Climate change and conservation of crop wild relatives

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Abstract

Crop wild relatives can be important sources of genes to adapt cultivated crops to changing climatic conditions. But their very survival is being placed in jeopardy by the impacts of climate change. Many populations of wild relative species will become extinct within the next 50 to 100 years. The most vulnerable of these include species with narrow climate envelopes, poor migration capacity, those that have been squeezed into fewer and smaller habitats by other disturbances, and species for which suitable climate envelopes will no longer exist, such as high-altitude species. Conservation strategies rarely include plans for managing the impacts of climate change on species and ecosystems. Genera- and species-specific regional assessments are required in order to devise conservation options for priority species. This paper discusses the threat of climate change to crop wild relatives and describes a simple conceptual model for conservation planning including in situ and ex situ approaches. Complementary in-situ and ex-situ strategies should combine climate and species distribution projections and establish criteria for selecting priority species and conservation areas. For some species, ex-situ conservation or human-mediated relocation may be the only means to avoid extinction.

Introduction

Crop wild relatives (CWR), which include crop ancestors as well as other related species, have been used for crop improvement for over 100 years (Plucknett *et al.* 1987). Many modern cultivars contain some genes that are derived from a wild relative. Genes of CWR enhance the genetic diversity of crops, which is important for reducing the risk of large-scale production losses to pests, diseases and climatic factors such as drought. Examples of CWR used in crop improvement include *Solanum demissum* for resistance to late blight in potato (Ross 1986), *Arachis cardenasii* for resistance to root knot nematode, corn earworm and potato leafhopper in peanuts (Rao *et al*. 2003), and wild rice (*Oryza rufipogon*) for tolerance to high acidic-sulfate soils in Vietnam (Nguyen *et al*. 2003).

The threat of climate change to crop wild relatives

It is clear that the relatively modest climatic changes over the past century have had a significant influence on the distribution, abundance, phenology and physiology of a wide range of species. Many shifts of species distribution towards the poles or upwards in altitude have been recorded, with progressively earlier migrations and breeding (e.g. Parmesan and Yohe 2003). Even with a best-case scenario of ‘absolute’ migration, high habitat/climate tolerances and no competitive inhibitors, hundreds to thousands of species from biodiversity hotspots (areas that are home to a disproportionate number of the world’s species) face extinction (Malcolm *et al*. 2006).

While many CWR species will be adversely impacted by climate change, conservation actions targeting this group of economically important plants are rare. In a recent study, on wild *Arachis* (peanut), wild *Solanum*

[1] On 1 December 2006, the International Plant Genetic Resources Institute (IPGRI) was renamed Bioversity International.

(potato) and wild *Vigna* (cowpea) to predict current and future species distribution, Jarvis *et al*. (submitted). predicted that by 2055, 24-31 of 51 *Arachis* species, 8-13 of 107 *Solanum* species and 1-3 of 48 of *Vigna* species could become extinct. The study also projected that habitat patches will become more fragmented, exacerbating vulnerability to further erosion.

What can we do to conserve CWR in the face of climate change?

The loss of genetic material from CWR has profound implications for natural and agricultural ecosystems. It reduces the potential for crop improvement and adaptation to changing environmental conditions. It also impacts food security through declines in food and fodder production. To stem this loss, CWR must be better conserved and used to adapt agricultural systems to climate change. A simple conceptual model for conservation actions, which incorporates the aspects described below, is included as Figure 1.

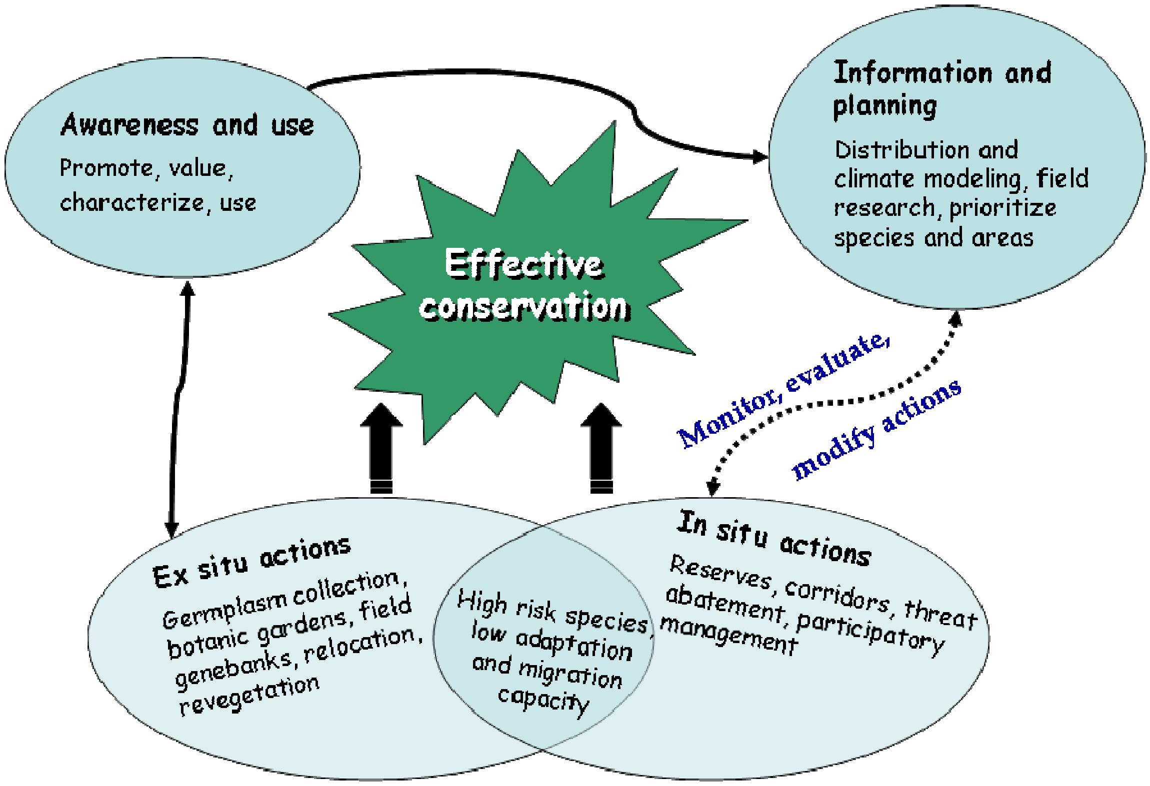

Fig. 1. Conceptual model for effective conservation of crop wild relatives considering the effects of climatic change.

Raise awareness of the importance of CWR

Recognition of a biological resource's commercial value tends to inspire efforts to conserve that resource. Concerted efforts are needed to raise awareness of the value of CWR at a local and global level. Botanical gardens have an important role to play in raising awareness and educating the public about the importance of CWR and climate change impacts.

Increase use of CWR

Seeds of many CWR have already been conserved in genebanks, but the world's genebanks are conserving only a fraction of the total genetic variability in CWR and relatively few accessions have been characterized for beneficial traits. Climate and species distribution models can be used to locate CWR populations with desirable traits for adaptation to changing climatic conditions.

In addition to their use in breeding, many CWR are used directly. A number of wild cowpea species in Africa contribute to food security through consumption of their tubers, fruit and seeds (Padulosi and Ng 1990). Wild yams (*Dioscorea* spp.) are an important source of carbohydrates and income in Madagascar (A. Lane pers. obs.), and wild fruits such as apple, pistachio and sea buckthorn are harvested for food in Central Asia and the Caucuses (Almaty 2003). CWR species also provide products such as animal fodder, building materials and medicines. Over-harvesting of some CWR from the wild is a threat to their persistence at a local level. This threat could be managed by developing the capacity of local communities to cultivate harvested species.

Improve knowledge of CWR status and the impacts of climate change

Understanding the impacts of climate variability on plant genetic resources is critical for planning effective conservation actions. Climate is one of the major factors governing the distribution of wild plant species (Woodward 1987), and models to project distribution under current and future climate conditions are commonly used. Some models are now incorporating species migration capacity and phenotypic plasticity, but it is not possible to account for all interactions that directly and indirectly affect a species. Although costly, combining modeling with field evaluations will result in more accurate predictions of the impacts of climate change on species distribution.

Plan for climate change

Alteration of ecosystem composition, structure and dynamics as a result of climate change must be considered when developing criteria for selecting new protected areas and managing existing ones. The combined effects of habitat fragmentation and climate change are serious issues for conservation (e.g. Young and Clarke 2000). Fragmentation creates barriers to migration and re-colonization; as habitat areas decrease, they become increasingly vulnerable.

Migration corridors

Areas preserved to connect landscape fragments – can facilitate range shifts of mobile species and expand the range of conservation.

Prioritize species and areas for conservation actions

Prioritization of species and areas would include criteria such as economic and social benefits, conservation status, viability of populations and economic feasibility for effective management. The genetic variability between populations of CWR is also important. Tolerance and resistance to disease are often traced to a small number of plants in a specific region, such as resistance to barley yellow dwarf virus originating in the highlands of Ethiopia, and resistance to Russian wheat aphid from Iran and neighboring countries (Nevo 1988). This highlights the importance of field-based research and conservation strategies that are area- and species-specific.

Species prioritized for conservation should include those that are rare or have narrow distributions, as they will suffer greater impacts than more common and widely distributed species. High risk of extinction is associated with narrow habitat/climate tolerances and shrinking distributions (Schwartz *et al*. 2006).

Areas selected for conservation should be evaluated for their potential as climate refugia for vulnerable species, sources of propagules for re-colonization and genes for ex-situ collections. Genetic reserves should contain target populations large enough to ensure persistence – the greater the number of individuals found in a given area, the greater the probability that the species will survive.

It is likely that climate change will result in species being lost from protected areas. Araujo *et al*. (2004) projected that 6-11% of 1,200 plants with European distribution could be lost from reserves in a 50-year period. For species with overlapping distributions, reserve networks could be identified to represent both current- and future-projected occurrences; for species with no overlap in distributions, new areas must be identified. These might include areas where the impacts of climate change are expected to be minimal and areas where new climates can provide habitats for emigrating species. Given that plant populations tend to migrate to higher altitudes, (e.g. Parmesan and Yohe 2003), establishing protected areas in mountainous zones may be a priority.

Relocate

Relocation of populations to areas with favorable climate might also be an option. Relocation of sedentary species has an especially important role in ensuring that species and gene pools are not irretrievably lost. Botanic gardens could play a key research role here by distributing germplasm to various gardens around the world and monitoring success of species establishment. By combining in-situ conservation with strategic restoration such as linking corridors between conservation areas, conservation can be more effective.

Collect vulnerable species and populations (ex-situ conservation)

Regardless of in-situ conservation efforts, some species may not migrate or adapt to climate change. For these species, ex-situ strategies are required. Ex-situ options include conservation in genebanks and establishment as living collections. Botanic gardens could provide a viable alternative for species that are threatened by climate change and for which in-situ conservation is not an option.

Monitor vegetation change

Vegetation monitoring is used to detect and predict changes in species composition and plant migrations caused by habitat degradation, pests and fires as well as climate change. Monitoring species over successive years provides a baseline for the detection of climate-induced vegetation changes (Stohlgren *et al*. 2000). Indicator species – those sensitive to environmental changes and which occur in restricted habitats within elevation and moisture envelopes – should be monitored in addition to CWR populations that occur more frequently.

Acknowledgements

This publication was supported by the UNEP/GEF project "In-situ conservation of crop wild relatives through enhanced information management and field application". Thanks to Toby Hodgkin who reviewed an earlier draft and to Hope Traficanti for editing the publication.

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