IN SITU CONSERVATION OF GENETIC RESOURCES
OF PLANTS: THE SCIENTIFIC AND
TECHNICAL BASE

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
# In Situ Conservation of Genetic Resources of Plants: The Scientific and Technical Basis

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Environmental management

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Monitoring of genetic reserves and wild populations
Development of a data base on in situ conservation
Dissemination of information
Education
Coordination at international level

REFERENCES
1. **INTRODUCTION**

This paper deals with genetic resources of plants and their conservation in protected natural areas. On site or in situ maintenance of the genetic variability of flora has been carried out, often informally or unintentionally, since first utilization of species and sites. In the last one hundred years and particularly within the last two decades, many programmes throughout the world have been initiated to protect species, ecosystems and natural landscapes from detrimental influences of changing land use practices. Concurrently, the usefulness of genetic resources of wild plant species, particularly intra-specific variability has been increasingly realized. Such resources are often a key to improvement of cultivated plants, just as wild species are a key to further plant domestications. Employment of in situ methods for the maintenance of genetic resources of wild plants is an important component of conservation of gene pools. The purposes of this paper are to outline the scientific and technical basis for use of on site conservation of phylogenetic resources and to make proposals for expanded international programmes in this field.

Before possible initiatives can be considered, three issues must be clarified: scientific principles for the use of genetic variability of wild plants; minimum standards conservation; and current programmes on genetic reserves. It will then be possible to consider three questions. The first is whether the present pattern of in situ conservation programmes is adequate for current needs; the second concerns the increasing demands for maintenance of and access to genetic resources of wild plants; and the third deals with present efforts for in situ conservation and possibilities of satisfying projected future needs.

**Definitions**

The definition of "genetic resources of wild plants" is a key factor, which will determine the scope of the discussion on why and how reproductive material and populations are conserved. **Genetic diversity** is a loose term and has been used to refer to species diversity; allelic diversity; allele frequency differences between individuals within populations and between populations; and combinations of species and allele diversity (Schonewald-Cox 1983). It is this fourth and broadest category that will be used in this paper. The heritable traits that are represented can be transmitted by reproductive material, also referred to as **germplasm**. When germplasm can be used for plant domestication or improvement, the variability found in the original material is considered a **plant genetic resource**. Additionally, in a broader sense, any genetic variability of beneficial species is an
unacknowledged or potential genetic resource. If the source of germplasm is a wild species, then the ecosystems that sustain individuals and populations form part of the phytogenetic resources.

It is important to differentiate whether a genetic resource is of actual or potential value. An actual genetic resource is the intra-specific variability of a plant that is currently utilised for human needs and that of other species which are or can be used for improvement of that plant and which therefore shares its gene pool. A potential genetic resource is the variability which may be able to contribute to a given gene pool with improved techniques; it also includes species that are not presently utilized but which may be in the future. In theory, any plant could be a genetic resource, and a potential resource is ultimately defined by our degree of optimism about expanding scientific capabilities; our definition of actual genetic resources on the other hand, reflect current levels of demand, interest and depth of research on particular wild and domesticated species.

A wild plant regenerates without direct human intervention. This includes species that cannot survive the ecological impacts caused by land use changes, species which are not directly affected by such ecological disturbance and "weedy" species which can actually benefit from it (Harlan 1983). It should be stressed that while this definition applies to survival of populations and species, it does not preclude the infusion of genetic traits of cultivated species into adjacent wild populations in the same gene pool. Such hybrid swarms can produce high levels of often very useful genetic variation.

Conservation of a resource is best defined as the actions and policies that assure its continued availability and existence. There are three dimensions to phytogenetic conservation: quantity, quality and time. Quantity refers to population numbers and the related amount of germplasm that is available for utilisation. Quality reflects both allelic composition and distribution within a population.

In preservation, the aim is to maintain all alleles and certain patterns of allelic distribution (including zygosity). Adaptive approaches aim at maintaining the portion of total allelic diversity that is thought to be necessary for assuring the capacity of a species or population to adapt to changes in the environment, as well as for projected needs for germplasm. Both adaptive and preservationist approaches, involve continuous evolution. Preservation suggests that loss of allelic diversity from land use changes, which are non-evolutionary, should be minimized; while adaptation is largely
concerned with maintaining traits which seem to best suit species for 
dynamically changing environments. The two are not exclusive though they 
may impose different management requirements. "The time scale of concern" 
(Frankel and Soule 1981) is the period over which conservation activities 
are projected and ranges from short-term practical utilization to long-
term "evolutionary responsibility" (Frankel and Soule 1981). Both approa-
ches are legitimate and, to a large extent, compatible. However, they 
derive from different, equally important, social needs. Wild plant variation 
must be conserved so that it can be utilized for socio-economic development 
in the ensuing decades. It must also be conserved as part of the larger 
effort to minimize destruction of biological diversity over a much greater 
span of time (Ehrlich and Mooney 1983; Ehrenfeld 1976).

In situ conservation is defined as the continuing maintenance of a 
population within the community of which it forms a part, in the environment 
to which it is adapted (Frankel 1976).

On site or in situ methods of conservation of plant genetic resources 
generally share three characteristics.

1. All growth phases of a target species are maintained, largely, within 
the ecosystem in which they originally evolved.

2. Land use of the sites is limited to those that will not have detrimen-
tal effects on the conservation objectives.

3. Regeneration of target species occurs without human manipulation or 
is confined to temporary measures to counter detrimental factors from 
adjacent land use and from landscape fragmentation. Examples of manipulation 
that may be necessary in heavily altered ecosystems are artificial 
regeneration using local seed; and manual weeding or controlled burning to 
temporarily suppress competing species.

The emphasis, in this paper, is on wild species. However, there are 
two groups of semi-domesticated species which require particular successio-
nal conditions and can be conserved in situ: weedy annuals, which often 
require initial or pioneer, successional phases, have evolved in conditions 
of on-going disturbance such as grazing, erosion and fire; and "wild" 
perennials in areas with thousands of years of habitation which are 
associated with narrow ecological amplitudes, largely produced by human 
activities.
While in situ conservation does not involve, strictly speaking, experimentation nor manipulation beyond that of replication or substitution of natural factors, these areas are often important for research and the procurement of germplasm.

**Use and value of genetic resources of wild plants**

Genetic variability of wild populations can be used to improve already cultivated species or wild species that are being domesticated for large-scale use. The majority of alleles in the gene pools of most useful plants exist in wild populations (Brown 1978). The extent of these pools, particularly the number of species which can contribute genetic variability, vary greatly between taxa. Boundaries of pools reflect the absence or presence of genetic "barriers", but are also a reflection of the level of research and technology that has been undertaken. Thus, over the last several decades, the recognized gene pools of many cultivated plants, especially well-researched crops, have been steadily expanding. On a less acknowledged level, intra-specific diversity in wild plants is central to utilisation and breeding. For instance, traditional utilisation of numerous medicinal species is presently confined to a small number of genotypes with specific properties, whereas an array of properties and, consequently uses, may be available. Genetic resources of medicinal plants, particularly those in the tropics, are becoming increasingly important to the pharmaceutical industries in developing as well as developed countries (Farnworth et al. 1983).

Not all species in a pool can contribute equally much variability and as easily. Three categories of membership in the gene pool of each species were devised by Harlan and de Wet (1971). The **primary gene pool** is comprised of species which can produce fertile hybrids. Those in the **secondary gene pool** can contribute genes less easily and produce hybrids of limited fertility. Species in **tertiary gene pools**, can contribute genes only with great difficulty and in very limited ways. In some cases, the gene pool is confined to species within the same genus such as rubber (Wycheley 1976); in others, such as Citrus and sugar cane, the recognized gene pools include species from numerous genera (Simmonds 1976).
Recently, the concept of primary, secondary and tertiary categories has been used to provide some order for understanding the subtle gradations within gene pools (Prescott-Allen and Prescott-Allen 1983). Such categorization might be useful for deciding, on an interim basis, which wild species in a gene pool are the highest priorities for conservation. However, it is difficult to compare the potential, long-term benefits of distantly related wild species that might provide few but highly beneficial genes with those species which can more easily provide more, but less useful, genetic material. Clearly, for needs of long-term improvement programmes, species in both categories are valuable and their conservation is imperative.

The ways in which germplasm is utilized in many respects determines the ways in which it will be conserved and which wild populations have priority. With plant domestication, there is too often an over-emphasis on the immediate progenitor and inadequate appreciation for the related populations which created it. This is due, in part, to lack of proven usefulness of the progenitors especially in terms of economic productivity, and lack of knowledge of their potential use in improvement. However, domestication of wild species usually requires selection and consequent narrowing of the gene pool. Conservation of the wider gene pools of earlier generations must therefore never be neglected.

Genetic variability for many cultivated plants has been steadily declining. The greater gene pools, particularly the most closely related ones, have become crucial to further improvement of many cultivated plants. The following is a list of the ways in which wild species have been used:

1. increasing yield vigour and rates of growth (Myers 1983b);
2. increasing disease resistance (Watson 1975, Dinor 1975);
3. improvement of product quality such as fruit with higher nutritional composition or wood that is more useful in construction.
4. greater adaptability to environmental conditions such as drought tolerance, and
5. compatibility with systems of production including establishment, treatment, pest management and harvesting.

Within this list two general patterns of use of genes are evident. One emphasizes use of single alleles to add desired characteristics to an already cultivated variety or provenance, the other uses entire combinations of genes, often called "co-adapted complexes" (Brown 1978), to create entirely new varieties of cultivated species.
Food and fibre crops

In use of wild plant genetic resources for food and fibre crops, emphasis is often on breeding and production of new varieties. Production of annuals is the largest "consumer" of genetic resources in that there is demand for new and improved seed on an annual or twice annual basis. This is also the sector where ex situ genebanks have been the most successful for storage and procurement of genetic material. Modern agricultural development has often involved the replacement of traditional "landraces" of crops, which contain considerable intra-sample diversity, by varieties where the genetic composition is uniform. Landraces were developed by early agriculturalists, with the primary selection factor being ability to produce in a wide range of environmental conditions. Modern varieties are developed primarily for maximized productivity and uniformity of produce. Stress tolerance is often sacrificed with a consequent more narrow amplitude for survival. Modern agricultural breeding is carried out at both the allele and co-adaptive complex levels. Incentives are greatest for increased production, quality and disease resistance. As most farmers now purchase seed annually instead of growing it themselves, loss of long-term adaptability is often not seen as significant, as varieties can be regularly changed to most prevailing needs and limitations. An additional point to note about use of wild plant germplasm for international agriculture is that virtually all of it is used for improvement. Very few new wild species have been introduced into cultivation in this century.

Wood and wood products

Cultivation of perennials (including those which produce wood) does not require the planting or sowing of new reproductive material for each site on an annual basis. However, the reproductive material that is utilised must include genetic combinations that can be successful under wide ranges of climatic and site conditions and changes in these over the period of growth and development of the plants. Emphasis in forestry, in many areas, is on introduction of new species and of use of small numbers of selected local species in managed plantations. There is a growing interest in utilizing and improving multi-purpose trees which can produce numerous economic and social benefits in addition to wood and wood products.

The limitations of an extended time-scale for genotypic evaluation and a long vegetative phase before the individuals reach sexual maturity have hampered advanced breeding of many forestry species. Emphasis has been on the identification and use of small numbers of particularly productive and hardy seed sources (=provenances). Usually there is enough variability
within populations to allow for on-site selection for local adaptability and yield. In recent decades, there has been increased production of more uniform seed, akin to that of annuals, for maximum productivity under narrower environmental amplitudes.

Forages

The use of reproductive material for improvement of forage species has a different emphasis than that of both crop and wood production. Genetic material must equip the populations to be self-sustaining. Success is partly measured by the number of repeated sowings that are necessary. Consequently, as well as the need for adaptability in immature and mature phases, the populations must possess the ability to regenerate and re-establish themselves in given conditions. This factor has helped to foster appreciation for maintenance and utilization of native plant communities. Emphasis on the use of exotic genetic material has often been associated with conversion to grassland, particularly from woodland and forest, and restoration of degraded areas. Genetic traits most commonly used have been related to productivity, aggressiveness in establishment in difficult environments and nutritional composition.

Medicinals

The vast majority of the drugs in the world today are derived from wild, semi-cultivated and cultivated plants. Most of this production involves traditional systems that rely on diverse, though highly effective, approaches to the use of genetic variability. Often there are sophisticated patterns of management favouring specific desirable traits that reflect considerable local knowledge of species. However, the use of medicinal genetic resources in modern cultivation (as opposed to traditional use) is poorly documented. The great number of useful species makes evaluation of the genetic resources of progenitors and related wild species a formidable task.

Environmental management

Plants that are used in environmental management include many species which are already categorized under previous uses as well as others which are used expressly for erosion control, shade shelter, turf, ornamentation and other services. Virtually all of these species are perennials or, if not, are self-maintaining. Use of wild plant genetic resources has emphasised for improvement of such traits as adaptability and speed of establishment for difficult environments and flower size for
ornamentals. As with medicinals, there is a vast number of wild species that could be utilized. Emphasis is usually on locating the most appropriate populations and/or genotypes for particular conditions.

While only a tiny portion of the total plant genetic resources has been utilized and a somewhat larger portion has been recognized as potentially valuable, the majority of species in the plant kingdom may not be consciously used for improvement and breeding for many centuries. However, we cannot foresee, at this early stage of the current "genetic revolution", which species will definitely not provide genetic resources valuable to mankind. This is problematic for defining acceptable levels of conservation (and loss) of plant genetic resources. However, loss of genetic variability, decline in species fitness, species extinction and gaps in ecosystems, can cause diminished capacities for "biosphere functions" (Erlich and Mooney 1983); loss of such natural services can be detrimental to economic pursuits and standards of living (Farnworth et al. 1983). In a very real sense, then, all genetic diversity is a resource and the first task of conservation becomes one of prioritizing the most strategic and vulnerable resources (Thibodeau 1983, Myers 1983A) and then linking them to various interests and time scales.

2. LOSS OF GENETIC RESOURCES OF WILD PLANTS

Conservation activities are necessary because without intervention a resource may become seriously degraded under ever-increasing pressure especially from human populations and domestic livestock. If a species goes extinct, the loss is irreversible. A spontaneous mutation might produce a similar allele but evolution can never recreate a species. Losses translate into diminished options for economic and social development as well as impoverished ecosystems. To understand the trends of losses and to be able to stop them from occurring, three types of information are necessary: taxonomic and ecological information on the threatened species; their distribution rates of loss; and qualitative and quantitative information on detrimental land use factors.

Sources of loss of genetic diversity

There are thus different stages of loss of genetic variability of wild plants, including decline of particular genotypes and of the alleles of which they are comprised. These could be considered specific types of genetic erosion which is the most difficult form of loss to monitor. A threatened or vulnerable (to extinction) category is used to indicate substantial shrinkage in
distribution which is usually accompanied by a corresponding, sometimes irreversible, loss of ecotypes, sub-species and other geographically related variability. The "endangered" category is used for species which have already lost so much intra-specific variability that their fitness for survival is impaired. Consequently, only active conservation measures hold a possibility of saving such species.

The rates of current loss of variability, as well as assessment of loss which already occurred in given areas, is either unknown or poorly quantified for most plant species in the world today. Occasionally, there are clues as to species which may have already disappeared, such as wild progenitors of cultivated plants which cannot be located; and distributional sketches that are constructed from herbaria and historical descriptions. The rates of species loss are likely to be highest in those regions of the world with the greatest numbers of species and where land use is least regulated. Conservation programmes in these areas are however, often difficult to implement. They include much of the developing world, virtually all of the tropics and a wide range of economic and political settings.

Decline in plant genetic diversity results from habitat change, generally caused by economic pursuits. While there are changes which partially or largely result from non-human factors, the vast proportion of current and prospective losses in plant genetic resources are caused directly or indirectly by the activities of man. Adequate land use planning is a key to devising conservation strategies compatible with socio-economic development. Economic activity per se, does not cause destruction of the genetic resources of wild plants. Utilization of natural resources can often be modified so as to serve both biological conservation interests and continued socio-economic development.

There are two major forms of landscape alteration that can depress populations of wild plants. The most dramatic changes are caused by conversion from one category of land use to another. Examples of this are: natural forest to crop and grazing land; grassland to forest; and natural vegetation to urban and industrial land use. If sufficient portions of the total area of species habitat is converted, loss of geographical variability will ensue. If, on the other hand, the number of individuals in a population diminish below a critical amount, allelic losses will result. If populations become sufficiently reduced and isolated, processes of landscape fragmentation and insularisation (Terborgh and Winter 1980, Wilcox 1982) will lead to "ecological disintegration" (Soule 1983). Species extinction, even at a reduced level, can in turn lead to disappearance of associated taxa.
Habitat alteration does not directly destroy or displace a natural ecosystem, but changes it selectively. Grazing, selective tree cutting, firewood collection and intensive gathering, produce such primary impacts (Ravenna 1977). Ecological changes may lead to secondary disturbances from factors such as soil erosion. One of the most extreme habitat alterations is caused by over-exploitation of specified goods, such as firewood or cabinet timbers. E.g. grazing usually destroys regenerative abilities of a range of vulnerable species. Frequent fire associated with land use usually favours as small number of species but suppresses others.

The preceding examples of conversion and alteration emphasize species extinctions. However, both categories also cause intra-specific variability to decline. Often species that are able to survive in these altered habitats do so through a shift from genotypes associated with stable environments ("k selection"), to those which can withstand more disturbed and stressful conditions ("r selection") (Franklin 1980).

Many of the earliest cultivated plants may have completed this shift to disturbance adaptation before they were domesticated. The small, remaining portions of gene pools that are dependent on more mature successional phase may consequently offer particularly distinctive traits (Pickett 1976). For example, the majority of the self-perpetuating populations of wheat appear to require early or constantly disturbed successional phases. However, there are also some reports of occurrences of this species in relatively, undisturbed oak woodland (Pielou 1976).

Today, virtually all countries of the world have committed themselves to the idea of conservation of both wild species and genetic resources of direct socio-economic benefit. However, genetic erosion and extinction of plant species are taking place at an accelerated pace. A number of causes for this contradiction can be identified. The value of many species for utilization has not been identified or publicized. An example of this is the situation with most wild relatives of crops. Their use in crop breeding has become increasingly important in the last several decades and the benefits of maintaining natural populations for procurement of germplasm and related research has only been recognized in the last decade. Yet today, most park and land use planners who are concerned with nature conservation do not know that these resources exist in their project areas and therefore cannot develop strategies which include their protection. Even if environmental planners are aware of the presence of given species in their areas of responsibility, they usually do not have precise information on distribution, status and biological requirements.
Patterns of genetic diversity and loss

The genetic variability of plants becomes a direct, economic resource when reproductive material is used to bring a new species into cultivation; when it improves an already cultivated species; or when it is key to exploitation of a wild species. Thus, genetic variability becomes a resource when it is utilised, or when its potential is recognized. Use of genetic material reflects available levels of scientific and technological development as well as accessibility of the resources. An increasing number of wild plants are today being used in the development of genetic material. Apart from some general patterns of concentration of genera in certain areas, described in the following paragraphs, plant genetic resources of both actual and potential value, are distributed randomly over the globe. Areas rich in species, however, will possess higher, overall genetic variability.

The concept of "centers of origin" for crops was developed by N.I. Vavilov, of the Soviet Union, in the 1920s. It revolutionized plant exploration and breeding for many of the major crops. Seven centers were initially identified where the major food crops originated and where diversity of ancient cultivated species, called "landraces", was highest. All of these regions are generally ecologically highly diverse, and have large numbers of genera and species. They were also centers of ancient agricultural societies and thus, were the areas in which wild plants were first domesticated. The natural diversity found in these regions afforded opportunities to make a selection from wide ranges of species and ecotypes to meet needs of early cultivation. In turn, there was often considerable gene flow from domesticates back to natural populations, which contributed to their further evolution.

Since Vavilov's pioneering contributions, a number of other versions of his central idea have been proposed, notably Harlan's (1971) "centers and non-centers". Definitions and methods for delineation have varied greatly. The term "center of diversity" has been used to refer to:

1. areas with high levels of allelic diversity for species in particular gene pools;
2. overlapping occurrences of both wild and domesticated species of the same genera;
3. overlapping occurrences of wild species that are related to cultivated species and;
4. combinations of all of the above.
It is generally agreed that centres of diversity do exist and do contain significant phylogenetic resources of crop-relatives. However, the application of this concept to wild species in general could lead to neglect of numerous other species; a thorough understanding of patterns of variability in a species is therefore a must and the approach of centres of variability should be seen only as an initial aid for a limited number of species.

An example of the limitations of the use of the "centres" concept is that of trees that provide wood and wood products in Western North America. The Siskyou Mountains of northwestern California represent the most concentrated overlaps of distributions of trees species, particularly useful conifers, in the region. However, the intra-specific variability of these populations is not necessarily more concentrated nor more useful than that of other parts of the distribution ranges of individual species. In fact, genotypes at the margins of the range of distribution have often developed special characteristics which make them tolerant to given environmental conditions and such marginal populations must be conserved in addition to conservation efforts in areas of species richness and overlap.

Endemic species are those that are confined to small areas and are often isolated by natural barriers such as seas or mountain ranges (Rabinowitz 1981, Reveil 1981). Endemism is often high in areas of the tropics that are thought to have had a stable environment over long periods. As well as susceptibility to land use changes, endemics are prone to extinction because the extent of their natural distribution is often so limited that disturbance easily diminishes populations below critical levels (Terborgh 1974). Site-specific information on distribution on which land use planners and managers can base decisions to minimize loss of these populations is often unavailable (Jain and Sastry 1981). Endemics of oceanic islands are often highly vulnerable to introduced species which alter their habitat as well as provide direct competition.

The humid tropics hold the highest concentration and largest portion of species of the major biomes. Often, the density of any one species is low and its overall distribution is limited (Elton 1975, Tracey 1981). Plant species, especially those most vulnerable to extinction, require very particular environmental and successional conditions and associated organisms. Secondary losses of species, resulting e.g. from insularization in forest fragments, can be pronounced (Lovejoy and Oren 1981). Knowledge on taxonomy and distribution is often highly incomplete for species in these regions; field work is difficult to conduct; and conservation measures are difficult to implement and monitor.
Disappearance of species due to conversion of rainforest to agriculture and grazing; and habitat alteration caused by e.g. the harvesting of timber, are often used as the metaphors for explaining accelerating global loss of genetic diversity. As is the case with most generalizations, reality is not as simple. Harvesting in closed canopy forest will cause the disappearance of some species, particularly endemics. However, most species can withstand some disturbance (e.g. harvesting) although on certain sites, regeneration of a number of them may be inadequate for their long-term survival. Complete land use change, on the other hand, poses a grave problem for species maintenance. Because of pressures from human populations and livestock it must be recognized that only through the establishment of well-designed reserves can the genetic diversity of certain areas or regions be conserved.

While habitat conversion in tropical rainforest may, in fact, not always be irreversible, the situation is more drastic in much of the seasonal tropics. Conversion may be e.g. in the form of replacement of savanna species to grasslands dominated by introduced species. In such situations, pressures on remaining woody species for fuel become extreme. Demands for more intensive and often, unsustainable, land use as a result of growing human populations or policy decisions are similarly often pronounced and their effects may be disastrous for the fragile ecosystems found in these areas. The seasonal tropics hold a large portion of the wild tropical species that can withstand, or require, ecological edges and related successional disturbances and, consequently can most easily be introduced into agriculture, forestry and urban settings with marginal environments.

Arid lands support a smaller number of species than other tropical and sub-tropical zones. However, plant genetic resources adapted to these extreme conditions will play a crucial role in restoring degraded lands (FAO, 1980).

Mediterranean-type ecosystems, including the edges of the basin itself and other parts of the Middle East as well as similar regions in California, Chile, South Africa and Australia, often hold diverse floras part of which are prone to destruction from changes in land use. As human pressures intensify, species extinction and loss of intra-specific variation have accelerated. Grazing, harvesting of wood, introduction of exotic species and provenances, and disruption of patterns of wildlife, have radically altered the natural vegetation in many areas. Species in coastal areas have often been the most effected as a result of urbanisation and tourist development.
The cool temperate and arctic zones generally have the lowest number of wild plant species per unit area. However, while the number of wild relatives of major crops is low, the genetic resources for wood, forages, pharmaceuticals and environmental management are substantial and are a key to long term sustainable, economic development. The situation as regards loss of genetic diversity is highly variable. While there are regions, particularly in Europe, where losses have been substantial, there are also large areas which have been left relatively intact. Networks of parks, ecological reserves and other protected areas are often fairly well developed and do, in many areas, adequately protect species that cannot withstand disturbance. The most neglected component of these conservation efforts is the protection of intra-specific diversity of widely-distributed species. Impacts from acid rain and related industrial pollution pose a major threat which is uncontrollable within the jurisdictions of current national plant conservation programmes.

Genetic resources of marine plants are neglected in most of the world. Pollution from urban and industrial activities, soil erosion etc. have caused substantial but largely unmeasured impacts on many species populations. Over-exploitation of a growing number of marine plants and animals will also diminish genetic variability and cause extinction of species. Similarly, conversion of delicate coastal ecosystems, such as mangroves (Hamilton and Snedaker 1984), can impair ecological functions and impoverish genetic variability.

Land use practices as determinants of loss of genetic resources

The following paragraphs outline four major types of land use and pinpoint those general practices which are most damaging to genetic variability. Habitat alteration and conversion, described earlier, are the results of such land use practices. It is important to stress that the present paper can simply outline major patterns. Response of individual species to environmental change will vary greatly with ecosystem, site and particular practices.

Grazing may have a range of negative effects on the components in an ecosystem. While excessive or selective grazing can destroy a population outright, there are also slower but equally damaging processes such as disruption of regeneration, compaction of soil and invasion of competing exotic plants. Especially in seasonal periods of stress, such factors can devastate the original vegetative cover. Better management of the grazing activities is a key to conservation; in some cases, however, fenced fragments of original vegetation may provide the only possibility for survival of the plants in areas of high grazing pressure.
Harvesting of wood and associated products can threaten populations when canopies of large, relatively undisturbed tracts are removed or altered. Often the main detrimental factors are not related to canopy removal, per se, but rather to the size, duration and frequency of such interventions. This is true for both shifting agriculture and logging. In many cases, secondary impacts from e.g. the use of heavy machinery leading to soil compaction and erosion may be highly detrimental. Conservation of forest species requires careful land use planning and regulation of harvesting practices as well as networks of permanent and relatively undisturbed reserves. Appropriate management in areas adjacent to the reserves is necessary to minimize secondary impacts, fragmentation, "edge" effects (Raney et al. 1981) and erosion within the reserves.

Crop production usually involves complete removal of the original vegetation, thus it is not possible to combine the maintenance of original genetic diversity and crop growing on the same site. In the establishment of in situ reserves, due consideration must be given to possible detrimental effects from adjacent areas, where pollution from fertilizers and pesticides may severely disrupt the ecosystem and which often are invaded by aggressive weed species.

Industrial and urban land uses also often involve total removal of natural vegetation and pollution. Except for rare cases, land use activities and genetic conservation on the same site are thus not feasible and reserves are vulnerable to secondary impacts. However, for expanding cities, the growing demand for urban "green space" occasionally does afford the careful planning and on-going protection that is required for successful conservation of wild plants and the ecosystems on which they depend.

While the rate of loss of wild plant genetic resources is severe in some regions recognition of conservation issues and the benefits, which may accrue from improved land use planning, are growing in most countries. There is, however, an increasing number of endangered species which need immediate attention and much larger numbers of species in need of active field work and/or surveys to enable action to be taken for conservation and management of inter and intraspecific genetic variation.
3. ROLE OF IN SITU METHODS IN CONSERVATION OF GENETIC RESOURCES OF PLANTS

A range of methods and approaches can be employed in the conservation of genetic resources of plants.

The major strategies involve conservation in situ and conservation ex situ.

Four different types of ex situ conservation can be distinguished. \(\text{Panmotic population areas and evolution gardens can be classed as experimental ecological reserves. The most widely employed type of ex situ, 'landscape-based' conservation, which includes experimental plantations, seed orchards and clone banks, is used to conserve and evaluate genetic variation, and to produce reproductive material. Botanical gardens involve a wide array of horticulturally related activities for exotic and local plants.}\)

The major efforts in ex situ conservation of the genetic resources of plants, to-day, are in seed storage. Plant tissue culture or in vitro methods are currently under intense development (Withers 1980), as they can be employed for ex situ conservation of plants which require vegetative reproduction or which have seed that cannot be stored.

In in situ conservation, it has been proposed to create a network consisting of clusters of "genetic reserves" (Jain 1975) with various designs, management activities and legal status that would reflect procurement and maintenance needs on a primarily-for-utilization to primarily-for-preservation/conservation spectrum. Thus, in the core area of a reserve, minimum interference would be allowed, whereas activities such as seed collection and management to favour target species would be part of the activities in the outer core areas.

In situ and ex situ conservation strategies are complementary and should, whenever possible, be used in parallel. Close collaboration is thus needed between development planners, managers of protected areas, scientists, breeders and users of genetic resources.

Patterns of germplasm conservation and utilization

Patterns and requirements of germplasm utilization and maintenance in situ and ex situ have both similarities and differences. They are suited for divergent, but complementary, needs. Below, a comparison is made of action and efficiency in five major activities connected with germplasm management: documentation and procurement, conservation, security, quality and administration.
To obtain material through ex situ channels involves finding information on the location of particular collections and requesting specified material from a curator. If the material is on hand and in adequate supply, it can be sent by mail. The pattern for obtaining germplasm from in situ or "dynamic" genebanks (Prescott-Allen and Prescott-Allen 1982) could work similarly: a breeder could obtain information on the location of material by requesting the scientists/managers responsible for the site with desired populations to obtain reproductive material and to ship it. Because of seasonal factors it would generally take longer to obtain the germplasm, and procuring it in the field might involve the employment of specialized labour; difficulties also include a frequent lack of geographic and biological data on populations possessing desirable traits. Thus, careful documentation of genetic variation and related ecological and geographical factors, is a major activity in in situ conservation, just as it is when employing ex situ strategies.

Maintenance of genetic resources implies perpetuation of the live organisms which produce reproductive materials. With in situ methods, populations remain within the ecosystems that created and sustain them and there is continuous evolution. Ex situ methods are oriented to immediate use of germplasm for breeding. Seed, vegetative or cultured (as in the case of microscopic organisms) material is collected from wild populations and stored in cool, dry environments (entire rooms or refrigeration units) and then "grown out" to produce more germplasm or to replenish material that loses viability over time. Growing out is often a difficult, expensive and labour-intensive operation that requires considerable expertise, space and resources.

Germplasm is a fragile resource. For ex situ material, technical problems with storage pose the greatest threat to security. For in situ populations, ecological factors as altered by fragmentation of natural vegetation and direct human pressure may, in turn, render natural populations vulnerable (Kemp 1975). A generalization about the relative security of in situ conservation methods is not possible.

Control of quality and composition of germplasm for utilisation in breeding from both in situ and ex situ conservation methods is problematic. With procurement from storage the breeder receives material, most often with inadequate documentation, which was collected from a wild population. The material may be typical or atypical of that population and it may have deteriorated in storage. Procurement of samples directly from natural areas allows the collector to assemble the desired data on phenotypes and
associated ecological conditions and use those sampling methods considered most appropriate. Such material will not have storage-related problems. A practical difficulty lies in differentiating genotypes from phenotypes in the field. However, just like in ex situ methods, this problem can be overcome by field evaluation of the material under uniform experimental conditions.

For administrative purposes, ex situ and in situ networks differ markedly both in structure and function. While ex situ gene banks are increasing in number, they will continue to be relatively centralized. A small number of curators, technicians and scientists will be responsible for on-going servicing and work on the premises in a static environment much like librarians and laboratory scientists do. In in situ conservation, a range of expertise is necessary. Effective and economically feasible coordination of numerous activities involving a wide range of scientific expertise is the over-riding concern. The interest groups for genetic reserves include not only the users of germplasm but also, land use and development planners, local residents and other advocates for nature conservation. The administrative differences between in situ and ex situ gene banks thus stem largely from different patterns of decision-making. While ex situ gene banks are operated solely to meet the needs of germplasm "consumers", in situ reserves are always under pressure from a range of additional needs.

In situ methods in conservation of species with limitations in seed storage

Recognizing the complementarity of in situ and ex situ methods for conservation of genetic material of wild plants, a number of reasons for the explicit use of in situ reserves can be pinpointed which are related to storage, sampling and research. The importance of these factors varies with species and patterns of utilisation for genetic material.

There is still a large number of economically important plant species which produce seed that cannot be satisfactorily stored for long periods. The seeds of these species are recalcitrant, which means that they cannot be dried without rapid loss of viability; they are also short-lived when moist. The list of plant species with storage limitations related to recalcitrance is substantial (King and Roberts 1979) and includes numerous tree species, particularly those from the humid tropics. Recalcitrance is not always an either/or matter. Seed of some recalcitrant species may survive only for 24 hours while life of others, in certain conditions, may be extended over several weeks. The factors that cause recalcitrance are not precisely understood. Seed of some wild species within genera such as Citrus, or even particular genotypes within the same species, may be storable
while others are not. Although storage technologies are constantly improving it is clear that all problems in this respect cannot be overcome in the foreseeable future. Genetic resources of species which reproduce by vegetative means, or of species reproduced clonally by man (as in the case of a number of temperate fruit trees), are also difficult to store (Hawkes 1975). Improvement of techniques of in vitro culture should make ex situ storage of this type of material more feasible, however, these methods may not be capable of maintaining full allelic variability of samples.

In addition to the cases where germplasm of particular species cannot be stored for any length of time, there is a general problem of deterioration in storage, resulting in genetic erosion within ex situ gene banks (NAS 1978). This is caused by two main factors: varying response of different genotypes to storage environment; and non-random patterns of germination and development of individuals grown out for the regeneration of samples (Allard 1970; Abdalla and Roberts 1968).

Another fundamental problem with ex situ conservation methods is caused by limitations in sampling. Although this problem is also present when using in situ strategies (siting and size of reserves), maintenance of wild populations allows for on-going sampling and evaluation which increase odds for random capture of existing alleles (Marshall and Brown 1975).

Ecological advantages of in situ methods

The advantages of in situ conservation methods include the possibilities to study the species in their natural ecosystems (Salick 1983). Morphological, ecological and environmental factors can thus be related to genetic variation to facilitate evaluation and utilisation. Maintaining the site of a natural population in a relatively unaltered state allows for on-going research and better collection of genealogical or "eco-geographical" data on an on-going basis. Secondly, if dealing with species and habitats where genetic variability is high; cost of land is low; collecting is expensive and storage is difficult and expensive, it will be most cost-effective for at least a portion of the base collections to be conserved through in situ methods. This is particularly the case for natural areas that might also have other values such as general biological conservation, heritage, recreation and tourism.

Maintaining wild populations in areas where related cultivated species are of social and economic importance could, in the long-term,
stimulate locally based efforts for research and improvement. Total reliance on maintenance of genetic resources in ex situ gene banks that may be in distant centers and across national boundaries, could pose difficulties for secure access in the event of political problems between national governments. While in situ methods cannot change the possibility of political restrictions, a diversified conservation strategy will be less vulnerable to such difficulties.

Occasionally, situations arise where demands for reproductive material cannot be fully satisfied from ex situ gene banks. The existence of some protected wild populations can be considered "safety value" in such situations.

Limitations of in situ methods

Although the advantages of in situ conservation are numerous, there are also some acknowledged difficulties. A site, especially a small area, is often vulnerable to impacts from surrounding areas. Activities within protected natural areas may be difficult to regulate and restrictions are difficult and expensive to enforce. Since total genetic variability of a species rarely occurs in a single population, numerous reserves, often distributed over a range of sites, regions and even countries, may be necessary. The infrastructure which is required to ensure full access to desired genetic material in wild populations will require international cooperation as well as commitments on national and local levels, and will involve a number of component operations which will be discussed below.

4. COMPONENT OPERATIONS OF IN SITU CONSERVATION

In situ conservation methods involve a set of activities of varying duration, as well as on-going coordination. While it is counter-productive to judge what is and is not truly in situ conservation, some minimum requirements must be set if we are to know if a genetic resource is adequately conserved. Such requirements are important for the users of genetic material originating from the reserves. These component operations can be broken down as follows:

1. Exploration and initial field research
   (a) identification of gene pools of priority species;
   (b) survey including biological, environmental and ecological aspects.
2. Formulation of conservation objectives
   (c) clarification of needs and motives for conservation of particular gene pools, specification of exact objectives;
   (d) formulation of minimum requirements.

3. Site assessment
   (e) assessment of populations and sites;
   (f) survey of already-established protected areas and related ex situ and in situ conservation activities;
   (g) site selection.

4. Design and acquisition
   (h) design of reserves, including delimitation of core and outer areas as well as buffer zones.
   (i) harmonizing conservation objectives with surrounding land use practices through site and regional planning;
   (j) designation of protected legal status through acquisition, administrative designation or legislation.

5. Management
   (k) management interventions to achieve stated objectives and to regulate undesirable impacts from over-utilization, habitat fragmentation etc.;
   (l) monitoring and research;
   (m) collection utilisation and evaluation of germplasm.

The effectiveness of conservation efforts must be continuously monitored and evaluated in the light of stated objectives. This presupposes that such objectives are well defined, both as regards the conservation of inter and intra-specific diversity, while at the same time being flexible enough to meet changing needs.

Survey of wild species

Any conservation effort must begin with the identification of gene pools and populations of particular interest. Targets for action may include a single species; several species that comprise the primary and secondary gene pools of cultivated species; all species within a genus or several genera; and select individuals within a number of genera at all these levels. Species of actual as well as potential socio economic value could
be included. To maximize future opportunities, it would be prudent to conserve as many potentially useful species and different populations as possible. However, economic constraints will force us to specify our priorities in **in situ** as well as in **ex situ** conservation activities. Thus, low-priority species must often be conserved through biome or ecosystem approaches, as a "bonus" additional to the **in situ** conservation of priority species found in the same habitats.

Taxonomic clarification must precede the selection of species and areas for conservation. Especially in many tropical genera, taxonomy is unfortunately still unclear (Kleineschmidt 1978); in other cases, revisions are badly needed.

Occurrence data is the prerequisite for identifying geographic distribution as well as for subsequent identification of intra-specific variation. Herbarium data and rare inventories of already established protected natural areas, must logically lead to follow-up fieldwork (France 1977, Ashton 1981, Henifin et al. 1981a). For species occurring in remote areas with difficult terrain, this can be onerous. The existence of populations can sometimes be postulated by use of technologies such as aerial photography, satellite images and other forms of remote sensing (Baltaxe 1980). However, such technologies can only support, never substitute, ground checking. The quality of field work will be a major determinant of the effectiveness of the ensuing phases of conservation (Henifin et al. 1981b).

Within the distribution range of a species, distinct sub-species and ecotypes may often be found which result from obvious geographical and site factors. Discerning genotypic variability is more problematic. Field work can correlate information on ecological, geographic and morphological factors (Robbins and Hughes 1983). However, many "hidden" characteristics, such as those related to disease resistance, will not be apparent without thorough evaluation of the material in a range of environmental conditions. The difficulties to capture highly localised and isolated alleles is even more problematic (Hamrick 1983, Chambers and Bayless 1983). Electrophoretic techniques are sometimes used, however, they are currently extremely expensive to apply; there is also some doubt as to the correlation between traits detectable by isozyme studies with those of economic traits. There are thus, grave difficulties in sampling, using as a basis geographical factors. Precise measurement of zygosity, an important determinant of minimum population size for maintenance of alleles, is also difficult in practice. These difficulties will make it more essential than ever to focus primary activities on priority species, aiming at high quality of action.
A prerequisite to formulating precise objectives for conservation is an understanding of the biology of the species. Additional field work is often required to determine ecological relationships, successional phases and phenology (Bradshaw and Doody 1978).

The status of a species in relation to impacts of changing land use practices is crucial in formulating conservation strategies (Ayensu 1980, D'Arcy 1977, Budowski 1977). Biological information is a key to determining the precise relationship between human activities and the decline of a species. If a population is not affected by current or projected land use activities, it can be identified for research, on-going germplasm collection and monitoring purposes. If only a small number of vulnerable populations remain, then immediate intervention favouring strict conservation is necessary.

Formulation of minimum requirements

Once species have been targeted for conservation, questions will emerge on choice of populations, the minimum size of reserves, and the environmental conditions which are necessary for maintaining desired intra-specific diversity. One of the basic goals in genetic conservation is maintenance or restoration of fitness (Soule 1984), which will enable the individuals, populations or species to survive and perpetuate themselves under given conditions. Other goals are dictated by particular needs in germplasm utilization. Defining the desired level of diversity for conservation of particular gene pools (Namkoong 1983, Derry 1970) is the central determinant of minimum requirements to be set for conservation activities, and will directly influence strategies used for their implementation. For example, germplasm of a species with great economic importance such as with wild perennial maize, Zea spp., in Mexico, might contain traits that are so valuable that conservation of maximum allelic diversity is an undisputable goal (Futuyma 1983).

At this point, it is important to bear in mind the similarities and differences between genetic and ecosystem conservation (Frankel 1983). At the ecosystem level, greater loss of genetic diversity is acceptable without the goals being seriously impaired. Thus, the disappearance of one of a range of populations of a given species will not be very detrimental to overall ecosystem functions. On the other hand, in phylogenetic conservation, populations that represent intra-specific variability are the focus.
There are three categories of minimum requirements that must be kept in mind when planning genetic conservation. The minimum viable population reflects the lowest acceptable number of individuals with reproductive capabilities. The minimum number of populations is a reflection of the amount and distribution of intra-specific variability found within a species. Ecological and environmental factors reflect the need for and interrelationship with associated species.

The concept of the minimum viable population (Hooper 1970, Shaffer 1981, Wilcox 1984, Lehmkuhle 1984) has emerged from animal ecology, especially from studies of large mammals found in perilously low numbers. It is a means to integrate conservation needs into land use planning on a scientific and quantitative basis. The implications of the concept to saving endangered plant species and to maintaining intra-specific diversity, are just beginning to be considered. One method for arriving at an estimated MVP is to determine the smallest number of interbreeding individuals needed to ensure that in-breeding depression is not a hazard (under the proviso that maintenance of particular alleles is not a concern); another method is to determine the smallest number of individuals needed to ensure that low frequency alleles could continue to exist in the population (Namkoong et al. 1980).

The minimum number of different MVPs that are necessary for adequate conservation, will reflect factors that determine the structure of populations (Liu and Godt 1983). These factors include clinal or ecotypic patterns of allelic variability and heterozygosity (Schaal and Levin 1976, Beardmore 1983). For instance, species which are widely distributed over different ecotypes and are characterized by considerable homozygosity, may require conservation of numerous discontinuous populations. In contrast, with greater heterozygosity, a smaller number of larger populations might be more appropriate.

The ecological, environmental and factors which must be considered in the choice of sites and populations for conservation can often be determined simultaneously with the previous two sets of factors (minimum viable population, and minimum number of populations). Some closely co-evolved species, such as Gilbert's (1980) concept of "mobile links" (invertebrates and vertebrates) are a key to survival of many species, and must be given due consideration in establishment and management of in situ reserves. Ecological factors that control competitors are often important consideration, as is knowledge on successional conditions and edge effects within species mosaics. These latter ones are often crucial to maintaining high levels of selection pressure, leading to wide allelic diversity.
(Stern and Roche 1974, Axel 1983, Campbell 1979). Factors which affect plant succession are the presence, total lack or particular frequency of disturbances such as those caused by wildfire (Stone 1965) and large mammals.

There may sometimes also be a necessity to define minimum requirements for factors that maintain population structure and selection pressures. For instance, in order to maintain the given allele frequencies of a population of an out-breeding species, certain levels of isolation may be needed. Forest reserves that are surrounded by plantations of the same species, established using reproductive material derived from non-local populations, are highly vulnerable to a genetic contamination from these introduced populations (Maini 1971).

The above outline of types of minimum requirements has so far ignored the difficult topics of minimum area and shape of protected areas. The theory of island biogeography has been used to promote a number of principles for conserving both animal and plant species (Diamond 1975, 1976). However, it has also been the source of on-going scientific controversy. Debates have centred on the comparative advantages of small numbers of large areas versus large numbers of smaller ones (Simberloff 1976, 1982) and the various implications that this decision may have on reserve design (Higgs 1981, Margules et al. 1982, Simberloff and Abele 1982). For plant conservation, it is assumed that area alone is rarely a determinant for survival and maintenance of intra-specific diversity, but that the habitat diversity that various areas can afford is very important in this respect. Similarly shape of the reserve will only have indirect effects through determining importance of possible detrimental impacts of surrounding land use practices.

A compiled set of conservation objectives might look something like this:

- (n) populations - each representing a different ecotype;
- a minimum population size for each of (n) individuals, (m2) of which are reproductively mature;
- a list of species for each ecotype that must be preserved over a reasonable time-scale (for instance, 500 years). Each of these associated species might need their own minimum population sizes;
and
- a list of successional phases that should be present within the conservation area. (This latter factor relates closely to the section on management below).
The above set of objectives could be more complex or simpler, depending on the time scale of concern, the biological requirements of the populations and the desired level of conservation of genetic diversity. For instance, to maintain intra-specific diversity, methods for determining minimum requirements may have to take into account genetic drift, gene flow and natural selection (Merrell 1981, Allendorf 1983).

The more precise a set of objectives are, the better the possibility of successful conservation. However, as objectives of conservation become more specific, flexibility for their integration into overall development plans is diminished. A balance must thus be struck between such potentially contrasting needs.

Survey of sites

Assessment of sites with known target populations for the purpose of identifying those which are best suited for genetic conservation, requires detailed preliminary field surveys over a wide range of environmental gradients (Medwecka-Kornas 1981). The information assembled should help identify the populations which could best satisfy the established conservation objectives as well as needs for long-term research and germplasm utilization. Often, it is best to have two phases of surveying of sites. Initial efforts can thus focus on identifying populations that exist in established protected natural areas. After this phase is completed, the areas with remaining occurrences can be assessed.

In most countries in the world today, biological conservation is implemented through the establishment of different categories of protected areas, covered by various types of prescriptions and management legislation. Discerning the extent and gaps in these programmes can be considered a key to preliminarily determining the total number of protected populations of given species. In addition to the biological and environmental data that must be obtained in on-the-site visits, it is necessary to critically evaluate the effectiveness of current protection activities and management status.

Once assessment of the populations within protected areas is complete, needs for other protected areas, established with the primary objective of genetic conservation, will emerge.

Where more than one combination of possible protected sites that could satisfy a set of minimum requirements for genetic conservation can be identified, there exists an opportunity to more carefully plan for the needs for
optimal germplasm access; and for the close integration of conservation with socio-economic development. This is the case in a majority of the species that could be considered international priorities for genetic conservation. The criteria that can be applied to identify the most suitable conservation sites are numerous. The following is a list of some of the most important of these.

1. Sites should be accessible for easy procurement of germplasm. Thus, they should be in relative proximity to roads, water or air transportation; have relatively accessible terrain for walking; and be located in the proximity to facilities where related field research may be carried out.

2. Sites should be chosen where protection would be least disruptive to traditional land use needs and patterns of ownership.

3. Sites should be chosen where protection would permanently remove from use the least amount of marketable natural resources earlier benefiting local populations.

4. Sites in which conservation can produce other benefits such as watershed protection, animal habitat, heritage and other cultural values are to be preferred.

5. Sites which hold important genetic resources of numerous species are preferable to those in which only one priority species is found.

6. Sites should be chosen where management requirements for conserving target populations is technically feasible. The most obviously problematic sites which require the highest management inputs can be given lower priority.

7. Ownership and jurisdiction must be taken into account and related to the timescale of concern for the planned conservation activities.

Reserve design

The zoning of protected areas to distinguish land that should be strictly protected from that which can be managed and utilized for other needs compatible with genetic resource management, involves a number of steps that are based on the minimum requirements for conservation. There
may be a number of areas within each occurrence which could, in theory, satisfy these minimum requirements. The criteria listed for site selection above, can also be applied in reserve design.

In reserve design for genetic conservation the focus is often on robust populations and mosaics of plant communities (Foster 1980). The design of a single reserve is not as important as the relationships within clusters of protected areas (McCrone 1984).

Selecting the most appropriate category of protected area is part of reserve design. This is particularly important where there are already a number of established local programmes in nature conservation. The types of protection and management that can be implemented vary greatly between countries and in federal systems between states or provinces. IUCN (International Union for Conservation of Nature and Natural Resources) has created a set of internationally recognized categories of protected areas (IUCN 1978). The full scope of these already existing conservation programmes should be used, creating a patchwork of complementary resources which will ensure the conservation of the full variation of target species.

A nature or genetic reserve may not look any different or contain any different species or ecological characteristics than adjacent areas. The key to understanding what comprises a reserve is the idea of protection and management. One must then ask "protection from what?" and "management for what purposes?". On-going management is outlined in the following section and is mentioned here in relation to zoning. Land use planning within the reserve will help specify those areas which require added protection; or which can withstand certain forms of utilization without impinging upon minimum conservation requirements. In recent years, the concept of the pristine "core" and the lightly utilized but highly regulated and monitored "buffer zone" has gained increased acceptance. Unfortunately, too often the "buffer" label has been used as a euphemism to obscure the fact that utilization within buffers is not very different from that in surrounding, conventionally exploited areas. Therefore efficient conservation in these non-core areas has, in practice, often been negligible.

**Management**

Any activities within protected areas or reserves, which are aimed at maintaining species and ecosystems for conservation goals, can be termed "management" (Pyle 1980). There are three main categories of influences which create needs for these activities. The major set of detrimental factors are socially derived and require "positive management" (Hall 1983).
Illicit and exploitative activities such as wood cutting or clearing pose the most obvious threats and require not only "policing" but also longer term solutions to problems which are often social in nature. Excessive levels of sanctioned uses, including collecting genetic material, requires surveillance and regulation.

The second set of requirements for management result from the indirect impacts of surrounding land use. Reserves often become isolated fragments where natural patterns of gene flow and successional mosaics no longer exist (Westhoff 1970). Management is sometimes needed to replicate dynamic ecological factors (van der Maarel 1970, Bratton and White 1981). Unfortunately, with severe disintegration of ecosystems, the activities that are necessary to compensate for losses can be quite extensive and are often unfeasible. "Preventive" management may involve intervening in adjacent lands to control potential problems such as invasive, weedy plants or feral animals. The third category of management activities includes the conscious intervention in favour of the survival and development of target species, such as climber cutting, prescribed fire etc.

A central principle of reserve design is to minimise needs for on-going management. An important aspect of formulating management prescriptions is to re-enforce the self-regulating processes within ecosystems or at least those which can sustain genetic resources. Unfortunately, management is often the weakest component in biological conservation programmes. Formulation of prescriptions has often been stymied by an over-emphasis on defining what is original, "natural", and integral to natural ecosystems at one extreme or, at the other, by a destructive myopia for enhancing favoured species at the expense of long-term diversity and resilience. Implementation of prescriptions has often been very poor especially where there are funding limitations and where long-term benefits are not perceived by local land managers.

Monitoring of populations of wild plants provides the scientific basis for intervening in natural ecosystems for specific conservation needs (White and Bratton 1981). Assessment of change can be based on recurrent surveys that can be oriented around permanent study areas (Bratton 1981). The minimum conservation requirements can provide a basis for monitoring the coevolved complexes on which the populations that are targeted with conservation depend. These requirements provide a basis for evaluating the adequacy of a protected area on an on-going basis. The timing and frequency of collection of field data can be based on day-to-day, seasonal or periodic fluctuations. "Patrolling" (Hall 1983) to determine impacts
Informal approaches to in situ conservation

The activities outlined above are geared to those species in which substantial portions of intra-specific diversity is presently in jeopardy. Fortunately, in many other wild species, existing genetic resources are not yet gravely affected by modern land use practices. Formal protected natural area status may thus not be an immediate necessity for many of them. This releases organizational and financial resources for those species for which survival requires immediate positive intervention. Even less vulnerable species may require the support of in situ conservation, but these activities can, at least in the short-term, be informal and relatively flexible in character.

An in situ conservation effort can begin with identification of a site that is valuable for collection of seed and related research. Visiting the areas, over time, can sometimes be the best way to determine whether formal, genetic reserve status is necessary. Development of personal, cooperative relationships with local residents and land use planners can often be much more effective in protecting a targeted population and the ecosystem that sustains it, than a "top down" reserve designation approach that conflicts with local perspectives and needs.

Recovery Plans

In contrast to common species which only require surveys, documentation and monitoring for conservation, are those which are presently on the verge of extinction. These species have usually had most or all of their habitats altered or converted. Their distribution and viable habitats are reduced to small areas which often must be protected in total. If the species in question are to recover and survive on an indefinite basis, a great deal of "nurturing" is required; this often implies considerable ecological manipulation and the conventional steps for in situ conservation may not be enough.

Three main tasks in recovery efforts are removal of detrimental influences; substitution; and assistance to increase population size sufficiently to survive future fluctuations in numbers. A stable, resilient population can then gradually develop. However, diminished allelic variability caused by the "bottleneck" effect (Clegg and Brown 1963), will negatively influence the biological flexibility of such a "salvaged" population for some time to come. This can only be remedied by very slow mutation rates which in turn can be enhanced by larger population size better able to adapt to changing environments and less prone to random drift.
Sublethal or lethal genes that can randomly expand in small populations pose a dilemma for genetic conservation. Genes that do not contribute to the success of an organism in a changing environment might still be useful for research and contribution of germplasm. There may, however, in some cases be some practical short-term reasons for having such alleles culled, even though this, in effect, lowers allelic variability.

5. REVIEW OF CURRENT PROGRAMMES OF IN SITU CONSERVATION OF GENETIC RESOURCES OF PLANTS

The scientific concepts of both in situ conservation and genetic resources have come-of-age within the last two decades. However, in many areas, earlier activities have consciously or inadvertently contributed to maintenance of plant species and their intra-specific variability for long periods of time. The need for comprehensive, secure and concerted efforts for in situ conservation has arisen because land use practices that are detrimental to wild plant populations have intensified and the demand for comprehensive access to wild gene pools for germplasm collection and utilisation are increasing. Additionally, the expanded storage capacities that would be needed to hold samples of the genetic variability of a range wild species of actual or potential value, may be largely unworkable. Unfortunately, existing protected areas in the world, are often inadequate for the needs of conservation of genetic and, in particular, intra-specific variability. It is, however, important to bear in mind that the need for maintaining this level of genetic diversity has only recently been appreciated and that existing networks are quickly responding to its challenge.

In many current programmes of protected areas, there are policy limitations for conservation of both plant and genetic variability. Networks of germplasm utilization and biological conservation often function separately both institutionally and academically, at national as well as international levels. In addition, much of the design criteria of parks and other protected areas have been oriented to favour vertebrates, largely neglecting the needs for plant conservation. Cadgil (1984) presents an expanded critique of the over-emphasis on fauna in modern reserves. He notes that more balanced and traditional conservation approaches that often involved concerns for particular genetic resources were debased by intrusion of the traditional western focus on game species and suggests that, "we shall therefore have to re-examine and re-design our system of
Emphasis in biological conservation can, in practice, be laid at three different levels of biotic diversity: community, inter-specific, and intra-specific. Most of the reserves in the world today are designed and managed for either ecosystem conservation or for the conservation of vertebrates. This latter category has arisen from the need to respond to threats of regional disappearance or total extinction of game. It has also been applied to rare plants. Ecosystem conservation, on the other hand, has been concerned with maintaining tracts of natural landscapes and the species diversity found in them.

Both the above approaches are based on certain assumptions viz. (i) that if a reserve is sufficiently large in area to protect and sustain large animals, other plant and animal species in the associated ecosystem will also be maintained; and (ii) that a protected ecosystem is in an equilibrium and will continue to sustain all the species that originally occurred in the area. A third assumption frequently made is that large reserves, per se, will maintain intra-specific diversity. Although the value of existing reserves is fully acknowledged, extrapolation of possible impacts outside of the objectives originally planned must be made with care. Only through on-going monitoring can their exact value for new objectives be ascertained.

In addition to the above, there are a number of limitations which must be considered when incorporating existing reserves into networks established for the conservation in situ of plant genetic resources: (i) Plant species have not been recognized as a valuable genetic resource and little or no information is generally available on existence, maintenance and utilization of intra-specific variability. Most of the reserves that currently protect valuable taxa are thus unlikely to safeguard this variability. (ii) Inventories and information on plant species found in the majority of designated parks and reserves are either non-existent or incomplete. (iii) Maintenance of intra-specific variability of plants is still not a management objective for the majority of protected areas. (iv) Most current reserves do not provide for procurement of reproductive material. Once identified and acknowledged, the above limitations can be either overcome or mitigated and existing reserves can form a link in situ networks.

There are local, state and provincial programmes of protected areas for a variety of biological and wildland conservation concerns which are today internationally largely unrecognized but which may well be able to conserve important local variability. Their value both at local and
international levels will be compounded if included as an element in a conservation network.

In addition to local programmes, there is also a small number of regionally oriented programmes for protected areas. For instance, the Council of Europe provides the "European Diploma" at the request of member states for natural areas of "international value". The 1979 Convention on the Conservation of European Wildlife and Natural Habitats has sections for conservation of wild plants and their habitats. Another example of a regionally oriented effort is the "Programa Internacional" of the U.S. based Nature Conservancy (TNC), which provides scientific and technical expertise and is developing a data base for the conservation of natural diversity in Latin America.

Currently there are no global programmes of protected natural areas with truly international jurisdiction. The International Union for Conservation of Nature and Natural Resources (IUCN), a non-governmental organization, with a number of member states and affiliated organizations, works closely with the World Wildlife Fund International (WWF), which has politically oriented national affiliates. WWF provides financial resources while IUCN has scientific expertise for wildlife and habitat conservation. Projects are supported at the request of, or in coordination with, national governments. Some IUCN supported projects also involve participation of, and funding from, United Nations Agencies.

IUCN is also known for promoting basic principles for conservation and linking them to social and economic development. Its World Conservation Strategy (IUCN 1981), prepared in collaboration with FAO, UNESCO and UNEP, represents a historical break-through in acknowledging both the importance of genetic diversity and the imperatives for its maintenance.

Within the UN, there are a number of organizations which are concerned with biological conservation. The Man and Biosphere Programme (MAB) of Unesco comprises an extensive and expanding network of natural areas, research facilities and scientists. The MAB Secretariat, itself, provides expertise and funding for a range of research and management activities focused on the conservation of natural ecosystems. The Forestry Department of FAO similarly provides expertise and funding for conservation in forest and wildland areas in the major fields of protected area and national park management; and the conservation and utilization of genetic resources. The United Nations Environment Programmes (UNEP) funds projects which involve the establishment of protected areas and biological conservation and
Coordination of activities on a global level is assured by (i) the Ecosystems Conservation Group (IUCN, FAO, UNESCO and UNEP); and (ii) the Designated Officials for Environmental Matters (UN agencies).

At its last meeting (February 1984), the Ecosystems Conservation Group agreed that FAO should be the "lead agency" in in situ conservation of plant genetic resources. Within FAO the coordinating role has been given to its Forestry Department.

Current programmes on protected areas and the conservation of wild plant genetic resources

The network of Biosphere Reserves established by UNESCO within the framework of its MAB programme is indicative of the strengths and limitations of research-oriented programmes in the field of protected areas. Its efforts have emphasized ecosystem (di Castri and Robertson 1982) or, in some cases, what might be better labelled "biome" (Dasmann 1972) conservation, see also Eidsvik 1984, Harrison et al. 1982, McNeely and Miller 1983, IUCN 1981). However, roughly 80 per cent of the current biosphere reserves were originally national parks and may therefore, in some cases, have some limitations in their use to protect the genetic variability of the plants found in the reserve. In spite of this, the MAB network provides key opportunities, at the international level, for conservation, procurement and research of genetic material (Hawkes 1982).

The MAB programme is thus among the pioneers in the application of scientific principles to in situ conservation of genetic resources (MAB 1973, 1974). A Biosphere Reserve Action Plan is presently under preparation which addresses the question of fuller use of existing MAB reserves for conservation and utilization of these resources. Efforts are also underway to carry out inventories of plant genetic resources within existing reserves. Dissemination of information, research for better methods of surveying and monitoring and coordination of activities on an international level, are also included in the MAB programme.

Within the framework of its global programme on forest genetic resources, FAO's Forestry Department supports national institutes in member countries in their efforts to explore, conserve, collect, evaluate and utilize genetic resources of woody species. The FAO Panel of Experts on Forest Gene Resources helps coordinate these activities and advises the Director General of the Organization on priorities of action in related fields, including conservation in situ of woody plant genetic resources.
Action-oriented programs in the fields of forest genetic resources and protected areas are also carried out or coordinated by the Organization on national and international levels. Special emphasis has, during the past 4-5 years, been placed on the conservation in situ of forest genetic resources, including the management and utilization of intra-specific genetic variability (see p. 38).

WWF/IUCN have often in the past emphasized faunal conservation over that of flora. In recent years steps have been taken to remedy this imbalance. The IUCN Plant Red Data Book (Lucas and Syngue 1978) was a pioneering effort to compile profiles on some of the increasing number of threatened and endangered plants in the world. The 1984-85 IUCN/WWF Plants Conservation Programme includes numerous individual projects on the establishment of protected areas and, in a number of cases, maintenance of intra-specific variability, is also considered.

In 1984, the IUCN created a professional post for a "Plants Officer", in charge of the programme on the conservation of plant genetic resources. Both the Threatened Plants and the Protected Areas Units of the Conservation Monitoring Centre of IUCN are also considering ways of rendering data collected by them more relevant for locating and determining status of species with priority genetic resources.

Increased awareness of the importance of conservation of genetic resources of wild plants in their natural habitats is creating new opportunities for action in in situ conservation. For instance, the Environment Review Section of the World Bank (World Bank 1984) has proposed an approach to identifying needs for wildland conservation and to help preserve biological diversity parallel with development planning. The concerns of the World Bank are also reflected in the international community at large, which increasingly recognizes the importance of evaluating potential ecological impacts of development programmes.

The growing number of national programmes for the protection of endangered species can be used to conserve species and taxa that have a rapidly dwindling distribution and are threatened by habitat conversion and alteration. Some programmes provide funding, necessary legal powers and expertise for formulating and implementing recovery plans for such species (Ściedyk et al. 1978). The Convention on Trade in Endangered Species (CITES) developed by IUCN could be employed to diminish destructive collecting of live plants by making their export and sale difficult.
Genetic conservation programmes by utilization categories

The largest genetic conservation efforts operational today have developed around national research institutes which utilize reproductive material for plant domestication and improvement. Relatively comprehensive national plant genetic resources programmes can be found in the Soviet Union, Europe and the U.S.A. In contrast, much of these in the developing countries is carried out at regional institutes.

As mentioned above, FAO's Forestry Department coordinates international activities in the forest genetic resources field. The International Board for Plant Genetic Resources (IBPGR) of the Consultative Group on International Agricultural Research (CGIAR) coordinates international efforts in plant genetic resources of especially food crops. IBPGR supports a diverse range of activities, including conservation and plant exploration, and provides technical expertise and funds for research, training and publications. Together with UNESCO it is the only significant international body in the field or plant genetic resources in which the U.S.S.R. actively participates. The IBPGR Secretariat is part of the Plant Production and Protection Division of the Agriculture Department of FAO.

The sections below outline the employment of protected areas and reserves in utilization-oriented genetic conservation programmes coordinated on global, regional and national levels.

**Food and fibre crops**

Conservation of genetic resources of food and fibre crops is carried out on both national and international levels. *Ex situ* methods are currently employed where possible. There are, however, some scattered national and local efforts for *in situ* conservation of wild relatives of crop species (Singh 1981). Many of the genetic reserves that lack international affiliations are poorly known. The Biosphere Reserves in the U.S.S.R. are the best documented efforts at conserving genetic resources of wild relatives of crops through an international programme (UNESCO/MAE).

Since its inception a decade ago, the emphasis of the work of IBPGR has gradually expanded from considering mainly landraces to the conservation also of wild relatives of cultivated plants. An example of such activities is its report on the genetic resources of tomato (Esquinca-Alcazar 1981).

IBPGR has not been directly involved with implementation of *in situ* conservation programmes (IBPGR 1984). However, IBPGR working groups and
committees have made a number of recommendations for in situ conservation of wild relatives of some of its priority crops (IBPGR 1981C);

- citrus and sugarcane, India: 1978 IBPGR Workshop on South Asia Plant Genetic Resources (IBPGR Secretariat 1978);
- inventories of species of economic significances within South East Asia biosphere reserves: 1980 South East Asia Regional Committee (IBPGR 1980);
- conservation of wild relatives of crops (Prescott-Allen and Prescott-Allen 1981; consultants' report);
- employment of biosphere reserves for in situ conservation of wild relatives: 1981 South East Asia Regional Committee (IBPGR 1981 A);
- Citrus spp.: 1981 Working Group on the Genetic Resources of Citrus (IBPGR 1981B);
- Cassava: 1982 Working Group on Cassava Genetic Resources (IBPGR Secretariat 1982, CIAT 1982);
- Prunus spp.: 1983 Working Group on Prunus and;

In 1984, IBPGR made its first policy statement on in situ conservation and later convened a Task Group on Eco-Geographical Surveying and in situ Conservation, which provided advice on scientific principles and priorities. The IBPGR has also joined the 1984-85 World Wildlife Fund Plants Campaign and has provided the initial funding to this agency for a survey of wild mango, Mangifera spp, in the protected natural areas of Borneo (Sabah, Sarawak and Kalimantan).

**Wood and Wood products**

In situ conservation efforts for genetic resources of wood and wood products have been and continue to be more extensive than with annual food crops. Woody perennials often pose problems for storage and for procurement of adequate amounts of seed. Consequently, in situ seed stands have been used as convenient adjuncts to, or substitutes for, base collections for numerous species for decades. Reserves have also been specifically set aside for in situ conservation of forest genetic resources, such as "Stands for Breeding Materials" in Japan; the Society of American Forester's "Natural Areas" (U.S. Department of State 1984); and the Finnish "Standard Stands" (Hagman 1971). Many more efforts are part of the general,
biological conservation networks initiated through regional, national and international efforts. Many such reserves were designated part of the International Biological Programme in the early 1970s.

FAO's Panel of Experts on Forest Genetic Resources, mentioned above, is the major international body that identifies needs for in situ conservation of species used for the production of wood and wood products as well as environmental stabilisation. Since its first session in 1968 (FAO 1969), the needs for utilization and dynamic management of nature reserves have been stressed. The second and third sessions (FAO 1972, 1974) developed guidelines for in situ conservation and the fourth and fifth (FAO 1977, 1984), in addition, drew up operational priorities (see also FAO 1980 B). FAO's Forestry Department, with financial assistance from UNEP, has assisted in the implementation of in situ conservation of Zambian teca, Baikisco pluriijuga, through the establishment of two botanical reserves in that country. With partial funding from the IBPGR, FAO's Forestry Department has also developed an extensive programme on the genetic conservation of arid zone arboreal species (FAO 1980A, 1983), which has involved numerous in situ conservation efforts. This Department has also published a series of case studies on the methodology of conservation of forest genetic resources, including in situ conservation (FAO 1975). An FAO/UNEP Expert Consultation on in situ conservation of forest genetic resources was organized by FAO in 1980 (FAO 1981). A manual on in situ conservation of forest genetic resources is presently under preparation and will be published in Working Paper form within 1984.

Forages

Main emphasis of much of the efforts in conservation of forage species is presently on the local level. Activities are often carried out by national and provincial agencies, and conservation of genetic resources of these species is often combined with more general biological conservation. A list of priority forage species and genera of international importance, with priority in in situ conservation, was included in the recommendations of the Report on the 1984 IBPGR Task Group mentioned on page 37.

Medicinals

The situation with in situ conservation efforts for medicinal plants is complex because of the great number of important species and the often local scope of their use. Most of the efforts for the conservation of these species has often been unintentional, supported by traditional patterns of management of areas such as the sacred groves of India and,
more recently, through local and national programmes of protected areas. In recent years, there has been a number of proposals for the establishment of "sanctuaries" for important medicinal plants, particularly in South Asia. IUCN, in close collaboration with the World Health Organization, has recently started some action aimed at the conservation of medicinal plants in a number of rural, Third World areas.

Environmental management

In situ conservation efforts in species that can be employed to stabilize, restore and enhance the environment have been carried out mainly within local and national nature conservation programmes, although elements of such conservation programmes are also included in the programmes of FAO's Forestry Department. The International Council for Research in Agro-Forestry (ICRAF) is concerned with utilization of multi-purpose trees, which form an important component of the plants in this category. ICRAF's efforts have, however, centered mainly on identification of sources of reproductive material, procurement and genetic evaluation.

Jurisdiction and scope of current programmes

Existing programmes of protected areas are not capable of fully satisfying the needs for in situ conservation of the genetic resources of plants. However, these networks can provide the basis for implementation of improved management, establishment of new reserves, research efforts and procurement of reproductive material.

Coordination on local, national, regional and international levels of in situ conservation of different categories of plants will not be easy, but will be essential.

It will probably not be possible to bring all protected areas, considered necessary for genetic conservation, under national jurisdictions; it may also be both politically and economically more desirable to involve local authorities in such work. Coordination of all local activities, including research, monitoring and procurement of germplasm, would in this case be done at national level, and networks based on these national efforts combined into regional and international programmes.

A considerable difficulty in the establishment, management and utilization of in situ reserves stems from the fact that the same species often occurs in several countries. Without access to a range of representative
populations, which requires international cooperation, the utility of the genetic resources found in the reserves is diminished. This question could be particularly important in the numerous situations where countries with wild plant genetic resources do not, at present, use them in cultivation. The incentive for in situ conservation, in these cases, might be the spirit of international cooperation and the hope that, over the long-term, recipient countries would reciprocally contribute their wild genetic resources. An example is the wild oil palm, *Elaeis* spp. which originates in West Central Africa and Northern South America. Oil palm is one of the most rapidly expanding plantation crops in the tropics (Harden 1976). Genetic material from wild species can be very useful in improvement (Johnson 1984). A number of palm species are on the verge of extinction and numerous others are rapidly declining due to habitat loss (Moore 1977). Most of the actual and potential benefits derived from utilization of the wild genetic resources of this genus are occurring outside the natural distribution range. As there may be little immediate interest for nations in those regions to devote resources to intra-specific conservation, incentives such as possibilities for exchange of genetic material of interest within the framework of international programmes may be needed, in addition to possible international financial assistance.

Research

Research currently being done on in situ conservation falls into two main categories: that which is biologically oriented and may be, in part, concerned with nature conservation; and that which is related to the use of genetic variability in economic activities. In both cases, research is intensifying. However, the potentially fertile overlap between the two areas is often neglected.

Current conservation-related research in botany and plant ecology is often devoted to the study of ecosystems. However, in many cases, like e.g. in the case of the tropical moist forest, taxonomic diversity is very large and it may therefore be necessary to initially focus on individual species and genera, i.e. the components of the ecosystem, rather than the ecosystem as a whole, in order to reach results of practical value.

Research on the utilization of wild species may be conducted in laboratories far from natural sites. Close integration of activities is needed to allow for field surveys of genera, species and intra-specific diversity to be coupled with evaluation of use properties and improvement
Information systems

With large amounts of information on thousands of plant species, computers can be an invaluable tool for rapid and comprehensive access to information. For more modest needs, a well-organized filing cabinet may be sufficient. Whatever the method of storage and retrieval, the basis for any information system is field data: researchers on the ground making observations and obtaining samples. No matter how sophisticated a computer system, its accuracy, and consequently usefulness, is only as good as the quality of the field data that has been entered. Morse et al. (1981) describes some systems for organizing data on conservation of various categories of phytogenetic resources.

There are no existing databases created for the specific needs of storing data on wild plant genetic resources or their in situ conservation. However, there are a number of programmes which have been created for different purposes, but which could be used to produce an information network in situ conservation. The Conservation Monitoring Centre (CMC) of IUCN can provide data on the status and relevant research on many of the plant species that have been identified as threatened or endangered, as well as descriptions of protected areas in most countries. Although species information available from the Threatened Plants Unit of IUCN usually does not give information on intra-specific variability, biological requirements or potentials for germplasm utilization, the two sets of data could be usefully combined to support conservation activities. For many valuable species, however, there has not been enough field research and essential information may thus be missing.

Most economic plants are not threatened or endangered on a species level, however, as their range of distribution diminishes, so may the amount of valuable genetic variability found in them at intra-specific level. Although the Protected Areas Unit mentioned above includes in its database lists of plant communities and of some of the main or dominant species, many economic plants or their wild relatives may often not be included. Even if an occurrence is noted, site and population data, which are the key for evaluating effectiveness of current conservation methods locating desired genetic material, are often not available. This is partly explained by the fact that the CMC was created for a different set of needs viz. to provide general information on ecosystem conservation. However, through adapting to changing needs, the CMC has succeeded in becoming a centre to which other more specialized conservation activities can be linked. For example, CMC is part of an informal monitoring network which includes UNEP's Global Environmental Monitoring System (GEMS). While this
latter data base has a much wider scope than does CMC and thus focuses even less on the specific question of conservation of genetic resources, some use may, in the future, be derived from data included in it, especially on the location of populations of target species.

There is a number of regional and national data bases that are concerned with biological conservation or protection of wild plants. Most have the same limitations as does the CMC. A number of these data bases, particularly in the Western Hemisphere, employ "elements-of-diversity" approaches (Jenkins 1981). Regional ecosystems are comprised of numerous species and community types. Data bases are concerned with important subsets or "elements", defined by vulnerability to extinction or by rarity. This approach could be expanded to include important plant species that are not necessarily vulnerable on the species level but in which attention may be needed in respect of intra-specific diversity; such diversity could be differentiated as sub-elements.

Information systems for documentation of ex situ collections of genetic material often involve micro-computers in regional institutes as well as in more central locations such as the IBPGR Secretariat in Rome. If the target populations in an in situ reserve were thought of as samples that are roughly analogous to those in ex situ genebanks, current data collection and documentation systems could be extended to include such reserves. However, the software would need to be expanded to cater for additional geographical and ecological data important in the documentation of in situ resources.

There are a number of data bases that catalogue useful plants, many of which are wild or only partly domesticated. E.g. ICRAF has developed a sophisticated data system for multi-purpose trees; and the Survey of Economic Plants for Arid and Semi-Arid Tropics (SEFASAT) at the Royal Botanical Gardens, Kew, U.K. is storing data on economic plants of arid regions. It might be possible to expand some of these systems to include information on wild populations as sources of reproductive material.

RECOMMENDATIONS

The growing concern for in situ conservation of the genetic resources of wild plants represents the convergence of remarkable different needs and interest groups. While this provides renewed opportunities for cooperative efforts, programmes must be carefully developed to respond to a wide range of needs and perspectives. In addition to new conservation areas to be
established considerations of the conservation of intra-specific variability must be added to the management objectives of earlier established protected areas. A similar expansion of perspectives and activities must take place within user groups of genetic resources. Emphasis on short-term needs for introduction and improvement must be augmented by participation in programmes aimed at long-term biological conservation.

The following recommendations comprise a rough blueprint for the beginnings of a global network for in situ conservation of the genetic resources of wild plants. The time-frame for accomplishing these first steps is roughly 1985-90, though current fiscal and administrative constraints are recognized. To assure early implementation, the resources and personnel of all of the international organizations that are already involved with phytogenetic conservation will need to be better coordinated. The role of FAO in the formation of such a network should be one of a catalyst and coordinator. Because FAO lacks membership of some countries such as the U.S.S.R. and the German Democratic Republic, which both have well-developed programmes for conservation of genetic resources of plants (Brezhnev 1975), formation of any in situ network implies cooperating and cooperating also with non-member countries.

In the creation of an in situ network, simultaneous efforts are necessary in survey and exploration; and the development of improved methods for the establishment and management of reserves. In parallel with the technical activities, those concerned with policy, funding and overall coordination must be considered. The respective roles of FAO, UNESCO, UNEP, IUCN and IBPGR should be streamlined to avoid duplication of effort.

**Identification of plants of actual or potential value for genetic conservation**

Identification of useful plants that require genetic conservation, at both international and national levels, has been going on over the last decade. A start has also been made to identify species of local and regional significance.

Lists of plants of international importance have been compiled for food and industrial crops (IBPGR 1981), wood and wood products plus woody species for environmental management (FAO 1984) and forage species (see p. 38). These should be augmented with lists of medicinal plants and non-woody species used in environmental management. Currently available lists of important species for genetic conservation should be periodically revised and updated in the light of new knowledge and manifested needs.
The above lists will include both plants which have already been domesticated and for which wild progenitors may still exist; and those which are in the early stages of domestication and where the majority of the gene pools are found in wild populations. These important species and genera, which have not yet been sufficiently well explored taxonomically, should be identified for further research. Lists of genetic resources of wild species of importance locally or regionally, should be circulated to international and national agencies to highlight their economic significance and the need for conservation.

Field surveys of distribution and intra-specific diversity

Once genetic resources of wild species have been identified, detailed information on their distribution, ecological and genetic variability and status should be obtained and mapped. Because of the lack of field research and, consequently, the limited value of the information available for many wild species, desk studies cannot provide sufficient information on which to base conservation and utilization activities without prior intensive field work. Two main types of survey can be distinguished: the gene pool approach, where all the important species within a particular genus are surveyed throughout their distribution; and the regional or district approach, where all of the important genetic resources in a given area or region are surveyed. Genotypic evaluation of the material, which usually involves the establishment of field trials or study areas, is an essential component of these surveys. Both the above types of programme of exploration must be rapidly expanded in coming years and funding and manpower presently dedicated to them must be increased on international, regional, national and local levels.

Surveys of genetic resources in existing protected areas

The efforts presently underway to inventory plant species in parks and reserves should be greatly accelerated. Information provided from such inventories should also be expanded so that, in addition to simple lists of species found in the reserves, data are collected also on their density and occurrence in relation to environmental gradients. Where possible, concerns for genetic resources of particular wild species should be conveyed to field researchers and data on intra-specific ecological variability should be sought from them.

As with taxonomic research and general surveys, higher levels of funding are needed for these activities over the next five years.
Development and application of methods for formulating minimum requirements for conservation

Theoretical knowledge for determining minimum requirements and methodologies for conservation of genetic variability have been rapidly increasing over the last two decades. However, this knowledge has, in practice, been only rarely applied to plant species, especially as regards the maintenance of intra-specific variability. Similarly, the debates on minimum area requirements and reserve shape for long-term conservation have often been focused on animal species. More manuals on a variety of topics, like the UNEP funded FAO manual on in situ conservation of forest genetic resources, are needed.

The development and evaluation of scientific methods for formulating criteria for minimum viable population size, related ecological requirements including that of associated "indicator species", and reserve design for particular populations must be intensified and such research must be given high priority for funding. Proven methods and case studies should be documented and information on them disseminated to planners and land managers.

Technical support for national programmes of in situ conservation of plant genetic resources

While a meeting of experts can draw up lists of priority species and methodologies of conservation, implementation is a matter of national land use planning and policy. The numerous steps requiring environmental planning and management and, in particular, the careful integration of conservation requirements with socio-economic development, involve a great deal of scientific and technical expertise. Consequently, a substantial portion of the total budget of the international organizations which cooperate on in situ conservation of phytogenetic resources, needs to be channelled to technical assistance for and coordination of projects that deal on the levels of specific sites, species and populations.

Monitoring of genetic reserves and wild populations

While day-to-day monitoring should be an integral part of in situ conservation, periodic comprehensive field assessments will be necessary to evaluate effectiveness of the protection and management measures applied, and early action will have to be taken to remedy any problems or discrepancies found. Especially in the case of genetic resources being conserved in a number of different countries, international coordination of such activities will be necessary.
Development of a data base on in situ conservation

In the programmes outlined above, valuable data will be gathered on distribution and genetic variation of target species. Early provision must be made to store such data in standardized and easily retrievable form. The likelihood that in situ gene banks will be cross-sectoral and scattered makes this provision particularly important.

Such a data base should be designed to be equally useful for the purposes of conservation and to location and procurement of desired genetic material. The system must thus be sophisticated enough to: (i) process geographical and site-related information; (ii) include programmes for modelling and formulating conservation objectives; and (iii) allow for addition of new information from monitoring. The major international organizations that are involved with conservation of genetic resources, FAO, Unesco, UNEP, IUCN and IBPGR, should cooperate to develop and fund a computerized information system closely linked to that held at IUCN's Conservation Monitoring Centre at Kew.

Dissemination of information

An important determinant for long-term conservation will be the raising of awareness of this economically and morally important question at international, regional, national and local levels. Consequently, it will be advantageous to encourage the full utilization of available genetic resources and to highlight resulting benefits. It is particularly important that local utilization of genetic material be encouraged and that this be part of a broader effort to stimulate plant introduction and improvement in developing countries. Improved dissemination of information is a pre-requisite for progress on these lines.

Education

Methods for in situ conservation should be taught in training programmes on phylogenetic resources, forestry, land use planning and conservation biology. International courses and related training should be coordinated between those agencies which are concerned with formal or on-the-job training, viz. Unesco, FAO and IBPGR. The need for more technicians, experts and scientists, particularly from developing countries, should be assessed.
Coordination at international level

The most pressing needs identified above are surveys of important gene pools; identification of gaps in present conservation programmes; initiation of vigorous field activities; and the mobilization of increased funding. To achieve these goals, formal coordination of international and national action is needed, as well as the establishment of ad hoc technical groups called upon to help solve specific, technical problems.

Cooperation on international level can be achieved through meetings of the Ecosystems Conservation Group (see above), and the activation of its ad hoc Working Group on Plant Genetic Resources, established in February 1984.
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