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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

OPTIONS TO PROMOTE FOOD SECURITY: ON-FARM MANAGEMENT AND *IN SITU* CONSERVATION OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

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This options paper has been prepared as a contribution to the discussion on issues related to on-farm management of plant genetic resources for food and agriculture and in situ conservation of crop wild relatives and wild plants for food, particularly in developing countries.

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I. EXECUTIVE SUMMARY

1. The *Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* (SoWPGR-2) (FAO, 2010) underlined the need for and importance of on-farm management of plant genetic resources for food and agriculture (PGRFA) and *in situ* conservation of crop wild relatives (CWR) and underutilized species, particularly in the face of emerging environmental challenges and demographic pressures. It noted that although there has been some advancement in increasing awareness about on-farm management and the potential value of CWR, there are major conservation, management, sustainable exploitation and research gaps that require attention.

2. The Commission on Genetic Resources for Food and Agriculture (Commission), at its Twelfth Regular Session[3], urged greater attention to be given to crops that are essential for food security and an option paper that addresses issues of on-farm management of plant genetic resources for food and agriculture (PGRFA) and *in situ* conservation of crop wild relatives and wild plants for food, particularly in developing countries.

3. This study provides an analysis of the issues, options and associated challenges in on-farm management of plant diversity and *in situ* conservation of CWR, particularly in developing countries. At the national level, development of landraces (LR) and CWR conservation strategies is an option, while taking into account local needs and indigenous knowledge of farmers and providing the necessary resources for long term commitment. At its core would be a national network of conservation sites to maintain LR and CWR diversity. At the international level, a call to establish a global network for the *in situ* conservation of the CWR diversity of crops important for food security is reiterated. A background study, commissioned by FAO has already been published which identifies high priority sites for the *in situ* conservation of a range of priority crop gene pools and the methodology of how this full target might be achieved[4]. There is an allied need to develop improved indicators of diversity, genetic erosion and vulnerability that can be applied to establish national, regional and global baselines for locating and monitoring diversity, and changes in diversity over time. The promotion of the use of genetic resources by researchers, farmers and breeders that characterize, evaluate and screen PGRFA for novel traits is challenging yet necessary.

4. The paper emphasizes that strong, multidisciplinary collaborations are required at the national, regional and international level. At the national level, a strengthened linkage between ministries of agriculture and of the environment can be encouraged to promote monitoring of the status and trends in PGRFA and thereby ensure their adequate conservation. Regional and global level coordination is needed to strengthen linkages between existing *ex situ* and *in situ* conservation efforts. Therefore, the various options reviewed should be seen as complementary and promote a holistic approach.

5. Since the last meeting of the Commission, the Secretariat of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) has launched the Leading the Field initiative and the Benefit-sharing Fund for the biennium 2010–2011[5] which call for proposals that help to ensure sustainable food security by assisting farmers to adapt to climate change through a targeted set of high impact activities on the conservation and sustainable use of PGRFA. A major focus among others is to strengthen on-farm management of genetic diversity, including local and indigenous knowledge; the addition of value to local crops and varieties to combat climate change through the on-farm evaluation, selection and management of local and introduced genetic diversity (including new, improved varieties bred by professional plant breeders); farmer breeding

[3] CGRFA-12/09/Report

[4] CGRFA-11/07/11

[5] http://www.planttreaty.org/funding_en.htm

and selection activities; conserving and making available local and indigenous knowledge; developing outlets for local crops and varieties; adding value to local crops and varieties; and linking farmers with communities elsewhere nationally, regionally and internationally to promote the sharing of material and information relating to climate change[6].

6. To conclude, it is necessary to:

- Reaffirm the need for collaboration and coordination among national, regional and international levels to promote on-farm management and *in situ* conservation of plant diversity;
- Recommend that the Commission considers the requirement for establishment of a global network for *in situ* conservation of CWR diversity.

II. INTRODUCTION

7. At its Twelfth Regular Session, the Commission urged that greater attention be given to crops that are essential for food security, and reiterated the importance of on-farm management of PGRFA and *in situ* conservation of crop wild relatives and wild plants for food, particularly in developing countries. As defined by the Convention on Biological Diversity (CBD, 1992) and FAO (2001), *in situ* conservation means "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated plant species, in the surroundings where they have developed their distinctive properties". Therefore, *in situ* conservation encompasses two complementary approaches to the conservation of PGRFA: 1) on-farm management of traditional crops, or landraces and 2) management of wild populations in natural or semi-natural habitats. Both cultivated (and to some degree wild) PGRFA can be maintained and conserved on-farm but many species of CWR that may be important as gene donors for crop improvement and wild plants used as a direct food source occur only in natural or semi-natural habitats; therefore, conservation of these species requires the protection of sites and habitats, combined with population monitoring and management (genetic reserve conservation[7]).

8. Management of PGRFA on-farm and in genetic reserves involves a wide range of stakeholders and a complex array of techniques and activities. There is a need for a coordinated effort at local, national, regional and global levels in order to make efficient use of resources and to ensure that the most important PGRFA for food security and interdependence are sustained to meet the combined challenges of climate and demographic change, as well as the needs of the most vulnerable people in rural areas, particularly in developing countries.

9. This paper reviews the current status of and options for the *in situ* management of PGRFA in developing countries, highlighting common challenges and the key issues that need to be addressed.

III. GLOBAL PLANT GENETIC DIVERSITY

10. PGRFA can be defined as "the genetic material of plant origin of actual or potential value for food and agriculture" (FAO, 2001). PGRFA comprise modern cultivars, breeding lines and genetic stocks, obsolete cultivars, ecotypes, landraces (LR) and crop wild relatives (CWR) (Maxted *et al.*, 2008a), as well as weedy races and primitive forms of crops (Figure 1, Box 1).

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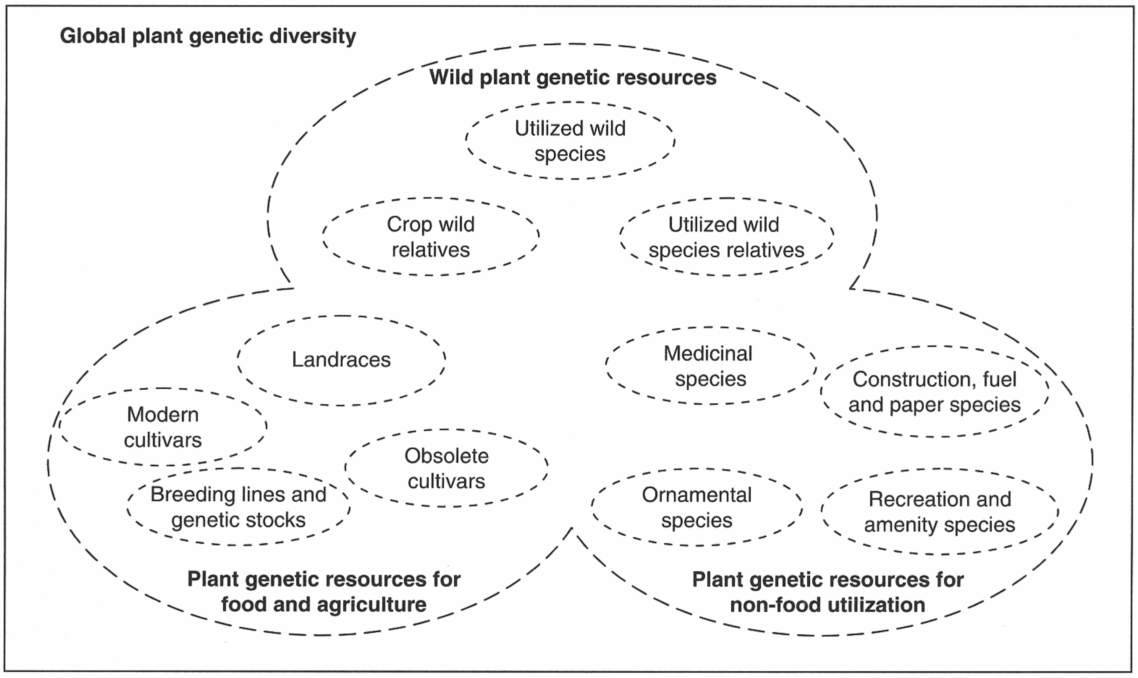
[6] ftp://ftp.fao.org/ag/agp/planttreaty/funding/experts/bsf_exp_p01_en.pdf

[7] Genetic reserves are sites designated for the management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long□term conservation (Maxted *et al.*, 1997).

Figure 1. Components of Plant Genetic Resources



Source: Maxted *et al.*, 2008a

Box 1. Definitions of different types of PGRFA

- **Cultivars**: cultivated plant varieties that have been formally approved and registered.
- **Breeding lines:** genetic lines bred in a crossing programme before they are named and officially released for commercial cultivation; **élite lines** are breeding lines that possess most of the characteristics being sought for a particular environment or plant.
- **Obsolete cultivars:** plant varieties that are considered of no importance at present or no longer popular and used by the community.
- **Landraces:** unique varieties of crops that have adapted to local conditions through a process of farmer selection.
- **Weedy races:** crop varieties that are no longer cultivated and have now become naturalized in the wild.
- **Primitive forms:** crop varieties that have not been subjected to intensive breeding or growers' selection; they have features or traits that are similar to wild relatives.
- **Ecotypes:** a population or group of populations that are genetically adapted to a particular set of environmental conditions where they naturally occur.
- **Crop wild relatives:** wild species related to crops, including **crop progenitors.**

11. Of these different types of PGRFA, LR and CWR are the most threatened and least well conserved-both *in situ* and *ex situ*; this is despite the fact that in recent years there has been increased recognition of their importance for food and livelihood security, particularly in the context of climate change. The particular food security value of CWR has been recognized at least since Darwin discussed their conservation (1868), but it was Vavilov (1926) who was the first to address their conservation in practical terms. However, CWR have been 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) and it is only relatively recently that systematic CWR diversity conservation been

promoted (e.g., Maxted *et al*., 1997a; Meilleur and Hodgkin, 2004; Heywood and Dulloo, 2005; Stolton *et al*., 2006; Maxted *et al*., 2008b). This is despite the fact that 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) and their economic value is also well-known; for example, one recent estimate is that approximately 30 percent 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).

IV. THE IMPORTANCE OF LR AND CWR FOR FOOD AND LIVELIHOOD SECURITY

12. LR and CWR constitute important components of a nation's PGRFA available for utilization by humankind, especially in ensuring food and livelihood security. LR are traditional crop varieties and have been defined as "dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems" (Camacho Villa *et al.*, 2005). 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. CWR are species closely related to crops, including crop progenitors, and are defined by their potential ability to contribute beneficial traits to crops such as pest or disease resistance, yield improvement or stability (Maxted *et al.*, 2006). Almost all modern varieties of crops contain some genes derived from a CWR and possibly all contain genes from LR, so they are both a critical resource with a vital role in food security for the 21st century. 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.

13. 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 LR and CWR 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).

14. 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.

V. LOSS AND DEMAND FOR PLANT DIVERSITY

15. Despite their, importance, there is an increasing loss of PGRFA diversity due to a number of social, economic and ecological reasons:

a. 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;

b. LR and CWR are expected to be affected by climate change (e.g., see Parmesan and Yohe, 2003; Root *et al*., 2003; Maxted *et al*., 2004; 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);

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.

16. 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 LR and CWR 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.

17. While both LR and CWR diversity is under threat from climate change, 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 LR and CWR diversity is outlined in Box 2.

Box 2. Threat assessment of LR and CWR 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 percent of European vascular plant species were classified as threatened using the 1994 IUCN Red List Categories and Criteria (IUCN, 1994, and 50 percent of Europe's 4,700 vascular plant endemics are considered to be threatened to some degree (www.redlist.org). 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). 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. 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 percent LR of all crops had been lost.

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). The most commonly applied means of assessing threat to wild taxa is by applying the 2001 IUCN Red List Categories and Criteria (IUCN, 2001); however, a review of CWR taxa published in the 2004 IUCN Red List of Threatened Species showed that of the more than 25,000 CWR species present in Europe, less than 1 percent had been assessed using these criteria (Kell *et al*., 2008). Further, Maxted and Kell (2009) reviewed whether the CWR within 14 global priority crop gene pools had been threat assessed using the same criteria and found that only one, *Solanum*, had been partially assessed. Although there is currently no comprehensive review of CWR threat assessment, work is underway to assess around 600 species selected on the basis of food security and economic value in Europe as part of an initiative to publish the first European Red List (http://ec.europa.eu/environment/nature/conservation/species/redlist/) (Maxted *et al.*, in prep.). Also 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 (Hunter and Heywood, 2011). It is anticipated that these initiatives will act as a catalyst for more countries and regions to follow suit.

Although the IUCN Red List Categories and Criteria (IUCN, 2001) is a commonly used system for threat assessment, these criteria are mainly tailored to the assessment of species as taxonomic entities and do not take into consideration threat to the components of genetic diversity within species. Because the specific target of PGRFA conservation is to maintain genetic diversity, there is a need to work with IUCN to develop an 'extension' to the current IUCN Red List criteria that takes into account threat assessment of genetic as well as taxonomic diversity (Maxted *et al.*, 2011). The inadequacies of the IUCN Red List criteria in terms of assessing intra-taxon genetic diversity means that the system is unsuitable for assessing threats to LR. However, Joshi *et al.* (2004) used the IUCN Red List Categories and Criteria ethos to design a set of categories and criteria for LR threat assessment and independently, Porfiri *et al.* (2009) also proposed a methodology to assess threat to LR diversity. There is clearly scope for development and broader application of such potentially useful techniques.

VI. CURRENT TRENDS AT THE NATIONAL AND INTERNATIONAL LEVEL

18. While the value of LR and CWR 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. LR and CWR 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).

19. With the degradation and extinction of LR and CWR 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 LR and CWR 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.

20. 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 percent 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).

21. The SoWPGR-2 (FAO, 2010) 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'etre* 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 LR and CWR conservation will pragmatically only be maintained if there is systematic use of the broad range of LR and CWR 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 (Box 3). 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.*, 2011) and it is anticipated that the research will provide useful results and recommendations for other regions and countries.

VII. THE USE OF PGRFA DIVERSITY FOR CROP IMPROVEMENT

22. There are numerous ways in which LR/CWR diversity use in breeding can be promoted, but traditionally this has focused on trying to identify 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 percent lack characterization data and 95 percent lack evaluation data, making the use of such germplasm, including CWR germplasm, much more difficult than it need be. The SoWPGR-2 (FAO, 2010) 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".

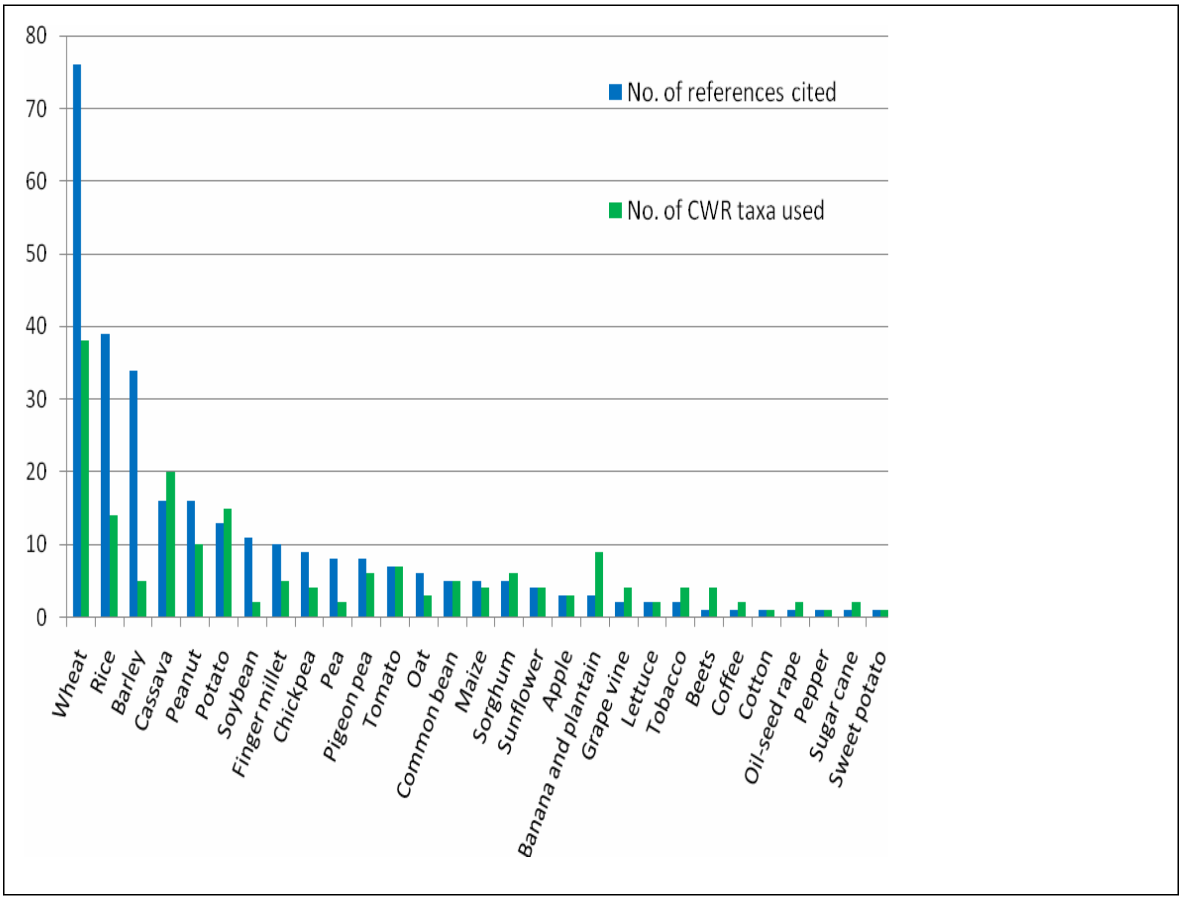
23. The bottleneck over systematic characterization and evaluation has been acknowledged almost since the need for their conservation was recognized in the late 1960s and early 1970s (Frankel and Bennett, 1970). It could be argued that simply increasing the amount of 'traditional' characterization and 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.

Box 3. The 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 2). 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 percent of citations recorded prior to 1970, 13 percent in the 1970s, 15 percent in the 1980s, 32 percent in the 1990s and 38 percent 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 percent, pest and disease resistance 17 percent, abiotic stress 13 percent, yield increase 10 percent, cytoplasmic male sterility and fertility restorers 4 percent, quality improvers 11 percent and husbandry improvement 6 percent 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 2. EVIDENCE OF CWR DIVERSITY USE



Source: Maxted and Kell, 2009

VIII. PGRFA CONSERVATION TECHNIQUES

24. 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; Guarino *et al*., 1995; Hawkes *et al*., 2000; Smith *et al*., 2003) (Box 4). 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, 1995; Maxted *et al.*, 1997a; Heywood and Dulloo, 2005; Stolton *et al.*, 2006; Negri *et al*. 2009).

25. 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.

Box 4. PGRFA conservation techniques

There are two fundamental strategies used in the conservation of PGRFA and within each strategy a range of techniques exists (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 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 reserve[8] 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.*, 1997b). 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. Also, importantly the conservation is long term, because significant resources will have been invested in the site to establish the genetic reserve. This technique is the most appropriate for the bulk of CWR species, whether they are closely or distantly related to crop plants, or 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.*, 1997b).
- **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.*, 1997b). 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.

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[8] Synonymous terms include genetic reserve management units, gene management zones, gene or genetic sanctuaries, crop reservations.

***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 its 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), which holds the world's largest collection of rice genetic resources, and the Millennium Seed Bank at the Royal Botanic Gardens, Kew, which holds the largest collection of seed of 24,000 species, primarily from global drylands. 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 (Global Crop Diversity Trust, 2007).

26. 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 percent of governmental, 14 percent of CGIAR and 6 percent 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 percent 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.*, 2008b). Later, Dias *et al.* (in press) calculated that a total of around 9 percent 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.

27. 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.*, 1997c; Heywood and Dulloo, 2006; 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 Daĝ, 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 (Tewskbury *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).

28. 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; in press) and they therefore do not in themselves constitute the desired global network of genetic reserves that is needed to systematically conserve CWR genetic diversity.

IX. OPTIONS FOR ON-FARM AND *IN SITU* CONSERVATION OF PGRFA

OPTION 1 – FLORISTIC OR MONOGRAPHIC APPROACH

29. 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 LR and/or CWR 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). The floristic approach is comprehensive because it attempts to encompass all LR/CWR diversity that occurs within a geographical unit; however, while being comprehensive for the geographical unit, the full geographic range of an individual taxon may or may not be included, depending on whether it is endemic to that geographical unit. The monographic approach on the other hand focuses on LR/CWR diversity within target crop gene pools which are usually identified on the basis of their perceived value for food security and/or economic stability. Both approaches will ultimately conclude with the systematic conservation of priority LR and CWR diversity via a network of on-farm conservation sites and genetic reserves, with backup in *ex situ* collections. Examples of the floristic and monographic approaches in formulating a conservation strategy are provided in Box 5.

30. Whether a floristic or monographic approach is taken is likely to depend on: a) the quantity and quality of existing data and b) the resources available to prepare the conservation strategy. The scope of the parent organization undertaking the conservation may also impact the approach; 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 LR and CWR diversity it is likely that both approaches need to be combined (national strategies and crop gene pool strategies for the highest priority crops).

Box 5. Examples of floristic and monographic approaches

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). In order to create the CWR Catalogue for Europe and the Mediterranean, four major sources of information were utilized (Kell *et al*. 2008): Mansfeld's World Database of Agricultural and Horticultural Crops (Hanelt and IPK 2001, IPK 2003) for genera containing cultivated plants (excluding forestry and ornamental species), Schultze-Motel (1966) for genera containing forestry crops, the Community Plant Variety Office (CPVO) (Kwakkenbos, pers. comm. 2004) for genera containing ornamental crops and the Medicinal and Aromatic Plant Resources of the World Database (MAPROW) (Schippmann, pers. comm. 2004) to include a wider range of medicinal and aromatic plant genera. A list of crop genus names was generated using these four references and matched with the taxa in Euro+Med PlantBase (version January 2006) (http://www.euromed.org.uk). The CWR Catalogue for Europe and the Mediterranean was finally generated by extracting the taxa within accepted and synonymous genera matching the crop genus name list (Kell *et al*. 2008).

The Portuguese CWR taxa were then extracted from this Catalogue. 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 study 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. See Magos Brehm *et al.* (2008), Magos Brehm (2008) and Magos Brehm *et al.* (2010) for more details.

Monographic approach at global level: Conservation strategy for Aegilops *species* (Maxted *et al.* 2008c).

Taxonomic, ecological, geographic and conservation information for 22 *Aegilops* species were collated from ICARDA[9], EURISCO[10], GRIN[11] and SINGER[12] datasets, and subsequently used to identify gaps in current conservation, both *in situ* and *ex situ*, 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 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 were made.

OPTION 2 – LOCAL, NATIONAL, REGIONAL OR GLOBAL GEOGRAPHIC SCALES

31. LR/CWR conservation strategies 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 LR/CWR 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 LR and CWR conservation strategy should link with local, regional and ultimately the global 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 LR/CWR conservation strategies to ensure they form a series of local, national, regional and global *in situ* LR/CWR conservation sites. In practice, however, it should be acknowledged that implementing such complementary geographic approach while being an immediate option for systematic CWR conservation is likely to be a longer term option for systematic LR conservation if for no other reason than the extent of knowledge available on relative CWR and LR diversity.

OPTION 3 – CENTRALIZED OR PARTICIPATORY CONSERVATION

32. In writing a paper that attempts to address global food security, particularly given the threat currently facing LR and CWR diversity, it is difficult to precisely categorize the contribution of local communities and farmers *versus* conservationists. While an overview is required to identify LR and CWR diversity hotspots and implement on-farm or genetic reserve conservation in a network that maximizes the conserved LR and CWR diversity for the benefit of all humanity, 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 LR and CWR diversity for millennia and so maintaining a

[9] http://www.icarda.org/GeneBank.htm

[10] http://eurisco.ecpgr.org/

[11] http://www.ars-grin.gov/

[12] http://singer.cgiar.org/

complementary bottom-up approach is equally important. Therefore, just as LR/CWR conservation at local, national, regional and global scales interact to ensure effective complementarity conservation, so both centralized and participatory approaches to conservation also ensure effective complementarity conservation.

OPTION 4 – ON-FARM CONSERVATION OR CONSERVATION OF TRADITIONAL FARMING SYSTEMS

33. 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

34. 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. This is because many CWR are associated with pre-climax vegetation and the conservation of populations in these habitats requires intrusive management to maintain them in their pre-climax state-interventions that are often provided by farmers in the form of controlled grazing or cutting. Therefore, even when undertaking genetic reserve CWR conservation, it commonly involves conservationists working with farmers.

35. 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 landraces has also shown that the conservationist can have a key role in helping farmers develop alternative niche markets for the landraces to be conserved, raising the value of the resource and so sustain landrace maintenance (Heinonen and Veteläinen, 2009; Nikolaou and Maxted, 2009; Martin *et al.*, 2009; Veteläinen *et al.*, 2009).

OPTION 6 – STATUS QUO OR LEGISLATIVE PROTECTION

36. To promote sustainable *in situ* LR/CWR conservation there is a need to encourage and facilitate stronger legislative protection of sites (i.e. on-farm or genetic reserve) 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 on-farm sites or genetic reserves where the status quo without specific protection is unviable. This is particularly important for sites designated in Vavilov Centres of Origin/CWR hotspots, all of which are located in Developing Countries, which are likely to contain the highest proportion of unique LR/CWR 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

37. The CBD and ITPGRFA stress that the two conservation strategies (*ex situ* and *in situ*) should not be viewed as alternatives or in opposition to one another but rather should be practised as complementary approaches to conservation. The adoption of this holistic approach requires the conservationist to look at the characteristics and needs of the LR or CWR 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 is the germplasm 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?

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

OPTION 8 – CONSERVATION OR CONSERVATION LINKED TO USE

39. 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.*, 1997b). This utilitarian concept is fundamental to PGRFA conservation where the goal is to ensure that the maximum possible genetic diversity of LR or CWR diversity is maintained and available for potential utilization. Further, it can be argued that to be effective, conservation has to be linked to use because sustainable use is seen as the long-term means of sustaining active conservation.

X. RESEARCH NEEDS AND PRIORITY ACTIONS

RESEARCH NEEDS FOR LR CONSERVATION AND USE

40. To support LR conservation and food security there are a number of particular areas of research needed to improve our knowledge of where to target LR and on-farm conservation efforts, how to conserve LR that are found outside formal on-farm conservation schemes, the causes of loss of LR diversity, how climate change is likely to impact LR populations, and how to involve local communities in the conservation and use of LR. Recommendations for priority research studies are outlined below. A wider use of LR and their enhanced maintenance within dynamic management systems can help communities facing the current climatic and socio-

economic changes caused by continuous innovations and developments in agriculture, human population dynamics and economic changes. With this aim in mind there is a need to:

- Have a better understanding of present LR diversity;
- Strengthen research capacity in conducting inventories and surveys using new molecular tools;
- Understand population dynamics in relationship to factors such as migration, drift and human and environmental selection pressures;
- Develop improved indicators of diversity, genetic erosion and vulnerability that can be applied to establish national, regional and global baselines for locating and monitoring diversity, and changes in diversity over time;
- Develop and agree an assessment technique that is able to assess genetic erosion within LR, that is comparable with the IUCN Red List assessment process used for wild species;
- Review the impact of climate change on LR diversity and how populations might be managed to allow them to adapt, mitigate or be resilient to its potential impact;
- Review the usefulness of LR in environmentally friendly agronomic systems;
- Understand the socio-economic factors driving on-farm maintenance of LR;
- Develop models and exemplars of local community and decentralized participatory conservation that complement formal sector approaches to conservation;
- Establish the degree to which local cultural identity is linked to LR and provide good examples of inter-relationship between local LR and local culture, this could lead into what might be termed 'agro-biocultural restoration' and transmission to the future generations of pride in their agronomic heritage while actively promoting both the conservation of local LR diversity as well as the on-farm system itself;
- Demonstrate the vital role farmers and local communities have in utilizing and thus maintaining LR diversity;
- Publicize examples of long-term sustainable on-farm conservation; too often on-farm sites are identified and established during research projects but once project funding support ceases the on-farm site management deteriorates, so there is also a need to generate long-term funding strategies for on-farm conservation;
- Investigate how complementary local, national, regional and global networks of LR on-farm sites might be established in an integrated manner, given the relatively poor knowledge of LR diversity;
- Develop a global strategy for LR conservation and management;
- Promote the development of national strategies and support initiatives for the *in situ* and *ex situ* conservation of LR as well as its sustainable use;
- Promote the *in situ* on-farm use of LR diversity by farmers, researchers and breeders, which is likely to involve more on-farm based characterization, evaluation and screening for novel traits;
- Promote general public awareness about the value of LR as well as the need to conserve and sustainably manage them.

PRIORITY ACTIONS FOR CWR CONSERVATION AND USE

41. The research agenda has both been clearer and already more thoroughly addressed for CWR than for LR. A number of recent initiatives have tackled some key areas in CWR conservation, particularly with regard to the development of CWR conservation strategy planning, as well as initiating quality standards for CWR genetic reserves and starting to address the issue

of linking CWR conservation with use by plant breeders. Further, because CWR are wild plant species and there is already significant experience in the *in situ* conservation of wild plant species in protected areas, many lessons can be learnt from the existing literature to conserve CWR. Therefore, the recommended agenda for CWR is more for concrete actions rather than for research, although there are still ongoing research needs. To support CWR conservation for food security we need to:

- Identify which are the global priority CWR taxa to aid targeting of conservation action and resources;
- Implement the Global Network of CWR genetic reserves as it is likely to be focused on existing protected areas, the biodiversity and agrobiodiversity conservation communities will need to work much more closely together; therefore, there is a need for consensus-building activities between the two communities;
- Test and refine methodologies for *in situ* CWR genetic reserve location, establishment and management;
- Recognize that there is likely to be a strong correlation between the sites identified as part of the Global Network of CWR genetic reserves and the Vavilov Centres of Origin and Diversity and that these are almost exclusively located in developing countries where there may be limited technical and financial resources available to support this new global responsibility; therefore, there is a need for a funding mechanism to be established;
- Recognize that CWR are often found outside of protected areas (often within an agricultural context or human created habitat like a roadside) and that there is a need to develop sustainable methodologies for CWR conservation within these anthropogenic environments;
- Employ gap analysis techniques as an established evidence-based means of targeting conservation activities, both *in situ* and *ex situ*, to ensure that limited resources are used efficiently and effectively—this technique should be applied for all priority CWR;
- Develop improved indicators of diversity, genetic erosion and vulnerability that can be applied to establish national, regional and global baselines for locating and monitoring diversity, and changes in diversity over time;
- Apply the IUCN Red List assessment process to all priority CWR, while recognizing that this process cannot be used to assess genetic distinctiveness or erosion and that a complementary technique is required to assess threat at the level of intra-specific CWR genetic diversity;
- Study the potential impacts of climate change on CWR diversity, starting with the highest priority taxa;
- Recognize that the conservation status of CWR is directly linked to local community-based land management, which can potentially impact positively or negatively on CWR diversity therefore, a study of patterns of community usage should be undertaken to identify how both CWR conservation and use might be promoted at the local community level;
- Promote the development of national strategies and support initiatives for the *in situ* and *ex situ* conservation of CWR;
- Actively develop novel techniques to promote CWR utilization by breeders, farmers and other users;
- Promote general public awareness about the value of CWR as well as the need to conserve them.

42. Given the critical importance of *in situ* LR and CWR maintenance for food security and given the alarming rate of genetic erosion of these plant genetic resources, FAO is developing a toolkit that can help nations, particularly developing countries, in formulating national programmes and strategies for the systematic on-farm and *in situ* conservation of LR and CWR. The toolkit is a practical counterpart to this document.

XI. CONCLUSIONS AND RECOMMENDATIONS

43. The overall conclusion of this Options Paper is that the *status quo* in terms of maintaining PGRFA, specifically LR and CWR diversity, is not an option if human well-being and food security is to be maintained. The rate of genetic erosion and even extinction of PGRFA is alarming and persistent and therefore action must be implemented to more effectively and systematically conserve LR and CWR diversity. The two key recommendations are as follows:

44. *Key recommendation 1:* Reaffirm the need for collaboration and coordination among national, regional and international levels to promote on-farm management and in situ conservation of plant diversity.

45. The point has been stressed throughout this paper that LR and CWR conservation in relation to a food security strategy requires a coordinated effort at national, regional and global levels, as well as between those engaged in LR and CWR conservation and the LR and CWR diversity user community. The effective establishment of a network of LR on-farm sites or CWR genetic reserves will also necessitate a coordinated approach between the professional PGRFA conservation community and the nature conservation community. The threat facing LR and CWR diversity is evident and the need for active conservation is urgent, but this is a complex goal; therefore, there is a continuing need for stakeholder collaboration and scientific coordination to oversee effective implementation.

46. *Key recommendation 2:* The FAO Commission on Genetic Resources for Food and Agriculture considers the requirement for the establishment of a global network for in situ conservation of CWR diversity

47. Given the known value of CWR in crop improvement and their potential value in climate change mitigation and future food security, it is perhaps surprising that there has to date been no systematic attempt at global level to conserve CWR diversity, either *in situ* or *ex situ*. This has largely been because CWR tend to fall between the remit of the ecological, or nature conservation community who mainly focus on rare or threatened wild plant species and habitats, and the agricultural conservation community who focus on conservation of intra-crop variation. In many cases, the selection of global protected areas has been *ad hoc*-depending largely on previous land use, ownership or human habitation, recreation and tourism, or historical protection-CWR conservation has not been a consideration. Stolten *et al.* (2006) listed protected areas with reported CWR species presence and while this list provides a useful initial indication of which CWR may be found within existing protected areas, it is important to stress that in these cases the CWR themselves are unlikely to be actively managed.

48. It is obvious from the growing threats that CWR face globally and the increased requirement for their genetic diversity in attempting to counter climate change, that CWR genetic diversity is currently far from secure and more concerted *in situ* and *ex situ* conservation action must be a priority. The Global Crop Diversity Trust and partners have recently launched a ten year project to ensure priority CWR are conserved *ex situ*; however, *in situ* conservation remains the preferred option because of the need to retain dynamic evolutionary interactions, the sheer number of CWR involved and the need to conserve their full range of genetic diversity. Therefore, there is a need for complementary *in situ* action and the establishment of a Global Network of CWR Genetic Reserves to ensure full CWR genetic diversity is conserved. The Commission has already published a background study for the establishment of a global network of CWR genetic reserves (Maxted and Kell, 2009) now the recommendations from this study need to be translated into concrete actions.

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