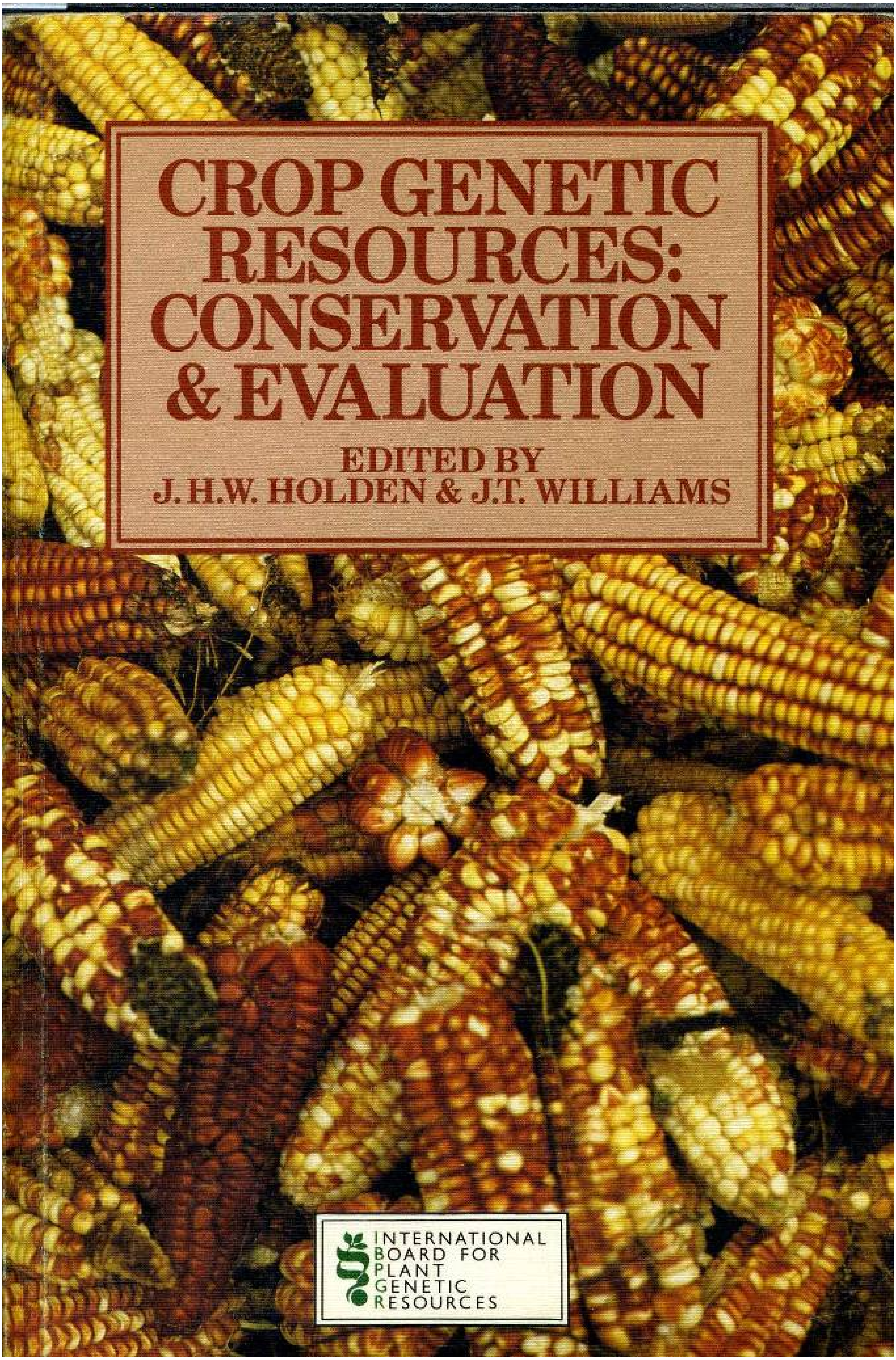
CROP GENETIC RESOURCES: CONSERVATION & EVALUATION

EDITED BY
J.H.W. HOLDEN & J.T. WILLIAMS



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CROP GENETIC RESOURCES: CONSERVATION & EVALUATION

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Contents

12 *In situ* conservation of wild relatives of crops

G. B. INGRAM and J. T. WILLIAMS

Introduction

In situ conservation methods are those that maintain germplasm in wild populations by paying due regard to the natural ecosystems of which the conserved populations are a part. In particular, this method of conservation is of significance to the wild relatives of crops that can be used in plant breeding. This topic is of growing interest to a number of fields of science including crop genetics, conservation biology and environmental planning, as well as to national and international policy makers.

In virtually every part of the world, there are wildland protection projects purporting to provide *in situ* conservation of wild relatives of crop plants. These have arisen largely because of the active concern of scientists involved in plant genetics and breeding, and of others in environmental planning and management. Through the increased awareness of potential social benefits to be derived from the maintenance of genetic diversity and because for a number of crops, especially vegetatively propagated tropical species where there are limitations on the effectiveness of *ex situ* methods of conservation, *in situ* preservation of ancestral species has become a stated international priority. It is therefore necessary to consider the scientific principles on which strategies for *in situ* conservation should be based, the techniques that can be employed to implement these strategies and the relationship of reserves as adjuncts to and complements of the conservation activities for crop genetic resources that are already underway.

Problems obviously arise when a conservation topic becomes fashionable. It is difficult to cut through the emotive generalisations, and often unfounded optimism, to identify what precisely needs to be done to conserve resources that are under threat of extinction, when funding is strictly limited. Specific conservation objectives and their translation into practice to ensure maintenance of genetic diversity of particular species in specific sites are too often defeated by inadequate formulation and by poor implementation of plans. Species preserved in their natural habitats have the potential for continued evolution. However, conservation of ecosystems and biomes does not ensure continuing adaptive change unless the genetic base of the species is sufficiently wide (Frankel 1970). It is the opinion of the authors that the maintenance of continued adaptive evolution and of intraspecific genetic diversity are inadequately considered by the majority of the *in situ* programmes that are presently in operation; nor have the long-term effects been considered in terms of population structure. These failings are a consequence of poor understanding between conservation biologists primarily interested in rare or threatened species, environmental planners concerned with preservation of the ecosystem and crop geneticists occupied with the practical utilisation of germplasm. In general therefore there is a poor comprehension of the nature of the resource and of the requirements for its maintenance: financial support of both basic research and applied programmes has not necessarily been the limiting factor on success to date.

We must pose a difficult question: if changes in land use and pressures from development projects – both of which destroy habitats – continue to intensify (and all indications are that they will), can the current or even expanded global efforts for *in situ* conservation succeed in conserving wild species relatives of the world's major food and industrial crops? This is clearly an area for urgent concern and major policy decisions.

With the type of information currently available, it would be dishonest to pretend to be able to answer the question posed, but it is clear that success in *in situ* conservation requires a more clearly defined scientific basis to policy decisions. The rest of this chapter attempts to identify the deficiencies in our understanding that must be overcome if we are to develop successful *in situ* programmes. Current practices, often of dubious scientific validity, are reviewed, and possible standards that may be appropriate for particular wild crop relatives are discussed.

Consideration of the ways and means of maintaining crop relatives in the wild comes at a time when there is increasing interest and concern on a world scale for the security and availability of this natural resource. The care, given by the IBPGR to the safeguarding of materials, *ex situ*, over the past decade of its operations (see Williams, Ch. 1 of this volume) must now be translated into similar effective protection of germplasm, of a limited number of species, *in situ*, and into ensuring the availability of access to these materials for use in crop improvement. Such actions are now an international obligation and it remains for this to be translated into accepted responsibility and effective action.

New developments in *in situ* conservation must not detract from the overwhelming need for more effective *ex situ* conservation programmes for crop species. Most seed-propagated staple food crops such as rice, maize, wheat, legumes and vegetables must be conserved *ex situ* simply because *in situ* preservation of landraces and old varieties would require a return to or the preservation of microcosms of primitive agricultural systems, which is of course unacceptable and impracticable. In any case, the majority of such landraces have long since been lost. The crops of immediate interest for *in situ* conservation are the perennials that are vegetatively propagated (Hawkes 1975) and those with seed that cannot survive cold storage (King & Roberts 1979, Hawkes 1982, see Hanson, Ch. 4, and de Langhe, Ch. 9 of this volume). Even so, *in situ* methods will be adjuncts to rapidly developing *in vitro* systems. It is the wild relatives of the perennial vegetatively propagated species, and in several cases seed-producing forages, that justify *in situ* conservation, and this is a very limited part of the total spectrum of crop genetic resources. In the case of a number of vegetatively propagated species of which it is possible to store the seeds (e.g. *Citrus*, apple, potato, sweet potato, sugarcane, etc.), man's responsibility to posterity is probably to store sufficient seeds to preserve the maximum genetic diversity rather than to concentrate on the conservation of particular gene combinations in the form of clones. It is only when seeds are short-lived that there is an overriding need for *in situ* conservation as the primary method of conservation, otherwise it should be seen as one of several complementary procedures.

The resource

For most crops, there are related wild and weedy species which, along with the cultivars old and new, form a genepool which may be exploited to create new crop varieties. Using the terminology of Harlan and deWet (1971), the related species can be regarded as forming primary, secondary and tertiary genepools. Wild species in the primary pool can produce fertile hybrids with cultivars, but those in the secondary field contribute germplasm less easily. The tertiary pool is only available to some crops for a limited number of genetic traits. A cursory examination of the list of global and regional priorities of food and industrial crops of the IBPGR (1981) suggests that the wild relatives could well number several hundred species.

Patterns of evolution and domestication of annual seed crops have in general resulted from selection pressures imposed by sowing and harvesting cycles. Weeds also evolved in such man-made habitats and hybridisation and introgression between cultivars, and related weedy and wild forms in the centres of diversity, is a part of the pattern of variability. Of course, the rate and scale of adaptive change varies widely between crops: for example it is very marked in the cereals, but less so in the perennial tree fruits. It is important to understand the types of population structure that have arisen from the patterns of diversity in the wild species. For instance, there may be small related populations reproductively isolated from one another *sensu* Mayr (1954), large isolated populations and other populations that overlap in their distributions and exchange genes through their points of contact.

An understanding of the patterns of distribution and diversity of the wild relatives of each crop is essential for the formulation of strategies for their conservation. For instance, part of the wild rice genepool, the perennial *Oryza rufipogon*, is pantropical and comprises numerous populations some exhibiting evidence of hybridity with annuals and cultivars (Ogbe & Williams 1978). If this species is to be conserved as *in situ* populations, where should the genetic reserves be sited bearing in mind the great distribution range? Mango provides a contrasting example where the wild species have a wide continental distribution but characteristically have two centres of diversity in Kalimantan and Burma where the species cluster. Which populations should be preserved, when some species will be of value in breeding and others will be useful as rootstocks, and bearing in mind that todays value judgements may be inappropriate at the end of the century? These considerations, which raise their own serious problems, arise from a need to assign priorities and make choices since it is perfectly clear that it is not possible to conserve all diversity. Another useful example is provided by the wheat genepool. This could be as narrow as *Triticum* and *Aegilops* (which could anyway be equally well conserved *ex situ*) or as broad as the Triticeae including wild *Agropyron* and *Haynaldia*. Thus, for the purposes of conservation of germplasm for use in crop enhancement, it is not possible to consider the resources in purely biological terms and to apply necessarily the general approaches of nature conservation. Each group of wild relatives of a crop must be initially assessed for potential value as germplasm for crop improvements before a strategy can be developed for maintaining genetic diversity in relation to that crop. These examples reveal some of the major dilemmas facing those who would conserve wild relatives of crops. Because of rapid changes in agricultural systems, and in the potential for manipulative changes in applied crop genetics, the long-term usefulness of *all* genetic diversity is quite impossible to determine at any one time.

Nevertheless, it is necessary to identify those aspects of variation that are of value to agriculture. Examples of crop plant characteristics to which wild relatives have in the past, and could in the future, contribute useful genetic variation are: (a) increasing yield; (b) increased disease resistances, both qualitative and quantitative (Watson 1970); (c) improvements in growth patterns and growth rates; (d) wider adaptability to environmental conditions for extending the range of crops (Harlan 1976); (e) adaptation to changing agricultural practices such as harvesting technologies, which increase options leading to more economically viable and socially appropriate agricultural development; and (f) improved nutritional quality.

Of course in recent years, with the advent of protoplast fusion and other genetic manipulations, germplasm from distantly related species may be utilised in crop breeding. In this sense, all biological diversity may be regarded as useful, but next to primitive cultivated forms, wild relatives will usually provide the most useful and readily exploitable variation for use in breeding.

Wild crop relatives can have value to humanity other than by simply providing germplasm for breeding. These species are part of natural landscapes that produce food and materials of local significance. Furthermore, the world's dwindling natural areas hold other categories of useful plants that provide socially valuable products for forage, fuel, shelter, fibre, horticulture and landscape amenity. Fuller use and better conservation of this wealth of genetic variability can lead to more sustainable forms of rural development (Roche 1978). In many cases, natural areas provide additional but indirect benefits through environmental stabilisation, watershed maintenance and wildlife habitats.

These are two aspects of *ex situ* conservation in genebanks that may make it desirable to ensure indefinite maintenance of some wild populations of most crops. Seed storage can act as a differential selection factor in that seed characteristics that confer decreased survival rates and characters associated with them can be selected against in cold storage (Abdalla & Roberts 1968). Subsequent research has tended to confirm the operation of other subtle and non-random influences. One possible solution to damage arising from long-term storage is more frequent regeneration. However, this in turn can exert different but strong selection pressures on seedling survival and reproductive output. It is also one of the most expensive, time-consuming (especially for perennials) and least easily manageable aspects of *ex situ* operations. As we shall see, *in situ* conservation involves its own set of risks and difficulties, but can function as an added 'evolutionary insurance' for long-term germplasm availability.

The second concern that makes maintenance of wild populations important to any conservation effort is the great difficulty of adequately sampling wild populations for *ex situ* storage in genebanks. Collectors can only sample a small portion of the total variation of species (Marshall & Brown 1975), and gaps in intraspecific variability in genebanks can be complemented by a continuing presence in the wild which may be resampled for the filling of gaps at a later date.

Diversity in wild relatives

The concept of 'biological diversity', is defined as 'the variety of life forms, the ecological roles they perform and the genetic diversity they contain' (Wilcox 1984). The concept of genetic diversity has been variously applied to several aspects of natural systems. As a result there is a certain confusion in its application to biological conservation. For instance, Schonewald-Cox (1983) noted that the term can be used to mean (a) species diversity (b) allelic diversity (c) allelic frequency differences between individuals within populations and between populations and (d) a combination of species diversity with allelic variations.

In the last decade the assessment and conservation of genetic diversity in ecosystems has largely been in the form of the maintenance of species diversity. At this level, the concept is based on taxonomic patterns, which are inadequate as a foundation for both the maintenance of germplasm (which is useful for plant breeding) and for long-term survival of species (Frankel & Soulé 1981). In contrast, the maintenance of allelic diversity, the preoccupation of geneticists, is most effective when the species is in a state of stable equilibrium with its environment. The conclusion is that both species diversity and allelic diversity are important in the conservation of wild relatives of crops in ecosystems.

When considering the distribution of the broad array of species currently maintained in the wild state, and which include those that have potential value for future crop improvement, two characteristic but contrasting distribution patterns may be defined. In one, distribution is limited to ecosystems within the centres of origin of the crop. These are regions with long histories of human occupation and associated agriculture. In many cases there has been continuing evolution of the species, or a group of species, through occasional hybridisations, long periods of introgression and frequent development of weedy races. This is characteristic of many annual seed crops such as sorghum, pearl millet, chickpea and lentil. In the other type, wild forms are found in those areas where cultivation and evolution in primitive agricultural systems were first established but which have been superseded by agricultural development elsewhere. *Vitis* is an excellent example with wild species of potential value being distributed through the Americas, from the Caribbean to Peru, and from the Near-East eastwards to northern China. Eggplant also fits into this category with its evolution under domestication in South Asia and its species diversity in Africa.

There are a number of biogeographical factors that influence plant species and intraspecific diversity which should be considered in discussions on how to locate valuable associations of wild plants and to propose areas for genetic reserves:

(a) None of the major food crops and their progenitors are associated with climax vegetation (Jain 1975), but a number of other crops with priority for genetic conservation are (e.g. rubber, tropical fruits, and some root and tuber crops). A genus may well include some species that are dependent on very narrow ranges of disturbance, such as particular ecozones of fire-dependent vegetation, and other species that can only survive in extremely stable rain forest environments.

(b) Species diversity is often highest in stable heterogeneous associations such as tropical moist forests. Although it is clear that the largest numbers of plant species are in the humid tropics, the factors that generate speciation and that influence allelic and ecotypic variation differ greatly between sites, regions and populations. There is a rough correlation between simple numbers of species or alpha diversity (Whittaker 1972, Peet 1974) and the size of geographic 'isolates' (Wilcox 1980). Small isolates such as islands generally have smaller total numbers of species than larger complexes of habitats (Johnson *et al.* 1968). However, the question of whether the determining factor is area or the increased habitat diversity that is afforded by larger tracts is the source of vigorous and continuing scientific debate. The natural distribution of particular plant species can vary from extreme localisation to dispersion over vast transcontinental areas. There are distributions that are limited by topographic features, those that are scattered in numerous isolated populations (Allendorf 1983) and those that function as single interbreeding populations over large areas.

(c) Allelic variability can vary within and between populations. The accumulation of mutants increases with population size, hence larger populations tend towards greater variability (Connel & Orias 1964). Chambers (1983) notes the importance of ecotypic factors in maintaining diversity, whereas Hamrick (1983) warns that geographic range as the primary basis for the delineation of diversity is 'unacceptable'.

(d) The densities of wild species can vary from dense stands to widely separated individuals.

(e) Concepts of centres of diversity of wild relatives have been derived from studies on the origin, diversity and spread of domesticates. Too often the literature urging conservation *in situ* of these relatives has limited its proposals to the classical Vavilovian centres. There is a misconception that a few prime *in situ* areas within these Vavilovian centres will adequately conserve the potential genotypes for future crop improvement. As discussed above, strategies must be related to the characteristics of particular species and areas. Genetic variation from marginal or outlying populations can be as useful as that from centres of diversity. Consequently, crop scientists should encourage *in situ* conservation of wild relatives in many areas other than the classical Vavilovian centres.

Loss of genetic variability

Loss of diversity through destruction of species has often been inappropriately called 'genetic erosion' by direct analogy with that occurring in the primitive populations of domesticates. Ideally the total genepools should be preserved but this is of course an impossible task and attention by the agriculturists is rightly addressed to those wild species that have been involved in the evolutionary divergence of the domesticates and to others in which scientific knowledge can hint at potential for utilisation in the future. From a crop genetic resources point of view, preservation without prospects of utilisation is a non-starter. For some of these endangered plant species for which there is no discernible prospect of utilisation, 'non-resource' rationales (Ehrenfeld 1976) are best employed without invoking the highly speculative needs of breeders or adducing unreal economic advantages.

The reliable information that is currently available on the destruction of wildlands by modern land use development is largely orientated to the national and biome scale. From the rather imprecise data available, authors such as Myers (1980, 1981) make extremely rough but dramatic predictions, such as the loss of one million species by the year 2000. However, predicted

trends rarely match reality and many fewer species could become extinct though it is impossible to anticipate. Indeed there will not be time for proper taxonomic definition of these species, not to mention germplasm collecting, and most will be destroyed without us being aware, and some undoubtedly will be crop relatives.

The species lost may represent larger or smaller portions of the broader genepool of crop relatives. Their demise will represent lost opportunites for social and economic development (notably for plant breeding) and lost 'services' from the ecosystems of which they are part. Complementary to the natural processes of evolutionary extinction, new species and patterns of variability will evolve. However, this is a very slow process and even the most optimistic view suggests that the evolutionary lag that follows impoverishment will continue for millenia.

Our understanding of the loss of intraspecific and population variability and of its implications are even more incomplete than of losses at the species level. Although a substantial portion of wild species related to crops may be expected to survive into the 21st century, for most, drastic changes can be expected in distributions and ranges of adaptive genotypes. Thus the long-term survival prospects for many wild species related to crops are precarious. Extinction of a portion of ecotypic variation of crop relatives could represent the loss of valuable genetic complexes to future plant breeding, but if the larger part of the allelic variation survived, reassembly of desired genetic associations would be possible through breeding and selection. At present, there is no method of monitoring this fine level of genetic diversity in field populations, nor is there likely to be in a general way. Isolated research studies which serve as models are as much as can reasonably be hoped for.

A major gap in our knowledge of *in situ* conservation is the lack of taxonomic treatments of many genera containing domesticates and their related species, coupled with a lack of data on their ecology. This gap is particularly pronounced in the humid tropics which hold a large portion, perhaps as high as 40 per cent, of the world total number of plant species (Jain & Sastry 1981). The lack of adequate data has led the IBPGR to stress the need for more detailed field surveys of ecogeographical and also epidemiological characteristics of these genera. Such ecogeographical data on taxa would be a help in defining conservation needs.

Studies on population genetics show that, for outbreeding species, populations are in a state of genetic flux. The frequency of an allele in a population has a sampling variance related to population size; a gene frequency can drift up or down from generation to generation and, if population size varies between generations, there are genetic consequences of loss or of fixation of alleles especially if there are major habitat disturbances. Thus it is important to recognise that marked variation in population size and allelic frequencies are often normal features of normal viable populations.

Information on the breeding systems of individual species is critical. Along with much imperfectly understood taxonomy we know little about factors that govern reproduction and the mating system in, for example, wild relatives of tropical fruits or other crops derived from the tropical forests, and national planning of *in situ* conservation for these species is not possible in the absence of information on these important aspects of reproductive biology.

Component operations of *in situ* conservation

In situ conservation planning should involve a diverse range of activities centred on the plant populations in the designated habitats such as taxonomic studies, ecogeographical surveys, regional environmental analysis, formulation of practical conservation objectives, delimitation of sites, on-going monitoring of conserved populations, the policing of boundaries to ensure security, and educational and propaganda activities among neighbouring farmers and graziers to explain purposes and seek co-operation. The co-ordination of these interrelated activities is a major task in the successful implementation of conservation objectives.

Until other methods are widely available, taxonomic categories must be used for assessing and describing diversity in wild species that are to be conserved. However, the classical taxonomic dilemmas of lumping or splitting can have important practical consequences in conservation. For example, a plant may be distributed across a region in substantial numbers. If the assemblage of variable forms is regarded as a single species, its future may seem secure. If, on the other hand, different components of the variable range have been accorded specific status, some may appear, because of low numbers, to be in imminent danger of extinction and therefore in need of conservation.

Distributions of species (and populations) can be mapped along with environmental and ecological gradients (Ashton 1981) so that population densities and distributions can be related to them. Periodic monitoring of species densities will be necessary to assess the survival of target species under pressure from agricultural or social change.

When promising sites have been identified, criteria for the design of reserves can be applied and the assignment of priorities must take into account the biotic and abiotic factors that maintain the populations (Radford *et al.* 1981). Decisions on minimum viable populations (Shaffer 1981) and minimum habitat area (Wilcox 1984) must be made. There are a number of approaches to identifying the most appropriate ecosystem and landscape units in which to conserve target populations. However, few are quantitative and fewer still consider intraspecific diversity. Most, such as Prance's (1976) criteria for preserves in the Amazon Basin, are orientated to locating areas with highest species diversity. Although such areas are significant for particular purposes, others with lower species diversity, but with substantial genotypic diversity or simply with a useful species or population, may be equally or more desirable for *in situ* conservation for the purposes of germplasm utilisation.

When a first list of possible sites has been produced, a second-stage analysis will be necessary for criteria such as (a) accessibility for collecting, (b) acquisition costs, (c) security, (d) management requirements and (e) impacts from current and projected land uses and compatibility with regional development plans and other wildlife conservation projects. Genetic reserves are to be preferred when part of larger protected nature reserves.

Having considered these factors, it should then be possible to identify potential boundaries of reserves. Designs of reserves, especially of their area and shape, have been the subject of heated debate for nearly a decade. The focus has been on two issues: the validity of theories for predicting species loss, over time, in fragments of natural landscapes (often referred to as 'island biogeography') and the comparative advantages and disadvantages of large contiguous reserves and combinations of smaller natural areas (Diamond 1975, Higgs 1981, Simberloff & Abele 1982, Margules *et al.* 1982). It should be noted that nearly all of the data on which these ideas of supposedly general applicability are based, are derived from vertebrates and, in particular, birds. Survival requirements of plant species have largely been ignored. Scientific understanding of how species are actually affected by insularity, and the application of this knowledge to the definition of minimum reserve size, has only recently begun to emerge (Gilbert 1980, Lovejoy & Oren 1981). The task of defining minimum area for particular species, which is linked to minimum viable population size (Wilcox 1982), is a central and essential preliminary to site planning in *in situ* programmes.

The choice of sites for wild plant conservation is not simply a matter of size. Land use in surrounding areas can have a major influence on the ecology of the conservation site and on the type of management that will be necessary for maintenance of natural ecosystems. Management factors can be divided into two categories. Preventative measures, such as legal limitations on destructive logging practices, or on the use of potentially invasive livestock or plants, and management factors, which are activities that minimise destructive and illegal acts such as tree cutting or unauthorised grazing after a reserve has been established (Pyle 1980).

Of course, the application of legal and management controls requires political will, financial support, organisational infrastructure and trained personnel, and these are often lacking in parts of the world where conservation is most needed. Some of these deficiencies in administrative resources can be off-set by allocation of larger areas where the additional size of the reserve may act as a safety factor.

Whatever the strategy to be adopted for the conservation of the wild crop relatives, it should be compatible with regional development and other wildland conservation objectives (Thelen and Child 1984). This is important because genetic reserves, as part of larger protected natural areas, are often most efficient in the use of land and personnel. The concept of the 'reserve cluster', which originated with efforts to establish and manage biosphere reserves (IUCN 1979), is highly relevant to *in situ* conservation of germplasm. Often, a complex of various categories of protected natural areas (McNeely & Miller 1983), some of which are concerned with conservation of wild relatives of crops, can act as a sufficiently large spatial unit to minimise the impact of landscape fragmentation and consequent 'ecological disintegration' (Soulé 1983). However, networks of smaller, more isolated preserves such as the 'virgin jungle reserves' of Malaysia, can provide critical protection for genetic variability scattered over large areas, as well as for local endemic species. Aternatively, reserves that are established in areas of significance to crop genetics can act as nuclei around which clusters of protected natural areas, with various complementary wildland conservation objectives, can be built.

When conserving biota, there is always the question of 'desired diversity' (Namkoong 1983). Such a concern should run through all phases of *in situ* operations, especially in the formulation of objectives and in the design of reserves. Although long-term species survival is always the underlying objective, the tactics necessary for maintenance of intraspecific diversity are not so clear. One general principle is that populations must possess sufficient numbers and genetic heterozygosity to permit adaptive responses to changing environments (Frankel & Soulé 1981).

Continuous, though perhaps intermittent, monitoring of genetic reserves is essential to the maintenance and use of the germplasm they contain. Davy and Jefferies (1981) outline approaches to monitoring rare plant populations. Demographic methods can be employed to ascertain gross numbers and aggregations but other approaches will be necessary for testing whether variability within populations is being maintained.

A number of constraints have to be considered. Land can be expensive to acquire, although most of the *in situ* efforts in the world today are on public lands. Regulations for the control of reserves should be framed in such a way that sensible non-destructive collecting of germplasm is not prevented. The legal intricacies of gaining and maintaining access to genetic resources on private or communal lands can be formidable and need due consideration.

Security is another constraint. The mammoth issues of legal enforcement and social acceptance in land management for *in situ* conservation have to be faced. Examples of the successful maintenance of germplasm within preserves are to be found in developed countries such as those of North America and the Soviet Union, where there is enough funding to have permanent workers on-site who act as wardens, and in cases where modern conservation needs have been integrated into traditional cultural and land use patterns (Gadgi 1984). However, for many parts of the world with valuable species, the social climate for nature conservation is either unfavourable or positively hostile, and it is of the greatest importance to adopt a realistic point of view on this regrettable but understandable attitude.

Discussion

Of the total global effort for conserving wild plant diversity only a small portion has involved *ex situ* efforts. This has been limited to species related to crops of high economic value that can be successfully and easily preserved as seed in genebanks. Most wild plant genetic diversity has not been considered sufficiently important to human welfare to merit such intensive conservation. Instead, its survival has been dependent on the survival of the remaining wildlands. However, as more ecosystems are destroyed and as the survival of valuable species is jeopardised, *ex situ* methods as primary means of conservation for some wild species are inevitable.

In recent years the technology for *ex situ* conservation has changed rapidly. Whereas a decade ago only seed-propagated species could be considered, *in vitro* techniques for vegetatively propagated species are being developed following the leadership of the *In Vitro* Committee of IBPGR (IBPGR 1983, 1984a). Additionally, this Committee has stressed that intensive field work is necessary to identify patterns of variability, and this could involve the development of rapid screening methods using biochemical characterisation. Using the results of these studies on variability, there should be a planned build-up of *ex situ* field genebanks (clonal repositories, living collections, plantations, orchards etc.), and these active collections should be maintained also as *in vitro* active genebanks and as long-term genebanks using cryopreservation. It is important to stress that the *In Vitro* Committee of IBPGR assessed many field genebanks and found that they had been built up with little attempt to include a representative sample of genetic variability. In fact many are breeders' collections often built up in a fortuitous way. In many cases the reason for preserving them is historical sentiment or current usefulness in breeding, and not genetic conservation *per se*. Continued research into techniques of cryopreservation and *in vitro* culture, which are not genotype specific – many current techniques work only for a limited range of cultivars – will reduce the need for *in situ* conservation until it occupies a position as one of a series of optional complementary methods of conservation.

In an era of accelerating losses of biological diversity, the question is not whether the need for *ex situ* conservation is greater or less than that for *in situ* conservation, but rather how both may be used to best advantage to ensure both long-term species survival and an adequate supply of germplasm for improvement of related crops. It is clear that *in situ* conservation of particular crops and their wild relatives results, at present, more from *ad hoc* unco-ordinated efforts than from analysis and planning. Although policy commitments for *in situ* conservation may at last be increasing (despite this having been identified as an urgent need for more than a decade by crop geneticists), a scientific basis for action on particular species in specific environments has been lacking.

One of Tisdell's (1983) major points in his critique of the World Conservation Strategy is that although it proposes a combination of *in situ* and *ex-situ* protection, the question of costs, a major determinant in developing conservation programmes, is not considered. Increasingly, the protection of wild relatives of crops is used as an important reason for the designation of more protected natural areas. Although the world needs to conserve more of its wildlands than it does at present, and although a global network of reserves that include wild relatives of crops is an imperative, clarity of thought in planning is essential to effective action. Consequently, a rational approach to germplasm conservation methods has to be proposed.

An essential first step will be the definition of criteria for the *in situ* conservation of wild relatives of crops. They must include the following:

(a) The global and regional priorities of the crop accorded by the IBPGR (1981). These are derived from a consideration of a number of factors including assessments of genetic erosion, socio-economic importance, current status of *ex situ* conservation and requirements of breeders.
(b) Adequacy of existing *ex situ*, and in some cases *in situ*, conservation.
(c) For clonal species and some others such as cacao and coconut the degree of development of *in vitro* methods, especially cryopreservation, and the expectancy that ongoing or proposed research will provide the necessary technology.
(d) Assessment of degree of land use changes in the areas of distribution of the species.

Although these criteria were not then defined they were inherent in the wish of the IBPGR to consolidate existing information when in 1979 it commissioned from IUCN a report on the significance of wild relatives of crops (Prescott-Allen and Prescott-Allen 1981). The matter was discussed at an FAO/UNEP/IBPGR Technical Conference in 1981. As a result, recommendations were made for an *ad hoc* group representing all agencies to discuss the matter further. This has not taken place nor, to date, have substantive improvements for conservation of wild relatives of crops in international programmes resulted. *In situ* conservation may be advancing more quickly at national levels, but no evidence that this is so is available to the authors.

The following categories of networks of genetic reserves need to be expanded in the coming decade. Three of these involve international responsibility:

(a) Biosphere reserves as part of Unesco's 'Man and the Biosphere' programme include reserves and natural parks in which many wild relatives are present. For example, in areas of the Near-East and other cradles of agriculture, as well as in regions with relic climatic climax vegetation. Expansion of this network along with more intensive research on target populations, and the organisation of data in data bases to facilitate germplasm utilisation, would go a long way to fulfilling the recommendations made by the IBPGR Regional Committee for Southeast Asia (Williams et al. 1975), by Brezhnev (1975) concerning reserves for *Prunus*, fodder grasses and wheat in the Caucasus, and by numerous others. Germplasm of major crops that could be conserved in this way include coconut, *Cacao*, cassava, taro, *Artocarpus*, banana, *Citrus* and many other tropical and temperate fruits.

(b) Special-purpose reserves should be established or expanded for screening and mapping of disease resistances in the areas where important diseases are endemic.

(c) There are other networks of *in situ* conservation sites, often regionally or nationally orientated, such as ecological reserves specifically for the conservation of endangered species and ecosystems. In some cases these would coincide with those in category (a), but where they do not and cannot adequately include the full range of variability of target species, special reserves are needed (see IBPGR 1984b, for rubber). Such reserves could be of value for wild species of sugarcane, for perennial rice, wild groundnut in the four centres of Krapovickas, coffee, and the *Corollinae* relatives of beet.

(d) Specially designed networks of reserves for widely distributed genera where diversity in wild species is not fully understood such as *Dioscorea*, *Vitis* and *Allium*. Harlan (1976) notes that a primary limiting factor in the use of genetic material from wild relatives is its unavailability. A network of well-documented reserves could stimulate use of, for example, *Vitis* germplasm for crop enhancement, and this success could in turn stimulate demand for *in situ* conservation of other wild crop relatives.

In addition to wild relatives of crops that are of international significance, there are others of regional interest such as peach palm and *Passiflora* in Central and South America, *Durio* spp. in Southeast Asia, *Pandanus* spp. in the Pacific and numerous others.

Having commented on minor species we should mention the wild species that appear to have potential for development as new crops, since much has been written on this subject in recent years. Some have been subjects of well funded research efforts, without so far achieving any significant success. In policy discussions for *in situ* conservation it would be wise to leave our evolutionary options open and it would be prudent to attempt to conserve a number of them. The problem is which? Although many show potential (Creech 1963, Ritchie 1979) we should remember that ultimate success will be determined by market forces and it should be recalled that only three major crops have been domesticated and exploited in recent times: sugarbeet, rubber and oil palm. Market forces may well permit exploitation of new species for novel high value products such as complex organic molecules of value in the pharmaceutical, cosmetic or insecticide industries. Scientific expertise for the rapid remodelling of wild species is readily available; the questions attached to such enterprises usually concern their economic viability.

It seems unrealistic therefore to suppose that conservation of species of unproven potential will occur when more pressing needs can be readily discerned in ancestral forms of major crops.

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