting LR (Veteläinen *et al.* 2009a, Mercer and Perales 2010). Nevertheless, climatic change can lead to non-analogous climate conditions and their consequences are thus difficult to predict. Therefore, CWR and LR diversity is under threat from climate change, while at the same time they offer a critical means of mitigating the predicted impact of changes in climate.

New varieties may be produced by plant breeders, either independently of, or in collaboration with farmers. However, the continued cultivation of LR by farmers is also likely to continue to be of direct importance for food and livelihood security for individual families and communities; particularly the poorest people living in rural and marginal areas. LR are adapted to local environmental conditions and may be more productive, more nutritious, have a wider range of culinary uses, are less likely to suffer from pests, diseases and abiotic stresses, and have a wider cropping window. While many farmers who have replaced LR with modern cultivars have benefited, the consequences of introducing modern, highly bred, high yielding varieties into marginal lands can be disastrous because these varieties have been bred for general rather specific agro-ecosystem suitability. For example, the increase of uniformity and productivity of rapeseed agriculture led to the creation of optimal conditions for the spread of blackleg epidemic (caused by *Leptosphaeria maculans*) in Canada (Juska *et al.*, 1997). Marginal lands by definition deviate from the norm and here modern cultivars grown as monocultures are not adapted to the wide range of local environmental conditions; thus, they tend to be more vulnerable to pests and diseases and the effects of extreme environmental variables, such as drought, heat stress or flooding. However, LR have been selected by farmers over millennia to provide maximum production value despite the wide range of local environmental conditions; therefore, under these marginal conditions they can still out-perform modern cultivars.

1.2 Threats and demands for agrobiodiversity

Despite the importance of CWR and LR, there is an increasing loss of this diversity due to a number of social, economic and ecological factors:

- a. CWR and LR are expected to be affected by climate change (e.g., see Parmesan and Yohe, 2003; Root *et al.*, 2003; Thuiller *et al.*, 2005; Jarvis *et al.*, 2008; Lenoir *et al.*, 2008)— changes that are expected to augment the risk of pest and disease spread and to affect precipitation regimes and cropping patterns in cultivated species (Veteläinen *et al.*, 2009a; Mercer and Perales, 2010);
- b. LR are being lost due to their replacement with modern cultivars, the pressure of changing markets, as well as family needs and aspirations, which may include the abandonment of traditional practices; while CWR, like any other wild plant species are threatened by the loss, degradation and fragmentation of their natural habitats and competition from alien species;
- c. CWR are often associated with disturbed habitats such as field margins, forest edges and roadsides, and these populations are not being adequately conserved by ecosystem conservation agencies;
- d. LR are often associated with low-input traditional farming systems, many of which are being converted to more intensive high-input systems;
- e. CWR and LR diversity suffers from a lack of knowledge regarding its breadth, location and real use potential; for example, inventories are lacking for most countries and conserved CWR and LR diversity is largely uncharacterised or unevaluated (FAO 2010a). In particular, the lack of knowledge on how many traditional seed-saved varieties remain extant as well as on their traditional cultivation practices has been a severe constraint in their conservation and utilization. LR are commonly maintained by older people and diversity is being lost as their cultivation is not being undertaken by younger generations (Maxted 2006).

Further, climate change is predicted to have an even greater impact on diversity. Average temperatures are predicted to rise by 2–4°C over the next 50 years and cause considerable disturbance to regional and seasonal patterns of precipitation (IPCC 2007). Climate acts directly on growth and reproduction of plant species (e.g., Andrello *et al.* 2012) through physiological constraints and/or indirectly through ecological factors such as competition for resources (Shao and Halpin 1995), so changes in climate will inevitably affect species' survival. Several studies have already reported significant effects of climatic change over ecosystems and species (e.g. Parmesan and Yohe 2003, Root *et al.* 2003). Fischlin *et al.* (2007), for example, predict that by 2100, 10–30% of species globally are likely to go extinct as a result of climate change. Negative effects of climate change include loss, expansion, relocation and fragmentation of habitats, and changes in distribution, abundance, phenology and physiology of a wide range of species (Hughes 2000, Walther *et al.* 2002, Jarvis *et al.* 2008), as well as disruption of biotic interactions (Hughes 2000).

Thuiller *et al.* (2005) modelled the impact of different climate change scenarios on

the distribution of 1350 plant species and concluded that more than half of the species are predicted to become threatened with extinction by 2080 if they are unable to disperse. On the other hand, plant taxa have the ability to respond to climatic changes, as happened during the Quaternary when there were large-scale distribution shifts (Huntley 1990), so it is expected that they still maintain the ability to do so. In fact, the Thuiller *et al.* (2005) study predicted that if taxa are able to adapt through migration, then about 22% would become Critically Endangered and 2% Extinct. Additionally, some studies have reported a shift in species distribution towards the Poles or upwards in altitude with gradual earlier seasonal migrations and breeding (e.g. Parmesan and Yohe 2003, Root *et al.* 2003, Lenoir *et al.* 2008). Specifically for CWR, a comparative study of the likely impact on three crop gene pools (Jarvis *et al.* 2008) found 16–22% of CWR species would go extinct by 2055 and the majority of species showed greater than 50% loss of distributional range and the range that remained was highly fragmented.

Yet there is increasing demand to utilise this threatened resource:

- i. If crops are to increase production levels there is a need for new trait diversity outside that which has been historically used by farmers and plant breeders—CWR and LR offer the necessary, novel genetic diversity that can enhance crop productivity or commodity improvement, promote disease and pest resistance and increase tolerance of adverse or marginal environments;
- ii. Globally, agriculture is being practiced in more adverse or marginal environments, whether due to human degradation of habitats or the demand for food forcing the expansion of agricultural lands—the desired traits to grow crops in these environments are found in LR and CWR diversity;
- iii. There is a continuous and growing demand for novel diversity by breeders to be used in the development of new varieties due to the relatively short-term commercial lifespan of modern cultivars (usually 5–10 years);
- iv. Conventional and biotechnological breeding techniques have improved dramatically in recent years enabling more precise targeting of desirable traits, relatively easy transfer to the crop and less problems with the transfer of unwanted characteristics from exotic LR and CWR material; and
- v. The conservation of CWR in existing protected areas offers an additional ecosystem service to the protected areas themselves, so for limited additional resource commitment the perceived value of the protected areas can be significantly enhanced.

While both CWR and LR diversity is threatened, at the same time it offers a critical means of mitigating its impact on food security. Despite this wide recognition, it is only very recently that efforts to systematically assess their threat status have been undertaken. There are two main reasons for this: firstly, because of the already identified gap in the remit of conservation agencies to conserve CWR, and secondly, because of the technical challenges in quantifying and locating LR diversity—a prerequisite to their threat assessment. The current status of the threat to CWR and LR diversity is outlined in Box 2.

Box 2. Threat assessment of CWR and LR diversity—current status

Significant progress has been made in assessing the loss of botanical diversity, particularly for regions where the flora is well known; for example, 21% of European vascular plant species were classified as threatened using the 1994 IUCN Red List Categories and Criteria (IUCN, 1994, and 50% of Europe's 4,700 vascular plant endemics are considered to be threatened to some degree (www.redlist.org). CWR are intrinsically no different to other wild plant species, and, like them, many are currently threatened with loss of diversity and/or extinction (Maxted *et al.*, 1997b; Stolton *et al.*, 2006), however, a review of Red List assessments using the more detailed current IUCN Red List Categories and Criteria (IUCN, 2001) showed that of the more than 25,000 CWR species present in Europe, less than 1% had been assessed (Kell *et al.*, 2008). Further, Maxted and Kell (2009) reviewed whether the CWR within 14 global priority crop gene pools had been threat assessed and found that only one, *Solanum*, had been partially assessed using the 2001 IUCN Red List Categories and Criteria.

Even though there is currently no comprehensive global review of CWR threat assessment, if as shown by Kell *et al.* (2008) the majority of wild plant species may be considered CWR (as there is at least one crop in the majority of genera), then a Global Red List of plants would be indicative of the threat facing CWR. Therefore, when the Sampled Red List Index for Plants project (Brummitt and Bachman 2010) recently found that 20% of all plants are currently threatened with extinction it can be implied that a similar proportion of CWR are likely to also be threatened. However, more specifically for European CWR IUCN Red List assessment was recently undertaken for 591 European CWR species in 25 crop gene pools/groups (Bilz *et al.*, 2011) and found that 11.5% (66) of the species are considered as threatened, with 3.3% (19) of them being Critically Endangered, 4.4% (22) Endangered and 3.8% (25) Vulnerable—a further 4.5% (26) of the species are classified as Near Threatened. While outside of Europe as part of the UNEP/GEF-supported project, 'In situ conservation of crop wild relatives through enhanced information management and field application', Bolivian CWR were prioritized and after collating ecogeographic data for 36 CWR genera and over 310 CWR species, threat assessments were undertaken and found that 14.6% (45) of the species are considered as threatened, with 2.3% (7) of them being Critically Endangered, 7.1% (22) Endangered and 5.2% (16) Vulnerable—a further 6.5% (20) of the species are classified as Near Threatened (Mora *et al.*, 2009). It is anticipated that these initiatives will act as a catalyst for more countries and regions to follow suit.

CWR resources are primarily threatened by loss, degradation and fragmentation of their natural habitats, whereas LR have been mostly affected by replacement with modern cultivars and changes in land use practices (monocultures, use of pesticides, etc.). Negri *et al.* (2009) argued that LR are the most threatened element of PGRFA because: a) they are being replaced by modern varieties promoted by agricultural advisors and breeding companies; b) the application of variety and seed certification legislation mitigates against the legal sale of LR; c) we have no idea how many traditional seed-saved varieties remain extant; d) we know widely from anecdotal evidence that LR maintainers are almost invariably elderly and their numbers are dwindling annually; e) the proportion of the total LR

diversity that is currently used by farmers or breeders is not systematically conserved *ex situ* in gene banks; f) there is only a handful of working on-farm LR conservation projects that are actively maintaining LR diversity; and g) LR conservation falls outside the remit of conventional conservation agencies. Having argued that LR are so uniquely threatened compared to other biodiversity components, globally there is no agreed method of LR threat assessment and no reliable estimate of how many LR are threatened.

Unlike CWR, it is not possible to use IUCN Red List Criteria within taxa, so they cannot be applied for LR assessment. There have in recent years been several attempts to either adapt the IUCN Red List Criteria or develop a parallel set of criteria to assess the level of threat facing LR diversity (Joshi *et al.* 2004; Porfiri *et al.* (2009) Padulosi *et al.*, 2012). However, there are few data available to assess LR extinction or genetic erosion—the data that are available are often not quantified rigorously, largely anecdotal or are based on variety nomenclature rather actual genetic diversity (FAO, 1999). However, there are individual papers that estimate the threat to or loss of LR diversity within a specific region; for example, Hammer *et al.* (1996) compared LR diversity extant between 1940 and 1991/93, and between 1950 and 1983/86 in Albania and southern Italy, and found that about 75% LR of all crops had been lost.

Thus it appears that the current threats to CWR and LR diversity is significant, if the potential threats posed by climate change are incorporated the threat to CWR and LR diversity is unprecedented.

At a strategic policy level the threat and use potential are recognised; the Convention on Biological Diversity (CBD) (CBD 1992 and www.biodiv.org), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (www.planttreaty.org/) and the Global Strategy for Plant Conservation (GSPC) (www.biodiv.org/programmes/cross-cutting/plant/) each stress the need to improve the efficiency and effectiveness of conservation actions targeting PGRFA. In decision VII/30, the Conference of the Parties (COP) of the CBD established the 2010 Biodiversity Targets (CBD 2002) that drew attention to the importance of conserving the “genetic diversity of crops, livestock, and harvested species of trees, fish and wildlife and other valuable species conserved ... restore, maintain, or reduce the decline of populations of species” and committed the parties “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”. Specifically in relation to PGRFA, having failed to achieve previous targets, the GSPC (CBD 2010a) of the CBD calls for: “70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge” by 2020 in Target 9. Further, more effective CWR conservation is specifically highlighted as a priority in Target 13 of the recently established CBD Strategic Plan (CBD 2010b): “By 2020, the loss of genetic diversity of cultivated plants and domestic farm animals in agricultural ecosystems and of wild relatives is halted and strategies have been developed and implemented for safeguarding the genetic diversity of other priority socio-economically valuable species as well as

selected wild species of plants and animals.” In addition, the first UN Millennium Development Goals (www.un.org/millenniumgoals/) highlighted the need of eradicating extreme poverty and hunger.

Therefore, both CWR and LR are critical components of PGRFA that can be utilized (either directly or indirectly) for wealth creation, food security and environmental sustainability in the 21st century; as such their conservation is critical to human well-being.

1.3 Agrobiodiversity conservation at national and international levels

While the value of CWR and LR for food and livelihood security is widely recognized, there is a lack of knowledge about the diversity that exists and precisely how that diversity may be used for crop improvement. CWR and LR inventories are lacking for most countries—without knowledge of how many populations, crops or taxa exist and at what locations, there is no possibility to plan for their systematic conservation. Furthermore, even for some of the most important crops in terms of global or regional food security, there is a lack of knowledge of the genetic relationships between taxa in the crop gene pool. On the other hand, *ex situ* conserved diversity remains largely uncharacterized or unevaluated. In addition, the lack of knowledge of how many traditional seed-saved varieties remain extant as well as of their traditional cultivation practices has been and remains a severe constraint in their conservation and utilization (Maxted, 2006; Negri *et al.*, 2009).

With the degradation and extinction of CWR and LR populations, not only is unique and valuable genetic diversity being lost, but also the associated indigenous cultivation and exploitation knowledge and the socio-economic and environmental benefits associated with their continued conservation and maintenance. There is therefore an urgent need to address the continued maintenance and conservation of CWR and LR at global, regional, national and local levels in order to maximize the availability of PGRFA for crop improvement and to increase productivity and food security—particularly for the most vulnerable farmers and rural people in developing countries.

This need has been encapsulated in a number of international conventions and strategies, notably the FAO International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (www.planttreaty.org), the FAO *Global Plan of Action for the Conservation and Sustainable Utilization of PGRFA* (*Global Plan of Action*, www.globalplanofaction.org), the CBD (www.biodiv.org) and the Global Strategy for Plant Conservation (GSPC) (www.biodiv.org/programmes/cross-cutting/plant/). In 2002, the Conference of the Parties (COP) of the CBD established the 2010 Biodiversity Targets (CBD, 2002) which drew attention to the importance of conserving the “genetic diversity of crops, livestock, and harvested species of trees, fish and wildlife and other valuable species” and committed the parties “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”. Specifically in relation to PGRFA, having failed to achieve previous targets, the GSPC (CBD, 2010a) calls for: “70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge” by 2020 (Target 9). Further, more effective CWR conservation is specifically highlighted as a priority in Target 13 of the recently established CBD Strategic Plan (CBD 2010b): “By 2020, the loss of genetic diversity of cultivated plants and domestic farm animals in agricultural ecosystems and of wild relatives is halted and strategies have been developed and implemented for safeguarding the genetic diversity of other priority socio-economically valuable species as well as selected

wild species of plants and animals.” In support of the ITPGRFA and endorsed by the COP to the CBD, the *Global Plan of Action* provides a “framework, guide and catalyst for action at community, national, regional and international levels” and “seeks to create an efficient system for the conservation and sustainable use of plant genetic resources, through better cooperation, coordination and planning and through the strengthening of capacities” (www.globalplanofaction.org).

The SoWPGR-2 (FAO, 2010a) notes that although the total number of *ex situ* holdings has increased since the First SoW Report (FAO, 1998), CWR diversity is still under-represented and further effort is required to mainstream on-farm conservation of LR diversity. It also highlights the fact that relatively little progress has been made in conserving wild PGRFA outside protected areas or in developing sustainable management techniques for plants harvested from the wild. The SoWPGR-2 also notes that *ex situ* conservation gaps are recognized and that action needs to be taken to fill these gaps. Given that the *raison d’être* for agrobiodiversity conservation is sustainable use by farmers and breeders, it is disappointing for the SoWPGR-2 to conclude that the number of plant breeders has remained relatively constant, while at the same time levels of public sector crop development have diminished and the private sector has focused on major crops alone. It can be argued that long-term security of CWR and LR conservation will pragmatically only be maintained if there is systematic use of the broad range of CWR and LR diversity conserved. There is therefore a need to strengthen plant breeding capacity and encourage greater pre-breeding initiatives that transfer adaptive traits from what many breeders regard as exotic backgrounds to more acceptable breeders’ material that avoid linkage drag of deleterious traits. One contemporary challenge for the conservation community is to work more closely with breeders to provide a more effective mechanism for access to genetic diversity of interest; an initiative of this kind has recently started in Europe (Maxted *et al.*, 2012) and it is anticipated that the research will provide useful results and recommendations for other regions and countries.



Common wild rice (Oryza rufipogon Griffin.) panicle found in Northern Laos during an rice expedition trip in 2009 (photo: Bao-Rong Lu).

Considering the socio-economic importance of CWR and LR, it is perhaps surprising that their conservation has not been more systematically addressed. The historic paradigm is that CWR and LR diversity is a resource that is and will always be readily available to breeders. Nonetheless, its erosion and extinction has reached levels where serious social and economic problems will arise unless threats are reduced and diversity secured as permanently as possible. To meet the new 2020 GSPC targets, along with other relevant international, regional and national strategies and legislation, a paradigm shift is required to systematically address the effective conservation of CWR and LR diversity, while at the same time promoting their enhanced but sustainable utilisation.

The *Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoWPGR-2) (FAO 2010a) reported a substantial increase in interest and awareness of the value of CWR for crop improvement and the need to conserve these species at national level. An outline Global Strategy for CWR Conservation and Use has been drafted (Heywood *et al.* 2008), a new Specialist Group on CWR has been recently established within IUCN/SSC (Dulloo and Maxted 2008), and protocols for the *in situ* conservation of CWR have been developed since the 1990s (see Gadgil *et al.* 1996, Maxted *et al.* 1997a, Tuxill and Nabhan 1998, Zencirci *et al.* 1998, Vaughan 2001, Heywood and Dulloo 2005, Stolton *et al.* 2006, Iriondo *et al.* 2008, Hunter and Heywood 2011, Iriondo *et al.* 2011). However, progress has been slower for systematic LR conservation which is perhaps surprising given their relative ease of utilisation compared to CWR. The conservation of CWR and LR is a complex goal, involving diverse disciplines: for CWR it involves the PGRFA and nature conservation communities, and for LR it involves PGRFA, breeders and farming communities.

	
Plant breeder in a modern laboratory (Photo FAO)	Traditional farmers in Koraput, India (Photo: L.B.Nilsen).

Countries generally lack an adequate and reliable funding mechanism for the development and implementation of national programmes for the conservation and use of PGRFA (FAO 2010a). Nonetheless, of the 101 countries that provided information for both the *First Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoWPGR-1) and SoWPGR-2, FAO (2010a) reported a slight increase in national PGRFA programmes from 53% in 1996 to 71% in 2009.

FAO (2010a) also reported a significant increase in the number of CWR inventories, with 28 countries reporting relevant activities compared to only 4 countries in 1996. However, these surveys are generally limited to single crops or small groups of species, or to certain regions within the countries. Despite this increase, no coordinated and systematic inventorying has been undertaken for both CWR and LR and this is mainly due to: lack of financial and human resources, deficient skills and knowledge, lack of (national) coordination, unclear responsibilities, low national priority, among other factors (FAO 2010a).

Regarding the *ex situ* conservation of PGRFA, FAO (2010a) reported an increased interest in collecting CWR, LR and neglected and under-utilized species. However, the majority of *ex situ* accessions are from major food staples, such as wheat and rice. On the other hand, many countries have reported an increase in the number of *in situ* and on-farm conservation activities, though these are not always well coordinated. The *in situ* conservation of PGRFA (in particular CWR) in wild ecosystems still occurs mainly passively without active management in protected areas (PA). On-farm management of genetic diversity has increasingly become part of national programmes, and the number of on-farm management projects carried out with the participation of local stakeholders has increased somewhat (FAO 2010a). However, most countries still do not have national programmes for *in situ* conservation of PGRFA. In fact, FAO (2010a) highlighted that *in situ* and *ex situ* conservation is still very incipient and further efforts are needed.

Box 3. Examples of inventories/surveys of CWR or crops as reported in some countries

AFRICA

Benin: inventories and surveys of Egusi, yam, banana, Bambara groundnut, nutsedge, local green leafy vegetables, CWR of fonio.

Mali: 16 inventories and surveys of 12 major crops (e.g. sorghum, millet, cowpea, rice, peanut, garlic, shallot, etc.) in different parts of the country; however, there is no comprehensive coverage of wild relatives of millet, sorghum and African rice.

Senegal: inventories of agricultural species of fonio, millet, maize, cowpea and some traditional leafy vegetables.

AMERICAS

Bolivia: CWR inventories of potato (*Solanum*), cassava (*Manihot*), sweet potato (*Ipomea*), quinoa and “cañahua” (*Chenopodium*), peanut (*Arachis*), beans (*Phaseolus*), peppers (*Capsicum*), tree tomato (*Cyphomandra*), papaya (*Vaconvella*), cherimoya (*Annona*), pineapple (*Ananas*), blackberry (*Rubus*), cocoa (*Theobroma*), cashew (*Anacardium*), palm (*Bactris*) and Acai (*Euterpe*); can be found at <http://www.cwrbolivia.gob.bo/inicio.php>.

Brazil: CWR and crop inventories of cucurbits, cotton, peanuts, rice, cassava, maize and “pupunha”.

ASIA AND THE PACIFIC

Japan: survey to determine what LR were cultivated (1984-2000).

Lao People’s Democratic Republic: survey of CWR and/or LR with the purpose of *ex situ* conservation of rice, and other annual or perennial crops (e.g. maize, cassava, sweet potato, sugarcane).

Sri Lanka: CWR inventories of rice, *Piper*, green gram/black gram (*Vigna*), banana, *Cinnamomum* and can be found at http://www.agridept.gov.lk/other_pages.php?heading=CWR.

NEAR EAST

Jordan: sixteen target crops gene pools of global or regional significance and their wild relatives were studied and strategies for their conservation (2002-2005).

Pakistan: CWR of particular crops have been identified (e.g. wheat, barley, rice, Sorghum, millet, cotton, mustard, kenaf, chickpea, pome fruits, tree nuts, etc.).

Uzbekistan: CWR of *Allium*, *Malus*, *Juglans*, *Pistacia*, *Amygdalus*, *Hordeum*.

Sources: FAO Country Reports (2010b), Hunter and Heywood (2011)

1.4 Use of agrobiodiversity for crop improvement

There are numerous ways in which LR/CWR diversity use in breeding can be promoted, but traditionally this has focused on identifying traits of interest through phenotypic characterization and evaluation. This has in many cases proved prohibitively expensive. The First SoW Report (FAO, 1998) highlights the fact that two thirds of globally conserved *ex situ* germplasm lack basic passport data, 80% lack characterization data and 95% lack evaluation data, making the use of such germplasm, including CWR germplasm, much more difficult than it need be. The SoWPGR-2 (FAO, 2010a) details several new international initiatives since 1998 that support the increased characterization and evaluation of germplasm, including the fairly widespread adoption of core collections that are adequately characterized and evaluated. However, it still concludes that “the country reports were virtually unanimous in suggesting that one of the most significant obstacles to a greater use of PGRFA is the lack of adequate characterization and evaluation data and the capacity to generate and manage such data”.

Box 4. Use of PGRFA diversity for crop improvement

LR and CWR present a tangible resource of actual or potential economic benefit for humankind at national, regional and global levels. Exploitation of their diversity has existed for millennia, with farmers using variation within and between species to improve their crops from the beginnings of agriculture. For example, subsistence farmers in Mexico would annually grow cultivated corn near its wild relatives to facilitate introgression between the CWR and the crop as a means of crop enhancement (Hoyt, 1988). These species and this process are as important to humankind today as they were to the earliest farmers. Developments

in the biotechnology industries are now allowing more precise transfer of genes, even in the case of CWR from more distantly related species, further enhancing the value of LR and CWR.

Tanksely and McCouch (1997) and Hajjar and Hodgkin (2007) argued that breeders were not fully exploiting the potential of CWR. Historically, breeders relied on searching for specific beneficial traits associated with particular CWR taxa rather than searching more generally for beneficial genes, and they avoided transfer into polyploid crops where transfer was more difficult (e.g., rice, sorghum and sweet potato). The likely use of LR diversity is thought to be extensive but precise quantification is limited because of the potential commercial sensitivity of the information to competing breeding companies. The use of CWR diversity in crop improvement programmes for 29 major crops has recently been reviewed by Maxted and Kell (2009), who reported that for these crops, there are 234 references that report the identification of useful traits in 183 CWR taxa (Figure 1). The review showed that the degree to which breeders use CWR species varies between crops, with CWR use being particularly prominent in barley, cassava, potato, rice, tomato and wheat improvement, rice and wheat being the two crops for which CWR have been most widely used, both in terms of number of CWR taxa used and successful attempts to introgress traits from the CWR to the crop. The number of publications for the papers detailing the use of CWR in breeding has increased gradually over time-presumably as a result of technological developments for trait transfer-with 2% of citations recorded prior to 1970, 13% in the 1970s, 15% in the 1980s, 32% in the 1990s and 38% after 1999. The most widespread CWR use has been and remains in the development of disease and pest resistance, with the references citing disease resistance objectives accounting for 39%, pest and disease resistance 17%, abiotic stress 13%, yield increase 10%, cytoplasmic male sterility and fertility restorers 4%, quality improvers 11% and husbandry improvement 6% of the reported inter-specific trait transfers. It can also be seen from this review that since the year 2000 the number of attempts to improve quality, husbandry and end-product commodities has increased substantially. However, the exploitation of the potential diversity contained in CWR species appears to be hit and miss as the approach by breeders to CWR use has not been systematic or comprehensive; therefore, the vast majority of CWR diversity remains untapped for utilization.

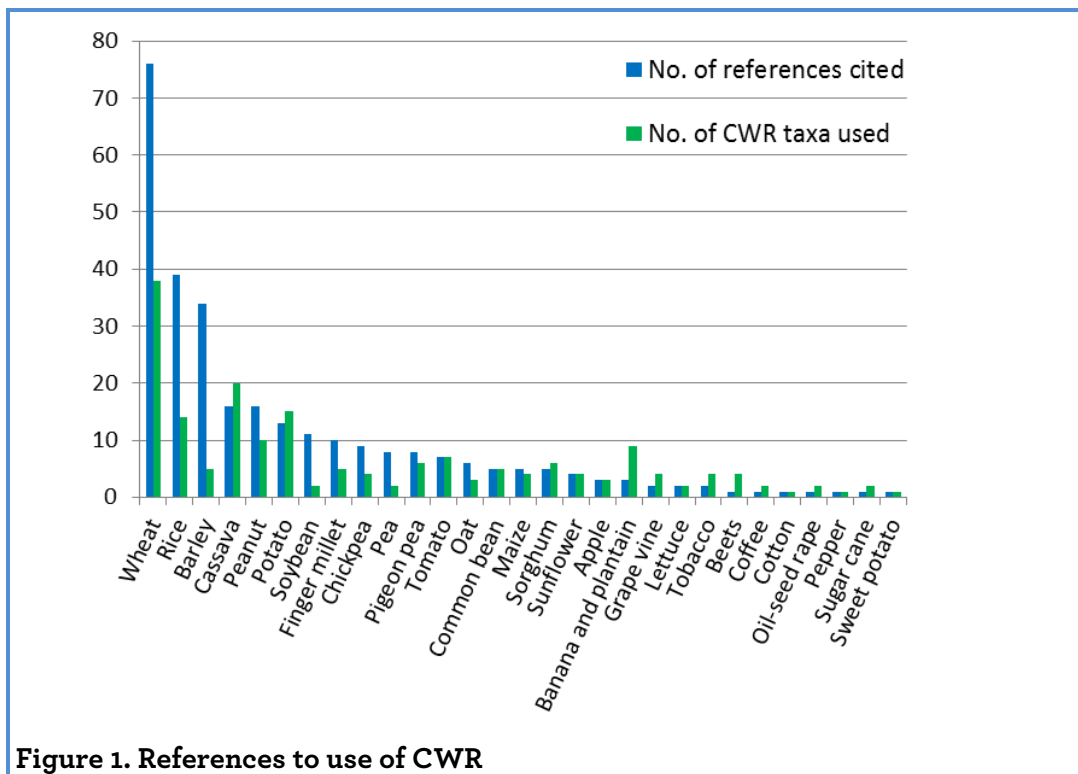


Figure 1. References to use of CWR

The bottleneck over systematic characterization and evaluation has been acknowledged almost since the need for their conservation was recognized in the late 1960s and early 1970s (Frankel and Bennett, 1970). It could be argued that simply increasing the amount of ‘traditional’ characterization and evaluation is unlikely to result in the required step change in the exploitation of LR/CWR diversity. However, such novel techniques as using ‘next generation technologies’ to screen thousands of samples of germplasm for those interesting gene variants that are adaptively important (Nordborg and Weigel, 2008) or ‘predictive characterization’ which uses spatial analysis of germplasm passport data to predict which germplasm might have desired traits (see Bhullar *et al.*, 2009), offer an alternative to conventional characterization and evaluation. Ultimately, unless the professionals involved with LR/CWR conservation can ensure that conserved germplasm is held in a form better suited for breeders and other user groups and that there is less of a barrier between conservation and utilization, then the use of conserved PGRFA diversity is not likely to improve.

1.5 Strategies for agrobiodiversity conservation

There are a number of potential approaches to achieve systematic global or sub-global (regional, national and local) CWR and LR conservation. Regardless of the approach, the systematic conservation of CWR and LR diversity involves the complementary application of *in situ* and *ex situ* strategies. The fundamental difference between these two strategies is: *ex situ* involves the location, sampling, transfer and storage of populations to conserve a particular species away from the original location, whereas *in situ* conservation involves the location, designation, management and monitoring of populations to conserve a particular species

within its natural habitat or where it has developed its distinctive characteristics (Maxted *et al.* 1997c). *In situ* conservation strategies have two distinct techniques: genetic reserve and on-farm conservation. Genetic reserves are designated for wild species (such as CWR) and are defined as “the location, management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long-term conservation” (Maxted *et al.* 1997b). On-farm targets LR conservation and is defined as “the sustainable management of genetic diversity of locally developed crop varieties (landraces), with associated wild and weedy species or forms, by farmers within traditional agricultural, horticultural or agri-silvicultural systems” (Maxted *et al.* 1997b). The precise combination of *in situ* and *ex situ* techniques will vary according to the species being conserved, resources available for conservation and the potential value and use of the species. Historically, PGRFA have primarily been conserved using *ex situ* methods (e.g., see Frankel and Bennet, 1970; Frankel, 1973; Frankel and Hawkes, 1975; Brown *et al.*, 1989; Frankel *et al.*, 1995; Guarino *et al.*, 1995; Hawkes *et al.*, 2000; Smith *et al.*, 2003) (Box 5). However, recent research has questioned whether LR diversity can be effectively conserved *ex situ* due to the genetic bottleneck associated with sampling and multiplication/regeneration in gene banks and the constantly and relatively rapidly changing genetic diversity within populations (Negri and Teranti, 2010), and has highlighted the fact that CWR are very poorly represented in *ex situ* collections worldwide (Maxted and Kell, 2009), most attention having been paid to maintaining obsolete cultivars, breeding lines, genetic stocks and LR. It is also widely agreed since the inception of the CBD that *in situ* conservation should be the primary conservation strategy, with *ex situ* employed as a backup, because in contrast to *ex situ* conservation, *in situ* conservation promotes natural gene exchange and continued evolution of LR and CWR populations (CBD, 1992; FAO, 1996, 2001; Brush, 1999; Maxted *et al.*, 1997a; Heywood and Dulloo, 2005; Stolton *et al.*, 2006; Negri *et al.* 2009).

Box 5. PGRFA conservation techniques

There are two fundamental strategies used for PGRFA conservation and within each there are a range of techniques (FAO, 1996):

***In situ* techniques**

In situ conservation is 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 (CBD, 1992). *In situ* conservation involves the location, designation, management and monitoring of target taxa in the location where they are found (Maxted *et al.*, 1997c). There are relatively few practical examples of *in situ* conservation for CWR species, but examples include *Zea perennis* in the Sierra de Manantlan, Mexico (UNESCO, 2007); *Aegilops* species in Ceylanpinar, Turkey (Ertug Firat and Tan, 1997); and *Solanum* species in Pisac Cusco, Peru (IUCN, 2003). *In situ* conservation of LR is also deficient but few examples do exist: sorghum, chickpea, field peas, and maize in Ethiopia (Worede 1997), and threatened crop LR that showed a potential market and/or a good adaptation to local soil and climatic

conditions (wheat, flax, lentil, grass pea, chickpea, cowpea and faba beans) in Georgia (Jorjadze and Berishvili, 2009).

- Genetic reserve¹ conservation involves the conservation of CWR in their native habitats. It may be defined as “the location, management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long-term conservation” (Maxted *et al.*, 1997c). Practically, this involves the location, designation, management and monitoring of genetic diversity at a particular location. The site is actively managed, even if that active management only involves regular monitoring of the target taxa, and conservation is long term, because significant resources will have been invested to establish the genetic reserve (Maxted *et al.*, 2008d). This technique is the most appropriate for the bulk of CWR species, whether they possess orthodox or non-orthodox seeds.
- On-farm conservation involves conserving LR within traditional farming systems and has been practised by farmers for millennia. Each season the farmers keep a proportion of harvested seed for re-sowing in the following year. Thus, the LR is highly adapted to the local environment and is likely to contain locally adapted alleles or gene complexes. On-farm conservation may be 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” (Maxted *et al.*, 1997c).
- Home garden conservation – crops are grown as small populations and the produce is used primarily for home consumption. Home garden conservation is a variation on on-farm conservation and may be defined as: “the sustainable management of genetic diversity of locally developed traditional crop varieties by individuals in their back-yard” (Maxted *et al.*, 1997c). Its focus is usually on vegetables, medicinal plants and spices (e.g., tomatoes, peppers, coumarin, mint, thyme, parsley, etc.). Orchard gardens, which are often expanded versions of kitchen gardens, can be valuable reserves of genetic diversity of fruit and timber trees, shrubs, pseudo-shrubs, such as banana and pawpaw, climbers and root and tuber crops as well as the herbs.

Ex situ techniques

Ex situ conservation is the conservation of components of biological diversity outside their natural habitats (CBD, 1992). The application of this strategy involves the location, sampling, transfer and storage of samples of the target taxa away from their native habitat (Maxted *et al.*, 1997c). LR and CWR 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 Centre (CIMMYT) gene bank with more than 160,000 accessions (i.e., samples collected at a specific location and time), the International Rice Research Institute (IRRI) with the largest collection of rice genetic resources, and the Millennium Seed Bank at the Royal Botanic Gardens, Kew with the largest collection of seed of 24,000 wild species. Important national/regional collections include: coffee in Côte d’Ivoire, Ethiopia, Cameroon, Kenya, Madagascar and Tanzania; sesame in Kenya; cassava in Malawi, Zambia and Tanzania, and sweet potato in Mauritius, Zambia, Swaziland and Tanzania (FAO, 2010a).

Furthermore, integral to *in situ* management of PGRFA are a number of potential positive socio-economic and environmental outcomes; these may include improved diet and nutrition, increased self-sufficiency and livelihood security for farmers and rural communities, maintenance of indigenous knowledge and local cultural practices, low-input sustainable land management practices, and the maintenance of ecosystem services—all factors that add weight to the need for promoting, supporting and sustaining *in situ* management of PGRFA.

Of the two conservation strategies (*in situ* and *ex situ*), the highest proportion of LR and CWR diversity is actively conserved *ex situ*; although the coverage is far from systematic. It is difficult to quantify the amount of LR diversity held *ex situ* because whether the material is LR is often not recorded. For LR there is also the problem over whether nomenclatural or genetic distinction is used to identify them; just because two farmers say they are growing different LR and give them different names, are they really genetically different? We have better knowledge of the *ex situ* conservation status of CWR, but most of this knowledge is based on studies of European gene bank collections. The First SoW Report (FAO, 1998) estimated that 4% of governmental, 14% of CGIAR and 6% of private gene bank holdings were of wild species; however, these included both CWR and non-CWR wild species. Dias and Gaiji (2005) estimated that approximately 4% of *ex situ* holdings in European gene banks are of CWR (37,528 accessions of 2629 species in 613 genera out of a total of 925,000 accessions of 7950 species in 1280 genera). The ratio of the number of accessions of cultivated species to wild species is striking, with an average of 167 for each cultivated species and 14 for each wild species, giving a ratio of 12:1, which is particularly surprising given that most diversity is located in wild species (Maxted *et al.*, 2008a). Later, Dias *et al.* (2012) calculated that a total of around 9% of gene bank accessions held by European gene banks are of wild origin and that these represent 7,279 species. This increase is most likely due to improved information management in gene banks and an increase in the number of gene banks providing data to the central European repository, EURISCO (<http://eurisco.ecpgr.org>), rather than a significant increase in the number of CWR samples being collected and stored.

There are few examples of on-farm conservation projects that have proven sustainable in the longer term, but methodologies for the design, establishment, management and monitoring of CWR in genetic reserves are available (see Gadgil *et al.*, 1996; Maxted *et al.*, 1997b; Heywood and Dulloo, 2005; Stolton *et al.*, 2006; Iriondo *et al.*, 2008); however, full practical implementation remains limited. As noted by Meilleur and Hodgkin (2004), there are: “weak links between the ‘site-selection and/or management-recommendations’ process and the ‘official-protected-site and/or management-change-designation’ process”. In other words, moving from the stage of identifying genetic reserve sites and making management recommendations, to official site designation and practical management remains a significant challenge. The lack of notable examples of the ‘CWR site selection to reserve establishment’ process may possibly be explained by the inherent requirement to bring together the agricultural conservation community who identify the priority CWR taxa and sites and the ecological conservation community who actively manage the protected areas in which the CWR genetic reserves would be established. However, there are some notable

examples of activities that have made a significant contribution to the process of conserving CWR *in situ*; these include the conservation of:

- Wild emmer wheat (*Triticum turgidum* var. *dicoccoides*) in the Ammiad reserve in the eastern Galilee, Israel (Anikster *et al.*, 1997; Safriel *et al.*, 1997);
- A close, perennial wild relative of maize (*Zea diploperennis*) in the MAB Sierra de Manantlán Biosphere Reserve endemic to Southwest Mexico (UNESCO, 2007);
- Various crop and forest CWR in reserves established in Kaz Dağ, Aegean Region, Ceylanpinar of Southeast Turkey, and Amanos, Mersin in Turkey (Firat and Tan, 1997; Tan, 1998; Tan and Tan, 2002);
- Forage *Vicia* and *Lathyrus* in Turkey (Maxted and Kell, 1998; Maxted *et al.*, 2003);
- *Lathyrus grimesii* in Nevada, USA (Hannan and Hellier, in Pavek *et al.*, 1999);
- Various cereal, forage and fruit trees in CWR reserves established in Lebanon, Syria, Palestinian Territories and Jordan (Amri *et al.*, 2008a, b);
- Grain CWR within the Erebuni Reserve near Yerevan, Armenia (Avagyan, 2008);
- Wild bean populations (*Phaseolus* spp.) in Costa Rica (Zoro Bi *et al.*, 2003; Baudoin *et al.*, 2008);
- *Phaseolus*, *Gossypium*, *Cucurbita*, *Zea* and *Lycopersicon* in Latin America (Debouck, 2001);
- *Solanum jamesii*, *S. fendleri* and other species in Pisac Cusco, Peru (Bamberg in Pavek *et al.*, 1999);
- Wild *Coffea* species in the Mascarene Islands (Dulloo *et al.*, 1999);
- *Allium columbianum*, *A. geyeri* and *A. fibrillum* in Washington State, USA (Hannan and Hellier, Pavek *et al.*, 1999; Hellier, 2000);
- *Carya floridana* and *C. myristiciformis* in the southern States of the USA (Grauke, Pavek *et al.*, 1999);
- *Capsicum annuum* var. *aviculare* in Mexico (Tewksbury *et al.*, 1999);
- *Beta vulgaris*, *Brassica insularis*, *B. oleracea* and *Olea europaea* in France (Mitteau and Soupizet, 2000);
- *Vitis rupestris*, *V. shuttleworthii*, *V. monticola* in central-Southeast USA (Pavek *et al.*, 2003).

Although these can be cited as positive examples of *in situ* CWR conservation, in many cases the sites identified may not be managed in the most appropriate manner to conserve the genetic diversity of the populations as described by Iriondo *et al.* (2008; 2012) and they therefore do not in themselves constitute the desired global network of genetic reserves that is needed to systematically conserve CWR genetic diversity.

The conservation of CWR and LR usually results from a combination of conservation actions at the macro- and micro-levels. Macro-conservation deals with the political, economic and strategic planning issues on habitat, species or genetic diversity conservation and can be implemented at global, regional, national and local levels. In other words, macro-conservation deals with the development of strategic plans targeting the conservation of specific elements of biodiversity, in this case of CWR and LR, but not its practical implementation. Micro-conservation comprises the distinct, practical, conservation actions (which make use of specific *in situ* and *ex situ* techniques) focused on individual habitats, species or intra-specific genetic diversity in order to implement the strategies developed at the macro-conservation level. As such the development and application of National management plans for CWR and LR conservation can be thought of as involving macro- and micro-conservation decision making and practically involving a combination of *in situ* and *ex situ* techniques.

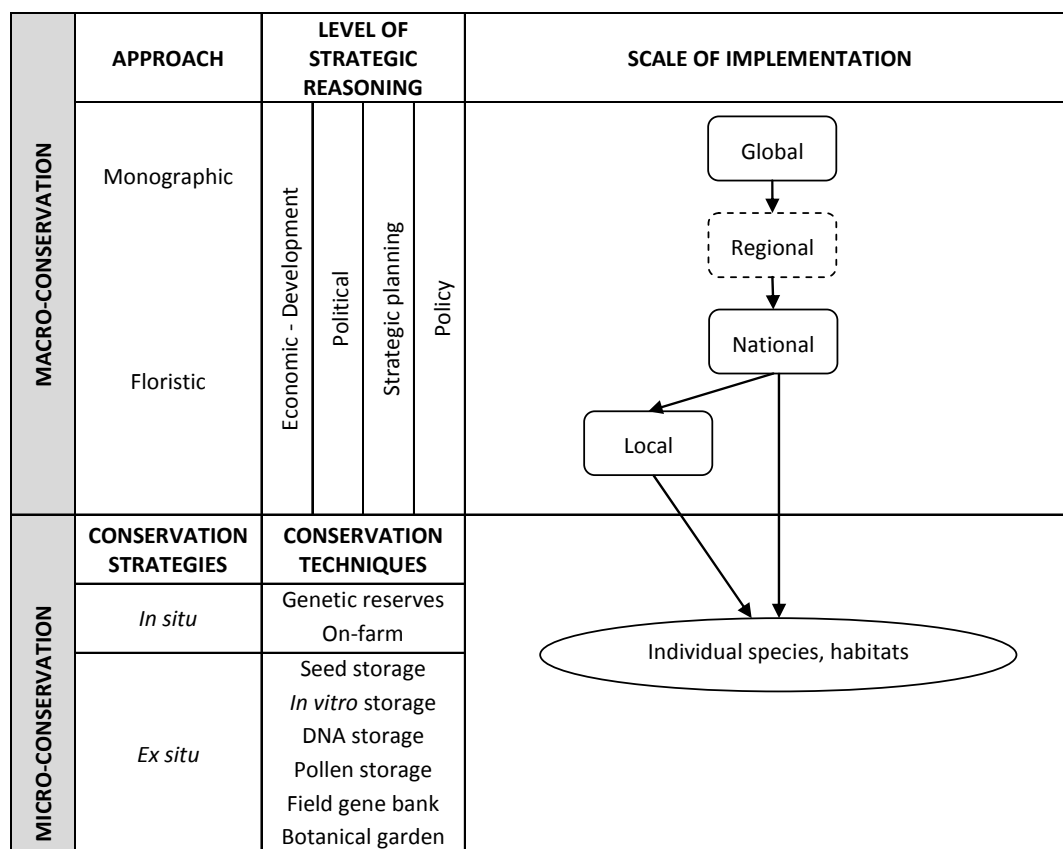


Figure 2. Conservation planning overview

At the macro-conservation level, a first decision has to be made regarding the two possible and distinct approaches on how to develop the conservation plan: whether to adopt a monographic or a floristic approach. The monographic approach focuses on priority crop gene pools and can be applied at different geographic levels (global, regional or national). It is monographic because the methodology is comprehensive for individual target taxa throughout their full geographic range or its full range within a geographically defined unit such a

region or a country. for CWR examples and for LR examples). It aims to systematically conserve the selected priority CWR or LR diversity via a network of *in situ* genetic reserves or on-farm sites with backup in *ex situ* collections. The floristic approach is taxa / crop comprehensive because it attempts to encompass all CWR / LR that occur within a geographical unit (i.e. a region, country, sub-national unit or sub-national region), regardless of the plant taxa / crops normal range. The full geographic range of an individual taxon may or may not be included, depending on whether it is endemic to the target country. It is commonly associated with the development of National management plans for CWR and LR Conservation.

Given the different intrinsic features that characterise CWR (wild species) and LR (crops), the application of the monographic and floristic approaches are similar in concept but may be slightly different in application depending on whether the target is CWR or LR diversity. With regard to the use of the term floristic for LR conservation, it is meant to imply the entire LR diversity found within a defined geographic area (e.g. local, region, country, even continental), just like a botanical flora encompasses the wild plant diversity found within a defined area. The monographic and floristic approaches, for both CWR and LR, may be seen as strategic in that they are likely to be implemented by national or global conservation agencies or institutions, and should not be seen as alternative but rather as a holistic matrix to maximize overall CWR or LR diversity conservation.

Box 6. Examples of the monographic approach to CWR conservation

At global level: Conservation strategy for Aegilops species

Taxonomic, ecological, geographic and conservation information for 22 *Aegilops* species were collated from ICARDA, EURISCO, GRIN and SINGER datasets, and subsequently used to identify gaps in current conservation and to develop a systematic conservation strategy for the genus. A total of 9866 unique geo-referenced records were collected between 1932 and 2004. Predicted distribution maps were obtained for the *Aegilops* taxa and compared in conservation gap analysis using GIS tools. The *ex situ* conservation status of each taxon was assessed and used to provide a priority ranking and nine out of the 22 taxa were identified as priorities for *ex situ* conservation. Future *ex situ* collections were recommended in several countries across the World. In addition, five complementary regions for *in situ* conservation of *Aegilops* diversity were identified in various countries. Within these five regions, 16 protected areas were identified as potential sites to establish genetic reserves. In addition, the most important *Aegilops* hotspot (on the Syrian/Lebanese border) was found to be outside a protected area and so recommendations for a novel protected area was made.

Source: Maxted *et al.* (2008b)

At regional level: Collection of wild rice in East and Southern Africa

A collecting programme targeting wild rice in East and Southern Africa took place. The collecting strategy was developed from an initial ecogeographic study based on several African and international herbaria and available literature on

occurrence and distribution of the target species within in the region, as well as on information provided by the national programme staff. A total of 17 collecting missions were undertaken in Kenya, Malawi, Mozambique, Namibia, Tanzania, Uganda, Zambia and Zimbabwe between April 1997 and April 1998. Passport data and herbarium specimens were collected for each accession during the collecting missions. Threats to the wild rice species were assessed as genetic erosion indicators. Seed fertility, maturity and production were also registered.

Source: Kiambi *et al.* (2005)

Box 7. Examples of the monographic approach to LR conservation

At regional level: Safeguarding and preservation of the biodiversity of the rice gene pool

A project coordinated by the International Rice Research Institute (IRRI) and financed by the Swiss Agency for Development and Cooperation (SDC) was carried out from 1994 to 2000 in 22 countries in Asia, sub-Saharan Africa, and Costa Rica. The project comprised three main components:

- Collection and *ex situ* conservation of cultivated and wild rice taxa;
- On-farm management of rice LR;
- Strengthening germplasm conservation by National Agricultural Research Systems (NARS), Non-Governmental Organizations (NGOs) and farmer organizations.

Regarding *ex situ* conservation of rice diversity, 165 collecting missions were carried out in 22 countries from 1995–2000. A total of 24,718 samples of *Oryza sativa* were collected, as well as 2,416 samples of 16 *Oryza* taxa, weedy types and mutative hybrids, and four species from three related genera (*Hygroryza*, *Leersia* and *Prosochloa*). The samples were then sent to the International Rice Gene bank (IRG) at IRRI for long-term *ex situ* conservation.

The two objectives of the on-farm conservation management component of the project were: (i) to increase knowledge on farmers' management of rice diversity, including the factors that contribute to it and its genetic implications, and (ii) to identify strategies to involve farmers' managed systems in the overall conservation of rice resources. Three study countries and sites (in India, Vietnam and the Philippines), that represented a broad cross section of rain-fed lowland and upland farming systems with different agricultural, policy and economic conditions, were selected. Biological and social sciences experts, as well as NARS and local people were involved in this component of the project. Socio-economic surveys, questionnaires on farmers' management of diversity, anthropological methods (including semi-structured and unstructured interviews), field seed collections, surveys for biotic constraints, and molecular marker analyses and field trials were used during the project in order to understand and optimise the on-farm management of rice LR diversity.

The third component of the project focused on the upgrading of gene bank facilities and facilitating germplasm collection of NARS, as well as on the training of national personnel and scientists participating in the on-farm conservation research on the skills needed to collect and conserve rice germplasm. Between

1995 and 1999, IRRI staff trained more than 670 people in 48 training courses in 14 countries and at IRRI headquarters in the Philippines. The training encompassed field collection and conservation, characterization, wild rice species, data management and documentation, gene bank management, seed health, analysis of socioeconomic data, and isozyme and molecular analysis of germplasm.

Source: IRRI (2000)

At national level: Races of maize in Mexico

The authors studied 32 races of maize in Mexico using morphological, cytological, genetic and agronomic characteristics and geographical distribution.

Source: Wellausen *et al.* (1952)

At whichever level of application, the monographic and floristic approaches target priority crops or crop gene pools and aim to systematically conserve them via a network of on-farm locations or genetic reserves, with backup in *ex situ* collections. Both the monographic and floristic approaches can be implemented at different scales: global, national, and local. A fourth macro-conservation scale of implementation might be added where there is a distinct continental or regional level of conservation activities between the global and national, as is the case of the Southern African Development Community, Sub-Saharan Africa, North Africa, Europe or West Asia.

Box 8. Examples of the floristic approach to CWR conservation

Floristic approach at regional level: CWR Catalogue for Europe and the Mediterranean

The CWR Catalogue for Europe and the Mediterranean (Kell *et al.* 2005) was created by generating a list of crop genera, matching these genera with those that occur in Europe and the Mediterranean, and then extracting the taxa within the matching genera.

The crop genus list was generated from four information sources: Mansfeld's World Database of Agricultural and Horticultural Crops (Hanelt and IPK Gatersleben, 2001; IPK Gatersleben, 2003), the 'Enumeration of cultivated forest plant species' (Schultze-Motel 1966) (for forestry species), the Community Plant Variety Office list of plant varieties (www.cpvo.eu.int) (for ornamental plants) and the Medicinal and Aromatic Plant Resources of the World (MAPROW) (U. Schippmann, pers. comm. Bonn 2004). This was matched with floristic data in Euro+Med PlantBase (version 2006), which is a database of the Euro-Mediterranean flora, including data on the status of occurrence of taxa in countries and/or sub-national units. The CWR Catalogue was generated by extracting the taxa within the genera in Euro+Med PlantBase matching the crop genus names.

Source: Kell *et al.* (2008)

Floristic approach at national level: Inventory of Portuguese CWR

The Portuguese CWR inventory was developed from a geographically filtered list from the CWR Catalogue for Europe and the Mediterranean (Kell *et al.* 2005). To ensure that all important crop genera as well as nationally grown crops were

considered, several documents were used for validation [the complete list of agricultural, vegetables, fruits and ornamental species produced by the Portuguese National Catalogue of Varieties (DGPC 2003), the Temperate and Boreal Forest Resources Assessment 2000 (TBFRA-2000) (UNECE/FAO 2000) for the forestry crops; a priority list of ornamental genera representing the recommendations from the Herbaceous Ornamental Crop Germplasm Committee (HOCGC) (OPGC 2002), the report by Pimenta (2004) on an updated list of ornamental plant species grown in Portugal]. Twenty-two priority species for conservation were identified based on eight criteria (native status, economic value, threatened status, *in situ* and *ex situ* conservation status, global and national distribution, and legislation) and combining different prioritization schemes (Magos Brehm *et al.* 2010). An ecogeographic survey, gap analysis, and species distribution modelling with current and future climate data were undertaken for target species. Additionally, a genetic diversity analysis for a subset of priority species was carried out. The results obtained with these different methodologies were combined in order to provide *in situ* and *ex situ* conservation recommendations for these wild plant resources.

Source: Magos Brehm (2008), Magos Brehm *et al.* (2008a, 2010)



Beta macrocarpa Guss, a wild relative of beet (*B. vulgaris* L.) in Quinta de Marim (Ria Formosa Natural Park, Portugal) (photo: Maria Cristina Duarte).

Box 9. Examples of the floristic approach to LR conservation

At regional level: Traditionally cultivated crops in Mexico

An ethnobotanical study of the cultivated crops at the “milpas”, a traditional polycrop farming system, at the NW of Yucatán, was carried out. “Milpas” are important traditional farming systems with many LR of different crops. They are characterised particularly by maize (*Zea mays*), beans (*Phaseolus* spp.) and pumpkins (*Cucurbita* spp.), together with many other crops (e.g. chillies and tomatoes) that vary from one region to another. It is a more resilient system than if the crops were cultivated as monocultures and these crops have an adaptive potential to different climates (from semi-deserts to temperate and tropical) and to all altitudes. “Milpas” are the main farming systems for the rural communities of

this area because they produce the main food crops. The diversity of this system allows the cultivation of many species and many LR which possess distinct characteristics. The authors focused on the more historically and culturally important crops produced at the “milpas”.

Source: Terán *et al.* (1998)

At regional level: Landraces in Central Italy

Since 1981, exploration and collecting missions allowed the identification of more than 400 LR from different plant species (forages, cereals, pulses, garden crops and fruit trees) found on-farm in Central Italy. The author studied current LR management and use by farmers and discussed the reasons why they have been maintained on-farm. Three case-studies (cowpea ‘fagiolina’ in the Trasimeno lake area, Perugia; emmer ‘farro’ at Monteleone di Spoleto, Valnerina, Terni; the ‘fagiolo a pisello’ - *Phaseolus vulgaris* L. - at Colle di Tora, Rieti) of efficient on-farm conservation were presented and threats identified.

Source: Negri (2003)

At national level: Vegetable landraces in England and Wales

An initial exercise for UK crop LR (Scholten *et al.* 2004) found a significant wealth of LR diversity that was often highly geographically localized and critically threatened with extinction. Previous studies indicated that maximum LR diversity was maintained in vegetables. A vegetable inventory was needed to provide the baseline data to a) identify conservation needs, b) enact systematic *in situ* and *ex situ* conservation, c) monitor change (including the assessment of genetic erosion), and d) enhance their use in meeting changing market demands and in promoting UK food security. LR data were collated from UK seed banks, via media releases and advertisements and by using an online questionnaire, internet searches, email correspondence, telephone calls and face to face meetings with a broad range of interest groups, companies and individuals. The results indicated that (i) seed banks do not contain the full range of English and Welsh vegetable LR diversity available, (ii) nationally registered ‘B’ List LR varieties are under threat as they are often maintained *in situ* by small commercial companies with limited resources, (iii) other vegetable LR are maintained *in situ* by commercial seed companies, NGOs, individual farmers, allotment-holders and home gardeners, but no direct governmental support is provided, and (iv) there has been a significant loss of vegetable LR diversity in England and Wales and much of the remaining diversity is threatened. The need to put in place strategies and plans to capture this diversity and nurture the culture that is responsible for creating and maintaining it was identified. Recommendations for the initiation of a LR protection scheme in England and Wales, enhancement of *ex situ* LR collections, education and public awareness of local LR diversity, and revision of opportunities for supporting LR cultivation through policy and legislative instruments were made.

Source: Kell *et al.* (2009)

1.6 Global agrobiodiversity conservation

A global approach aims at the systematic conservation of CWR and LR diversity as a means of maintaining global food security and meeting consumer choice. At global level, the monographic approach (targeting specific crops and crop gene pools) has to be used since there is no global Flora or list of CWR taxa, or checklist of global LR diversity. The requirement for a global approach is especially important because CWR and LR diversity, like plant diversity in general, is not evenly spread across the globe, but is concentrated into botanical (Mittermeier *et al.* 1999, Myers *et al.* 2000) and crop diversity hotspots (Vavilov 1926, Hawkes 1983), and maintaining food security requires a global overview if it is to be successful. Conservation in these highly diverse hotspots is thus necessarily independent of national political borders and needs to be coordinated if it is to be effective.

In response to this challenge, the FAO Commission on Genetic Resources for Food and Agriculture (CGRFA) has called for the development of a network of *in situ* conservation areas to conserve CWR diversity (Activity 4 of the *Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture* – FAO 1996). Within this context, the CGRFA commissioned a thematic background study on ‘the establishment of a global network for the *in situ* conservation of crop wild relatives: status and needs’ (Maxted and Kell 2009) to support the preparation of the SoWPGR-2 and as a basis for updating the *Global Plan of Action*. The objective of this study was to provide sufficient baseline information for planning the future work of the Commission in the establishment and monitoring of a network of *in situ* conservation areas for CWR using the gap analysis methodology developed by Maxted *et al.* (2008c). Specifically, the study aimed to:

- Identify which important areas for CWR are already part of existing protected areas, in particular in the centres of origin or diversification;
- Pinpoint existing conservation gaps in order to assess which important areas for CWR are yet to be protected within and outside existing protected areas;
- Provide the foundations for a long-term and cost-effective plan for CWR conservation.

The crops included in this background study were, firstly, those that have been identified as being of major importance for food security in one or more sub-regions of the world (FAO 1998) and that are listed in Annex I of the ITPGRFA (FAO 2001), which is a list of PGRFA established according to criteria of food security and country interdependence. These are: finger millet (*Eleusine coracana*), barley (*Hordeum vulgare*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), banana/plantain (*Musa acuminata*), rice (*Oryza sativa*), pearl millet (*Pennisetum glaucum*), potato (*Solanum tuberosum*), sorghum (*Sorghum bicolor*), wheat (*Triticum aestivum*) and maize (*Zea mays*). Each of these crops supplies more than 5% of the plant-derived energy intake in one or more sub-regions of the world (FAO 1998). Secondly, three further crops that are listed in Annex I of the ITPGRFA were also considered to be priority crops, because they are regionally important, and data were readily available—cowpea (*Vigna unguiculata*), faba bean (*Vicia faba*) and garden pea (*Pisum sativum*). These

priority crops represented different crop groups (cereals, food legumes, roots and tubers), with different breeding systems (cross-pollinating, self-pollinating, clonally propagated), as well as crops of temperate and tropical origin (Maxted and Kell 2009).

The authors made preliminary recommendations for the establishment of a global network of *in situ* conservation areas for the highest priority CWR species¹ from the 12 crop gene pools for which distribution data were available for the study. Although the locations of priority species were selected for only 12 crop gene pools they were located across the globe, primarily in the centres of crop diversity identified by Vavilov (1926), which remain the hotspots of crop and CWR diversity today. Note the eight Vavilov Centres of origin / diversity, indicated by blue enclosed lines, are likely to contain further priority site for other crop gene pools). The approach undertaken by the authors, a monographic approach at global level, included:

- A review of the uses of each crop and its socio-economic importance;
- Discussion of taxonomic issues, listing of the taxa in the crop gene pool and their degree of genetic and/or taxonomic relatedness;
- Notes on the distribution of the crop and its wild relatives, locating centre(s) of diversity;
- A review of crop breeding efforts that have utilized wild relatives;
- Identification of the highest priority taxa for immediate inclusion in the CWR genetic reserve network, with supporting justification;
- Identification of the highest priority sites for immediate inclusion in the CWR genetic reserve network, with supporting justification;
- Recommended conservation actions and requirements for further research.

The systematic *in situ* conservation of LR is far from being initiated either at the global or national level, and global or national networks of on-farm sites for LR conservation are yet to be implemented. In fact, Veteläinen *et al.* (2009b) highlighted the difficulty of systematically conserving all LR diversity on-farm due to the high numbers of existing LR but stressed that a coherent global network of on-farm conservation should be established in order to actively conserve the highest priority LR globally. A similar point could equally be made nationally for each individual country's priority crops.

The point should be stressed that although there is a strong logic for an intergovernmental institution on biodiversity for food security, in cooperation with international partners from environment and agriculture leading the required research and the establishment of global CWR and LR networks, national agencies do have a role. There is an onus on each country to conserve its CWR and LR diversity *in situ* and this will require the establishment of national networks of genetic reserves and on-farm sites. Where there is coincidence between global and national priorities, the national sites may also contribute to the global network.

¹ Primary and secondary wild relatives and/or CWR which are known to be threatened or have limited distributions.

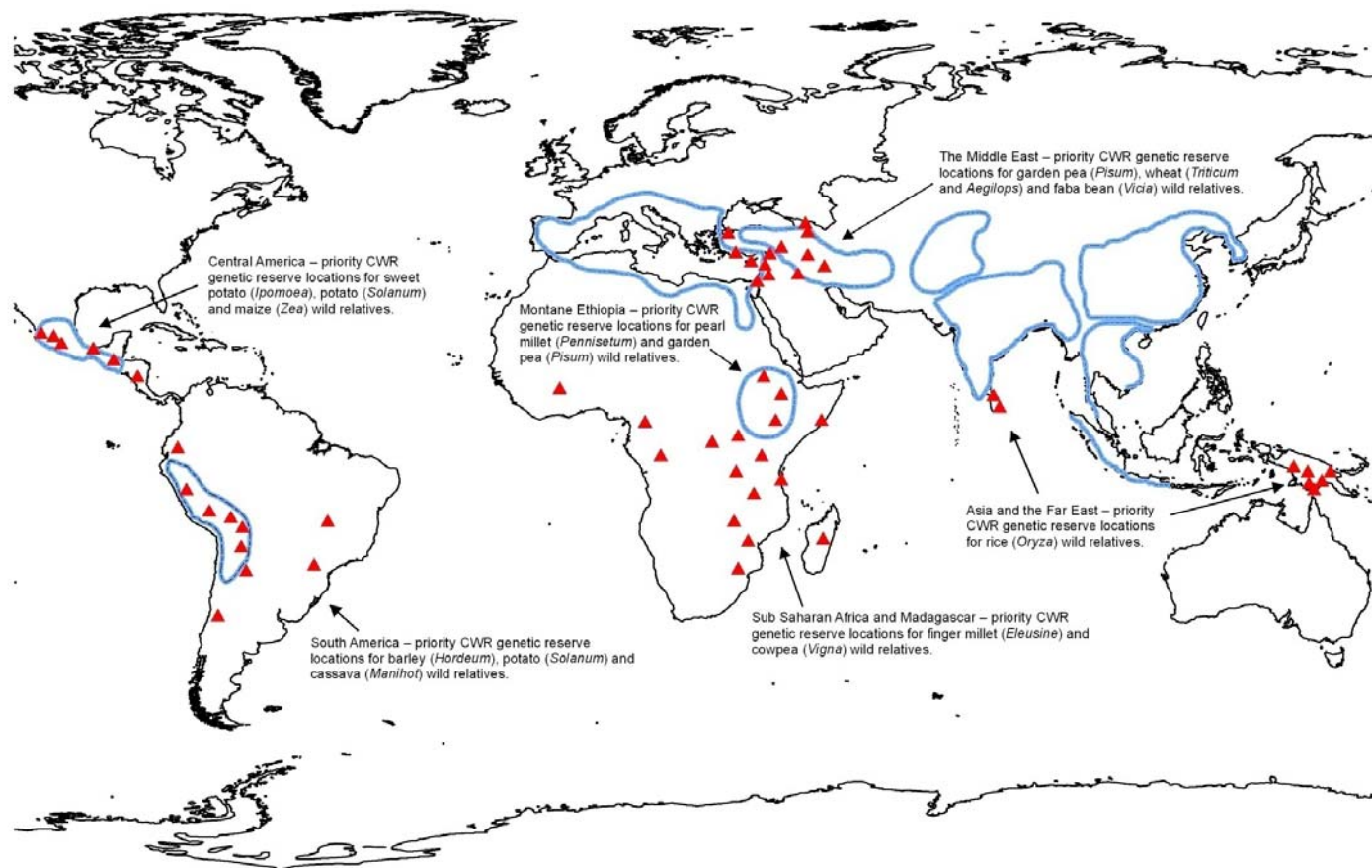


Figure 3. Global priority genetic reserve locations for CWR of 12 food crops ²

² Maxted and Kell (2009)

1.7 National agrobiodiversity conservation

Several decisions have to be made before starting to develop National management plans for CWR and LR conservation and these made be affected by the availability of existing data and resources. The first step is the creation of a CWR or LR inventory from existing botanical or crop data. Once the relevant taxa have been identified and collated, it is likely that a prioritization step will be undertaken because the number of taxa usually exceeds those that can be realistically actively conserved using the available resources. Next, the available baseline taxonomic, ecogeographic, genetic and threat data are collated for the priority taxa. Specifically regarding LR, maintainers' knowledge about the LR they grow is also relevant and should be gathered. Subsequently, a threat assessment and gap analysis study is carried out, culminating in the formulation of a National plan with clear conservation goals and recommendations for *in situ* and *ex situ* actions. As a result, a network of national conservation areas (genetic reserves for CWR and on-farm locations for LR) will be established, as well as *ex situ* conservation actions to ensure a safety backup of the genetic diversity. How to produce National management plans for CWR and LR conservation is discussed in detail in Part 2 of the book. The National management plans developed for any individual country aims at the macro-conservation level to maximise conserved taxonomic, ecogeographic and genetic diversity of the country's CWR or LR, while at the same time promoting its use. While at the micro-conservation level, effective conservation will be implemented at the individual conservation areas, gene bank managers and farmer communities.



Farmers showing their sorghum and cowpea LR in Zingnyama, Phalombe, Malawi (photo by Edwin A Chiwona).

Box 10. Options for *in situ* and on-farm conservation of PGRFA

Option 1 – Floristic or monographic approach

Taking the floristic or monographic approach refers to the breadth of coverage of the conservation strategy. A floristic approach means that a conservation strategy is developed for CWR and/or LR diversity that occurs in a defined geographical

area, which may be a sub-national area such as an administrative unit or protected area, a whole country, a supra-national region, or even the whole world. A monographic approach on the other hand is restricted to certain crop gene pools, but like the floristic approach may be carried out at any geographical scale. Although both approaches may be carried out at any geographic scale, the floristic approach is most likely to be national in scope, while the monographic approach is more likely to be global in scope because it involves the development of a conservation strategy for a crop gene pool and therefore would ideally encompass all the areas of the world in which the target taxa are native (in the case of CWR) or where they are being cultivated (in the case of LR).

Both approaches will ultimately conclude with the systematic conservation of priority CWR and LR diversity via a network of *in situ* conservation and on-farm conservation sites, with backup in *ex situ* collections. Whether a floristic or monographic approach is taken is likely to depend on: a) the quantity and quality of existing data, b) the resources available to prepare the conservation strategy, and c) the scope of the parent organization undertaking the conservation; for example, an international cereal research institute is likely to focus monographically on cereal crops, while a national biodiversity institute is likely to adopt a more floristic approach. It is worth noting that if the goal is to maximize CWR and LR diversity it is likely that both approaches need to be combined (National Strategies and crop gene pool strategies for the highest priority crops).

Option 2 – Local, national, regional or global geographic scales

National management plans for conservation of CWRs and LRs should ideally be complementary, depending on the geographical units included, even though the individual geographic scale is likely to be dictated by the remit of the parent organization undertaking the conservation. There is a need to develop interacting CWR/LR conservation strategies, such that one geographic level strategy is not seen in isolation, but contributes to the other levels. For example, a country's national CWR and LR management plans should link with local, regional and ultimately the global conservation strategy such that nationally designated on-farm and genetic reserve sites become part of a combined network of sites overseen at national level but managed at local level (individual genetic reserves), as well as part of a regional and global network overseen by the appropriate regional and global agencies. Therefore, it is not a choice between geographic scales, but the real choice is whether or not to ensure complementarity in approach between interacting CWR/LR management plans to ensure they form a series of local, national, regional and global *in situ* CWR/LR conservation sites. In practice, however, it should be acknowledged that in implementing such a complementary geographic approach is feasible for systematic CWR conservation now but is likely to be a longer term option for LR conservation if for no other reason than the extent of knowledge available on LR diversity.

Option 3 – Centralized or participatory conservation

It is difficult to precisely categorize the contribution of local communities and farmers *versus* conservationists to address global food security. While an overview is required to identify CWR and LR diversity hotspots and implement genetic reserve or on-farm conservation in a network that maximizes the conserved CWR and LR diversity for the benefit of all humanity, it is equally important to

recognize that on-farm or genetic reserve conservation is impossible without local community or farmer approval and action. It is perhaps inevitable that targeted global conservation involves a top-down approach but local communities have been managing, manipulating and exploiting CWR and LR diversity for millennia and so maintaining a complementary bottom-up approach is equally important. Therefore, just as CWR/LR conservation at local, national, regional and global scales interact to ensure effective complementary conservation, both centralized and participatory approaches to conservation also ensure effective complementary conservation.

Option 4 – On-farm conservation or conservation of traditional farming systems

The growing literature associated with LR conservation highlights a distinction in focus between at least two distinct, but associated, conservation activities. The distinction between the two is based on whether the focus is the conservation of genetic diversity within a particular farming system or the conservation of the traditional farming system itself, irrespective of what happens to the genetic diversity of LR material within that system (Maxted *et al.* 2002). These two variants of LR conservation are obviously interrelated, may often be complementary and may in certain cases be seen as one, but in other instances this may not be the case. For example, the introduction of a certain percentage of modern cultivars to a traditional farming system may sustain the system at that location, but could lead to gene replacement or displacement and therefore genetic erosion of the original localized LR material. The choice between the two is dependent on whether the parent organization undertaking the conservation wishes to conserve specific but dynamic LR or the system itself that maintains the agro-environment in which the native LR can continue to evolve.

Option 5 – Farmer or conservationist based in situ conservation

At first it might be thought that although farmers are key players in on-farm conservation of LR, they play a minimal role in CWR conservation. However, experience from the limited number of projects that have established genetic reserves (e.g., Firat and Tan 1997, Hunter and Heywood 2011) has shown that even where genetic reserves are established in association with existing protected areas, farmers are commonly involved. The reason being many CWR are found in pre-climax vegetation so population conservation requires controlled grazing or cutting. Therefore, even when undertaking genetic reserve CWR conservation, it commonly involves conservationists working with farmers.

It is more obvious that farmers and conservationists will need to work together to conserve LR diversity; however, it should be recognized that occasionally the LR conservation may be in conflict with the development aspirations of the local community, partially freezing the dynamic nature of LR diversity. Although the conservationist should never try to restrict or deny these aspirations, the conservationist may be able to promote LR diversity maintenance within the on-farm system by facilitating some form of Participatory Plant Breeding or Participatory Varietal Selection, which may vary from simply aiding farmer selection to full-blown crossing of lines and LR to generate segregating diversity for selection and production of improved breeders' lines (e.g., see Friis-Hansen and Sthapit 2000). Experience from past projects that have promoted on-farm conservation of LR has also shown that the conservationist can have a key role in

helping farmers develop alternative niche markets for the LR, raising the value of the resource and so sustain LR maintenance (Heinonen and Veteläinen 2009, Nikolaou and Maxted 2009, Martin *et al.* 2009, Veteläinen *et al.* 2009b).

Option 6 – Status quo or legislative protection

To promote sustainable *in situ* CWR/LR conservation there is a need to encourage and facilitate stronger legislative protection of sites (i.e. genetic reserve or on-farm) designated for conservation. Experience from ecosystem and wild species conservation has repeatedly shown that the establishment of protected areas requires significant investment of resources and once established legislative protection is required to ensure the long-term sustainability of the conservation investment. This protection is equally applicable for sites designated as genetic reserves or on-farm sites where the *status quo* without specific protection is unviable. This is particularly important for CWR hotspots/sites designated in Vavilov Centres of Origin, all of which are located in developing countries, which are likely to contain the highest proportion of unique CWR and LR diversity that we know is threatened and must be conserved if we are to seriously address global food security.

Option 7 – In situ or ex situ conservation

In situ and *ex situ* conservation should not be viewed as alternatives or in opposition to one another but rather should be practised as complementary approaches. The adoption of this holistic approach requires the conservationist to look at the characteristics and needs of the CWR or LR being conserved and then assess which combination of techniques offers the most appropriate option to maintain genetic diversity. Hawkes *et al.* (2000) suggested that to formulate the conservation strategy, the conservationist may also need to address not only genetic questions but also the practical and political ones:

- What are the species' storage characteristics?
- What do we know about the species' breeding system?
- Do we want to store the germplasm in the short, medium or long term?
- Where the germplasm is located and how accessible is it/does it need to be?
- Are there legal issues relating to access?
- How good is the infrastructure of the gene bank?
- What back-up is necessary/desirable?
- How might the resource be best exploited?

Given answers to these questions, the appropriate combination of techniques to conserve the CWR or LR can then be applied in a pragmatic and balanced manner.

Option 8 – Conservation or conservation linked to use

Historically, there have been two camps of thought in biodiversity conservation—those who see conservation as an end in its self (e.g., see McNeely and Guruswamy 1998) and those who believe there should be a direct and intimate link between conservation and use (humans conserve diversity because they wish to exploit it) (Maxted *et al.* 1997c). This utilitarian concept is fundamental to PGRFA conservation where the goal is to ensure that the maximum possible genetic diversity of CWR or LR diversity is maintained and available for potential utilization.

Source: Maxted *et al.* (2012)

1.8 Local agrobiodiversity conservation

National management plans for CWR and LR conservation result in the systematic representation of a nation's CWR or LR diversity in a network of *in situ* conservation or on-farm sites and, as a back-up measure, *ex situ* storage of genetically representative population samples in national and/or local gene banks. The implementation of the National plans at local level means that specific decisions regarding *in situ* and *ex situ* conservation actions and techniques need to be implemented locally and these will involve individual protected area/farmer or gene bank manager actively promoting CWR/LR conservation within areas or gene banks that they manage. A systematic, clear and constant dialogue and coordination between the developers of the National management plans, national agencies and local organisations (NGOs, farmers organisations, nature reserve managers, etc.), is thus fundamental. Although ideal locations for CWR genetic reserves or LR on-farm sites may have been identified at national level, there is an obvious need to confirm on-site that not only the desired CWR/LR diversity is actually present at the site, but also that there are enough economic and social conditions to maintain and actively conserve them or that those conditions can be created.



A young boy walking on his family's property at the edge of Rwanda's Volcanoes National Park (Photo: FAO)

The location and establishment of specific CWR *in situ* genetic reserves within the existing national network of PAs is an ideal way forward given possible financial constraints and the significant additional costs associated with the creation of new PAs for CWR conservation. However the latter should not be excluded from consideration, especially in countries with a limited existing PA network. Determination of the actual number of specific genetic reserves will be directed by science but will ultimately be pragmatic as it will be dictated by the financial resources available for *in situ* conservation as well as governmental and regional will. The practical implementation of the *in situ* genetic reserves within or outside existing PAs should be addressed at policy level and a strong commitment should be made. The National management plans for CWR and LR Conservation should

thus be integrated and linked to the GSPC (through the GSPC national focal point), the ITPGRFA, the National Biodiversity Strategies and Action Plans (NBSAPs)—the principal instruments for implementing the CBD at national level (<http://www.cbd.int/nbsap/>)—and to the National Plant Conservation Strategies, when existing. Whether CWR are conserved *in situ* within PAs or outside of them, it is advisable that the sites have some form of legal protection to help prevent sudden threats to conserved populations. On the other hand, local communities living within the target sites where genetic reserves are to be implemented should be actively involved so a holistic and thus efficient approach to conservation of CWR is implemented. Awareness of National management plans for CWR and LR conservation should be raised among the different stakeholders. These can take the form of local community conservation (training) workshops. Agreements with private owners (e.g. tax incentives) could be made, not only to ensure CWR are properly managed but also to recognise the local communities' role in conserving such a valuable resource.



Community training workshop (Photo L.B.Nilsen)

Regarding LR diversity, the implementation of on-farm conservation priorities may be quite challenging. The following steps will need to be taken: (i) Find out whether the target farmers have socio-economic conditions to maintain LR, (ii) Reformulate the *in situ* conservation goals (if needed), (iii) Integrate on-farm priorities with national/international agri-environmental schemes, (iv) Convince farmers to use and maintain LR, (v) Find out whether the priority target on-farm sites occur within formal PAs, (vi) Ensure local crop diversity exists in sufficient quantities within the production systems, (vii) Ensure local crop diversity is accessible to farmers, (viii) Ensure local crop diversity is valued among farmers, and (ix) Ensure farmers benefit from the use of local crop diversity (Jarvis *et al.* 2011).

In parallel to the establishment of the *in situ* priorities, there is also a need to locate, sample, transfer and store *ex situ* samples of priority CWR and LR. *Ex situ* conservation should not only provide a back-up or complementary mode of conservation, but also provide a practical means of access for the germplasm user community; therefore, even if populations are adequately conserved *in situ* they should be duplicated *ex situ* for the benefit of the germplasm user community.

Practically, the numbers of examples of local communities actually using CWR and/or LR diversity in their crop maintenance systems may be limited but as with *in situ* conservation, the local communities living within the target sites where collections are to be made should be actively involved and where these communities do use this diversity, the germplasm should also be maintained in local community gene banks. It is vital to establish community seed banks so local CWR/LR diversity is promoted and efficiently utilised. Community seed banks aim at identifying important traditional varieties and orienting the agricultural community towards conserving and cultivating them. These community seed banks have a vital role in ensuring food security especially in arid or semi-arid lands where food is short after extended periods of drought. Therefore, in a global change scenario where climatic changes are already happening, community seed banks are of utmost importance.



Community seed bank, India (Photo: Unknown)

1.9 Policy drivers of agrobiodiversity conservation and use

There are numerous drivers of policy change with regard to the conservation and use of agrobiodiversity:

- The intrinsic value of CWR and LR to safeguard food security, especially in a climate change scenario.
- The direct use of LR, especially to subsistence or marginal agriculture and poor communities, and indirect use as a potential source of novel genetic diversity for breeding.
- The indirect use of CWR for the improvement of crop varieties better adapted to changing environments (e.g., pest and disease resistance, temperature resistance, higher and more stable yield) and to meet consumer demands. In

fact, Pimentel *et al.* (1997) estimated that the contribution of agrobiodiversity to yield increase is about 30% of production and that a significant amount of this is due to wide crosses with wild accessions. As an example, in the 1970s the US maize crop was severely threatened by corn blight which destroyed almost US\$ 1,000 million worth of maize and reduced yields by as much as 50% in 1978 (FAO 2005). Blight resistant genes from Mexican maize CWR were used to solve this problem (Prance 1997).

- Improving food quality and for medicinal purposes. CWR have been utilised to donate genes coding for higher nutritional value (e.g., the introduction of genes for higher protein content in wheat—Khan *et al.* 2000) and for increased medicinal qualities (e.g., high levels of anti-cancer compounds in broccoli have been produced with genes from wild *Brassica oleracea* L.—Hodgkin and Hajjar 2007).
- The national economic benefits and wealth creation that arise from: (i) the creation of new niche markets based on the use of LR and traditional products manufactured with LR, (ii) the industry development based on the large scale (and possibly international) commercialization of new improved varieties, (iii) the eco-tourism development based on the conservation and sustainable utilisation of PGRFA.
- The reduced probability of economic losses with crops that fail to adapt to changing environments, potentially reducing production and insurance costs, and ultimately increasing the GDP or reducing foreign dependency.
- The environmental sustainability and social development that results from the active conservation and sustainable utilisation of PGRFA.
- The public opinion which forces governments to take action.
- The international recognition of a “Green economy” approach.
- The international obligations towards reaching the GSPC targets for 2020 (namely target 9, CBD 2010a), the Aichi targets of the CBD Strategic Plan (namely target 13, CBD 2010b) and the UN Millennium Development Goals (www.un.org/millenniumgoals/) in eradicating extreme poverty and hunger.

1.10 Aim and users of the resource book

In this Resource book we address the issue of how a systematic approach to CWR and LR conservation can be realized by nations, emphasizing the need to integrate local and global levels of implementation. The book is intended to help countries develop national management plans for CWR and LR conservation by following a series of basic steps:

- Creation of inventories;
- Prioritization for conservation action;
- Genetic data analysis;
- Ecogeographic surveying;
- Gap analysis;
- Establishment and implementation of *in situ* and *ex situ* conservation goals;
- Monitoring of diversity conserved;
- Promoting the use of diversity;
- Data management.

It is important to stress there is no single method for developing strategic plans for CWR and LR conservation because of issues concerning resource and baseline biodiversity data availability, the local community where the plan is to be implemented, as well as the focal area and remit of the agencies which are responsible for formulating and implementing it. Nevertheless, the process of developing national plans for conservation and use of CWRs and LRs can be viewed as a series of decisions and actions that follow the same basic pattern in all countries. The resource book should be viewed as a framework and guide for developing such plans, bearing in mind that the suggested steps do not necessarily have to follow the same predefined order, but developed and implemented within the confines of the available data and resources.

The Resource book is designed primarily for use by developing countries with limited resources and knowledge on their CWR and LR diversity and how to conserve it. The different groups of users may include agencies responsible for planning and implementing national plans, such as the national agricultural or environmental agencies; NGOs (e.g. farmers' organizations), local institutions (e.g. gene banks, universities, research institutes), and individual scientists.

1.11 How to use the Resource book

The Toolkit is designed for the user as a sequential but flexible process that culminates in the production of a National CWR or LR Conservation Plan. Nevertheless, it is possible to enter through several entry points.

HOW TO USE THE RESOURCE BOOK

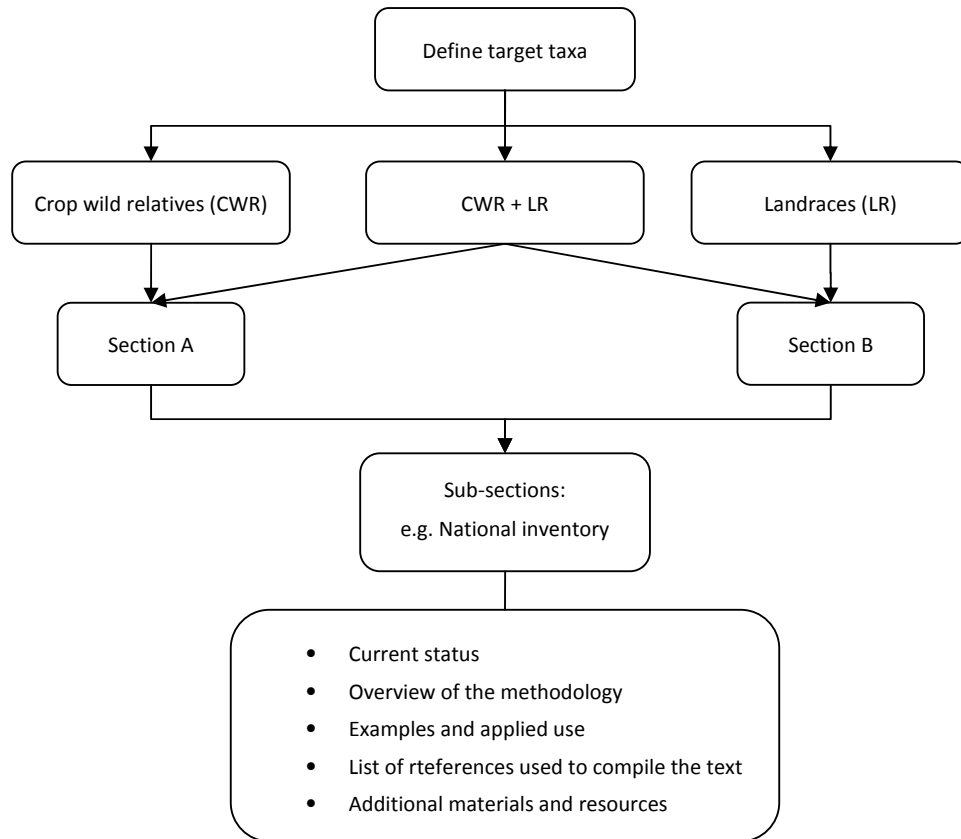


Figure 4 Schematic view of how the resource book can be used.

- The first decision the user needs to make regarding the target species is whether the user wants to develop a national management plan for conservation of CWRs or LRs, or for both.

- From there, the Resource book is divided into two main sections: section A for CWR and section B for LR.

Each of these main sections is then divided into sub-sections which are related to the different steps needed to develop a national management plan for the target groups (e.g. National CWR checklist and inventory).

- Each sub-section generally starts with “Overview”, followed by “Overview of the methodology”, “Examples and applied use”, “List of references used to compile the text” and “Additional materials and resources”.

- “Overview” provides a brief explanation of that sub-section, sometimes highlighting some of the developments in that particular area. It also gives a flowchart that may take the form of an expert system (composed of a series of

yes/no questions) that helps the user move through the various steps and helps choose which options are more adequate given a particular national context.

- “Methodology” provides a thorough description of the methodology suggested in order to undertake that particular step in the process of developing a national plan.
- “Examples and applied use” makes reference to case studies where key steps have been applied.
- “List of references used to compile the text” is the list of references used in the preparation of the text.
- “Additional materials and resources” includes extra information (books, scientific papers, grey literature, PowerPoint presentation, software, relevant projects, and web links) (see the icons used below) that not only provide the user with extra practical examples but also help them to visualise and understand how to undertake that particular step; it is generally divided into different topics.



Books, scientific papers, grey literature.



PowerPoint presentations.

WW

Web links.

W



Software, informatics tools.



Projects.

1.12 Additional resources

General references:

-  Heywood VH and Dulloo ME (2005) *In situ* conservation of wild plant species – a critical global review of good practices. IPGRI Technical Bulletin No. 11. IPGRI, Rome.
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