

## Planning Plant Genetic Conservation



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### Summary

Before conservationists embark on a project, they must be clear about why the taxon warrants conservation. The reason for the selection of taxa to conserve should be based on a series of measurable criteria, such as genetic distinctness, the probability of species extinction, the threat of genetic erosion and the potential economic value of the taxon now and in the future. Once a taxon has been chosen for conservation, better outcomes will be achieved if conservationists develop an understanding of the taxon's geographic distribution, habitat preferences, phenology, genetics and taxonomy. This information, necessary to the formulation of an effective conservation strategy, is acquired by conducting an "ecogeographic survey". This consists of collating and analysing all the current information available on the target taxon from literature, passport data on herbarium specimens, databases and taxonomic experts. The information generated during the course of an ecogeographic survey can also be used to begin the characterisation of collections of conserved plant germplasm.

## Introduction

Plant genetic resources have been defined as the "genetic material of plants, which is of value as a resource for the present and future generations of people" (IPGRI, 1993). Traditionally, this definition focused on crop plants and their wild relatives, but it is increasingly considered that all plant species are a potential resource for humanity. The ultimate goal of genetic resources conservation is to ensure that the maximum possible genetic diversity of a taxon is maintained and available for potential utilisation. Marshall and Brown (1975) described the process in the model presented in Figure 3.1:

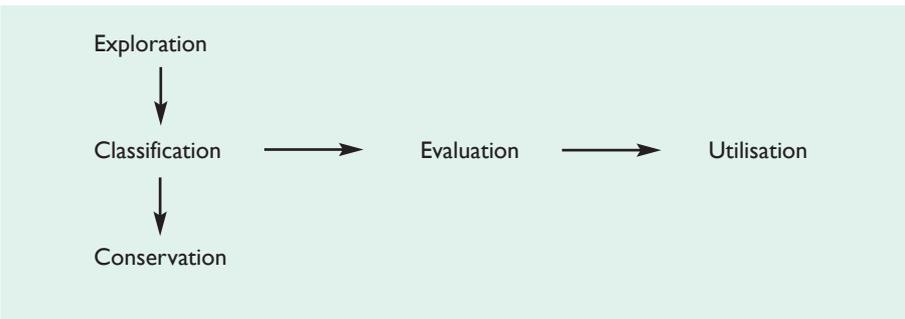


Figure 3.1 The exploration model (Marshall and Brown, 1975).

As useful as this early model proved in highlighting key components of conservation, it failed to sufficiently highlight the fact that **plant genetic resource conservation acts as a link between the genetic diversity of a plant and its utilisation or exploitation by humans**. Conservation and utilisation are not two distinct end goals of working with plant diversity, but in fact are intimately linked. This link is shown more explicitly in the simple model for plant genetic conservation shown in Figure 3.2.



Figure 3.2

Conservation: the link between genetic resources and utilisation (Maxted *et al.*, 1997a).

Building on these two simplistic frameworks, a more comprehensive model can be formulated that includes each of the many component steps in contemporary plant genetic conservation (Figure 3.3). The starting material is ‘raw’ plant genetic diversity and the ultimate products are useful plant materials, with the component conservation steps linking the two ends.

The first steps of the model are the planning stages, including how to go about selecting which taxa to conserve and where to find information on the selected group. This chapter will focus on these planning stages of plant conservation while other chapters in this volume will provide details of specific conservation techniques.

## Selection of Target Taxa

At an emotional level, all of us with an interest in, or love of, nature believe that each unit of biodiversity has intrinsic value, and as such should not be thoughtlessly destroyed by humankind but should be actively conserved. However, with the limited financial, temporal and technical resources currently available to conservationists, we are forced to set priorities and select which taxa to focus on. The genera, species, or varieties we focus our conservation activities on are often referred to as “target taxa”, and the process of choosing them should be objective, based on logical, scientific and economic principles related to their utility (McNeely, 1988; Pearce and Turner, 1990; Pearce and Morgan, 1994; Department of the Environment, 1996; McNeely and Guruswamy, 1998). The utility of a taxon can be valued through an integration of its conservation biology, the intended conservation purpose, the economic costs of conservation options and its current conservation status (Maxted *et al.*, 1997b).

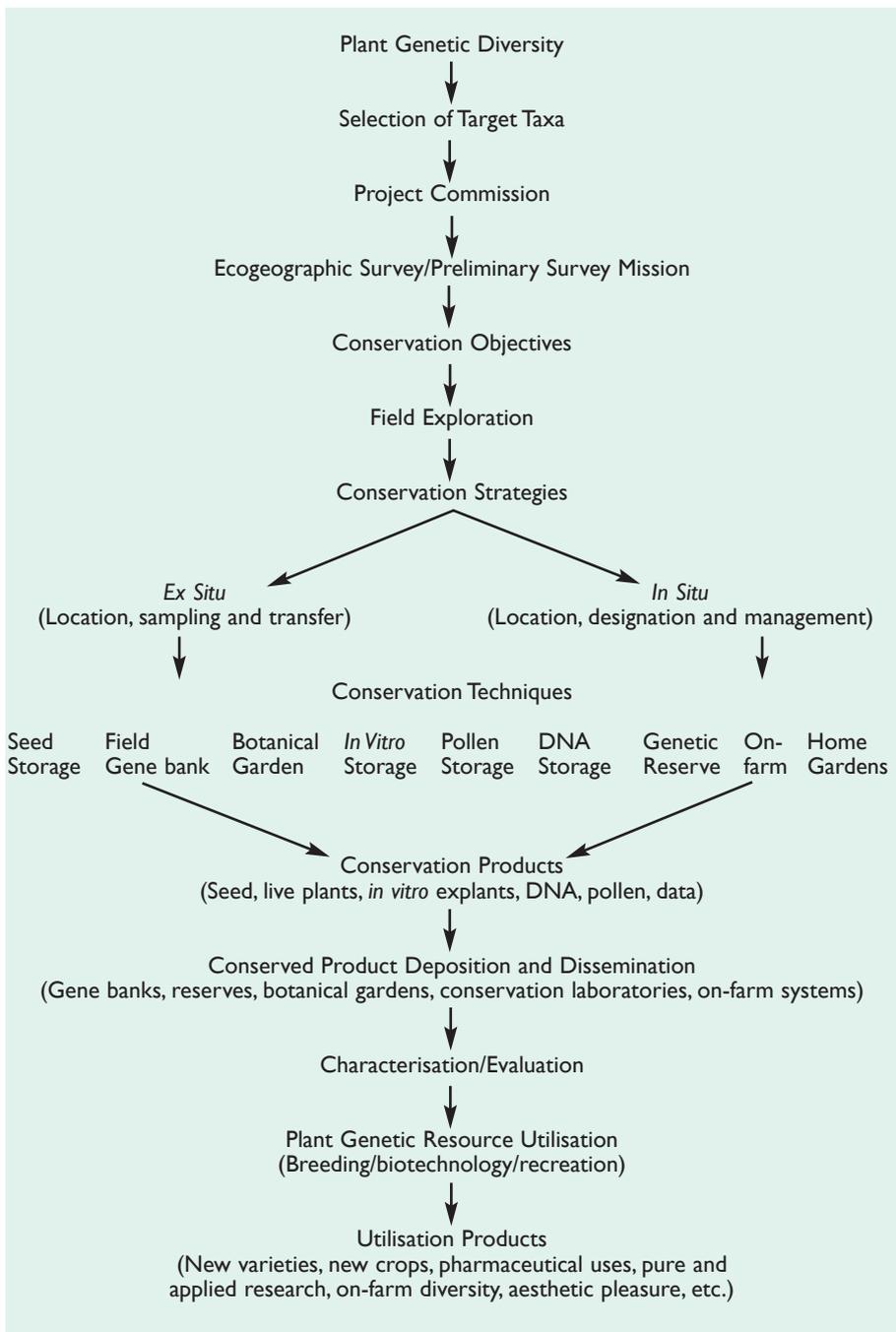


Figure 3.3

A model of plant genetic conservation (adapted from Maxted *et al.*, 1997a).

Conservation biology can then be usefully subdivided into:

- Taxonomic and genetic distinctiveness
- Ecogeographic distinctiveness
- Biological importance
- Current and likely future threats *in situ*.

Conservation purpose can be evaluated at a variety of scales: global; continental; regional; national; and local. Conservation purpose can be further subdivided into:

- Legislation
- Conservation agencies priorities
- Socio-economic use
- Cultural importance
- Ethical and aesthetic considerations.

Costs of conservation options are divided into:

- Relative costs of options
- Sustainability of options.

Current conservation status is determined by:

- Evaluation of genetic representation of conserved *in situ* or *ex situ* samples
- Evaluation of likely continued success of previously used conservation actions.

## 1. Conservation Biology

### 1.1. Taxonomic and genetic distinctiveness

If our goal is to conserve the maximum genetic diversity of higher plants, two distantly related taxa would achieve this goal more easily than two closely related taxa, as closely related taxa will share a greater proportion of genes. This approach can be applied to all levels of taxonomic hierarchy. As an example, consider a flora that supports only three species, two closely related species of dandelion and a third species, the taxonomically isolated species, *Welwitschia mirabilis* Hook.f. If resources are available to conserve only two of these species, logically, one of the dandelions and the *Welwitschia mirabilis* should be chosen. This example shows how the conservationist can use taxonomy and phylogeny (study of evolutionary relationships between taxa) to deliberately select complementary target taxa to conserve the maximum range of biodiversity.

### 1.2. Ecogeographic distinctiveness

Plant species that are widespread, in terms of geographical and ecological range, can generally be assumed to be under less threat of genetic erosion and extinction than those that are localised or restricted to a specific habitat. Higher conservation priority should therefore generally be given to species that are restricted in their habitat requirements and hence distribution. These species are often referred to as endemics, meaning that their distribution is restricted to a particular, specified region. Many countries have lists of their endemics, but the size of the country should be taken into account when using such information to select target taxa. The ecogeographic distinctiveness of a Jamaican endemic is very different to that of a Russian one.

### 1.3. Ecological importance

Some species within an ecosystem are thought to play a disproportionately important role in its overall function and its processes than others. These species are sometimes termed keystone species. They are essential to the overall integrity of the ecosystem and to the survival of other species within it. Generally, keystone species are critical to the interactions between trophic levels. The Brazil nut tree (*Bertholletia excelsa* Bonpl.), for example, as well as being economically important, plays an important ecological role in the forests of the Amazon basin in that it provides a critical food resource (large oil-rich seeds) for many other species, whose survival is associated with it. Keystone species are often given higher value when considering alternative target taxa for conservation, because of their pivotal role in maintaining the habitat or ecosystem. This is true, even when considering species for *ex situ* conservation, because of their reintroduction potential.

### 1.4. Current and likely future threats *in situ*

A taxon can be assigned a level of threat according to the IUCN Red List Categories (Figure 3.4) on the basis of data on numbers of mature individuals, population size trends, population fluctuations and distributions of populations, demographic patterns, and extinction probabilities in the wild. For example, those species classified, as 'Threatened' will have a priority for conservation higher than those classified as 'Least Concern'. These assessments can be applied at local, as well as global scales.

The IUCN Red List Categories for individual plant species at global and national levels can be obtained by consulting the 2000 IUCN Red List of Threatened Species (Hilton-Taylor, 2000), which is available on CD-ROM and the internet. This more rigorous classification of threats supersedes the earlier, more subjective categories listed in 1997. However, the 2000 categories have yet to be applied to the bulk of the plant species listed as threatened and endangered on the 1997 IUCN Red List of Threatened Plants (Walters and Gillett, 1998). Therefore, it may be wise to use the 2000 list in conjunction with the 1997 list, until the 2000 IUCN Red List Categories have been more widely applied. More recent information on Red Data Lists can be obtained from the IUCN website at <http://www.redlist.org/>.

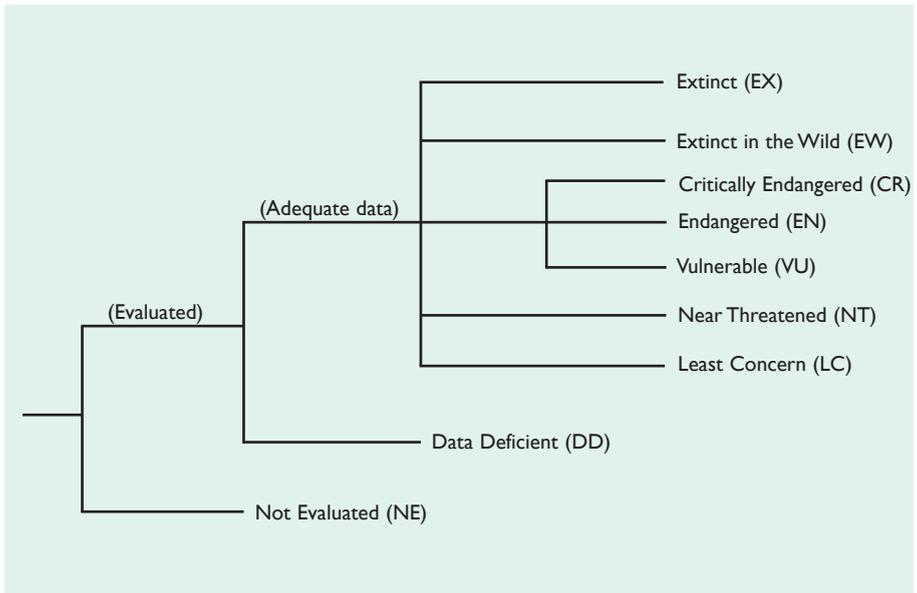


Figure 3.4 IUCN red list categories, Version 3.1 (IUCN, 2000).

Individual countries also have their own national Red Lists. An example of a species assessed using the IUCN Red List Categories is *Saintpaulia rupicola* B.L. Burtt, a wild relative of the African violet, the ornamental houseplant. This species is restricted to two remaining populations in the coastal forests of Kenya. Each population consists of about 100 individuals and their habitat is threatened from logging and agricultural encroachment. Under the IUCN Red List Categories, this species is classified as “Critically Endangered”.

The IUCN Red List Categories focus on threat of extinction faced by the species as a whole, but the genetic conservationist is also interested in loss of genetic diversity within the species. Within the 2000 IUCN Red List Categories, a species could still remain ‘unthreatened’ (categories LC or NT in Figure 3.4) whilst its global population reduces in number. In such circumstances, significant genetic diversity could be lost. It is therefore advisable to also assess the threat of genetic erosion faced by a species. A model for estimating the relative threat of genetic erosion that a taxon (wild or cultivated) faces in a defined region has been proposed by Guarino (1995). The model is based on scoring numerous parameters, such as: relative taxon distribution; whether the species distribution is declining, increasing or static; degree of farm mechanisation; relative use of herbicide and fertiliser; conservation status of the taxon; and the extent of its use, etc. The higher the score obtained, the greater the risk of genetic erosion. Interestingly, the model can be used without even visiting the area in question, providing the data are available for the parameters included in the model.

## **2. Conservation Purpose**

### **2.1. Legislation**

Some species are protected under international, regional or national legislation. Those species will also be given high priority for conservation by the parties to the legal instruments as they seek to implement their obligations. Table 3.1 lists some international and regional legislation of importance to plant genetic resource (PGR) conservation. Many countries have national legislation protecting specific areas, and in some cases, individual species. Lists of such laws may be obtained from the IUCN Environmental Law Programme web site (<http://iucn.org/themes/law/index.html>).

### **2.2. The priorities of conservation agencies**

The conservation priority ascribed to a particular taxon will be influenced by the mandate and priorities of the agency and interest groups involved. The conservation priorities of a country's ministries of agriculture, forestry and environment are likely to be different from one another. The ministry of agriculture will be mainly interested in crops and crop relatives, the ministry of forestry, in trees for timber, and the ministry of environment may have a more general ecosystem remit. Different levels of priority are also likely to be given to the same taxon by a variety of interest groups, such as ecologists and park managers; population geneticists and taxonomists; plant breeders, agriculturalists and economists; and traditional healers and sociologists.

There may be differences between local, national, regional and international agencies in their priorities. A species may not be considered threatened internationally, but within a particular country, perhaps on the edge of its natural distribution, it may be vulnerable and so warrant active conservation. Regional crop genetic resources networks, of which there are many throughout the world, often have conservation priorities that are somewhat distinct from those of any of their constituent national PGR programmes.

### **2.3. Socio-economic use**

For any taxon, socio-economic use varies with geographic scale. The socio-economic use made of a taxon at local, national, continental and global levels can vary greatly. Any assessment of use must apply at the same level as that set for the conservation purpose.

Plant species that have a socio-economic use, e.g., that provide food, fuel, medicines, building materials, tools, adornment, recreation, etc., for humankind will be given priority over species that are not perceived as having these uses, when selecting taxa for conservation. Crops and their wild relatives will often be given the highest priority (see Box 3.1).

When discussing the socio-economic value of wild relatives, the crop gene pool concept developed by Harlan and De Wet (1971) is often applied (Box 3.2 and Figure 3.5).

Acronym	Treaty	Date	Place
-	Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere	1940	Washington
<b>IPPC</b>	International Plant Protection Convention	1951	Rome
<b>Ramsar</b>	Convention on Wetlands of International Importance Especially as Waterfowl Habitat	1971	Ramsar
<b>WHC</b>	Convention Concerning the Protection of the World Cultural and Natural Heritage	1972	Paris
<b>CITES</b>	Convention on International Trade in Endangered Species of Wild Fauna and Flora	1973	Washington
<b>Berne</b>	Convention on the Conservation of European Wild Life and Natural Habitats (Europe)	1979	Berne
<b>ITTA</b>	International Tropical Timber Agreement	1983	Geneva
<b>CBD</b>	Convention on Biological Diversity	1992	Rio de Janeiro
-	Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (Europe)	1992	Brussels
<b>ITPGRFA</b>	International Treaty on Plant Genetic Resources for Food and Agriculture	2001	Rome
<b>GSPC</b>	Global Strategy for Plant Conservation	2002	The Hague

If we apply this concept to barley as an example, *Hordeum vulgare* L. subsp. *vulgare* and its progenitor *H. vulgare* subsp. *spontaneum* (C.Koch) Thell. would belong to GP1, *H. bulbosum* L. to GP2, and all the other *Hordeum* L. species to GP3. The highest value would be ascribed to the GP1 species, then GP2, and finally, GP3. This kind of priority setting can be refined on the basis of the expectation of finding novel genetic variation in different species, and the demand for specific traits by users. Some species within a given gene pool may be more likely to harbour desired traits.

#### 2.4. Cultural importance

Species may also be selected as target taxa for conservation because of their symbolic or religious significance in local or national culture. An example of such a species is the Cedar of Lebanon, *Cedrus libani* A. Rich., whose area of native forest has declined extensively in recent years. This species is an important national symbol in Lebanon, being represented on the nation's flag, money, and stamps, for example. Compared with other coniferous tree species, it does not have particular economic value, but it is being actively conserved because of its great symbolic value in national Lebanese culture. Similar examples are provided by Banyan (*Ficus benghalensis* L.) trees in India,

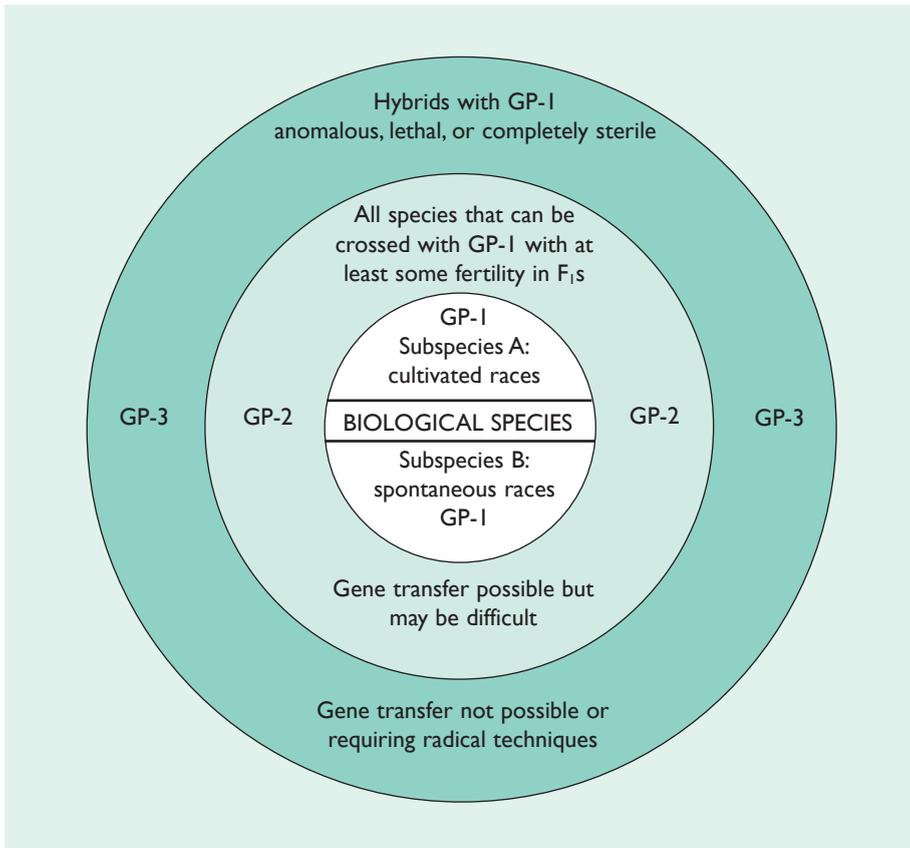
**Box 3.1 African oil palm (*Elaeis guineensis* Jacq.): the value of genetic resources to industry (Johnson, 1996)**

Africa has a relatively low diversity of palm species; it is the native habitat of the world's most economically important palm, *Elaeis guineensis*. The African oil palm has become, over the past three decades, a major world source of vegetable oil. At present, annual yields reach five to six tons of oil per hectare, more than any other oilseed crop. This enormous global industry is founded on a very narrow genetic base, derived mainly from four individual palms introduced from Africa to Asia. A major objective of the industry in recent years has been to broaden the genetic basis of the crop to maintain and improve production. Studies have shown the crucial value of natural (wild and sub-spontaneous) oil palm groves in Africa as a leading source of new genetic variation for production traits and disease resistance. For example, some Nigerian dwarf palms have yield potential that could double current production levels as well as reduce harvesting cost because of their short stature. Studies have also been carried out on *E. oleifera* (Kunth) Cortés, the American oil palm, and the only other species in the genus. Although its oil yields are uneconomic and it has an undesirable procumbent growth form, *E. oleifera* does have desirable traits and is therefore of some interest to breeders. It can be readily crossed with the African species, making feasible the transfer of traits such as moderate growth, disease resistance, and higher percentage of mono-unsaturated oils to the commercial crop.

Malaysia, the world's largest producer and exporter of palm oil, has taken the lead in genetic prospecting, through PORIM (Palm Oil Research Institute of Malaysia). Palms with desirable traits are conserved in a field gene bank in Malaysia and are being screened for traits. As a result of PORIM's research and that of other institutions in Asia, Africa, and Latin America, more scientific information is available on African oil palm than on any other palm species. This work has also demonstrated the importance of conserving and making available the widest possible range of wild genetic diversity for exploitation by breeders.

**Box 3.2 The concept of crop gene pools (Harlan and de Wet, 1971)**

- **Primary gene pool (GP1):** the true biological species including all cultivated, wild and weedy forms of a crop species. Hybrids among these taxa are fertile and gene transfer to the crop is simple and direct.
- **Secondary gene pool (GP2):** the group of species that can be artificially hybridised with the crop, but where gene transfer is difficult. Hybrids may be weak or partially sterile, or chromosomes pair poorly.
- **Tertiary gene pool (GP3):** includes all species that can be crossed with difficulty (e.g., requiring *in vitro* hybrid embryo culture), and where gene transfer is impossible or requires radical techniques (e.g., radiation induced chromosome breakage)



**Figure 3.5** Schematic diagram of gene pool concept (Reproduced with permission from Harlan and de Wet, 1971).

and the Swamp cypress (*Taxodium distichum* (L.) Rich.) revered by the Aztecs in Mexico. Taxa may also be ascribed value because of their importance in religious ceremonies, such as *Bauhinia guianensis* Aubl. among the Waimiri Indians of Brazil (Milliken *et al.*, 1992).

## 2.5. Ethical and aesthetic considerations

In selecting target taxa, one must not dismiss the ethical and the aesthetic reasoning for biological conservation. The ethical justification for conservation reflects the sympathy, responsibility and concern that most people feel towards other forms of life on earth and the ecosystems that house them. For many people, nature does have a utility apart from the value for human exploitation. Their quality of life is enhanced knowing that biodiversity is 'safe' for future generations. This stewardship value for humankind should not be overlooked.

Some species appeal more to the general public and hence receive more media attention in conservation programmes. These are often termed flagship species. In the plant kingdom, orchids are often considered as flagship species due to their remarkable beauty and the diversity of the family (c. 30,000 species). Large trees are also an easy focus for the public's concern. The conservation of flagship species is often easier to fund than less showy species, and can sometimes be used as a tool to raise awareness and so leverage funding for broader conservation projects.

### 3. Economic Costs of Conservation Options

#### 3.1. Relative cost of conservation

Faced with a limited budget, conservationists may be required to select between two alternative target taxa of otherwise equal "value". In such cases, the relative costs of conservation will clearly be a factor affecting the final decision. For example, the UK Biodiversity Steering Group report (Department of the Environment, 1995) costed the effective *in situ* conservation of 45 of the UK's most threatened or endangered plant species. They estimated that conserving the Killarney fern (*Trichomanes speciosum* Willd.) would cost £33,000 per year, while the starry breck lichen (*Buellia asterelle* L.) would cost £1,000 per year. All other factors being equal, the conservation of the starry breck lichen might therefore be given priority over the Killarney fern.

The number of target taxa it is possible to conserve in a single reserve will also affect the choice of taxa. If it is possible to conserve more than one target taxon in a reserve, simple economics will dictate that species that can be conserved together in one multi-purpose reserve will be given a higher priority than those requiring distinct reserves of their own.

The relative costs of launching a collecting programme for *ex situ* conservation or establishing *in situ* reserves for different species will affect the selection of target taxa.

#### 3.2. Sustainability of conservation

Conservation, whether *in situ* or *ex situ*, is by definition long term and requires a relatively large investment of resources, whether in building a gene bank or establishing a reserve. There would therefore be little value in collecting and storing seed, establishing a genetic reserve, or encouraging farmers to practise on farm conservation, unless the conservation activity was likely to be sustainable in at least the medium to long term. The conservation of certain species may not be equally sustainable under each conservation technique. For example, for some species, such as ephemeral weeds, there would be difficulties in establishing a genetic reserve, as the plants require regular, repeated soil disturbance. Therefore, if funds were specifically allocated for the establishment of a genetic reserve, these species would be inappropriate as target taxa, i.e., unless the repeated soil disturbance could also be guaranteed.

#### 4. Current Conservation Status

Before a taxon can be finally given high priority for conservation, current conservation activities must be reviewed. If sufficient genetic diversity is already being conserved from a range of agricultural systems, ecological habitats and geographical locations using both *in situ* and/or *ex situ* techniques, then additional conservation efforts may not be necessary. Details of what material is currently being conserved can be obtained from catalogues, databases and other records of the holdings of gene banks, botanical gardens and *in situ* conservation areas. Box 3.3 identifies some of the principal sources of information.

As an example, Box 3.4 shows the sort of information that is available about a particular gene bank from the IPGRI directory of *ex situ* germplasm collections for pineapple.

Care must be taken when interpreting such information from catalogues, directories and databases:

- Conserved material may be incorrectly *identified*, though it should be possible to check the identifications by consulting voucher specimens, or by identifying living material in field gene banks, or during regeneration or characterisation.
- *Duplication of accessions* between collections is common security practice. However, without a proper comparison of the accessions' origins, a misleading impression of the actual number of unique conserved accessions can arise.
- The conservationist should also be aware that although accessions may be conserved using one technique, say either in an *ex situ* seed bank or *in situ* genetic reserve, there may be *insufficient duplication between techniques to provide safe complementary coverage*.
- Conserved material may for various reasons be *dead* or *in a very poor condition*.
- A conserved accession may not reflect the genetic diversity of the source population due to *poor sampling in the field*.
- Material may be *unavailable to some potential users for policy reasons*.
- The available information may be *out of date*.

Throughout their natural range, conservation of many taxa will have been implemented in a haphazard or biased way. Areas easily accessible to the collectors are probably over-sampled and less accessible areas are probably under-sampled. Politically unstable areas are particularly likely to have been avoided. Common species in a genus will probably have been over-collected relative to the rarer ones.

**Box 3.3 Sources of information used to establish current conservation status of a species**

- IPGRI (International Plant Genetic Resources Institute) directories of germplasm collections. IPGRI (formerly the International Board for Plant Genetic Resources [IBPGR]) periodically produces crop or crop relative specific directories on world gene bank holdings e.g., on tropical and subtropical fruits and tree nuts (IBPGR, 1992); many are now available via the Internet <http://www.cgiar.org/ipgri/>.
- ECP/GR (European Cooperative Programme on Genetic Resources) contains information on germplasm accession holdings in Europe, which can be contacted via the Internet <http://www.cgiar.org/ecpgr/>.
- EPGRIS (European Plant Genetic Resources Information Infrastructure) contains further information on *ex situ* crop germplasm holdings in Europe, which can be contacted via the internet <http://www.ecpgr.cgiar.org/epgris/>.
- GRIN (Germplasm Resources Information Network), which provides information about US genetic resource holdings and can be contacted via the internet <http://www.ars-grin.gov/>.
- SINGER - System-wide Information Network for Genetic Resources. This database that holds details of *ex situ* collections of the CGIAR centres. The database can be accessed via the Internet <http://www.cgiar.org/singer> or can be obtained on CD-ROM.
- WIEWS the World Information and Early Warning System on Plant Genetic Resources. This is a database that contains information on national PGR holdings and can be contacted via the internet [www.fao.org/ag/agp/pgr/wiews/](http://www.fao.org/ag/agp/pgr/wiews/).
- Gene bank managers. Directly contacting the database manager of individual gene banks is worthwhile providing you have some knowledge of their interest in your target taxon.
- Heywood *et al.* (1991) International Directory of Botanic Gardens. 5th edition. More recent information may be obtained *via* the internet at the Botanical Garden Conservation International <http://www.bgci.org.uk/>.
- IUCN (1994) 1993 United Nations List of National Parks and Protected Areas. IUCN, Gland, Switzerland and Cambridge, UK.
- IUCN (1992) Protected Areas of the World: A review of national systems. Volume 1: Indomalaya, Oceania, Australia and Antarctica, Volume 2: Palaearctic, Volume 3: Afrotropical, Volume 4: Nearctic and Neotropical. IUCN, Gland, Switzerland.
- Plant conservation and breeding publications and reports. The plant conservation and use literature is an important source of information on what material is currently conserved and where. PlantGene CD is a useful searchable source for abstracts.

**Box 3.4 Directories of germplasm collections**

IPGRI publish a series of directories on *ex situ* germplasm collections and also make the information available on the Internet. Below is a typical entry for an institute with an *ex situ* collection of pineapple germplasm.

**BRASIL:**

**CENTRO NACIONAL DE PESQUISA DE MANDIOCA E FRUTICULTURA- EMBRAPA** **TEL: +55 (0) 75 7212120**  
**C.P. 007, RUA EMBRAPA S/N** **FAX: +55 (0) 75 7212074**  
**ELECTR. MAIL:**

**Curator/person in charge:** J.R.S. Cabral

Details of holdings:

*Aechmea mertensii*, 1

*Ananas ananassoides*, 34 wild/weedy species from Brazil (34)

*A. bracteatus*, 12 wild/weedy species from Brazil (12)

*A. comosus*, 212 advanced cultivars, wild/weedy spp from Brazil (212)

*A. erectifolius*, 4 wild/weedy species from Brazil (4)

*Ananas species*, 24 from Australia, Malaysia

*Billbergia spp.*, 3 wild/weedy species from Brazil (3)

*Bromelia balansae*, 8

*B. caratas*, 2

*B. goeldiana*, 4

*B. laciniosa*, 1

*B. plumieri*, 1

*Bromelia spp.*, 32 wild/weedy species from Brazil (32)

*Pseudananas sagenarius*, 14

*Tillandsia spp.*, 4 wild/weedy species from Brazil (4)

**Maintenance collection:** Field collection

**Duplication sites:** INSTITUTO AGRONOMO DE CAMPINAS, CAMPINAS, SAN PAULO, BRAZIL. EMPRESA DE PESQUISA AGROPECUARIA DO ESTADO DO RIO DE JANEIRO, NITEROI-RIO DE JANEIRO, BRAZIL. EMPRESA PERNAMBUCANA DE PESQUISA AGROPECUARIA, RECIFE-PERNAMBUCO, BRAZIL.

**Availability germplasm:** Restricted

**Quarantine regulations:** Export restricted due to fusariose by *Fusarium moniliforme*

**Evaluation status:** On-going for fruit quality and resistance to diseases and insects

**Documentation:** Partial, manual and computerised

Each of these points underlines the need for careful interpretation of current conservation status, but if gaps in conserved materials are apparent, then further conservation action is likely to be required. The identification of gaps in representation of conserved diversity is referred to as ‘gap analysis’.

There is, however, a requirement to conserve biological diversity at the ecosystem, habitat, species and genetic levels, using both *ex situ* as well as *in situ* techniques for the latter two levels. Gap analysis is being increasingly used over the complete range of techniques.

Discussions of *ex situ* collecting proposals with crop breeders, agronomists, ecologists and other experts are valuable in addition to those with gene bank managers. They will be able to help identify geographical gaps in collections as well as places of possible interest, such as areas where resistance or adaptation genes have been found in the past, or are thought likely to occur.

## Formal Target Identification

The various factors discussed above give ‘value’ to species and thus aid the efficient selection of priority taxa for conservation. It is by weighing each in accordance with the mandate of the commissioning agency that the conservationist will be able to determine relative conservation priorities more objectively. It should be understood that direct comparison of taxa is often hampered by the limited information available on which to base the comparison. However, the fact that the information resources are limited need not invalidate the comparison, provided this is taken into account.

The value of formal target identification is the establishment of a rational baseline from which to measure future progress. This is equally valuable, whether it forms the basis of:

- A case generated by an interest group, to win the support of a conservation agency.
- A commission between a conservation agency and an external executing organisation.
- An understanding between the policy and fieldwork arms of an institute with a conservation mandate.

The formal target should provide a detailed project specification and commission statement outlining the objectives, the target taxon and target area to be investigated, as well as any other specific requirements, such as whether the conservation should focus on *in situ* or *ex situ* strategies. The target taxon and target area may vary in breadth from one species in a restricted area to a whole genus or family worldwide. It is undoubtedly true that the more detailed the commission statement, the easier it will be to enact.

**Box 3.5 An example of a conservation project commission (Maxted et al., 2000)**

An ecogeographic survey is commissioned for the genus *Vigna* L. in Sub-Saharan Africa. The survey has the objective of identifying areas that contain novel genetic diversity not already conserved that could be utilised in selection or breeding programmes for the benefit of African agriculture. The report should contain a detailed *in situ* or *ex situ* conservation strategy for the genus, including collecting routes, timing and suitable local contacts, as well as locations where genetic reserves could be established. It should also attempt to identify those *Vigna* species of immediate and medium-term potential value to African agriculture.

An example of a project commission for an ecogeographic survey, the precursor of any conservation activity, is provided for cowpea (*Vigna unguiculata* (L.) Walp.) and its relatives in Africa in Box 3.5. Cowpea represents an important source of protein for many African communities, being grown on 9.6 million hectares in 2000 with a yield of 3,220 kg/ha (FAOSTAT, 2001), and therefore has major socio-economic importance in Africa.

Ecogeographic surveys are an efficient way of adding to the information gathered during target setting and producing a rational conservation strategy.

## Ecogeographic Surveys

In order to develop an efficient and effective conservation strategy using complementary *in situ* and *ex situ* techniques, we must have a clear understanding of each target taxon's geographical distribution, its habitat preferences and requirements, its genetics, reproductive biology and taxonomy.

The details of the localities where past collection have been made, the so-called 'passport data', associated with herbarium and germplasm collections, are a key source of information to guide future conservation activities. For example, if the passport data for a particular species indicates that it has previously been found only in the mangrove swamps of Southeast Asia, then these areas are likely to contain the species today. Looking for it on nearby mountainsides or even mangrove swamps in the Caribbean will be of little use. Southeast Asian mangrove swamps would therefore be considered potential sites for genetic reserves, and for a collecting mission.

The ecological, geographic, genetic, reproductive biology and taxonomic data are collectively referred to as ecogeographic data and their analysis is a necessary prerequisite of efficient conservation. A definition of an ecogeographic study and some examples of ecogeography studies or surveys are provided in Box 3.6.

**Box 3.6 Definition of an ecogeographic study (Maxted et al., 1995)**

An ecogeographic study is the process of gathering and synthesising ecological, geographical and taxonomic information about a taxon. The results are predictive and can be used to assist in the formulation of conservation priorities.

**Examples of ecogeographic studies or surveys.**

Bothmer von, R., Jacobsen, N., Baden, C., Jørgensen and Linde-Laursen, I. (1995). *An ecogeographic study of the genus Hordeum*. Second edition. Systematic and ecogeographic studies on crop genepools 7. IPGRI, Rome, Italy.

Edmonds, J.M. (1990). *Herbarium Survey of African Corchorus L. Species*. Systematic and ecogeographic studies on crop genepools 4. IBPGR, Rome, Italy.

Ehrman, T. and Cocks, P.S. (1990). Ecogeography of annual legumes in Syria: distribution patterns. *Journal of Applied Ecology* **27**: 578–591.

Hughes, C.E. (1998). *The genus Leucaena: a plant genetic resources manual*. Tropical Forestry papers 34. Oxford Forestry Institute, Oxford, UK.

Maxted, N. (1995). *An ecogeographic study of Vicia subgenus Vicia*. Systematic and ecogeographic studies in crop genepools 8. IPGRI, Rome, Italy.

**An Ecogeographic Model**

A model for the process of undertaking an ecogeographic survey is outlined in Figure 3.6. The model is divided into three phases and these are now considered in detail.

**Ecogeographic Survey Phase 1:***Project Design***1. Identification of Taxon Expertise**

The acquisition of ecogeographic data by the conservationist can be enhanced by discussion with appropriate specialists. Taxon experts will be able to help by: suggesting relevant literature; recommend Floras, monographs and taxonomic databases; suggesting which herbaria and/or gene banks to visit; and also by putting the conservationist in contact with other specialists. Box 3.7 introduces some options for identifying appropriate taxon experts.

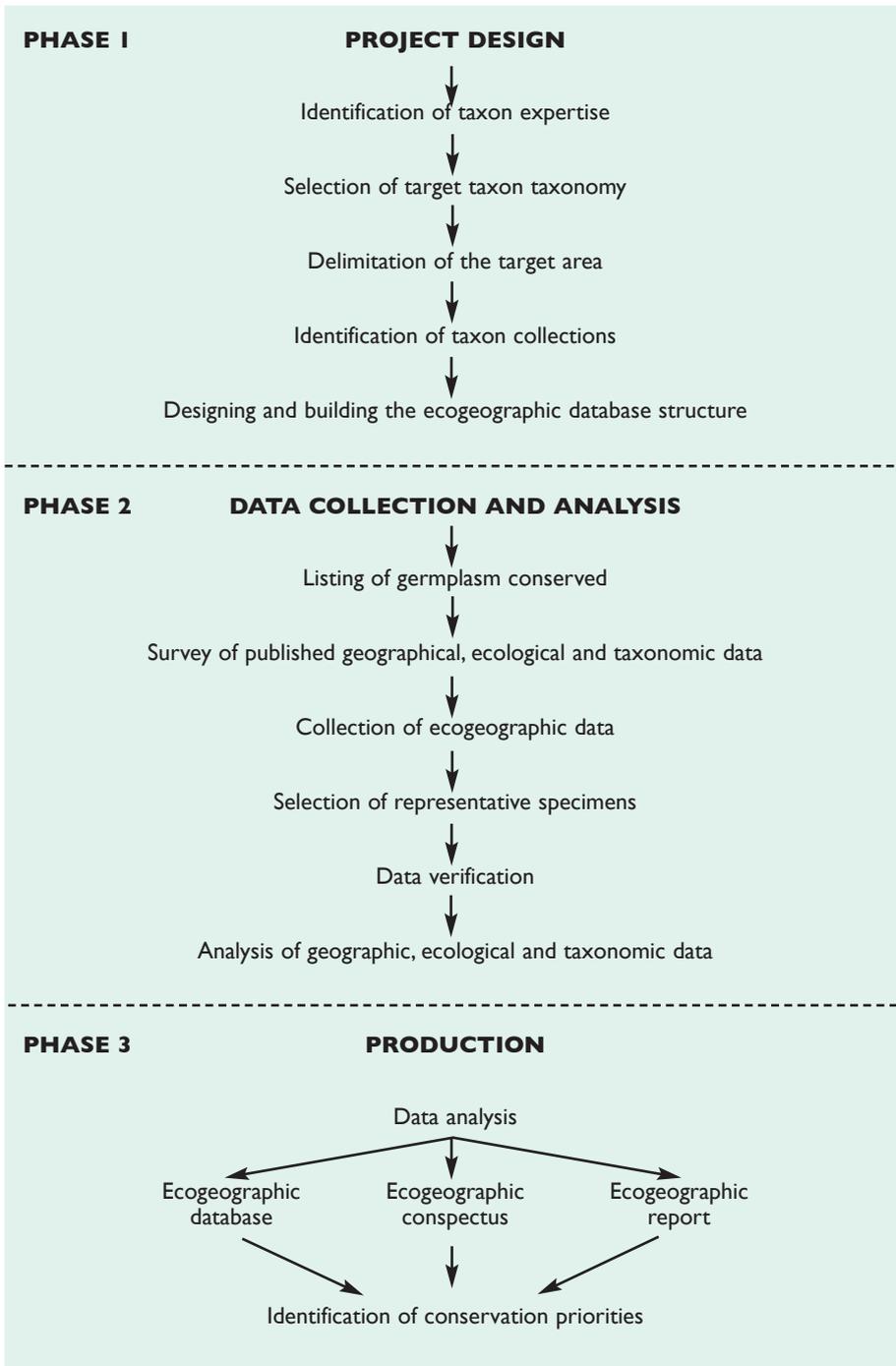


Figure 3.6

A schematic model of an ecogeographic survey (Maxted *et al.*, 1995).

**Box 3.7 Where to find taxon experts**

- Authors of taxonomic literature on the target taxon.  
Holmgren, P.K. and Holmgren, N.H. (1992). *Plant specialists index. Regnum Vegetabile 124*. International Association for Plant Taxonomy and New York Botanical Garden, New York, USA.  
Holmgren, P.K., Holmgren N.H. and Barnett, A. (1990). *Index herbariorum I: The herbaria of the world. Edition 8. Regnum Vegetabile 120*. International Association for Plant Taxonomy and New York Botanical Garden, New York, USA.
- Plant Taxonomists Online (contact Jane Mygatt, [jmygatt@bootes.unm.edu](mailto:jmygatt@bootes.unm.edu)).
- The database of experts in botany and mycology maintained by University of Oulu, Finland (contact Anne Jäkäläniemi at [anne.jakalaniemi@oulu.fi](mailto:anne.jakalaniemi@oulu.fi)).
- The Internet, for example the site maintained by the University of Helsinki <http://www.helsinki.fi/kmus/botmenu.html>

**2. Selection of Target Taxon Taxonomy**

It is essential to have a good taxonomic understanding of the target group prior to undertaking an ecogeographic survey. This will eliminate the confusion caused by the use of alternative names to describe the same species. This understanding can be obtained from various sources: target taxon specialists; recent classifications of the group; revisions and monographs; and floristic sources (Boxes 3.8 and 3.8A). These will help the conservationist identify the generally accepted classification of the group. Once this is established, the same taxonomy should be used throughout the project.

**3. Delimitation of the Target Area**

The target area of the taxon being studied will often be restricted by the terms of reference of the project commission (e.g., the genus *Sesamum* L. in Namibia), but if it is unspecified, the taxon should be studied throughout its range. Taking the broadest possible view of the target area should avoid any incompatibility problems between multiple studies on the same taxon.

**4. Identification of Taxon Collections**

The key data in ecogeographic studies are the passport data from herbarium specimens or germplasm accessions. Thus the conservationist will ideally visit both major international, regional and national herbaria as well as germplasm collections holding the target taxon from the target area. However, such a programme of visits will be expensive, so careful selection is crucial. Realistically, given limited financial resources, it may only be possible to visit the national collections, but these can provide invaluable information for the

**Box 3.8 Some sources of taxonomic information and literature**

- **Key Record of Taxonomic Literature:** the most comprehensive listing of taxonomic literature relating to vascular plants published by the Royal Botanic Gardens, Kew. It appears quarterly and can also be accessed on-line through the Bath Information and Data Services at: <http://www.bids.ac.uk/dbases.html>
- **International Plant Names Index (IPNI):** is a database of the names and associated basic bibliographical details of all seed plants. Its goal is to eliminate the need for repeated reference to primary sources for basic bibliographic information about plant names. The data are freely available and are gradually being standardised and checked. IPNI is the product of a collaboration between The Royal Botanic Gardens, Kew, The Harvard University Herbaria, and the Australian National Herbarium and can be accessed at <http://www.ipni.org/>
- **Regnum Vegetabile Vol. 94:** the standard international reference on taxonomic literature indexed on author and edited by Stafleu and Cowan (1976). It is published in multiple volumes starting in 1976 by Bohn, Scheltema and Holkema, Utrecht.
- **Vascular Plant Families and Genera:** a publication compiled by Brummit (1992), published by the Royal Botanic Gardens, Kew. It is also available on-line at: <http://www.rbgekew.org.uk>.
- **Plant Book:** a comprehensive listing of higher plant names with basic botanical information compiled by Mabberley (1997) and published by Cambridge University Press.
- **Authors of Plant Names:** a publication compiled by Brummit and Powell (1992), published by the Royal Botanic Gardens, Kew. It is also available on-line at: <http://www.rbgekew.org.uk>.
- **Monographic databases:** various taxonomic groups have web sites and databases that provide detailed taxonomic information, e.g., ILDIS (International Legume Database and Information Service) provides monographic information for the family *Leguminosae*. It is also available on-line at: <http://www.ildis.org/>

**Box 3.8A Some sources of regional taxonomic information and literature**

- Davis, S.D., Droop, S.J.M., Gregerson, P., Henson, L., Leon, C.J., Lamlein Villa-Lobos, J., Syngé, H. and Zantovska, J. (1986). *Plants in danger: what do we know?* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.
- Frodin, D.G., (2001). *Guide to the standard floras of the world*. Second edition. Cambridge University Press, Cambridge, UK
- Prendergast, H.D.V. (1995). Published sources of information on wild species, pp. 153–179. In: L. Guarino, V.R. Ramanatha Rao and R. Reid (eds). *Collecting plant genetic diversity: technical guidelines*. CAB International, Wallingford, Oxon, UK.

**Table 3.2 Likely advantages and disadvantages of different types of herbaria (Maxted et al., 1995)**

Type of herbaria	Advantages	Disadvantages
<b>Major international herbaria</b>	<ul style="list-style-type: none"> <li>• Broad taxonomic coverage, possibly including material used in the production of revisions and monographs, so specimens are likely to be better curated and more accurately identified</li> <li>• Broad international geographical coverage, possibly including material used in the production of local Floras</li> <li>• Skilled researchers available to provide general advice</li> <li>• Appropriate taxonomic and geographical specialists</li> <li>• Type material of target taxa</li> <li>• Good botanical library</li> </ul>	<ul style="list-style-type: none"> <li>• Predominance of old collections, geographic locations in passport data more difficult to interpret, hence lowering their predictive value.</li> <li>• Geographical names associated with older collection sites may have changed more recently</li> </ul>
<b>Local herbaria</b>	<ul style="list-style-type: none"> <li>• Good local regional coverage of target area</li> <li>• Better documented material as the herbarium is likely to have been more recently established</li> <li>• Regional specialists present who can assist in deciphering local geographical names</li> </ul>	<ul style="list-style-type: none"> <li>• Limited resources for herbarium maintenance</li> <li>• Lack of target taxon specialists</li> <li>• Limited botanical library</li> </ul>

study or survey (Table 3.2). Target taxon and area specialists will be able to advise which herbaria, gene banks and libraries the conservationist should visit. *Index Herbariorum* (see Box 3.7) and *Regnum Vegetabile* (see Box 3.8) can also be used to find where historical plant collections are held.

The conservationist will need to establish which gene banks have important collections of the target taxon. Most gene banks have databases containing passport information on the germplasm collections they maintain and some are now accessible via the internet. These data should be available from the target setting process. If not, the most appropriate gene banks to contact may be identified by contacting the various sources listed in Box 3.3.

## 5. Designing and Building the Ecogeographic Database Structure

Before any data is collected, the conservationists will need to design and build the database to contain the data. It is recommended that the file structure is kept as simple as possible and that one of the more commonly used database management systems is used to facilitate subsequent data transfer. Where a portable computer is available, data should be entered directly into a database.

### Ecogeographic Survey Phase 2:

#### *Data Collection and Analysis*

##### 1. Listing of Germplasm Conserved

This should be available from the target setting process. If not, please see the section current conservation status under 'Selection of Target Taxa'.

##### 2. Survey of Published Geographical, Ecological and Taxonomic Data

The collation of these data from published sources can be undertaken while visiting the major herbaria with good botanical libraries attached. The appropriate literature will include: monographs; revisions; floras; scientific papers; soil, vegetation and climatic maps; atlases; gazetteers; etc. As well as printed media, information can be accessed from CD-ROMs, relevant databases and the internet. The kinds of data that might be obtained from literature and databases sources are listed in Table 3.3, using a forage vetch species found in Turkey as an example.

As Table 3.3 shows, it is often impossible to obtain data for all the possible data fields for a given taxon.

##### 3. Collection of Ecogeographic Data

The kinds of information that a conservationist can obtain from passport data associated with herbarium specimens and germplasm accessions are listed in Table 3.4. This listing is extensive and it is unlikely that all will be recorded for any single specimen, but the first seven data types are essential, if the data is to have predictive use. Care must be taken before accepting the scientific names noted on herbarium sheets; the identification should always be checked against the selected taxonomy to ensure the species concepts are consistently applied and misinterpretation of data patterns is avoided.

#### 4. Selection of Specimens

The time and travel budgets available will always limit the scope of ecogeographic investigations. The herbaria of the world contain millions of specimens and the number of specimens of a given target taxon can be vast. A combination of these factors forces the researcher to select specimens of the target taxon for inclusion in the survey or study. During the course of an ecogeographic project, several thousand specimens of the target taxon may be available. Much of this could be due to duplication of specimens between herbaria by the original collectors. This is most frequently the case for species with high socio-economic use. Each of these specimens will require identification against the collector's number. A proportion will be selected to have their passport data recorded in the database.

Where material is more available than time, how do you select the most appropriate specimens from which to record passport data? They will be those specimens:

1. Which relate to the geographic area included in the target.
2. Which are unique.
3. With detailed ecogeographic passport data.
4. With latitude and longitude data or enough location details to allow this to be estimated.

**Table 3.3 Ecogeographic data that might be gathered from a media survey (Maxted and Kell, 1998)**

Ecogeographic data category	Example
<b>Accepted taxon name</b>	<i>Vicia sativa</i> L. subspecies <i>amphicarpa</i> (Dorth.) Asch. & Graebn.
<b>Locally used taxon name</b>	No known local names
<b>Distribution</b>	South east Turkey
<b>Timing of local flowering and fruiting</b>	May–June
<b>Habitat preference</b>	Steppe
<b>Topographic preference</b>	None observed
<b>Soil preference</b>	Sandy loam
<b>Geological preference</b>	None observed
<b>Climatic and micro-climatic preference</b>	Dry < 100 mm/yr
<b>Reproductive biology</b>	Auto and cleistogamous
<b>Genotypic and phenotypic variation</b>	None observed
<b>Biotic interactions</b> (pests, pathogens, herbivores)	None observed
<b>Archaeological information</b>	None available
<b>Ethnobotanical information</b>	None available
<b>Conservation status</b>	Not threatened

**Table 3.4 Ecogeographic data types that might be recorded from passport data associated with a herbarium specimen or a germplasm accession (Maxted and Kell, 1998). Those items marked with an asterisk could be coded in the database**

<b>Ecogeographic data</b>	<b>Example data for a <i>Vicia</i> species</b>
<b>Sample identification*</b>	<i>Vicia sativa</i> subspecies <i>amphicarpa</i>
<b>Herbarium, gene bank or botanic garden where specimen/ accession is deposited*</b>	AARI
<b>Collector's name and number</b>	Kitiki, Kell and Maxted 4108
<b>Collection date*</b>	20.04.96
<b>Phenological data*</b> (Does specimen have flowers or fruit?) Fruit – no	Flower – yes
<b>Provenance*</b>	Hatay, Turkey
<b>Location</b>	Saylak; 24 kms from Kirikhan on road to Tasoluk
<b>Latitude</b>	36°38' N
<b>Longitude</b>	36°24' E
<b>Altitude*</b>	295m
<b>Habitat*</b>	Field and field margins
<b>Soil type*</b>	Red Mediterranean
<b>Vegetation type*</b>	Low shrubs and grasses
<b>Site slope and aspect*</b>	Slope <10%, with an eastern aspect
<b>Land use and/or agricultural practice*</b>	Corn field and rough pasture
<b>Palatability*</b>	Signs of grazing
<b>Vernacular names</b>	None known
<b>Plant uses</b>	Pasture species

5. Which are representative of the geographic and ecological range of the taxon.
6. Which have been recently collected, which indicates that the population is more likely to still be extant.
7. Which are taxonomically or ecogeographically unusual, i.e., recording relatively outlying specimens are necessary if the full range of the taxon is to be understood.

How many specimens should be included in the survey? There is no single number answer. Initially, each new specimen will contain a significant amount of new ecogeographic information, but beyond 50 specimens, the compiler should be on the look out for the point when novel ecogeographic combinations no longer occur in the specimens being examined.

## 5. Data Verification

Before attempting any detailed data analysis, the ecogeographic database must be searched for errors and corrected. Indexing the database (i.e., re-arranging the records in alphabetical or numerical order using the database software) on each field in turn may highlight typing errors or invalid entries. Mapping latitude and longitude data will reveal potential errors where specimens map to impossible places, e.g., if in the sea or in a different country than that recorded, errors may be assumed. In all cases, the true locations will need to be verified. If this is not possible, the specimen should be discarded.

## 6. Analysis of Geographic, Ecological and Taxonomic Data

The raw ecological and geographical data included in the database can be analysed in various different ways to help identify the particular geographical locations and habitats favoured by the target taxa.

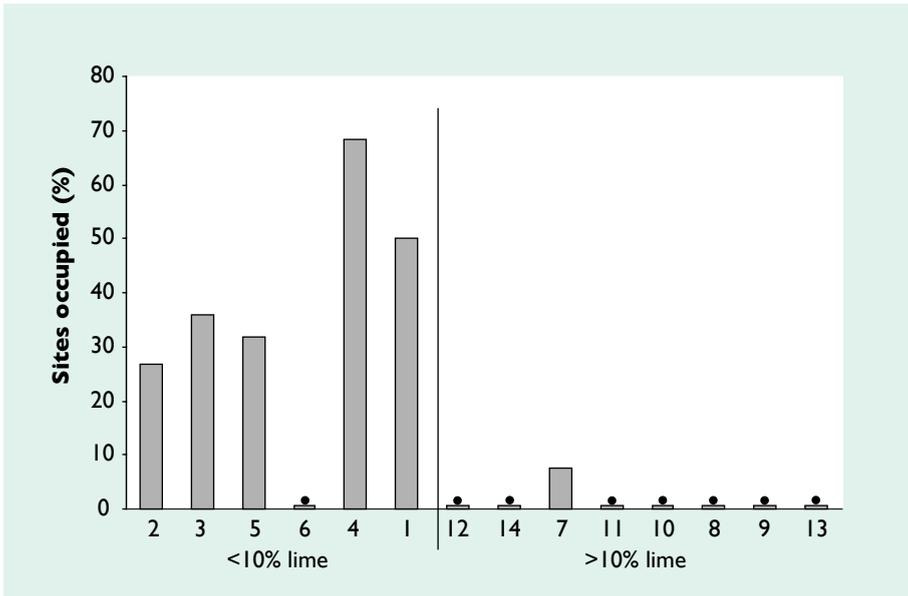
### 6.1. Frequency distributions

One of the simplest means of ecogeographic data analyses is the calculation of the frequency or the number of specimens collected from sites characterised by different biotic and abiotic features e.g., grid squares, climate zones, soil types, aspect, habitat types, etc. The results can be presented in the form of graphs and pie charts. Data arranged in this fashion will help to identify the particular niche occupied by the target taxon. In this way the analysis can be used to indicate areas previously uncollected, where the species is likely to occur. An example is shown in Figure 3.7, which clearly shows that the species is a calcifuge in its edaphic requirements.

Frequency distributions can often be compiled directly by the database software. Correlation of the abundance or frequency of taxa with environmental factors (such as altitude, latitude, and soil characteristic) will produce error terms and can be used predicatively. Association of morphological characters with particular environmental conditions will help indicate in the field, possible ecotypic variation, both in wild and cultivated material.

### 6.2. Mapping of ecogeographic data

Another approach to the analysis of ecogeographic data involves mapping the known collection sites of taxa. These distribution maps can be used in conjunction with topographical, climate, geological or soil maps to deduce ecological preferences.



**Figure 3.7** The percentage of sites occupied by the calcifuge, *Trifolium pilulare* Boiss. The soils are arranged from left to right in order of increasing lime content. Sites are numbered.

Plant geographical distribution data is usually mapped in two basic ways: (1) shading or line maps that enclose an area and (2) dot distribution maps (Figure 3.8). Dot distribution maps are generally preferred to enclosed line maps as the latter can be ambiguous. Enclosed line maps cannot show the frequency of a taxon within a region and give undue weight to the importance of outlying specimens. Superimposing morphological, ecological or taxonomic information on the symbol indicating the location will provide a more biologically meaningful picture.

Note in Figure 3.8 that if an enclosed line was drawn around the sites where *Vicia sericocarpa* Fenzl was found in Turkey, it would give a misleading picture of its distribution. The single location in North West Turkey greatly extends the range of the taxon and gives a misleading picture of distribution for a taxon most frequently found in South East Turkey.

### 6.3. Computer-aided mapping and spatial analysis

Simple mapping programmes or more sophisticated Geographical Information Systems (GIS) are more efficient than manual processes. They greatly assist the production of distribution maps and spatial analysis of geo-referenced data. Mapping programmes allow the import of latitude and

longitude co-ordinates from the ecogeographic database and their plotting on to customised maps of the particular region of the world where the species is found. Once in the GIS, the ecogeographic distribution data for a particular taxon can be analysed against known ecological polygons, aerial photographs, field surveys, remote sensing, etc. Superimposing the digitised maps or layers on the computer screen (see Figure 3.9) can identify associations.

#### 6.4. Predictive distribution

Unlike most socio-economic species, geographic distribution data for many wild species may be scanty. GIS packages have been developed that predict where the species might be expected to occur on the basis of known location data. GIS tools such as BIOCLIM (Busby, 1991; see also GARP, Genetic Algorithm for Rule-set Production, an extension of the BIOCLIM approach), DOMAIN (Carpenter *et al.*, 1993) and FloraMap (Jones and Gladkov, 1999; Jones *et al.*, 1997) attempt this type of extrapolation using climate data (Box 3.9). An example of the output provided by FloraMap is shown in Figure 3.10.

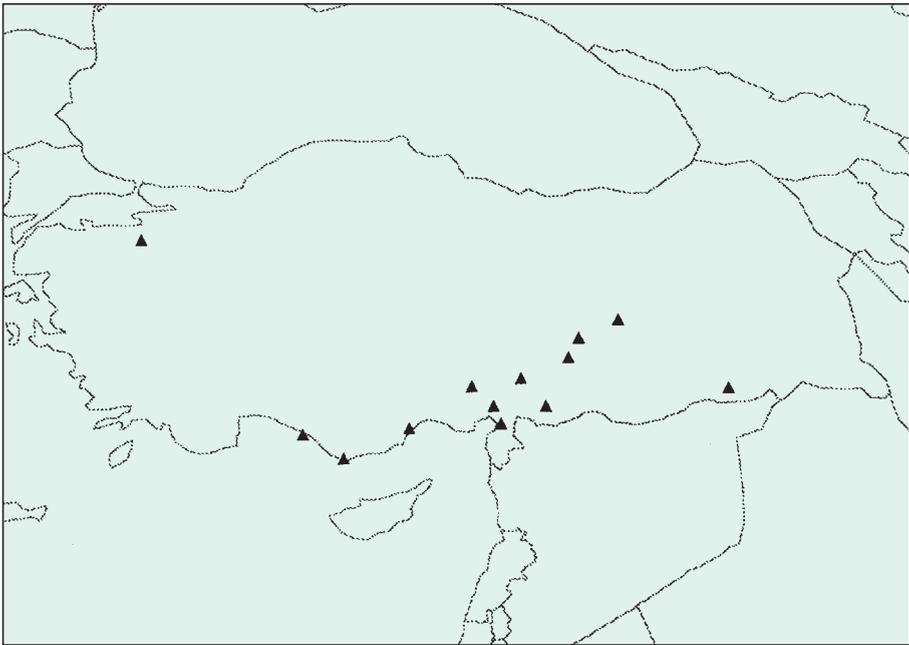
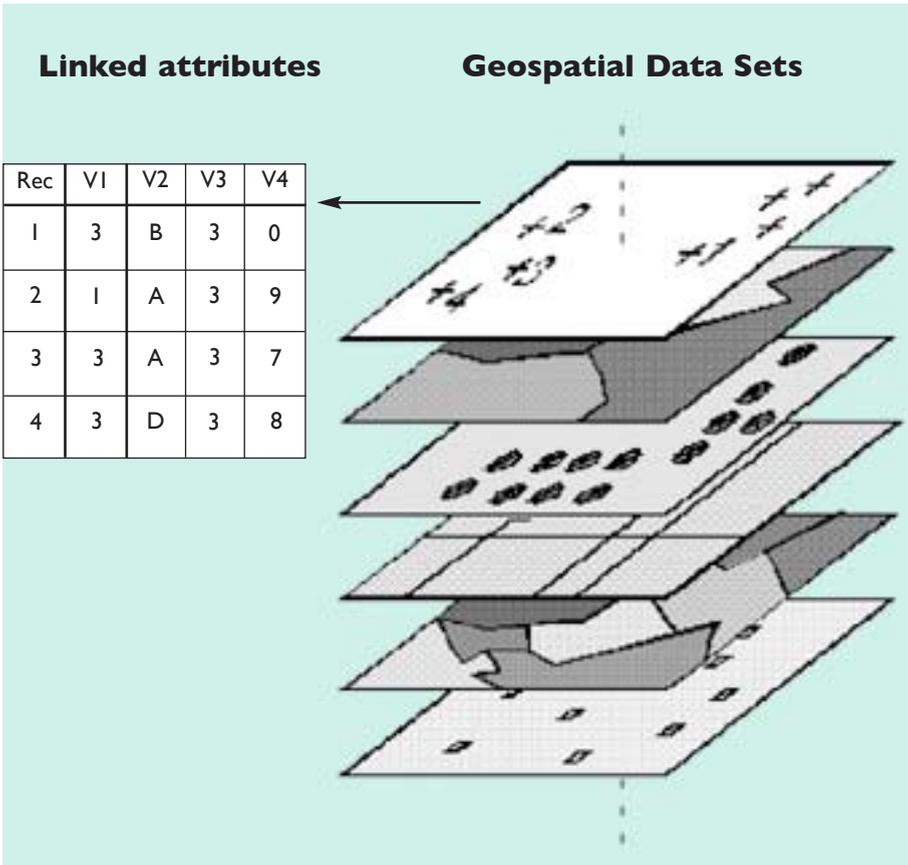


Figure 3.8

Example of dot distribution map for *Vicia sericocarpa* Fenzl (Maxted, 1995).



**Figure 3.9** Concept of Using Layers in a GIS. The linked attributes table shows a possible scoring of records (Rec) against the different variables given in the geospatial data sets (V1, V2, etc.).

The density of shading in Figure 3.10 indicates areas with increasingly high levels of climatic similarity with the sites where the species has previously been found (indicated by the dots, which represent germplasm accessions and herbarium records), and therefore in theory, increasing probability of finding the species. The climate variables used were monthly rainfall totals, monthly average temperatures and monthly average diurnal temperature range.

### 6.5. Areas of high species diversity

Some geographic areas show greater taxonomic or genetic diversity than others. When attempting to prioritise *ex situ* collecting or locate *in situ* reserves, it is important to know where such areas may be found. These analyses are flexible and can be used at the flora, genus or species levels and at a global and national scale. Measures of genetic diversity are usually based on morphological characters or molecular markers. Thus, Pickersgill (1984) used characterisation data to calculate the morphological diversity shown by accessions of cultivated *Capsicum* L. spp. in different grid cells within Central and South America. Ferguson *et al.* (1998) calculated diversity in wild *Lens* Mill. spp. using genetic RAPD markers. To support this type of analysis by gene banks, IPGRI and The International Potato Centre, CIP are collaborating in the development of software called DIVA-GIS, which calculates diversity indices for all the cells in a user-defined grid given latitude, longitude and characterisation data for a set of accessions, and maps the results. DIVA-GIS also supports a complementary method for mapping diversity, the “point-based” approach described by Nelson *et al.* (1997). Figure 3.11 shows sample DIVA-GIS outputs for the same dataset using the grid and point-centred approaches.

The squares in Figure 3.11 indicate the location of sites with complementary species composition, such that the largest number of species is captured in the least number of squares.

#### Box 3.9 Some useful web addresses for mapping applications

DIVA-GIS

<http://www.cipotato.org/diva>

BIOCLIM

[http://dino.wiz.uni-kassel.de/model\\_db/mdb/bioclim.html](http://dino.wiz.uni-kassel.de/model_db/mdb/bioclim.html)

GARP

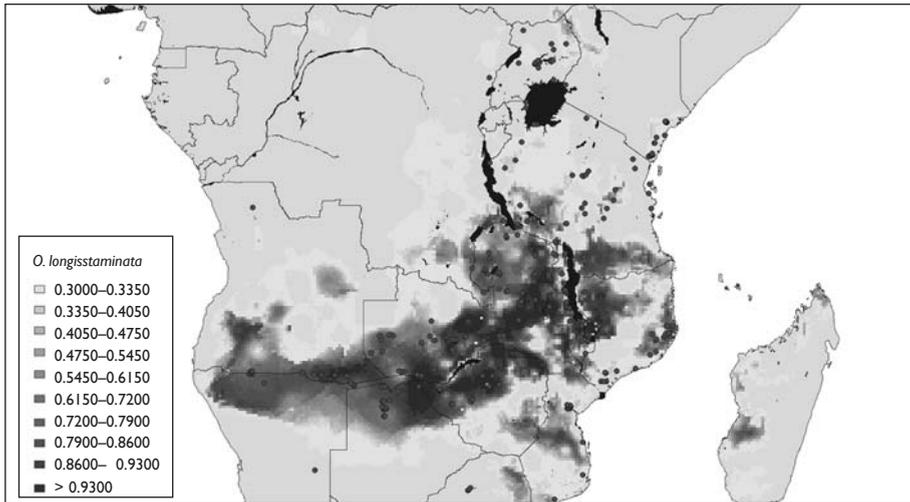
[http://kaos.erin.gov.au/general/biodiv\\_model/ERIN/GARP/home.html](http://kaos.erin.gov.au/general/biodiv_model/ERIN/GARP/home.html)

DOMAIN

[http://www.cgiar.org/cifor/research/intro\\_d.html](http://www.cgiar.org/cifor/research/intro_d.html)

FloraMap

<http://www.ciat.cgiar.org/floramap/>

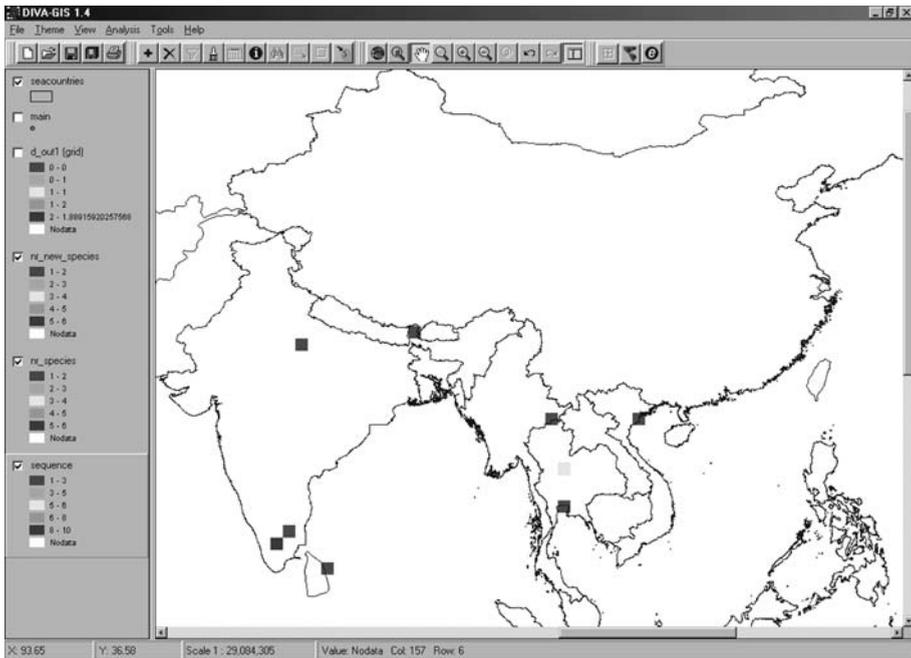


**Figure 3.10** Results of FloraMap analysis of the distribution of *Oryza longistaminata* A. Chev. and Roehr. in southern Africa (Kiambi, 2000). See text for details.

Another way of showing areas of flora or taxon concentration is to use isoflor maps. They show a series of inclusive contour lines, each line delimiting a greater or lesser concentration of taxa. Figure 3.12 shows an isoflor map for a group of temperate forage vetches (*Vicia* section *Hypechusa* (Alef.) Asch. and Graebn.). To produce the isoflor map, species distributions are superimposed onto a single map, and then contour lines are drawn around areas of the map with the same number of species. The centre of diversity is located in the area enclosed by the most contour lines and in the example for *Vicia* section *Hypechusa*, this can be seen to be in southern Syria. Isoflor maps can be produced for infra-specific taxa within species (e.g., subspecies, crop landraces) as well as for species within sections or genera.

### 6.6. Complementary areas

A further refinement in the identification of areas of diversity is to ensure two areas have complementary rather than the same diversity. This is necessitated by the fact that two areas may have equal richness or diversity of taxa or morphotypes, but the ones in one square may be similar to each other (i.e., closely related), while those in the other may be more different. The procedure described by Vane-Wright *et al.* (1991), and available in their **WORLDMAP** software (<http://www.nhm.ac.uk/science/projects/worldmap>), allows the diversity measure to be weighted for the distinctness of taxonomic units, calculated from a phylogeny based on the cladistic analysis of the presence/absence of characters.



**Figure 3.11** Results of DIVA-GIS analysis of the distribution of *Vigna L.* species in Southeast Asia (Reprinted with permission from Tomooka, Vaughan, Moss and Maxted, 2003).

Iterative procedures such as that described by Rebelo and Sigfried (1992) can be used to choose the smallest number of spatial units such that each species, morphotype, etc., will be present in at least one (or two, three, etc.) unit(s) in the set. The DIVA-GIS software tool supports complementarity analysis as described by Rebelo and Sigfried (1992).

### 6.7. Under-conserved areas

The WORLDMAP software (<http://www.nhm.ac.uk/science/projects/worldmap/>) allows the user to select a grid square so that a subsequent run identifies those grid squares that are complementary to the selected one (Hopkinson *et al.*, 2001). If the selected grid square is the most diverse, the process approximates that of Rebelo and Sigfried (1992). On the other hand, if the selected grid square includes an existing protected area, the result is a form of “gap analysis.” The concept, and some applications, are discussed in greater detail by Scott *et al.* (1993). See also <http://www.gap.uidaho.edu/gap> for an application of this methodology.

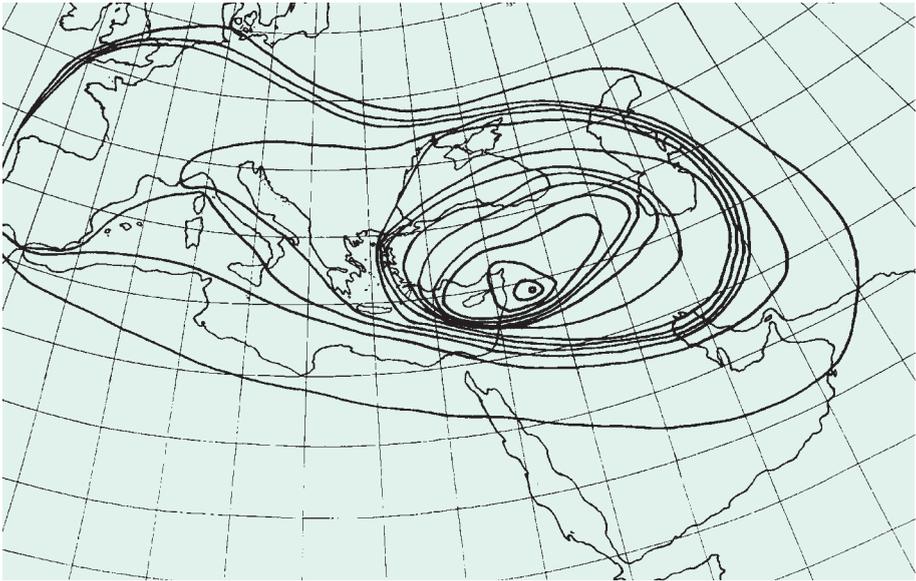


Figure 3.12 Isoflor map of *Vicia* section *Hypechusa* (Alef.) Asch. and Graebn. (Maxted, 1995).

A more detailed discussion of the range of GIS analysis is beyond the scope of this chapter but those wishing such an insight are referred to Guarino *et al.* (2001). Of the range of GIS biodiversity programs currently available, DIVA-GIS offers the most comprehensive range of analysis and has the added advantage that it can be downloaded from the internet free of charge.

### 6.8. Multivariate analysis

The above analytical methods deal primarily with one environmental factor at a time, or a single morphological variable. Ecogeographic data, however, is multivariate, in that two or more items of data (e.g., rainfall, soil type, aspect) are available for each accession or specimen, so where the ecogeographic data is sufficiently robust, multivariate statistics can be applied.

## Ecogeographic Survey Phase 3:

### *Production*

#### 1. Data synthesis

The final, production, phase of the project commences with the synthesis of all the data and analysis collected during the study. The researcher should be aware of any degree of unavoidable bias in the database, and hence, whether the specimens or accessions sampled are likely to reflect the true geographical and ecological range of the taxon. If a particular habitat appears under-represented in the database, is it because the taxon is absent from that habitat, or because that type of habitat has not been sampled, or even because the target taxon has not been recognised in that habitat?

#### 2. The Ecogeographic Database, Conspectus and Report

The ecogeographic database, conspectus and report are the three essential products of an ecogeographic study.

##### 2.1. The database

The ecogeographic database contains the raw data of the project, collated from the literature, herbarium specimens and gene bank accessions.

##### 2.2. The conspectus

The conspectus summarises the ecological, geographical, genetic and taxonomic information for the target taxon through part or the whole of its range. The conspectus is arranged by taxon name, which can be listed either alphabetically or in taxonomic order. In both cases, it is helpful to provide an index to the taxa included in the study. When possible, the information detailed in Table 3.5 should be included.

##### 2.3. The report

The report analyses and discusses the contents of the database and conspectus and must draw general conclusions concerning the taxon's ecogeography, presenting a concise list of conservation priorities. If possible, the following points should be covered:

- Delimitation of the target taxon.
- Classification of the target taxon that has been used and why.
- Mode of selection of specimens.
- Ecogeographic database file structures and inter-relationships.
- Discussion of database content.

Table 3.5 Example record for an ecogeographic conspectus (Maxted and Kell, 1998)	
Ecogeographic conspectus	Example data
<b>Accepted taxon name</b> , author(s), date of publication, place of publication	<i>Vicia sativa</i> L. subspecies <i>amphicarpa</i> (Dorth.) Asch. & Graebn., Fl. Algerie, 1: 268 (1889).
<b>Reference to published descriptions and iconography</b>	Fl. Eur., 2: 134; Fl. Iran., 53–54; Fl. Iraq, 3: 537–538; Fl. Pal., 2: 207; Fl. Syr., 2: 403–404; Fl. Tur., 3: 321; Fl. USSR., 13: 465; Fl. Iran., Tab. 35, fig. 2.
<b>Phenology</b> , flowering season	March–August
<b>Vernacular names</b>	None known
<b>Geographical distribution</b>	International: AFG, ALB, AUS(I), BEL, CSK, CYP, ESP, FRA, GRC, ISR, IRQ, IRN, ITA, JOR, LBN, LBY, MRT, PRT, ROM, SUN, SYR, TUR, YUG.
<b>Distribution maps</b>	See Figure . . . . .
<b>Reproductive system</b>	Inbreeding and cleistogamous
<b>Ecological notes</b> , including altitude (minimum and maximum), habitat, topographic, soil, geological, climate and micro-climatic preference, biotic interactions and other habitat details	Alt. 20–2000 m; Soils, calcic brown, calcic brown & terra rossa, chalky calcic brown, chalky white, heavy black, terra rossa; Hab. dry disturbed or agricultural land.
<b>Geographical notes</b> , including an interpretation of the taxon's geographical distribution	This subspecies has a wide distribution throughout the Mediterranean
<b>Taxonomic notes</b> , including synonyms and confusions	Regarded as <i>V. amphicarpa</i> Dorthes in Eastern Europe, easily identified by the presence of amphicarpic flowers and pods.
<b>Agronomic notes</b> , including notes on any distinct genotypic and phenotypic variation within the taxon	This subspecies has potential as a forage plant for dry areas. The amphicarpic pods are resistant to grazing and so regeneration of pasture following grazing is high.
<b>Conservation notes</b> , containing an assessment of the variability currently conserved, the potential genetic erosion faced and the conservation status of the taxon in the field	Not threatened. Not subject to genetic erosion. The species is well represented in <i>ex situ</i> collections in Turkey, the Near East and the World. However, it is not currently actively conserved <i>in situ</i> .

- Discussion of target taxon ecology.
- Discussion of target taxon phytogeography and distribution, and a summary of the distribution in tabular form.
- Discussion of any interesting taxonomic variants encountered during the study.
- Discussion of the current and potential uses of the target taxon.
- Discussion of the relationship between the cultivated species and their wild relatives.
- Discussion of any particular identification problems associated with the group and a presentation of identification aids to vegetative, floral and fruiting specimens.
- Discussion of *in situ* and *ex situ* conservation activities associated with the target taxon, including the extent of diversity already conserved.
- Discussion of the genetic erosion threat facing the group.
- Discussion of priorities and suggested strategy for future conservation of the target taxon.

It should be noted that it is less easy to obtain ecological data from herbarium specimen passport data than it is to obtain geographic or taxonomic data. Therefore, lack of background data may hamper the drawing of firm ecological conclusions from the study products. However, whatever information is available is a valuable asset and will aid formulation of an appropriate conservation regime.

### **3. Identification of Conservation Priorities**

The primary aim of the ecogeographic survey is to clearly identify conservation priorities and suggest appropriate strategies for the target taxon's conservation. During the survey process, data from the literature, herbarium specimens and germplasm accessions are collated, summarised and synthesised into the three main ecogeographic products. The pattern of variation within both the target area and the target taxon is investigated and an estimate of potential genetic erosion, and current conservation status, made. On the basis of the various products of the ecogeographic survey or study, the conservationist can formulate future conservation priorities and strategies (*in situ* and *ex situ*) for the target taxon.

## Field Surveys

If the necessary ecogeographic data for the target taxon are unavailable or limited, the conservationist will not have sufficient biological knowledge of the target taxon to formulate an effective conservation strategy. In such cases, it will be necessary to conduct preliminary field surveys to gather the required ecogeographic data.

The field survey may be in the form of ‘coarse grid sampling’, which involves travelling throughout the target region and sampling sites at relatively wide intervals over the whole region. The field survey will, by gathering fresh ecogeographic data, help to determine the distribution of the target taxon, its habitat requirements and biological relationships, population numbers and sizes, as well as any imminent threats, and so permit conclusions to be drawn about the most appropriate conservation strategy.

A number of the other chapters in this volume relate to germplasm collecting, and detail how to collect voucher specimens of plants and appropriate passport data. The specimens and data collected during the field survey can then be used to formulate further conservation priorities and develop an appropriate strategy, thus providing the same output as the ecogeographic survey.

## Conclusion

Plant conservation will always be limited by the resources available. Therefore there is a need to use these resources in the most efficient and effective manner. Careful selection of which taxa are to be prioritised for conservation action along with the collation and analysis of the taxa’s ecology, geography, genetics and taxonomy will ensure the best use is made of limited resources. Selection of target taxa and some form of ecogeographic survey are a necessary prerequisite for conservation. They permit the assessment of its conservation status, prediction of areas and habitats in which the taxon is likely to be found, as well as facilitating the establishment of detailed conservation priorities, and the most appropriate strategies for the effective *in situ* and *ex situ* conservation of plant taxa.

## References

- Bothmer von, R., Jacobsen, N., Baden, C., Jørgensen and Linde-Laursen, I. (1995). *An ecogeographic study of the genus Hordeum*. Second edition. Systematic and ecogeographic studies on crop gene pools 7. IPGRI, Rome, Italy.
- Brummitt, R.K. (1992). *Vascular plant families and genera*. Royal Botanic Gardens, Kew, UK.
- Brummitt, R.K. and Powell, C.E. (1992). *Authors of plant names*. Royal Botanic Gardens, Kew, UK.
- Busby, J.R. (1991). BIOCLIM – a bioclimate prediction system, pp. 4–68. In: C.R. Margules and M.P. Austin (eds). *Nature conservation: cost effective biological surveys and data analysis*. CSIRO, Melbourne, Australia.
- Carpenter, G., Gillison, A.N. and Winter, J. (1993). DOMAIN: a flexible modelling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation* **2**: 667–680.
- Davis, S.D., Droop, S.J.M., Gregerson, P., Henson, L., Leon, C.J., Lamlein Villa-Lobos, J., Synge, H. and Zantovska, J. (1986). *Plants in danger: what do we know?* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.
- Department of the Environment (1995). *Biodiversity: the UK steering group report. Volume 1: meeting the Rio challenge*. Department of the Environment, London, UK.
- Department of the Environment (1996). *Towards a methodology for costing biodiversity targets in the UK*. Department of the Environment, London, UK.
- Edmonds, J.M. (1990). *Herbarium Survey of African Corchorus L. Species*. Systematic and ecogeographic studies on crop gene pools 4. IBPGR, Rome, Italy.
- Ehrman, T. and Cocks, P.S. (1990). Ecogeography of annual legumes in Syria: distribution patterns. *Journal of Applied Ecology* **27**: 578–591.
- FAOSTAT (2001). Agricultural data. <http://apps.fao.org/notes>.
- Ferguson, M.E., Ford-Lloyd, B.V., Robertson, L.D., Maxted, N. and Newbury, H.J. (1998). Mapping the geographical distribution of genetic variation in the genus *Lens* for the enhanced conservation of plant genetic diversity. *Molecular Ecology* **7**: 1743–1755.
- Frodin, D.G. (2001). *Guide to the standard floras of the world*. Second edition. Cambridge University Press, Cambridge, UK.
- Guarino, L. (1995). Mapping the eco-geographic distribution of biodiversity, pp. 287–315. In: L. Guarino, V.R. Rao and R. Reid (eds). *Collecting plant genetic diversity: technical guidelines*. CAB International, Wallingford, Oxon, UK.
- Guarino, L., Jarvis, A., Hijmans, R.J. and Maxted, N. (2002). Geographical information systems (GIS) and the conservation and use of plant genetic resources, pp. 387–404. In: J.M.M. Engels, V.R. Ramanatha Rao, A.H.D. Brown and M.T. Jackson (eds). *Managing plant genetic diversity*. CABI Publishing, Wallingford, Oxon, UK.
- Harlan, J.R. and de Wet, J.M.J. (1971). Towards a rational classification of cultivated plants. *Taxon* **20**: 509–517.
- Hawkes, J.G., Maxted, N. and Ford-Lloyd, B.V. (2000). *The ex situ conservation of plant genetic resources*. Kluwer, Dordrecht, The Netherlands.
- Heywood, C.A., Heywood, V.H. and Wyse-Jackson, P. (1991). *International directory of botanic gardens. Fifth edition*. Koeltz Scientific Books, Koenigstein, Germany.

- Hilton-Taylor, C. (Compiler), (2000). *2000 IUCN red list of threatened species*. IUCN, Gland, Switzerland and Cambridge, UK.
- Holmgren, P.K. and Holmgren, N.H. (1992). *Plant specialists index. Regnum Vegetabile 124*. International Association for Plant Taxonomy and New York Botanical Garden, New York, USA.
- Holmgren, P.K., Holmgren N.H. and Barnett, A. (1990). *Index herbariorum I: The herbaria of the world. Edition 8. Regnum Vegetabile 120*. International Association for Plant Taxonomy and New York Botanical Garden, New York, USA.
- Hopkinson, P., Travis, J.M.J., Evans, J., Gregory, R.D., Telfer, M.G. and Williams, P. (2001). Flexibility and the use of indicator taxa in the selection of sites for nature reserves. *Biodiversity and Conservation* **10**: 271–285.
- Hughes, C.E. (1998). *The genus Leucaena: a plant genetic resources manual*. Tropical Forestry papers 34. Oxford Forestry Institute, Oxford, UK.
- IBPGR (1992). *Directory of germplasm collections. 1 Tropical and subtropical fruits and tree nuts*. International Board for Plant Genetic Resources, Rome, Italy.
- IPGRI (1993). *Diversity for development*. International Plant Genetic Resources Institute, Rome, Italy.
- IUCN (1992). *Protected areas of the world: A review of national systems. Volume 1: Indomalaya, Oceania, Australia and Antarctica, Volume 2: Palaeartic, Volume 3: Afrotropical, Volume 4: Nearctic and Neotropical*. IUCN, Gland, Switzerland.
- IUCN (1994). *1993 United Nations list of national parks and protected areas*. IUCN, Gland, Switzerland and Cambridge, UK.
- IUCN (2000). *IUCN red list categories: Version 3.1. Prepared by the IUCN Species Survival Commission*. IUCN, Gland, Switzerland and Cambridge, UK.
- Johnson, D. (1996). *Palms: their conservation and sustained utilisation. Status survey and conservation action plan*. IUCN, Gland, Switzerland.
- Jones, P.G. and Gladkov, A. (1999). *FloraMap: A computer tool for the distribution of plants and other organisms in the wild*. CIAT, Cali, Colombia.
- Jones, P.G., Beebe, S.E., Tohme, J. and Galwey, N.W. (1997). The use of geographical information systems in biodiversity exploration and conservation. *Biodiversity and Conservation* **6**: 947–958.
- Kiambi, K.D. (2000). *Ecogeographic and genetic studies of Oryza sp. in Africa*. Unpublished PhD Thesis University of Birmingham, Birmingham, UK.
- Mabberley, D.J. (1997). *The plant book: a portable dictionary of vascular plants. Second edition*. Cambridge University Press, Cambridge, UK.
- Marshall, D.R. and Brown, H.D. (1975). Optimum sampling strategies in conservation, pp. 53–80. In: O.H. Frankel and J.G. Hawkes (eds). *Crop genetic resources for today and tomorrow*. Cambridge University Press, Cambridge, UK.
- Maxted, N. (1995). *An ecogeographic study of Vicia subgenus Vicia*. Systematic and ecogeographic studies in crop gene pools 8. IPGRI, Rome, Italy.
- Maxted, N., Ford-Lloyd, B.V., and Hawkes, J.G. (1997a). Complementary conservation strategies, pp. 15–41. In: N. Maxted, B.V. Ford-Lloyd and J.G. Hawkes (eds). *Plant genetic conservation: the in situ approach*. Chapman & Hall, London, UK.
- Maxted, N., Hawkes, J.G., Guarino, L. and Sawkins, M. (1997b). The selection of taxa for plant genetic conservation. *Genetic Resources and Crop Evolution* **44**: 337–348.

- Maxted, N. and Kell, S. (1998). Ecogeographic techniques and *in situ* conservation: a case study for the legume genus *Vicia* in Turkey, pp. 323–344. In: N. Zencirci, Z. Kaya, Y. Anikster and W.T. Adams (eds). *The Proceedings of International Symposium on In Situ Conservation of Plant Diversity*. Central Research Institute for Field Crops, Ankara, Turkey.
- Maxted, N., Mabuza, P. and Kell, S.P. (2000). Ecogeographic techniques and conservation: a case study for the legume genus *Vigna* in Africa, pp. 63–91. In: K. Oono (editor-in-chief). *The Seventh Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan International workshop on genetic resources, National Institute of Agrobiological Resources, Tsukuba, Tbaraki, Japan, 13–15 October 1999: Part 1: Wild legumes*. Research Council Secretariat of MAFF and National Institute of Agrobiological Resources, Tsukuba, Japan.
- Maxted, N., van Slageren, M.W. and Rihan, J.R. (1995). Ecogeographic surveys, pp. 255–28. In: L. Guarino, V.R. Ramanatha Rao, and R. Reid (eds). *Collecting plant genetic diversity: technical guidelines*. CAB International, Wallingford, Oxon, UK.
- McNeely, J.A. (1988). *Economics and biological diversity: developing and using economic incentives to conserve biological resources*. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.
- McNeely, J.A. and Guruswamy L.D. (1998). Conclusions: how to save the biodiversity of planet earth, pp. 376–391. In: D.G. Lakshman and J.A. McNeely (eds). *Protection of global biodiversity: converging strategies*. Duke University Press, Durham, NC, USA.
- Milliken, W., Miller, R.P., Pollard, S.R. and Wandelli, E.V. (1992). *Ethnobotany of the Waimiri Atoari Indians of Brazil*. Royal Botanic Gardens, Kew, UK.
- Nelson A., LeClerc G. and Grum M. (1997). *The development of an integrated Td/Tk and C interface to determine, visualize and interrogate infraspecific biodiversity*. Internal CIAT document. GIS Laboratory, CIAT, Cali, Colombia.
- Pearce, D.W. and Turner, R.K. (1990). *Economics of natural resources and the environment*. Harvester Wheatsheaf, New York, USA.
- Pearce, D.W. and Morgan, D. (1994). *The economic value of biodiversity*. Earthscan, London, UK.
- Pickersgill, B. (1984). Migrations of chili peppers, *Capsicum* spp. in the Americas. In: D. Stone (ed). *Pre-Columbian plant migration. Papers of the Peabody Museum of Archaeology and Ethnology* 76: 105–123. Harvard University Press, Boston, USA.
- Prendergast, H.D.V. (1995). Published sources of information on wild species, pp. 153–179. In: L. Guarino, V.R. Ramanatha Rao and R. Reid (eds). *Collecting plant genetic diversity: technical guidelines*. CAB International, Wallingford, Oxon, UK.
- Rebelo, A.G. and Sigfried, W.R. (1992). Where should nature reserves be located in the Cape Floristic Region, South Africa? Models for the spatial configuration of a reserve network aimed at maximizing the protection of diversity. *Conservation Biology* 6: 243–252.
- Scott, J.M., Davis, F., Csuti, B., Noss, R., Butterfield, B., Groves, C., Anderson, H., Caicco, S., Dérchia, F., Edwards, T.C., Ulliman, J. and Wright, R.G. (1993). Gap analysis: a geographic approach to protection of biological diversity. *Wildlife Monographs* 123: 1–41.
- Stafleu F.A. and Cowan, R.S. (1976 – Onward). *Taxonomic literature: A selective guide to botanical publications and collections with dates, commentaries and types. Standard international reference on taxonomic literature indexed on author*. Bohn, Scheltema & Holkema, Utrecht, The Netherlands.

- Tomooka, N., Vaughan, D.A., Moss, H. and Maxted, N. (2003). *The Asian Vigna: ecogeography and genetic resources of the genus Vigna subgenus Ceratotropis*. Kluwer, Dordrecht, The Netherlands.
- Vane-Wright, R.I., Humphries, C.J. and Williams, P.H. (1991). What to protect? Systematics and the agony of choice. *Biological Conservation* **55**: 235–254.
- Walter, K.S. and Gillett, H.J. (1998). *1997 IUCN red list of threatened plants*. Compiled by the World Conservation Monitoring Centre. IUCN – The World Conservation Union, Gland, Switzerland and Cambridge, UK.