Chapter 8

Establishing an Information Baseline: Ecogeographic Surveying

Before sensible conservation decisions can be made, a basic understanding of the taxonomy, genetic diversity, geographic distribution, ecological adaptation and ethnobotany of a plant group, as well as of the geography, ecology, climate and human communities of the target region, is essential (Guarino et al, 2005).

Aims and purpose

Before any conservation action on a target taxa can be undertaken, sufficient information about the taxa must be gathered in order to make informed decisions and establish appropriate priorities for the development of a practical conservation strategy. Box 8.2 outlines the different kinds of information about the taxa that should be gathered. This information can be obtained from the literature, herbarium specimens, genebanks, botanic gardens, arboreta and meteorological stations, as well as from field surveys, so as to establish a knowledge baseline.

An ecogeographic study is a process of gathering and synthesizing ecological, geographic and taxonomic information. The results … can be used to help formulate conservation strategies and collecting priorities (Maxted et al, 1995).

The process of gathering this information is sometimes referred to as an *ecogeographical survey or study* (IBPGR, 1985; Maxted et al, 1995; Dulloo et al, 2008) and is a key first step in the development of any conservation strategy, whether *in situ* or *ex situ*. An ecogeographical survey aims to determine: (i) the distributions of particular taxa in particular regions and ecosystems; (ii) the patterns of infra-specific diversity; and (iii) the relationships between survival and frequency of variants and associated ecological conditions. The term ecogeographic survey

Box 8.1 Examples of ecogeographic surveys

Coffea (Dulloo et al, 1999; Maxted et al, 1999): an herbarium-based ecogeographic survey was made, supplemented by detailed field surveys of wild *Coffea* species in the Mascarene Islands. The geographical and ecological distribution of the different *Coffea* species in the Mascarene Islands, principally in Mauritius, was determined. Genetic diversity hotspots were mapped and an assessment was made of the IUCN conservation status of native *Coffea* species.

Vicia (Maxted, 1995; Bennett and Maxted, 1997).

Corchorus (Edmonds, 1990).

Medicago (Bennett et al, 2006).

Phaseolus (Nabhan, 1990).

Lens (Ferguson and Robertson, 1996).

Leucaena (Hughes, 1998).

Annual legumes (Ehrman and Cocks, 1990).

South American *Solanum* (Smith and Peralta, 2002).

Trifolium (Bennett and Bullitta, 2003): an ecogeographical analysis of six species of *Trifolium* from Sardinia, with the aim of designing future collection missions and for the designation of important *in situ* reserves in Sardinia.

African *Vigna* (Maxted et al, 2004).

applies to various processes of gathering and collating information on the taxonomy, geographical distribution, ecological characteristics, genetic diversity and ethnobiology of the target species, as well as the geography, climate and the human setting of the regions under study (Guarino et al, 2002).[1] Ecogeographic information can be used to locate significant genetic material and representative populations can be monitored to guide the selection of representative samples for conservation and utilization (IBPGR, 1985). Although originally designed and applied in the context of conservation of gene pools of wild species such as CWR, the ecogeographic survey approach can be modified so as to apply to crops (Guarino et al, 2005).

A full ecogeographic survey requires considerable resources to carry out and may take several years to complete, especially in the case of wide-ranging species. While highly desirable, especially for CWR of major importance, this will seldom be possible and much more concise studies are often undertaken. Examples of ecogeographic surveys are given in Box 8.1.

The Bioversity International series 'Systematic and Ecogeographic Studies on Crop Genepools' covers some of the most important CWR and is available for download at: http://www.bioversityinternational.org/publications.

Ecogeographic surveys carried out during the UNEP/GEF CWR Project

In the course of the CWR Project, ecogeographical studies were made of the following species:

Armenia

Desktop studies were made of 99 species, of which 79 were the subject of field studies (Table 8.1).

Bolivia

Researchers from national partner institutions participating in the CWR Project in Bolivia, gathered ecogeographic data through field trips to the areas of distribution of species in different regions. During the period 2006 to 2009, researchers collected field data on 149 (out of 201) species identified in 2005, covering 14 genera (*Anacardium*, *Ananas* and *Pseudoananas*, *Annona*, *Arachis*, *Bactris*, *Chenopodium*, *Cyphomandra*, *Ipomoea*, *Manihot*, *Phaseolus*, *Rubus*, *Solanum*, *Theobroma* and one *Vasconcellea* segregated from *Carica*). The 14 genera were prioritized from an original group of 52 genera previously identified, based on criteria such as: potential use and importance of economic, social and cultural state of knowledge, including taxa in the International Treaty on Plant Genetic Resources for Food and Agriculture. The species are listed in Annex I.

The researchers also collected specimens that were then incorporated into the collections of the Herbaria Bolivia (BOLV, USZ and LPB) and accessions that

Table 8.1 *List of species surveyed ecogeographically in Armenia*

Triticum araraticum, T. boeoticum, T. urartu, *Aegilops crassa, A. tauschii, A. cylindrica, A. triunccialis, A. biunccialis, A. triaristata, A. columnaris, Ambylopyrum muticum, Hordeum spontaneum, H. glaucum, H. murinum, H. geniculatum, H. marinum, H. violaceum, H. bulbosum, *H. hrasdanicum, Secale vavilovii, S. montanum, *Cicer anatolicum, *Lens ervoides, L. orientalis, *Pisum arvense, P. elatius, Vavilovia formosa, Vicia villosa, *V. ervilia, V. cappadoixcica, Lathyrus pratensis, L. tuberosus, Onobrychis transcaucasic, O. altissima, O. hajastana, O. cadmea, O. oxytropoides, Medicago sativa, M. lupulina, *Trifolium sebastianii, T. hybridum, T. pratense, T. repens, Beta macrorhiza, B. corolliflora, B. lomatogona, *Spinacia tetrandra, Asparagus officinalis, A. verticillatus, A. persicus, Rumex acetosa, R. crispus, R. tuberosus, *R. scutatus, R. obtusifolius, Chaerophyllum aureum, C. bulbosum, Daucus carota, Falcaria vulgaris, Heracleum trachyloma, Allium atroviolaceum, A. rotundum, A. victorialis, Cucumis melo, Malva neglecta, Lactuca serriola, Malus orientalis, Pyrus caucasica, P. syriaca, P. takhtadzhianii, P. salicifolia, P. zangezura, P. tamamschjanae, P. medvedevii, P. pseudosyriaca, Sorbus hajastana, S. aucuparia, S. takhtajanii, S. subfusca, S. roopiana, S. persica, Crataegus orientalis, Crataegus pontica, Ficus carica, Armeniaca vulgaris, Amygdalus nairica, A. fenzliana, Cerasus avium, Prunus spinosa, P. divaricata, Diospyros lotus, Rubus idaeus, R. cartalinicus, R. armeniacus, *Ribes armenum, *R. biebersteinii, Punica granatum, Cornus mas, Juglans regia.

* Species that were the subject of desktop studies only

were added to local genebanks. Such efforts support an increased knowledge about CWR and help to ensure that key information is available for decision-making regarding research, production, public planning, conservation and use of CWR, and the design of policies and standards related to research, conservation and use of biodiversity.

Sri Lanka

Ecogeographic surveys of the following species were made: *Oryza nivara*, *Vigna aridicola*, *V. trilobata*, *V. stipulacea*, *V. dalzelliana*, *V. marina*, *V. radiata* var. *sublobata*, *Musa acuminata*, *M. balbisiana*, *Piper chuvya*, *P. longum*, *P. siriboa*, *P. walkeri*, *P. trineuron*, *P. zeylanicum*, *Cinnamomum dubium*, *C. ovalifolium*, *C. litseaefolium*, *C. capparu-coronde*, *C. citriodorum*, *C. sinharajaense* and *C. rivulorum*.

Uzbekistan

The following species were surveyed:

Malus sieversii (apple), *Allium pscemense* (onion), *Amygdalus communis*, *A. bucharica*, *A. spinosissima*, *A. petunnikovii* (almond), *Pistacia vera* (pistachio), *Juglans regia* (walnut), *Hordeum spontaneum* and *H. bulbosum (barley)*.

It should be noted that these surveys carried out as part of the UNEP/GEF CWR Project are probably the largest set of ecogeographic assessments ever undertaken and represent a major contribution to the practice.

The components of the knowledge baseline

The knowledge baseline component of an ecogeographic survey brings together a wide range of information about the target species, its distribution, habitat, uses and its presence in protected areas and the availability of germplasm collections (see Box 8.2). The amount of detail will depend largely on how well the species is known, how common it is, its economic uses and where it occurs. There is no 'correct' data set in this regard and a great deal of pragmatism must be applied in practice.

The main stages involved in an ecogeographic survey are given in Box 8.3. The Crop Genebank Knowledge Base has a useful training module on ecogeographic surveys, outlined in Box 8.3. It is available for download at: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=378&Itemid=538&lang=english (accessed 27 October 2010).

Gathering and collation of desktop *in situ* information

Much of the desktop information will be available from a country's national CWR or plant genetic resources strategy, if these exist, but the information will still need to be compiled. The national biodiversity strategies and action plans and various

Box 8.2 Elements needed for knowledge baseline

- Bringing together information on the main wild species of economic use in the country or region on:
    - the correct identity;
    - distribution;
    - reproductive biology;
    - breeding system;
    - demography; and
    - conservation status.
- Gathering information on:
    - how they are used, including local traditional knowledge;
    - the nature and extent of trade in these species;
    - the extent to which (if relevant) they are harvested from the wild and the consequences of this on the viability of wild populations; and
    - their cultivation and propagation.
- Establishing which species occur in protected areas, and to what extent.
- Gathering information on the availability of germplasm and authenticated stock for cultivation.
- Ecogeographic conspectus for each species.

Source: Heywood and Dulloo, 2005

Box 8.3 Phases of an ecogeographic study or survey

Phase I – Project design
- project commission;
- identification of taxon expertise;
- selection of target taxon taxonomy;
- delimitation of target region;
- identification of taxon collections;
- designing and building of ecogeographic database structure.

Phase II – Data collection and analysis
- listing of germplasm conserved;
- survey of taxonomic, ecological and geographical data sources;
- collection of ecogeographical data;
- data verification;
- analysis of taxonomic, ecological and ecogeographical data.

Phase III – Product generation
- data synthesis;
- ecogeographical database, conspectus and report;
- identification of conservation priorities.

Source: Maxted et al, 1995; Maxted and Kell, 1998

national reports submitted to the Convention on Biological Diversity (CBD) will also contain valuable information, as will country reports for the first *State of the World's Plant Genetic Resources for Food and Agriculture* (FAO, 1998) and the second Report approved at the Twelfth Regular Session of the Commission on Genetic Resources for Food and Agriculture in October 2009.

Data may be gathered from a range of sources (see also Chapter 6):

* literature, including floras, monographs, checklists and phytosociological studies;
* herbaria;
* botanic gardens and arboreta;
* passport data from genebanks;
* national or local meteorological service data sets (for annual and monthly rainfall, monthly minimum and maximum temperature);
* National Soil Survey and data sets;
* international, regional and national biodiversity databases and information systems.

Taxonomic information

Although it might appear obvious, correct identification of the taxa being surveyed or selected for conservation is essential. This is much more difficult than it seems, as the level of accuracy of identification of plant taxa in scientific literature is very variable and often quite low. Though fundamental when conducting research, often the scientific identification of the taxa is not checked for accuracy. Numerous cases where plants of reference have been misidentified can be cited; the consequences can be serious and very costly.

Reasons for the difficulties experienced in ensuring correct taxonomic identification include the fact that taxonomy and classification are highly specialized subjects and, with certain exceptions such as student Floras and Faunas, and simplified guides for amateurs, the formal products of taxonomy have traditionally not been user-friendly. Floras, monographs, revisions, checklists can be very daunting to the non-specialist as they are highly technical and often cater to the needs of taxonomists rather than the interests of less specialized users. Some identification guides are not written clearly and leave out fundamental information, such as an illustration of the species. Concern for the needs of users, including taxonomists, is a relatively recent development and components such as keys are missing from many classic works. Even when such components are included, they are often highly technical and difficult for an inexperienced user to understand (Heywood, 2004).

A particular case where taxonomic tools such as Floras are critical for conservation is in the preparation of lists of endangered species (Red Data Lists or Handbooks). Floras are a prime resource for the preparation of Red Data Lists and are relied upon, along with herbarium specimens, as a source of data for this purpose, particularly in developing countries. Floras are interpreted to estimate and infer the distribution ranges of the taxa concerned and their degree of rarity

(Golding and Smith, 2001). Unfortunately, Floras were not designed for this purpose, and the extraction and proper interpretation of data can be quite difficult without the assistance of a professional taxonomist.

It must also be stressed that despite the unique role of species as the basic unit in both biological classification and biological diversity, there is no universal agreement on how to define a species. The actual named species we handle in biodiversity studies are comparable only by designation, not in terms of their degree of evolutionary, genetic, ecological or morphological differentiation. In the majority of cases, it is likely that a conventional taxonomic species concept, i.e. one based primarily on morphological differentiation (see Bisby, 1995: Box 2.1–4), will be employed for identifying target species. In practical terms, the standard Flora(s) of the country should be used for species identification and the nomenclature adopted by the Flora(s) should be followed unless it is possible to determine the correct name (if different) through other sources. If a recent revision of the genus or group of species is available that should be used.

In addition, it must be recognized that species concepts differ from group to group and there are often national or regional differences in the way in which the species category is employed (Gentry, 1990; Heywood, 1991), which makes comparisons difficult. Species may be interpreted in some Floras in a wide sense, including species that are regarded as separate ones in other Floras. Likewise, some Floras will treat a particular taxon as a species, while others will treat the same taxon as a subspecies or even as a variety. In fact, infra-specific variants such as subspecies, ecotypes or chemical races or individual populations, rather than species, may be the focus of attention in agrobiodiversity (Yanchuk, 1997). There is a widespread tendency in much work on biodiversity and conservation (e.g. in Red Lists) to treat most species as though they were uniform, whereas many do, in fact, contain a great deal of variation that has been recognized taxonomically or genecologically. It will clearly make a difference when planning conservation actions if distinctive variants are recognized, as their behaviour and underlying genetic differentiation will vary from one to another and require appropriate treatment. This is especially true for CWR where particular alleles in a species' population may be the focus of interest.

While it is likely that, in the case of well-known rare and endangered wild species, few problems of identification will arise, for widespread species occurring in more than one country care should be taken, as the same species may be listed under different names in the Flora, depending on the country. In the absence of any agreed nomenclature, specialist taxonomic advice should be sought.

The same considerations apply at the generic level: an example concerns the genera *Triticum* and *Aegilops*, which have been commonly treated as separate while some taxonomists include *Aegilops* in *Triticum*. This is a matter of taxonomic opinion and neither interpretation is 'correct'. The consequence of these discrepancies is that the same CWR taxon may occur in the taxonomic literature under a range of different names or synonyms.

The problem of synonymy, whereby the same taxon (species, genus etc.) occurs in the literature and herbarium under more than one name, can be

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Box 8.4 Practical hints for dealing with taxonomy and names

Remember that if a species has a different name in a Flora or in a herbarium specimen from the one you recognize or are used to, it does not necessarily mean that it is a separate species – it may just be a synonym of that species.

Remember that the names given to species in the literature (scientific papers in journals, inventories, phytosociological or ecological surveys, etc.) may be incorrect and need checking.

If you cannot find a species in a particular Flora or handbook, consider whether it may be 'masquerading' under a different name (synonym) or in a different genus.

If you are unable to identify a specimen, prepare a herbarium sample to take to a taxonomist for identification. Make sure the sample has flowers and fruits, if possible.

If in doubt, consult with a taxonomist for assistance or advice.

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intractable for the non-specialist. A plant may have more than one name because:

* it has been described independently more than once by different taxonomists;
* a taxon, such as a species, is later shown to be the same as other earlier published species; or
* a taxon, such as a species, is treated by different taxonomists at different ranks, such as subspecies, or variety, or is placed in different genera by different specialists.

It is important, therefore, that those using taxonomic literature in compiling eco-geographical surveys be aware of these pitfalls.

Sources of taxonomic information

The taxonomic literature is enormous, stretching back centuries and is daunting for the non-professional user. Chapter 2 of the *Global Biodiversity Assessment* (Heywood, 1995) on the characterization of biodiversity (Bisby, 1995) is a valuable source of information. As noted in Chapter 6, in recent years, much taxonomic information has been stored electronically in databases and information systems. Electronic databases and electronic floras are increasingly being developed and should be consulted when available. They range from major international enterprises such as GRIN Taxonomy for Plants (http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl), TROPICOS (http://www.tropicos.org/) and Species 2000 (http://www.sp2000.org/), to national, local and specialized databases.

Taxonomic and other information about biodiversity (natural history collections, library materials, databases, etc.) is not distributed evenly around the globe. The Global Biodiversity Information Facility (GBIF) estimates that

Box 8.5 What is the Global Biodiversity Information Facility (GBIF)?

GBIF enables free and open access to biodiversity data online. It is an international government-initiated and -funded initiative focused on making biodiversity data available to all and anyone, for scientific research, conservation and sustainable development.

GBIF provides three core services and products:

* An information infrastructure – an internet-based index of a globally distributed network of interoperable databases that contain primary biodiversity data – information on museum specimens, field observations of plants and animals in nature and results from experiments – so that data holders across the world can access and share them.
* Community-developed tools, standards and protocols – the tools data providers need to format and share their data.
* Capacity building – the training, access to international experts and mentoring programmes that national and regional institutions need to become part of a decentralized network of biodiversity information facilities.
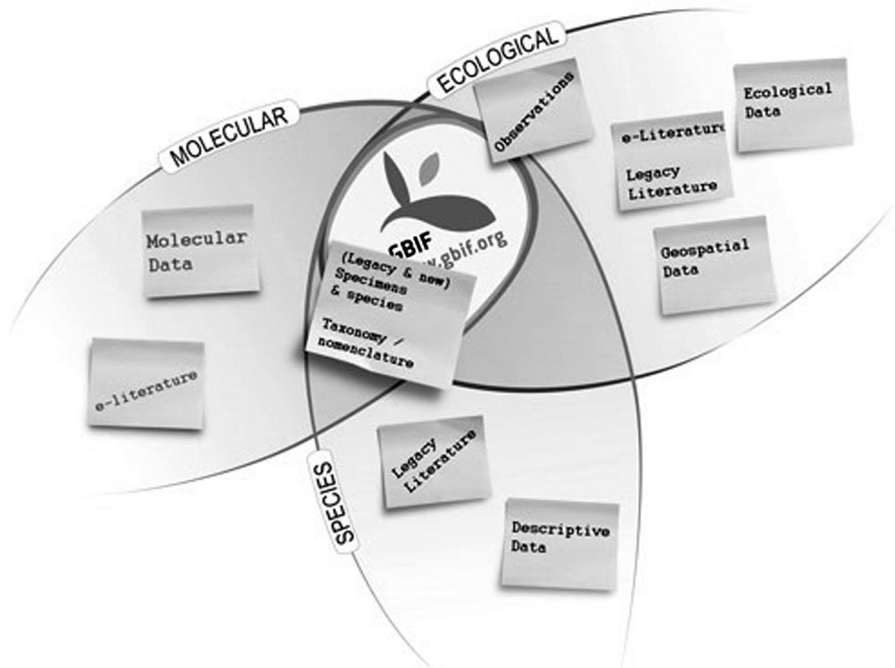
Source: About GBIF http://www.gbif.org/index.php?id=269

Figure 8.1 *About GBIF*

three-quarters or more of biodiversity data is stored in the developed world. However, most of the data that may be needed cannot be transferred because they are not digitized and/or the capacity to handle digital information is lacking. In order to address this issue and facilitate access to information on biodiversity, the GBIF (see Box 8.5) was initiated. GBIF is a global network of data providers building biodiversity information infrastructure and promoting the growth of biodiversity information content on the internet by working with partner initiatives and coordinating activities worldwide. It aims to be the first port of call for those seeking information on biodiversity.

Herbarium specimens are also a useful source of information (Pearce and Bytebier, 2002) and have been used in many ecogeographical surveys to help determine the distribution of taxa. Maxted (1995), for example, consulted material in 18 major international herbaria in his survey of *Vicia* subgenus *Vicia*. A study on American wild potatoes (Bamberg et al, 2003), included a survey of available herbarium material to help determine the location and distribution of the species and potential collection sites; information was also obtained from local botanists.

Herbarium label data are often insufficient or incomplete, or even difficult to interpret or decipher; the geographical location may be incomplete and the localities given cannot be traced. Likewise, ecological data are often poorly recorded, if at all, and this is especially true for older specimens. It should also be remembered that there is no guarantee that material in herbaria is correctly identified and, even if it is, it will not necessarily bear the correct name based on current research. If any doubts about the correct identification exist, professional assistance should be sought.

While herbarium and floristic data are useful sources of ecogeographical information, in the case of taxa that have not been extensively collected, the desktop information will need to be supplemented by field exploration. Field data are, in fact, desirable in most cases, so as to be able to gather information on ecology, demography, genetic variation, breeding system and so on.

The use of *common names* to identify taxa should be exercised with great caution. Many taxa have several common names that are often locally specific but not unique over larger areas. Common names are often inaccurately associated with scientific names (Kanashiro et al, 2002).

Distribution data

It is important to determine the full geographical distribution of the CWR species being targeted. Distributional information, like taxonomic data, may be obtained from a variety of sources: Floras and monographs; geobotanical, phytosociological and vegetation studies, which often contain lists of species recorded from particular areas; herbarium labels; biodiversity databases; etc. Again, it is important to remember that CWR species may occur in the literature and on herbarium specimen labels under a range of different synonyms. Moreover, they may be polymorphic and contain one or more named and distinct subspecies or varieties.

Box 8.6 Geographic information system (GIS)

Put simply, a GIS is a collection of computer hardware and software tools used to enter, edit, store, manipulate and display spatial (geographically referenced) data. The data input can be from maps, aerial photos, satellites, surveys and other sources, and can be presented in the form of maps, reports and plans.

Typically, a GIS is used for manipulating maps with linked databases. These maps may be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image of a map. Layers of data are organized in a particular manner for study and statistical analysis. GIS organizes geographic data into a series of thematic layers and tables.

Georeferencing is the process of converting text descriptions of locations to those which can be read by a computer, and which can be used by software such as GIS. The BioGeomancer Project (http://www.biogeomancer.org/understanding.html) provides tools to improve results for organizations with large amounts of data to georeference by: automating the georeferencing of bulk data; learning from existing georeferences; accessing map and place-name gazetteers; generating computer-readable geographic locations and error descriptions according to accepted standards; and providing tools for validating results.

BioGeomancer is a worldwide collaboration of natural history and geospatial data experts. The primary goal of the project is to maximize the quality and quantity of biodiversity data that can be mapped in support of scientific research, planning, conservation and management. The project promotes discussion, manages geospatial data and data standards, and develops software tools in support of this mission.

The BioGeomancer consortium is developing an online workbench, web services and desktop applications that will provide georeferencing for collectors, curators and users of natural history specimens, including software tools to allow natural language processing of archival data records collected in many different formats.

Various methods and tools have been developed for the prediction of the geographic distribution of species. A recent study (Elith et al, 2006) compares the performance of 16 methods such as GARP, Domain, Bioclim and Maxent, on over 226 species from six regions of the world (see also Lobo, 2008). These methods require the use of a geographic information system (GIS) (Box 8.6), and commercial software packages such as ESRI's ArcGIS (ArcInfo, ArcEditor, ArcView), MapInfo, ERDAS ER Mapper and IDRISI Taiga GIS can be used for this purpose. In addition, some GIS software has been specially developed for conducting work with genetic resources, such as FloraMap,[2] which was developed and widely used at the International Centre for Tropical Agriculture (CIAT), although, it is now rather outdated and has been discontinued in favour of Maxent. Another package is DIVA-GIS, developed by the International Potato Centre (CIP) in collaboration with the International Plant Genetic Resources Institute (IPGRI) (now Bioversity International), and with support from the System-wide Genetic Resources Programme (SGRP). The software is available
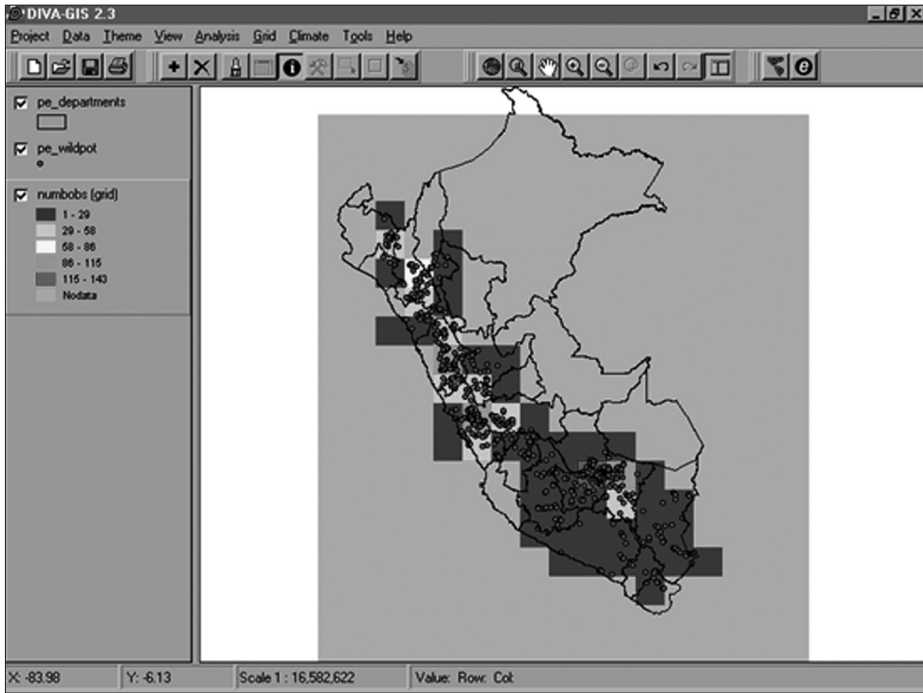
Figure 8.2 *DIVA-GIS – The Create Grid and Output Options windows, together with a main map window showing wild potato species richness in Peru*

Source: Hijmans et al, 2001

free of charge from the CIP website (https://research.cip.cgiar.org/confluence/display/divagis/Downloads) and from http://diva-gis.org/ (Hijmans et al, 2001) (Figure 8.2). It is important to carefully consider the choice of GIS software and the hardware used to run such programs, as mistakes can be costly. Peterson (2001) has developed models of species' ecological niches using an artificial-intelligence algorithm projected onto geography to predict species' distributions.

The Botanical Research and Herbarium Management System (BRAHMS) (http://dps.plants.ox.ac.uk/bol/) is a valuable resource for information on collection management, taxonomic work, botanical surveys and diversity analysis. A PowerPoint presentation on mapping the distribution of five species of Passiflora in Andean countries is available (see http://www.floramap-ciat.org/ing/poster-ppt.htm).

The Gap Analysis[3] team led by Andy Jarvis at CGIAR/IRRI/CIAT aims to develop an approach that will allow collectors (and other people related with *ex situ* and *in situ* conservation) to determine in which areas around the world traits and taxa are still unrepresented among target genebank collections managed by CGIAR-supported centres.

Bioclimatic niche-modelling techniques, which are used for projections of species distributions in climate change studies are discussed in Chapter 14.

Genetic variation

Genetic variation is at the heart of CWR conservation. It occurs at various levels in the populations of species and, in the case of CWR, particular alleles could provide the basis of valuable traits for breeding programmes. In order to be able to capture the desired amount of genetic variation in the conservation of a CWR, this will normally require a detailed understanding of the structure and partition-ing of the genetic variation that occurs in a species and its populations. This will largely determine the location of the reserves and the design of the conservation strategy and management plan. Moreover, the more genetic variation is captured, the more likely is the species to continue to evolve and generate new variation favouring its long-term persistence and survival; the species will also stand a better chance of adapting to face the challenges of climate change.

Previously, genetic variation was commonly inferred from morphological differentiation; however, in recent years, biochemical and molecular techniques have been developed, such as isozyme analysis and DNA-based techniques such as sequencing, AFLP, RFLP, polymerase chain reaction (PCR) techniques, RAPD and microsatellite or SSR. The advantage of using molecular markers for studying genetic diversity is that they are not influenced by environmental factors and reflect genetic similarity without previous knowledge of pedigree information (Kuleung et al, 2006). The various molecular markers perform differently and each has its own characteristics. As such, there is no single molecular approach suitable for all purposes and more than one type should be used to ascertain which is most appropriate for a particular species or for the different issues involved in CWR conservation and management.

A comparison of the different molecular screening approaches is given in Table 8.2, but it should be noted that this is a rapidly evolving field and the assis-tance of specialists should be sought when planning to undertake screening. Further details of these techniques and their application can be obtained from texts such as Barnes and Breen (2009), de Vicente and Fulton (2004), de Vicente et al (2004), and from the review by Karp (2002).

An example of the genetic diversity of the CWR *Malus sieversii* is given in Box 8.7 and the assessment of genetically significant variation in *Coffea* is given in Box 8.8. In the case of *Malus orientalis* (Volk et al, 2009), genotypic (seven microsatel-lite markers) and disease resistance data were collected for 776 trees from Armenia, Georgia, Turkey and Russia. A total of 106 alleles were identified in the trees from Georgia and Armenia and the average gene diversity ranged from 0.47 to 0.85 per locus; it was found that the genetic differentiation among sampling locations was greater than that between the two countries.

While it is often stated that as much as possible of the genetic variation in a species should be captured for genetic conservation (e.g. Hawkes, 1987), such a laudable aim should not be pursued if it is at the cost of allowing many other species to become extinct. How much effort should be devoted to the genetic sampling of a particular CWR will depend on the priority given to that species, the finances and resources available, and how easy or difficult it is to measure the

Table 8.2 *Common genetic marker technologies and their main characteristics*

	Abundance	Level of polymorphism	Locus specificity	Co-dominance of alleles	Reproducibility	Labour intensity
Allozymes	low	low	yes	yes	high	low
RFLP	high	medium	yes	yes	high	high
Mini-satellites	medium	high	no/yes	no/yes	high	high
PCR-sequencing	low	low	yes	yes	high	high
RAPD	high	medium	no	no	low	low
Micro-satellites	high	high	yes	yes	high	low
ISSR	medium-high	medium	no	no	medium-high	low
SSCP	low	low	yes	yes	medium	low-medium
CAPS	low	low-medium	yes	yes	high	low-medium
SCAR	low	medium	yes	yes/no	high	low
AFLP	high	medium	no	no/yes	high	medium

	Technical demands	Operational costs	Development costs	Quantity of DNA required	Amenability to automation
Allozymes	low	low	low	-	no
RFLP	high	high	medium-high	high	no
Mini-satellites	high	high	medium-high	high	no
PCR-sequencing	high	high	high	low	yes
RAPD	low	low	low	low	yes
Microsatellites	low-medium	low-medium	high	low	yes
ISSR	low-medium	low-medium	low	low	yes
SSCP	medium	low-medium	high	low	no
CAPS	low-medium	low-medium	high	low	yes
SCAR	low	low	high	low	yes
AFLP	medium	medium	low	medium	yes

variation. Of course, even if it is possible to make a detailed survey of the genetic variation in a CWR, it does not necessarily mean that it will be possible or feasible to include all of this variation in genetic reserves, but it will help select which populations should be conserved.

On the other hand, it has to be accepted that for many species, perhaps the majority, detailed data on genetic information is unlikely to become available in the foreseeable future, simply because of the costs and labour involved. As Gole et al (2002) note in connection with the conservation of the *Coffea arabica* gene pool, knowledge of the distribution and genetic structure of its populations 'is one

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Box 8.7 Genetic structure of the apple CWR *Malus sieversii* population from Xinjiang, China, revealed by SSR markers

A total of 109 *Malus sieversii* accessions from four geographical populations located in: Kuerdening in Mohe town, Gongliu County; Jiaowutuohai, Xinyuan County, Daxigou in Huocheng County of Ily State; and Baerluke Mountain in Yumin County of Tacheng State, Xinjiang Uygur Autonomous Region of China, were studied by simple sequence repeat (SSR) markers. The purpose of the study was to determine the genetic structure and diversity in these ecogeographical populations with eight pair SSR primers of apple. The results indicated an average of 16 bands were detected in the four populations. The percentage of polymorphic bands in Gongliu population (89.06 per cent) was the highest in the four populations. The average Nei's gene diversity index was 0.257 for all the loci. In total, 128 polymorphic loci were detected and the percentage of polymorphic loci (P) was 100 per cent, 88.28 per cent, 84.83 per cent, 87.50 per cent and 87.12 per cent, respectively, at the species level and Gongliu, Xinyuan, Huocheng and Yumin population levels. The Nei's gene diversity index (H = 0.2619) and Shannon's information index (I = 0.4082) in the species level were higher than in the population level. The Nei's gene diversity index and Shannon's information index in the four populations were: Gongliu > Huocheng > Xinyuan > Yumin. Gongliu population and Xinyuan population were the highest in genetic identity and the closest in genetic distance. Gene flow between the populations was 7.265, based on the genetic differentiation coefficient (GST = 0.064). The UPGMA cluster analysis indicated that the genetic relationships between the Gongliu and Xinyuan population were the closest, and the Yumin population had the greatest difference with the other three populations. The UPGMA cluster analysis indicated that the four geographical populations were relatively independent populations. Concurrently, there was also mild gene exchange between the populations. On the basis of the study of population genetic structure and the highest genetic diversity, the Gongliu population should be considered as high priority for the *in situ* conservation of *Malus sieversii* populations.

Source: Zhang et al, 2007

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of the major challenges for coffee research in Ethiopia since it is expensive and needs up-to-date laboratory equipment and highly skilled personnel, which Ethiopia cannot afford'. Faced with such a situation, recourse will have to be made to proxy information (Dulloo et al, 2008; see also Box 8.8) such as the use of morphological differentiation to reflect underlying genetic differences and genecological zonation which assumes that genetic variation will be reflected in the patterns of ecological variation (Theilade et al, 2000).

How many individuals, how many populations?

How many individuals and populations of a target species should be conserved so as to remain viable are among the most difficult questions in the conservation

Box 8.8 Assessment of genetic variation in *Coffea*

The patterns of genetic variation within and among 14 populations of three wild *Coffea* species endemic to Mauritius were studied using RAPD molecular techniques as a tool to assist in gap analysis of actively conserved biodiversity. Sites were principally sampled from Mauritius with a view to determine the genetic relationships within and between sites, as well as evaluating the effectiveness of the protected areas system in Mauritius in conserving genetic diversity of *Coffea* found on the island. Two other populations of *Coffea mauritiana* from the neighbouring island of La Réunion were also sampled. Cluster analysis of RAPD data confirmed the taxonomic classification of these taxa in three clusters corresponding to the species *C. macrocarpa*, *C. mauritiana* and *C. myrtifolia* and, in addition, showed the distinctiveness of Montagne des Creoles accessions as a separate entity. The results showed that there is as much variation within as among populations (Wright F coefficient = 0.522). Of the 85 polymorphic bands, 25 were unique to one of the above four clusters and 60 (75 per cent) were variable among the four clusters. Almost all individuals of the same population grouped together. The total genetic diversity across all the accessions studied is 0.216. The population genetic parameters, when calculated for the different clusters, show that there is more variation within the clusters than among them. The gene diversity indices (Hj) within each cluster, 'macrocarpa', 'mauritiana', 'MDC' and 'myrtifolia' were 0.168, 0.169, 0.159 and 0.117, respectively. Within the 'mauritiana' cluster, there was a clear distinction between the *C. mauritiana* accessions from Mauritius and La Réunion. Further, the 'mauritiana' cluster contained two samples from the Mondrain population, previously classified as *C. macrocarpa*. In the 'macrocarpa' cluster, the *C. macrocarpa* populations divided into two main groups. Bassin Blanc and the different morphotype in the Mondrain population formed a distinct group, while the rest of the *C. macrocarpa* populations clustered together in the second group. In the 'myrtifolia' cluster, there is a clear demarcation between the western and the eastern populations of *C. myrtifolia* consistent with geographical distribution of the populations.

Source: Dulloo, 1998

biology of species. As Heywood and Dulloo (2005) note, 'The number of individuals needed to maintain genetic diversity within populations has been the subject of considerable work and a great body of literature exists on topics such as population viability analysis (PVA), minimum viable population size (MVP), minimum effective population size and, in the case of metapopulations, the minimum viable metapopulation size (MVM) and minimum available suitable habitat (MASH) (Hanski et al, 1996)'. The minimum available habitat is a relatively new concept which has great potential in restoration, sampling for alleles or heterozygosity (see Box 8.9). Likewise, the question of how many populations should be included in a reserve or network of reserves so as to include the maximum representation of the genetic variation of the CWR must be addressed and will depend on the distribution of the species and populations, and how that variation is partitioned between the different populations, which may require

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Box 8.9 Population and metapopulation viability concepts

Population viability analysis (PVA) is the methodology of estimating the probability that a population of a specified size will persist for a specified length of time. It is a comprehensive analysis of the many environmental and demographic factors affecting survival of a (usually small) population (Morris and Doak, 2002).

The minimum viable population (MVP), a concept introduced by Soulé (1986) to population biology, is the smallest population size that will persist for some specified length of time with a specified probability.

The minimum amount of suitable habitat (MASH) is the number (as a rule of thumb, 15–20) of well-connected patches needed for the long-term survival of a metapopulation (Hanski et al, 1996; Hanski, 1999).

The minimum viable metapopulation size (MVM) is an estimate of the minimum number of interacting local populations necessary for long-term survival of a metapopulation (Hanski et al, 1996).

Source: Heywood and Dulloo, 2005

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considerable effort to ascertain (see Dulloo et al, 2008, pp31–32 for a review and discussion on this topic). However, as a rule of thumb, a minimum of five populations per genetic reserve is recommended for *in situ* conservation (Dulloo et al, 2008; Brown and Briggs, 1991). In many cases it may not be possible for practical, political or economic reasons to attempt a comprehensive coverage of the genetic variation.

Ecological information

Ascertaining the ecological conditions under which the selected species grows is one of the main concerns of an ecogeographic survey. Although some information may be derived from the literature and herbarium specimen label data, in most cases field exploration is essential. There are no agreed criteria for collecting ecological information but those commonly recommended are:

- habitat types – although there is no generally accepted global set of habitat types, many countries have produced their own classifications for use in official documents; the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) lists 218 habitat types in its Annex 1 (see Evans, 2006, for a list and discussion of the issues involved);
- condition of the habitat;
- disturbance regimes;
- threats to the habitat;
- topography;
- altitudinal range;

- soil types;
- slope and aspect;
- land use and/or agricultural practice.

For some species, a phytosociological characterization may be available or may be developed through field-work.

Reference should also be made to the list of descriptors that has been developed by Bioversity International to provide a standard format for the gathering, storage, retrieval and exchange of farmers' knowledge of plants (Bioversity and The Christensen Fund, 2009). For applying participatory approaches to data gathering, see Chapter 5 and Hamilton and Hamilton (2006) and Cunningham (2001).

Methodologies for field surveys

The amount of field-work that can be carried out will depend on the particular target species and local circumstances. Basically, at each site, latitude, longitude, and altitude should be determined by GPS, and location descriptors (geographical region, road or settlement name, proximity to prominent land marks) and site physical characteristics (habitat type, slope, aspect, and precise location of target species plants at the site, if found) should be recorded. Details of how to prepare for field-work are given by Hawkes et al (2000), although it should be noted that the recommendations are for *ex situ* approaches but can often be applied to surveying for *in situ* conservation. Training will need to be provided (see Chapter 15) although few centres or universities offer appropriate courses.

Data analysis and products

The data gathered in ecogeographical surveys may be analysed in various ways such as discriminant analysis or principal component analysis. For the visualization, analysis and management of spatial data, GIS-based packages such as ArcInfo, WorldMap or DIVA may be used.

One of the main products of an ecogeographic survey is the 'ecogeographic conspectus', which is a formal summary of the available taxonomic, geographic and ecological information of the target taxon, gathered from the herbarium and field surveys (Maxted et al, 1995). The conspectus is arranged by species and includes the following information: the accepted taxon name, authors, dates of publication, synonyms, morphological description, distribution, phenology, altitude, ecology and conservation notes. For example, Dulloo et al (1999) published an ecogeographic survey of the genus *Coffea* in the Mascarenes, which includes an ecogeographic conceptus (Box 8.10).

Box 8.10 Example of an ecogeographic conspectus

C. mauritiana Lam., Encycl. 1:550 (1783); DV Prodr. 4: 499 (1830); Bojer, H.M.: Baker, F.M.S.:152; Cordem., F.R.: 506; R.E. Vaughan. Maur. Inst. Bull. 1:44 (1937); A. Chevalier, Rev. Bot. Appl. 18: 830 (1938); Rivals, Et. Veg. Nat. Réunion: 174 (1960).

Synonyms: *C. sylvestris* Willd. ex. Roemer et Schultes, Syst. Vég. 5: 201 (1819). Type La Réunion. *C. nossikumbaensis* A.Chev., Rev. Bot. Appl. 18: 830 (1938). Type Nossi Kumba. *C. campaniensis* Leroy. Journ. Agr. Trop. Bot. Appl. 9: 530 (1962) Type Mauritius. *Geniostoma reticulatum* Cordem., F.R.: 464 Type La Réunion.

Morphological description: Shrub or small tree, reaching about 6m in height, with verticillate branches. Leaves glabrous, leathery, obovate to elliptical, acuminate, cuneiform and decurrent, 4–10cm long by 2–6cm wide with 6–8 pairs of secondary veins. Petiole 3–10mm in length. Stipule deltoid, 2–8mm long. Inflorescence auxiliary and upright. Fruit ovoid to oblong, 18–20mm long, yellowish green becoming purple at maturity.

Distribution: Endemic to Mauritius and Réunion. In Mauritius, *C. mauritiana* is restricted to Plaine Champagne, Mt Cocotte, Pétrin and Les Mares. The species has historically been recorded in three other localities, namely: Le Pouce Mountain, Nouvelle Découverte and Mon Gout. This species is more widespread on Réunion.

Phenology: Bud, August to November; flowers, November to December; fruits, April to August.

Altitude: 270–1500m. In La Réunion, *C. mauritiana* has a broad range of altitude, occurring at 270m at Mare Longue to c.1500m a.s.l. at Bebour. In Mauritius, the species altitudinal range is very narrow (700–760m).

Ecology: Mid to high altitude wet montane rainforest. In Mauritius, *C. mauritiana* is very localized and occurs on the upland plateau in the super-humid zones (rainfall varies between 2500 and 5000mm per annum (Vaughan and Wiehe, 1937) at Mt Cocotte and Plaine Champagne. Plaine Champagne, situated on an area of ground water laterite consisting of highly ferruginous slabs of cuirasses (Parish and Feillafe, 1965), sustains an open canopy of dwarf thickets of native species rarely exceeding more than 5m in height. The area has a rich floristic composition principally composed of *Sideroxylon cinereum* and *S. puberulum* (Sapotaceae), *Aphloia theiformis* (Flacourtiaceae), *Olea lancea* (Oleaceae), *Gaertnera* spp. (Rubiaceae), *Nuxia verticillata* (Loganiaceae), *Antirhea borbonica* (Rubiaceae) and *Syzygium glomeratum* (Myrtaceae). Because of the high rainfall of the area, the ground is covered with a thick cushion of bryophytes with many epiphytic and ground ferns and orchids. The habitat is highly invaded with *Psidium cattleianum* (Myrtaceae), which is the dominant species in the area.

The habitat at Mt Cocotte has been described as a cloud or mossy forest (Vaughan and Wiehe, 1937; Lorence, 1978). It is characterized by very high rainfall often exceeding 5000mm and is often enveloped in clouds and nocturnal mists (Vaughan and Wiehe, 1937). The vegetation community at Mt Cocotte is a relict of the original native vegetation of the area and is composed of such species as *Nuxia verticillata* (Loganiaceae), *Tambourissa* spp., *Monimia ovalifolia* (Monimiaceae), *Syzygium mammillatum*, *Eugenia* spp.

(Myrtaceae) and *Casearia mauritiana* (Flacourtiaceae). The vegetation is poorly stratified. The whole area is now very degraded, with high infestation of alien plants such as *Psidium cattleianum* (Myrtaceae), *Homalanthus populifolius* (Euphorbiaceae) and *Rubus alceifolius* (Rosaceae).

Conservation notes. IUCN Status: Mauritius CR (B 1,2); Réunion VU (C 2a). The IUCN conservation status for *C. mauritiana*, in Mauritius, is here classified as Critically Endangered (CR), under criteria B 1,2. The area of occupancy is less than 1km^2 and it is considered that there is only one major population at P. Champagne. The other sites (Mt Cocotte, Les Mares and Pétrin) all have very scattered individuals and do not form any population as such. The site is heavily invaded with alien plants, principally *Psidium cattleianum* (Chinese guava) and there is no sign of regeneration of *C. mauritiana*. The population is estimated to be between 350 and 400 plants at this site, contained within an area of about four to five hectares. In addition, there is a high influx of visitors into this area for the picking of Chinese guava fruits; this is a favourite pastime for many Mauritians, which can be damaging for the threatened flora of the island. At the other sites, particularly at Les Mares and Pétrin, only few specimens are known. At Les Mares, there is only one plant growing under high tension wire at the side of a road. Most of this area has been converted into exotic plantations of forestry species such as *Pinus elliottii*, and *Eucalyptus* spp. At Mt Cocotte, there is only a small sterile population of *C. mauritiana* population (15 individuals). These are located within a conservation management area, an intensely managed forest plot where alien species are excluded (Dulloo et al, 1996), and unfortunately is not regenerating. Over the past three years, two of the plants at this site have died.

In Réunion, *C. mauritiana* is more common than in Mauritius. During the course of this survey, only a few sites were visited and the species was found to be occasional in these areas. Consequently, it is difficult to assess the overall conservation status for the whole island. However, discussions with field-workers at the University of La Réunion suggest that the IUCN status for *C. mauritiana* may be considered as Vulnerable (T. Pailler, personal communication).

Source: modified from Dulloo et al, 1999

Results from each country

Armenia

Desktop study

The first step involved collating available information on the taxonomy, occurrence and distribution, biological features, conservation status and uses of the 104 target CWR species. This was done by searching the literature and by examining passport data from herbaria at the Institute of Botany of the National Academy of Sciences, Plant Genetic Resource Laboratory of Armenian State Agrarian University and the Department of Botany of Yerevan State University, as well as seed bank (*ex situ*) collections records at Armenian State Agrarian University. Literature sources consulted include: Takhtajan, *Flora of Armenia*; Grossheim,

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Box 8.11 Analytical tools used for the assessment of the CWR status and monitoring in each country

Armenia: DIVA-GIS and other GIS software were used in Red Listing and monitoring.

Bolivia: DIVA-GIS, ArcView and ArcGIS were used in determining the collection sites of species of 13 genera in the different departments of Bolivia, within and outside protected areas, and within and outside the community lands. During 2007 and 2008, Bioclim, Domain and Maxent prediction models were used to determine the potential distribution of the CWR and Maxent to determine the effect of climate change on distribution in priority selected species. GisWeb has also been developed as a tool for the visualization of maps of different types using the services of Google Maps. Maps include major and minor rivers and coverage of CWR in the national CWR portal. GisWeb offers satellite images of maps that can be zoomed in on to display further detail (Bellot and Cortez, 2010; Bellot and Justiniano, 2010).

Madagascar: Data analysis was done using Domain, FloraMap, ArcGIS and other GIS software. The Information Management Committee (IMC) is testing DIVA-GIS for data analysis.

Sri Lanka: DIVA-GIS was used to map current distribution and FloraMap to predict potential distribution.

Uzbekistan: DIVA-GIS and MapSource were used to generate species-distribution maps.

Flora of the Caucasus; Red Data Book of Armenia; Gabrielian and Zohary (2004), 'Wild relatives of food crops native to Armenia and Nakhichevan'; Czerepanov, *Vascular Plants of Russia and Adjacent States*; the Germplasm Resources Information Network (GRIN)/United States Department of Agriculture (USDA) database; and other relevant sources. Relevant experts were consulted when necessary.

Field-work

Extensive field surveys were conducted in the administrative regions (marzes) of Armenia and Yerevan city (Table 8.3) during two consecutive years, 2006 and 2007, from late spring till autumn. Surveys were conducted, where possible, during the flowering or fruit-bearing stage, when identification of species is easy. Slight adjustments were made for individual species and altitudes in different regions. For example, sites located at relatively high altitudes (1500–2000m) were visited later in the season (July–August) compared with lowland areas.

    The team conducting field surveys comprised experts, including taxonomists, from the Institute of Botany, Armenian State Agrarian University and the local CWR team. Although the majority of field surveys were organized (and funded) by the UNEP/GEF CWR Project, a few field trips were also supported by other projects underway at the Institute of Botany and Armenian State Agrarian University (Table 8.3).

Table 8.3 *Ecogeographic surveys and administrative regions (marzes)
visited in Armenia*

Date	Administrative regions (marzes)	Organized by	Expedition
01.06.2006	Ararat marz	CWR-Armenia and Armenian State Agrarian University	Omargo_1_2006
03.06.2006	Yerevan city and Kotayk marz	CWR-Armenia	Erebuni_1_2006
12.06.2006	Shirak and Aragatsotn marzes	CWR-Armenia	Talin_1_2006
20.06.2006	Kotayk marz	CWR-Armenia	Abovian_1_2006
06.07.2006	Yerevan city, Kotayk, Ararat, Aragatsotn and Tavush marzes	CWR-Armenia and Institute of Botany	O_6_2006
15.07.2006	Ararat, Vayots Dzor and Gegharkunik marzes	CWR-Armenia	Eghegnadzor_1_2006
02.08.2006	Vayots dzor, Kotayk, Lori and Tavush marzes	CWR-Armenia and Institute of Botany	O_5_2006
03.08.2006	Ararat marz	CWR-Armenia	Khosrov_1_2006
10.08.2006	Syunik marz	CWR-Armenia and Institute of Botany	O_4_2006
17.08.2006	Tavush, Lori and Aragatsotn marzes	CWR-Armenia	Dilijan_1_2006
20.08.2006	Ararat marz	CWR-Armenia and Institute of Botany	O_3_2006
27.08.2006	Aragatsotn marz	CWR-Armenia and Institute of Botany	O_2_2006
29.09.2006	Aragatsotn and Kotayk marzes	CWR-Armenia	AknaLich_1_2006
08.10.2006	Syunik marz	CWR-Armenia	ShikahoghZ_1_2006
01.06.2007	Aragatsotn and Kotayk marzes	CWR-Armenia and Institute of Botany	O3_Ivan_2007
10.06.2007	Vayots dzor and Syunik marzes	CWR-Armenia and Institute of Botany	O2_Ivan_2007
16.06.2007	Aragatsotn, Shirak and Lori marzes	CWR-Armenia	Stepanavan_1_2007
04.07.2007	Kotayk marz	CWR-Armenia	Erebuni_2_2007
14.07.2007	Ararat, Vayots Dzor and Syunik marzes	CWR-Armenia	Syunik_1_2007
21.07.2007	Kotayk, Syunik, Vayots Dzor and Lori marzes	CWR-Armenia and Institute of Botany	O_7_2007
24.07.2007	Yerevan city and Kotayk marz	CWR-Armenia	Erebuni_1_2007
28.07.2007	Gegharkunik marz	CWR-Armenia	Sevan _1_2007
29.07.2007	Tavush marz	CWR-Armenia and Institute of Botany	O1_Ivan_2007
28.08.2007	Yerevan city and Kotayk marz	CWR-Armenia	Garni_1_2007
30.08.2007	Aragatsotn marz	CWR-Armenia	Bjurakan_1_2007
07.09.2007	Syunik marz	CWR-Armenia and Institute of Botany	O4_Ivan_2007
23.09.2007	Tavush and Gegharkunik marzes	CWR-Armenia	Shamshadin_1_2007

The data collected during field surveys included:

- latitude, longitude and altitude (collected using a GPS);
- description of location, including administrative unit and nearest settlement;
- soil characteristics;
- conservation status of the area;
- average density (number of plants per unit area);
- approximate area occupied by each subpopulation, plant community;
- phenology of the populations (time of leaf break, flowering, etc.);
- current and potential threats to the populations.

Special questionnaires were developed to collect the data, which were entered into a database. If the species could not be properly identified, a specimen was taken for determination at the herbarium. Where possible, seeds (collected as heads) were collected for *ex situ* conservation at Armenian State Agrarian University seed bank as a complementary measure. The collection was done in such a way as to capture maximum genetic diversity of the population and not to endanger the natural population, following the IUCN technical guidelines on the management of *ex situ* populations (IUCN, 2002). The data collected were entered into a database (Microsoft Access).

Summary results of desktop research
It is important to note that the original list of 104 species was reduced to 99: it was decided to exclude two species from the list, as their presence in Armenia was debatable (*Aegilops umbellulata* and *Cicer minutum*); *Crysopsis sebastianii* was excluded as it is a synonym of *Trifolium sebastianii*, already included in the project; and *Vitis vinifera* was excluded from the list since an extensive project on the species was already funded by another international agency.

The information collected was used to draft the preliminary distribution of the species, as well as to plan the timetable and routes for field studies.

Summary results of field surveys
Field studies covered almost all of Armenia and all administrative regions (marzes) except for Armavir marz. In total, 571 populations representing 79 species were studied in the field and their details recorded. The remaining 20 species were not found in the field for different reasons: one species (*Aegilops crassa*) is assumed to be extinct in the wild in Armenia; others are rare and were not found in the field either because of time constraints or because passport data were not detailed enough and did not allow field-work to be planned to cover their locations.

As identified during field surveys, major threats to the populations included uncontrolled grazing and hay harvesting, urbanization (especially for the populations extending to Yerevan city), land privatization accompanied by construction of buildings and agricultural activities, road construction, mining activities in southern Armenia, climate change (especially increasing aridity) and the wild

harvesting of early leafy vegetables and wild fruits/berries. Results for selected species are presented in Tables 8.4–8.7.

Bolivia

Types of data recorded

From early 2006 until mid-2009, researchers from project partner institutions undertook field assessments and gathered ecogeographic data, having previously identified areas with potential distribution maps. Data was collected using field sheets prepared by each partner institution, taking into account the fields/ descriptors of the database for the National Information System of Crop

Table 8.4 *Triticum araraticum*

	Erebuni State Reserve (Monitoring data)	Armenia (Field survey data)
Population size:	1,832,000	65,900,000
Area occupied:	20.9ha	3200ha
Threats:	illegal grazing, chemical deposition	agricultural expansion, land use
General trend:	stable	decline

Table 8.5 *Triticum boeoticum*

	Erebuni State Reserve (Monitoring data)	Armenia (Field survey data)
Population size:	42,354,000	6,853,000,000
Area occupied:	52.3ha	14,400ha
Threats:	illegal grazing, chemical deposition	agricultural expansion, land use
General trend:	stable	decline

Table 8.6 *Triticum urartu*

	Erebuni State Reserve (Monitoring data)	Armenia (Field survey data)
Population size:	837,000	837,000
Area occupied:	5.2ha	5.2ha
Threats:	illegal grazing, chemical deposition	illegal grazing, chemical deposition
General trend:	decline	decline

Table 8.7 *Aegilops tauschii*

	Erebuni State Reserve (Monitoring data)	Armenia (Field survey data)
Population size:	3,400,000	5,647,000,000
Area occupied:	15ha	62,400ha
Threats:	illegal grazing, chemical deposition	agricultural expansion, land use
General trend:	stable	decline

Wild Relatives (NISCWR), which are organized into seven groups (taxon, site, contact, resource, accessions, specimen and population). These data are included in the NISCWR database, available to the general public through the National and International Portals: www.cropwildrelatives.org and www.cwrbolivia.gob.bo.

From 2006 to 2009, researchers from the partner institutions systematized desktop information and field data gathered from a total of 201 species of 14 genera: *Anacardium*, *Ananas* and *Pseudoananas*, *Annona*, *Arachis*, *Bactris*, *Capsicum*, *Chenopodium*, *Cyphomandra*, *Euterpe*, *Ipomoea*, *Manihot*, *Phaseolus*, *Rubus*, *Solanum*, *Theobroma* and *Vasconcellea* (*Carica*). The data recorded for the species of 14 genera according to the seven groups of descriptors/fields of the NISCWR are reflected in Table 8.8.

Population data for priority CWR taxa surveyed are given in Tables 8.9 and 8.10.

Sri Lanka

Ecogeographic surveys were conducted throughout the country, except for the Northern Province. A total of 1121 GPS locations were assigned to wild relatives of priority crops from the field survey, passport data, herbarium specimens and literature survey. Total GPS locations are given in the accompanying map (Figure 8.3) and presented separately for each genus.

Assemblage geographic coordinates were entered in the FloraMap, Garmin map sources and DIVA-GIS software programs for the preparation of distribution maps and predictive maps to identify remaining areas to be surveyed and to identify gaps in the surveys.

Two types of surveys were conducted during the project period. A literature survey was conducted to collect basic information on CWR while an actual field survey was launched to determine the present situation of past known locations and to find out new locations of the CWR. The field survey was conducted in different parts of the island as indicated in Table 8.11 and Figure 8.3. Ecogeographic descriptors were prepared using available and collected information of priority CWR for all possible species.

Ecogeographic surveying was carried out for priority wild species of Sri Lanka from August 2005 to December 2007, in targeted areas. Habitat and taxonomic data were recorded in a field data record form and herbarium specimens were prepared. Photographs were taken to highlight habitats and specific characteristics of the plants. A global positioning system (GPS) with map datum WGS 84 was used to mark the locations where wild species were found. Since most of the herbarium specimens lacked geographic coordinates, they were manually examined and approximate geographic coordinates were assigned using a coordinates book published on a website on the internet. Geographic coordinates obtained from the field survey, passport data and herbarium specimens were entered into the Garmin map sources and DIVA-GIS software for the preparation of distribution maps for each species. The distribution of the wild

Table 8.8 Kinds of data recorded for each genus from desktop revision and field assessments during the period 2006–2009, in Bolivia

Genera and the species for which data was recorded

Data type	Anacardium	Ananas Pseudoananas	Annona	Arachis	Bactris	Capsicum	Chenopodium	Cyphomandra	Euterpe	Ipomoea	Manihot	Phaseolus	Rubus	Solanum	Theobroma	Vasconcellea
1. Taxon																
1.1 Taxonomy	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1.2 Common names	x	x	x	x			x	x	x	x	x	x	x	x	x	x
1.3 Biological data	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
1.4 Uses	x		x	x			x	x	x	x	x	x	x	x	x	x
1.5 Conservation actions							x	x	x	x	x	x	x	x	x	
1.6 Legislation affecting the taxon									x	x						
1.7 Category of threat (Red List)	x	x	x	x			x	x	x	x	x	x	x	x	x	x
1.8 Distribution	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2. Site																
2.1 Administrative unit	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
2.2 Locality	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
2.3 Climate				x			x	x	x	x	x	x	x	x	x	x
2.4 Habitat	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
2.5 Relief and Topography							x							x		
2.6 Soil							x							x		
2.7 Administrative status																
2.7 Soil use							x							x		
3. Contact																
3.1 Category, institution, person, address, comments	x						x								x	
4. Source																
4.1 URL, Title, Author, Theme, Key words, Date, Editor: Name of Editor; Place of Publication	x						x							x	x	
5. Accession																
5.1 Number				x			x					x		x		
5.2 Date of acquisition				x			x					x		x		
5.3 Owner				x			x					x		x		
5.4 Taxon				x			x					x		x		
5.5 Source				x			x					x		x		

Table 8.8 *continued*

Data type	\<\-\-\- Genera and the species for which data was recorded \-\-\-\>															
	Anacardium	Ananas Pseudananas	Annona	Arachis	Bactris	Capsicum	Chenopodium	Cyphomandra	Euterpe	Ipomoea	Manihot	Phaseolus	Rubus	Solanum	Theobroma	Vasconcellea
5.6 Distribution			x	x			x					x		x	x	x
5.7 Name of accession			x	x			x					x		x	x	x
5.8 Donation																
5.9 Biology			x	x			x					x		x		
5.10 Other duplicate number			x	x			x					x		x		
5.11 Source																
5.12 Distribution			x	x			x					x		x		x
6. Specimen																
6.1 Number of specimen	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6.2 Date of acquisition	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
6.3 Entity	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
6.4 Taxonomy	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
6.5 Source (action, location)	x	x	x	x	x		x	x	x	x	x	x	x	x		
6.6 Sample	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
6.7 Donation (number of specimen, entity, date of donation, donation agreement, material transfer agreement, comments)																
6.8 Biology	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
6.9 Action (dates, actors, collection, ID of collection)	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
6.10 Sample (Identification storage, voucher, distribution)																
7. Population																
7.1 ID	x			x												
7.2 Date	x		x	x												
7.3 Actor	x			x												
7.4 Methodology	x			x												
7.5 Characterization (abundance, density cover, threats)	x			x									x			

Source: Beatriz Zapata Ferrufino, CWR Project, Bolivia

Table 8.9 *Number of populations for 14 wild species of* Arachis *genus studied by bio-geographic zones of Bolivia through thesis work (2007–2009), with field assessments and desk data within the framework of the CWR Project*

Genus	Province Biogeographic	Species	Populations recorded	Populations studied	% Populations studied
Arachis	Chaco boreal – western sector	Arachis batizocoi	23	5	13.0
		Arachis duranensis	51	5	7.8
	Cerrado – Chiquitano sector	Arachis cardenasii	51	20	39.2
		Arachis cruziana*	18	10	55.5
		Arachis chiquitana*	4	2	50.0
		Arachis glandulifera	45	11	24.4
		Arachis herzogii*	16	11	68.8
		Arachis kempff-mercadoi*	45	5	11.1
		Arachis krapovickasii*	6	2	33.3
		Arachis magna	26	8	30.7
		Arachis sp.*	5	5	100.0
	Beni – Lllanos de Moxos sector	Arachis benensis*	5	2	40.0
		Arachis trinitensis*	4	3	75.0
		Arachis willamsii*	7	4	57.0
TOTAL			306	90	29%

* species is endemic
Source: Ramos Canaviri, 2009

Table 8.10 *Number of localities in Bolivia visited by year for ecogeographic surveys*

Genus 2006–2009	Number of localities visited by year				Total localities
	2006	2007	2008	2009	
Anacardium	0	2	0	0	2
Ananas-Pseudoananas	5	5	2	0	12
Annona	32	53	30	0	115
Arachis	0	108	0	0	108
Bactris	0	0	0	0	0
Cyphomandra	0	12	1	0	13
Chenopodium	0	0	12	0	12
Euterpe	1	0	0	0	1
Ipomoea	10	27	31	0	68
Manihot	13	46	36	0	95
Phaseolus	0	0	22	0	22
Theobroma	20	16	21	0	57
Rubus	0	58	9	0	67
Solanum	6	20	9	5	40
Vasconcellea	0	26	11	0	37
Total number of localities	87	373	184	5	
Total number of localities in the period 2006–2009					649

Source: VMABCCGDF–Bioversity International, 2010. Informes Técnicos de Fase 2006–2008 de las instituciones socias del Proyecto CPS & Inventario de Especímenes colectados por las instituciones socias del Proyecto CPS en el periodo 2006–2009)
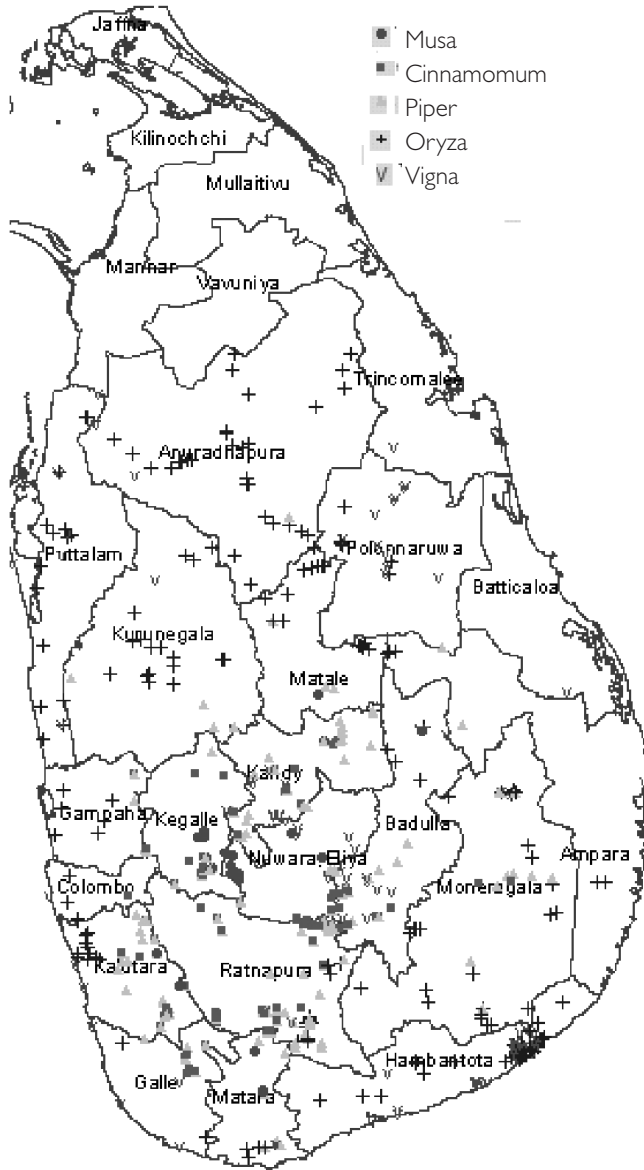
Figure 8.3 *Map of ecogeographic survey locations for priority CWR in Sri Lanka*

CWR of the priority crops occurring in Sri Lanka is depicted in the maps. GPS data were analysed by FloraMap distribution modelling and DIVA-GIS Bioclim modelling to map the probable areas in which wild species could be expected. The Red Listing category (conservation status) for each species was assigned on the basis of the ecogeographic survey data.

Table 8.11 *GPS locations summary for Sri Lanka*

Genus	Field surveys	PP+HS+Lit*	Total
Oryza	111	180	291
Musa	30	3	33
Vigna	129	56	185
Piper	241	100	341
Cinnamomum	182	89	271
Totals	693	428	1121

* PP=Passport data, HS=Herbarium specimen label data, Lit=Literature data

Uzbekistan

Summary of results of desktop research

Ecogeographic surveys were carried out for six priority species of CWR (see Figures 8.4–8.9):

- *Malus* – apple;
- *Amygdalus* – almond;
- *Juglans* – walnut;
- *Pistachia* – pistachio;
- *Allium* – onion;
- *Hordeum* – barley.

Field surveys were conducted by the Scientific Plant Production Centre 'Botanica'; R. Shreder Scientific Research Institute of Gardening, Viticulture and Winemaking; Uzbek Scientific Research Institute of Plant Industry; and the Republican Scientific Production Centre of Decorative Gardening and Forestry.

Surveys were conducted over four years at different stages of vegetation development in order to cover the current areas of distribution. A single methodology developed by project experts at the beginning of the project was employed. Before field surveys were undertaken, literature data and herbarium material were studied.

Field surveys were conducted by establishing pilot plots in various populations of priority species. The following data were studied during the surveys:

- composition of the plant communities in which the CWR populations occur;
- conservation status of the populations;
- threats to the populations;
- growth habit of the priority species;
- physical and geographical conditions of the area where pilot plots were established;
- longitude, latitude;
- local name of the plants;
- biometrical data;
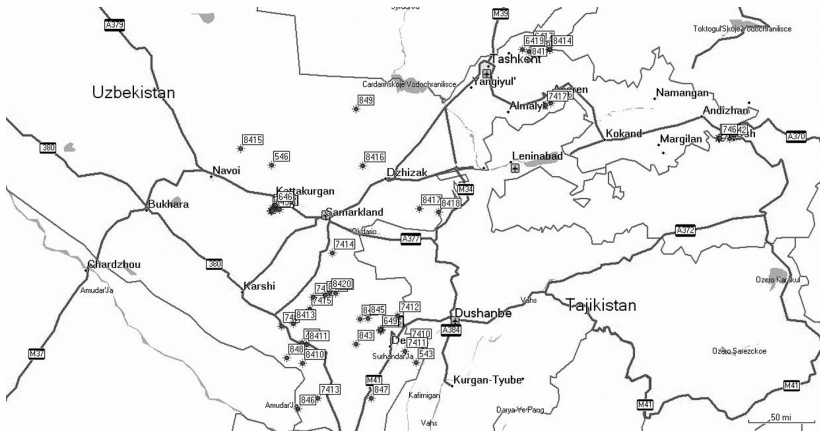- soil conditions;
- level of soil erosion.

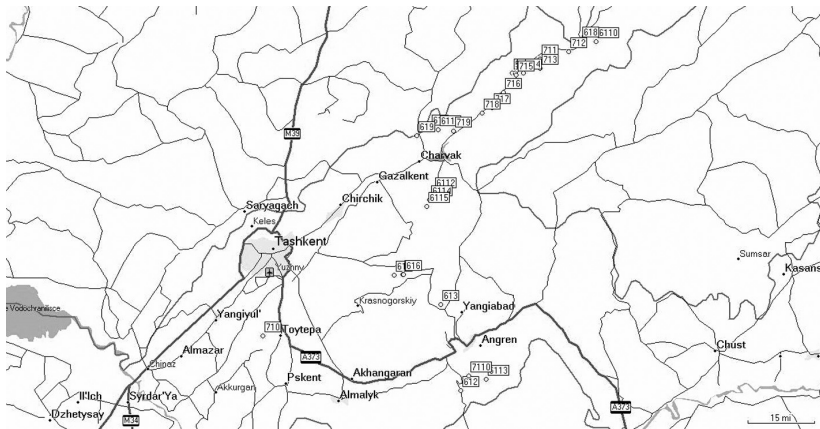**Figure 8.4** *Distribution of wild pistachio in Uzbekistan*
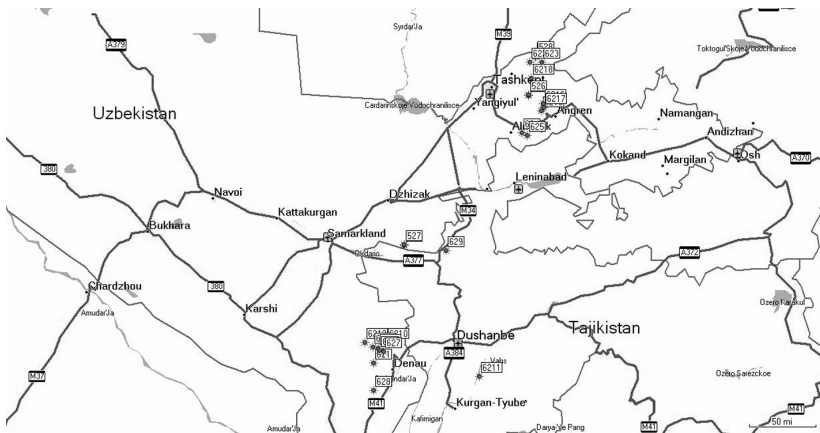

Figure 8.5 *Distribution of wild onion in Uzbekistan*

Figure 8.6 *Distribution of wild almond in Uzbekistan*
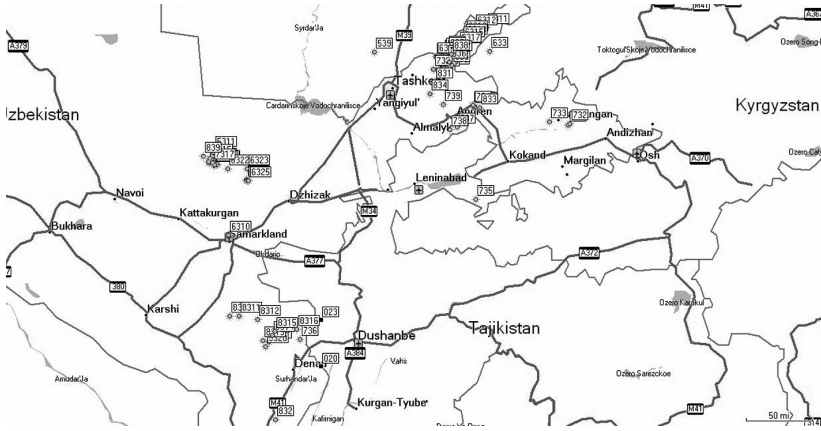
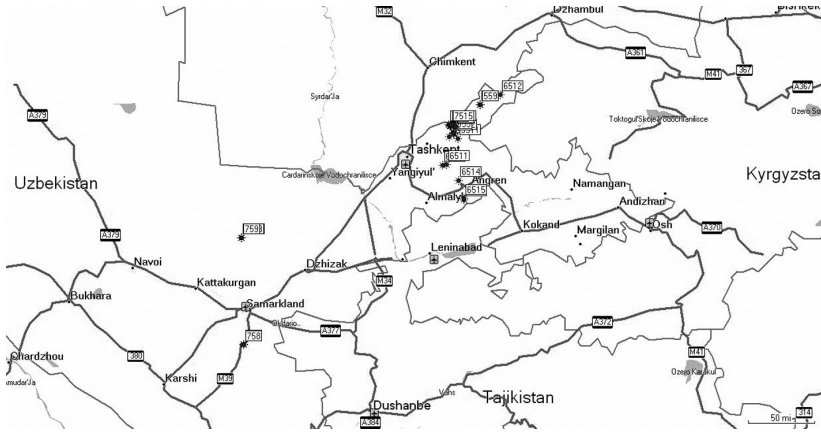**Figure 8.7** *Distribution of wild walnut in Uzbekistan*

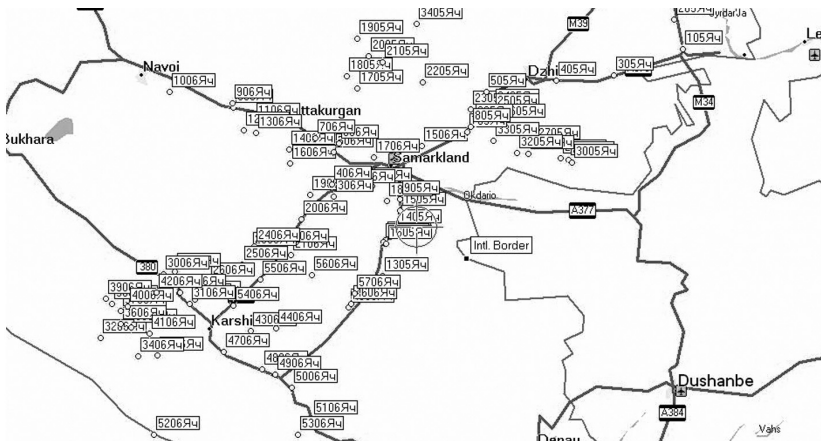**Figure 8.8** *Distribution of wild apple tree in Uzbekistan*

Figure 8.9 *Distribution of wild barley in Uzbekistan*

In total, 30 sets of data were used to define the current status and extent of distribution of the target species. All data were included in the database (in Russian and English). The database is being prepared for online use and access. The main threats for surveyed species were identified as: cattle grazing, uncontrolled collection of the fruit and using trees as timber.

Technical difficulties experienced

In Armenia, it is important to note that the distribution information extracted from herbarium passport data was treated with much caution. Some records were quite old and difficulties were encountered in handling outdated information, particularly old names of settlements and administrative subunits. In addition, only a few location descriptions were accompanied by coordinate readings. So mapping the possible distribution sites was a complex process. It started with an expert botanist putting dots on the map based on the information provided in the passport data, using his or her judgement on the possible collection site, after which the maps were georeferenced by a GIS expert.

In Bolivia, the following technical difficulties were noted:

- While the Global Project Coordination Unit at Bioversity had provided documents with methodologies for conducting ecogeographic surveys, there was no common understanding among the five project countries as to the meaning and scope of 'Geographical Survey'.
- Initially, because the descriptors (fields) of the CWR-Genetic Resources Information System (CWR-GRIS), developed by Bioversity for the national information systems of the CWR Project countries, were not agreed at an early stage between the five countries and Bioversity, field data were gathered using non-standard survey data sheets according to descriptors produced by the Bolivian national partner institutions. The herbaria emphasized the importance of collecting specimens and the genebanks emphasized the importance of collecting data of accessions.
- The relationship between components 2 and 3 (information system and *in situ* conservation actions) of the CWR Project were not clearly set out, leading to a failure to link the data required for database NISCWR and those needed for conservation and monitoring.
- It was not possible to gather all necessary data or conduct the required field assessments due to the different life cycles of the species, distance and travel costs. To gather population data, for example, more field trips and funds were needed; therefore, only data for two prioritized species were used. These data were collected through thesis work financed by the project.

In Sri Lanka, the following technical problems were experienced in undertaking ecogeographic surveys of CWR:

Season – Some species of CWR are annual and seasonal so the survey teams needed to visit the field at the correct time to find the species. In addition, funding was not received at the correct time, which also affected the survey work. For example, some populations of *O. rufipogon* are best seen in the field from December to March. Unavailability of project funds at the beginning of the year caused the surveying of *O. rufipogon* sites to be delayed until January and February.

Single or few plants in a population – Intrapopulation variation cannot be obtained when the number of individuals in a population is limited. For instance, only a single or few individuals were observed for most of the *Cinnamomum* species; this may cause problems in determining their estimated future rate of survival in the wild.

Preparation of herbarium specimens – Different species of CWR have different flowering times. Therefore, several visits had to be made to the same location to obtain herbarium specimens for correct identification. Additionally, some plants are very tall and unavailability of lower branches is also a problem in collecting herbarium specimens.

Distribution in specific areas – The ecogeographic surveys were conducted on a multi-species basis to save time and resources. Hence, the survey team concentrated on areas/region where the maximum number of species was expected. However, some species were distributed in very specific regions or areas and additional survey trips had to be made to those specific areas; only a few locations were found on these visits.

Unavailability of past survey information – Past survey information has not been well documented. The DIVA-GIS uses a UGS84 system while the maps used in the project were from the Sri Lanka Meteorology Department, which use a different coordinate system. There was limited capacity to convert these formats to make the systems compatible. As such, surveyed gaps were not clear, meaning that one must conduct an entire survey of a given species.

Incorrectly identified and old herbarium specimens – It was found that some herbarium specimens were incorrectly identified by authors and could therefore not be found when visits were made to areas where the specimens had been collected. Another problem was the unavailability of newly collected specimens in the National Herbarium for most CWR. Old herbarium specimens are difficult to handle, particularly flowering parts that are damaged.

Weak satellite signal – CWR are not always located in open areas. It was difficult to receive a satellite signal inside the forest areas when the upper forest canopy was thick. In this situation, GPS coordinates were taken at the nearest location with good satellite reception.

Lack of awareness – Protected areas of Sri Lanka are rich in wild relatives of food crops and wild food plants. Before conducting intensive surveys in these areas, the authorities of protected areas must have a good understanding of the importance of CWR in protected areas.

Identification of threat factors – Within a short period, it is difficult to identify the factors that threaten wild populations. Therefore, there should be several visits to the same location to identify the real threats to the populations; local knowledge will be important to gather further information.

Preparation of maps – GPS coordinates could not be plotted on the Sri Lankan Survey Department digital maps provided. Distribution prediction maps were prepared using available DIVA-GIS and FloraMap software. However, these software packages have only world climate data files that were too broad and were not specific for the localities surveyed.

The main problems encountered in Uzbekistan were:

- the wide distribution of priority species – not all distribution areas of apple and almond were surveyed during the four years of the project;
- the distribution areas of almond and pistachio are very remote;
- the number of ecogeographic surveys undertaken did not allow a full description of the phenology of populations;
- some territories where surveys were planned are in border regions with other countries and are not accessible.

Further sources of information

Bioversity International hosts a series of training modules on its website, including one on ecogeographical surveys: http://training/training_materials/ecogeographic_surveys.html

http://cropgenebank.sgrp.cgiar.org/images/flash/ecogeographic_surveys/index.htm

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Notes

1. Bennett (1997) uses the term ecogeography in this context which he defines as the collection and synthesis of ecological, geographical and taxonomic data.
2. CIAT (http://www.floramap-ciat.org/) and Jarvis et al (2005)
3. http://gisweb.ciat.cgiar.org/GapAnalysis/

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