Published information on the natural and human environment

9

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Introduction

Plant genetic resources collectors need information on different aspects of the environment of their target region. They need it to help them in a number of important tasks, which are listed in Box 9.1. In collecting plant germplasm for conservation, if direct information on genetic diversity is not available, the recommended strategy is the sampling of the widest possible range of different ecogeographic conditions (Chapter 5). It will thus be necessary to use data on features of the physical, biotic and human environment (such as climate, soil, vegetation and land use) in conjunction with data on the distribution of the target taxa derived from the literature, herbaria and existing germplasm collections, if collectors are to capture the greatest possible diversity of germplasm. Regions with a wider range of ecogeographic conditions will tend to be higher collecting priorities. Distribution data for target species often consist of nothing more than the name of a place: maps, atlases and gazetteers will be necessary to locate such sites. Knowing the range of conditions occurring in a given target area will also allow the collector to design a more user-friendly collecting form, actually listing the range of vegetation, soil types, etc. likely to be encountered (Chapter 19).

Certain types of information, for example on human demography, land use, deforestation and desertification hazard, can be useful guides in assessing the likelihood or severity of genetic erosion in an area, and hence also in determining the priority and urgency of collecting. In this category will also come data on climate change.

If the aim is to procure germplasm of particular taxa or genotypes with known ecological requirements or adapted to particular ecological conditions, again published sources of information on the environment will be essential planning tools. Where do acid soils occur in the target

Box 9.1
Uses of environmental information

- To define ecogeographically and agroecologically homogeneous areas, which can be used as the basis for stratified sampling.
- To estimate the extent of biodiversity in an area on the basis of the extent of heterogeneity in the physical, biotic or human setting.
- To develop better collecting forms.
- To estimate the threat and extent of genetic erosion.
- To predict the presence/absence of a species or genotype in a given area, on the basis of its ecological preferences.
- To predict the best timing for collecting.
- To find their way around in the field.
- To estimate the rate of loss of seed viability after collecting.
- To fully document the collection.

region? Where is rainfall below 500 mm? Are there any areas where these conditions coincide? These are the kinds of questions that collectors will often need answers to.

Information on the environment will also be necessary in deciding when to visit an area: the approximate timing of the flowering and fruiting season can be estimated from monthly temperature and rainfall data, and the estimate refined on the basis of actual weather reports. Climatic data can also be used to identify areas where seed viability loss after collecting is likely to be unacceptable, so that the collector's stay in the area can be minimized (Chapter 20).

Once in the field, maps of various kinds will be necessary to adapt the collecting route and to actually find localities. The environmental information gathered together before the mission will also be important in documenting collecting sites. The passport data associated with each germplasm sample will include not only data collected in the field at the collecting site, but often also data gleaned from maps and other reference sources (Chapter 19). These will be useful in interpreting the data that are collected when material is characterized and evaluated, for example. In turn, such analyses will inform not only the use of conserved germplasm, but also future exploration, allowing collecting strategies to be refined and improved.

A broad overview of the environment, complete with maps, explanatory text and bibliography can be found in the *Atlas of the Environment* (Lean *et al.*, 1990). Tables of national-level statistics on the state of the environment are also published annually as *World Resources* (WRI *et al.*, 1994). Data from such sources will be useful in developing global strategies and priorities, but the collector will also need sources of more detailed information. These are the subject of this chapter. Most detailed data on the environment will be in the form of published maps, though they may also be presented as tables and diagrams. However, geographically referenced environmental data are also available in digital form. Increasingly, countries are digitizing their maps of the physical environment and their biodiversity information. Though some digital data sets will be briefly mentioned here by way of introduction, a fuller discussion can be found in Chapter 16.

Types of environmental data

Geographic, climate and socioeconomic data sets are discussed below in turn, with examples and some information on sources.

Geography

Geography is used broadly here to include administrative boundaries, topography (forming a base data layer), geology, soils and land use. Various kinds of maps can provide information on different aspects of these topics. Digital base data layers are discussed in more detail in Chapter 16.

Cadastral maps

These show administrative boundaries. They can be useful when documenting the location of a collecting site, for which a primary administrative unit, and if possible secondary and tertiary units, should be quoted. In large and federal countries (e.g. India), maps of individual states or provinces are common.

Road maps

These are vital in planning routes both before setting out and from day to day in the field. They display the road network, the locations of cities and towns and sometimes administrative boundaries and the more obvious physical features, usually at a relatively small scale, typically about 1 : 1,750,000.

Topographical or relief maps

These show altitude contours and spot heights, in addition to roads, towns, lakes, rivers, etc. Sometimes, they include basic data on vegetation and land use. They will be useful in identifying areas of high environmental diversity and may be necessary for taking altitude readings in the field. Topographical maps at 1 : 250,000 or better are commonly taken to the field and annotated to show the location of collecting sites. Digital relief surfaces (or terrain models) for various regions are either already available or under development (Chapter 16).

Hydrological maps

These give information on groundwater and surface drainage as well as showing more obvious hydrological features, such as lakes, rivers, streams, swamps and dams, which are often of interest to the collector. Some 70 countries are contracting parties of the *Convention on Wetlands of International Importance Especially as Waterfowl Habitat* (also known as the *Ramsar Convention*). Many have carried out wetlands surveys in consultation with the Ramsar Convention Bureau and other interested organizations, such as the World Conservation Union (IUCN). One of the more important outputs of such surveys are maps of wetlands distributions within the country, using the standard classification system adopted as part of the Convention.

Geological maps

These show the distribution of different kinds of solid rocks and unconsolidated material. Most geological maps use as mapping units stratigraphic (i.e. age) categories rather than categories of more immediate interest to the plant collector (e.g. ones based on mineralogy). They may or may not include structural features such as faults and folds. The Commission for the Geological Map of the World publishes 11 *Listes des Cartes Géologiques Nationales et Internationales* (Parry and Perkins, 1987). There are also guides to available geological maps available on-line and on Compact Disk Read-Only Memory (CD-ROM) (see below).

Soil maps

Many different classification systems for soils are in use, ranging from local or national schemes to the international classifications of the Food and Agriculture Organization–United Nations Educational, Scientific and Cultural Organization (FAO–Unesco), the US Department of Agriculture (USDA) and the Commission de Pédologie et de Cartographie des Sols (CPCS). The FAO system (FAO–Unesco–ISRIC, 1988) was initially intended as a legend to the *Soil Map of the World* at 1 : 5 million, but it is in fact a soil classification and has been widely treated as such. The map is available in digital form. The US soil taxonomy (USDA, 1975) is widely used throughout the Americas, as is the CPCS (1977) system in francophone countries. Many countries use their own detailed national classification systems, but increasingly such systems are congruent with international classifications. The International Soil Reference and Information Centre (ISRIC) is preparing a worldwide digital database for soils and terrain on a scale of 1 : 1 million, converting existing soil maps to a common format (Chapter 16). Details of soil profile, texture, depth and colour may be shown on the more detailed soil maps. Specialized soil degradation maps may show the level of salinity, the degree of soil erosion, the presence of toxic substances, fertility and structure decline, etc. White (1983) reviews published soil mapping for Africa. FAO keeps an index of soil maps.

Land use maps

These show how the human population interacts with and exploits the land and the vegetation cover. Again, a local classification system may be used, or a more standard framework. Some examples of land use and farming systems classifications, and references, are given in Chapter 19. Land use maps may be very detailed, showing the distribution of individual crops. The *World Atlas of Agriculture* includes land use and relief maps and country monographs (Committee for the World Atlas of Agriculture, 1976).

Vegetation maps

These may employ a local classification, or one of the more widely adopted schemes, for example White's (1983), Unesco's (1973) and that used in the series of maps by the Institut de la Carte Internationale du Tapis Végétal (ICITV) (Chapter 10). In more specialized maps, the condition of the vegetation may also be shown, for example giving details of forest clearing, overgrazing, etc. This kind of information often comes from remote sensing. Chapter 10 deals with the published sources of information on the vegetation and ecology of an area, including maps.

Terrain maps

Various different types of terrain maps are in use. In one type, geomorphological physiographic units are derived from aerial photography and satellite imagery. More complex maps use a combination of physiography, soils, geology, climate and vegetation to define the different mapping units or land facets within land systems. Examples are the Land Resource Studies published by the Land Resources Development Centre (LRDC), UK, covering southern, central and western Africa. FAO, the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the International Institute for Aerospace Survey and Earth Sciences (ITC), The Netherlands, have also used land system mapping extensively. Hilwig (1987) gives a list of terrain, land use, land evaluation, vegetation and other surveys employing remote sensing methods.

Protected areas maps

Many countries produce detailed maps of individual protected areas, often for tourist use, as well as more general maps of the whole country showing the distribution of national parks and the like. A good example of the former is the *Road Map of the Etosha National Park*, published by the Ministry of Wildlife, Nature Conservation and Tourism of Namibia, which in addition to roads and important sights also shows and describes the different vegetation types of the park. Basic protected area information is also often included in other types of maps, for example road maps and land use maps. The World Conservation Monitoring Centre (WCMC) has a digital data set showing protected areas worldwide. Chapter 10 considers sources of information on protected areas.

Climate

Climate may be described in terms of individual parameters, such as temperature and rainfall, or by means of synoptic combinations of such parameters, which are believed to have increased predictive power. Such data may be presented as text descriptions, tables, diagrams or maps.

To the plant germplasm collector, the most relevant climate data will be annual, seasonal or monthly means, extremes and ranges for temperature and rainfall, and perhaps such secondary, derived statistics as the difference between average temperature in the hottest and coldest months and the relative lengths of wet and dry seasons. Climate data should be long-term norms. A 30-year period is the rule, but 25-year and ten-year periods produce satisfactory means for precipitation and temperature respectively, although they are not quite as satisfactory for extremes; in any case, means should be at least over five years (Reid, 1980). A very basic list of parameters would include:

- mean annual temperature (°C);
- mean minimum temperature of the coldest month (°C);
- mean maximum temperature of the warmest month (°C);
- mean annual rainfall (mm);
- seasonality of rainfall (summer, winter, bimodal or uniform);
- number of dry months (i.e. months with mean monthly rainfall <60 mm in the tropics or <30 mm in the subtropics, latitude >23.5°);
- incidence of frost.

A fuller list would include monthly figures for rainfall and for mean, minimum and maximum temperature. The absolute minimum and maximum temperature are sometimes recorded. The incidence of drought and snow can also be important. Measures of the reliability and predictability of rainfall (e.g. mean deviation as % of annual mean) are often more relevant than average values in semiarid areas.

Martyn (1992) gives a 'general presentation of the climates of the continents and oceans, plus more detailed discussions of the climates of large states and groups of smaller states'. The bibliography includes references to climatic atlases and other data sources. The World Meteorological Organization (WMO) also publishes a *Bibliography of Climatic Atlases and Maps*. Good examples of major climatic atlases are those published by WMO itself (e.g. WMO *et al.*, 1979). Another extensive general descriptive work is the multivolume *World Survey of Climatology* (Landsberg, 1969–76), which includes not only tables of monthly means but also detailed descriptions of the climates of the continents. The *Ecosystems of the World* series is a useful source of general data on climate and other features of the physical environment (see Chapter 10 for references).

Such broad-scale, synoptic studies are of course ultimately based on raw time-series data from individual meteorological stations. There are about 200,000 stations collecting meteorological data worldwide, about a quarter keeping records in digital form, but they are by no means evenly spread around the world, nor do they all gather the same information to comparable precision. It is often difficult to find out exactly what data are available from the national meteorological service, unless it is formally published (e.g. Servicio Meteorologico Nacional Mexico, 1976), even for national plant genetic resources programmes attached to the same government ministry. However, WMO publishes the *INFOCLIMA Catalogue of Climate System Data Sets*, which brings together information on the existence and availability of climate data sets (usually time series, rather than long-term means), as provided to WMO by countries and specialized data centres.

Long-term means for meteorological stations are available in published form in a number of international accounts in addition to national publications. Specht (1988), for example, brings together information from Mediterranean-type environments worldwide. Another useful collection, this one presenting climate data for the whole world, has been published by the British Meteorological Office (Anon., 1965). The compilation of Smithsonian Institution (1944) is similar. A series of publications for Asia, Africa and Latin America presents the average values of the main agroclimatic parameters in the form of monthly and yearly tables (FAO, 1984, 1985, 1987). These data pertain to the main observing stations and are grouped by country. In addition to these average values, rainfall has been given particular attention and synthetic monthly rainfall probability tables are presented in the second part of each publication, giving a fairly uniform coverage of the main agroecological zones. FAO maintains a database of climate information (FAOCLIM). The CD-ROM *World Weather Disc* (Weather Disc Association) contains climatological records dating back to the 18th century from thousands of weather stations worldwide.

The international agricultural research centres (IARCs) also hold climatic data in digital and other forms, and publish them in various ways. For example, the Centro Internacional de Agricultura Tropical (CIAT) has a climate database including information from several thousand stations in Latin America (the South American Monthly Meteorological Database (SAMMDATA)) and Africa (Jones, 1987). Examples of IARC publications in this field include general works such as Huke (1982) and Sivakumar *et al.* (1984) and crop-specific studies such as Virmani *et al.* (1991) and Carter *et al.* (1992).

Though long-term climate means for meteorological stations are usually presented in various types of tables, a standard climate diagram is sometimes used. This has months on the horizontal axis, and shows the annual course of mean monthly temperature and rainfall superimposed on each other against vertical axes along which 1°C is equivalent to 2 mm of rainfall. This relationship approximates evaporation, so that drought is denoted when the precipitation curve falls below the temperature curve. Walter and Lieth (1960–67) and Walter *et al.* (1975) display in atlas form about 10,000 such climate diagrams from all over the world, summarizing up to 11 temperature parameters as well as showing the mean monthly temperature and rainfall curves.

Numerous attempts have been made to classify climate on a global or regional basis by combining together a range of climatic parameters in some kind of predictive model. A list of the major classification schemes is given by Young (1987). The most famous are:

- the Köppen (1936) classification, based on mean annual and mean monthly rainfall and temperature;
- the Holdridge (1967) life zones system, based on potential evapotranspiration ratio;
- the FAO (1978–81) agroecological zones (AEZ) system, based on temperature during the growing period, length of growing period and seasonality of rainfall;
- on a more restricted scale, Emberger's (1955) classification of Mediterranean environments, based on mean annual rainfall, mean minimum temperature of the coldest month and mean maximum temperature of the warmest month.

Young (1987) recommends that the Köppen classification be employed to characterize sites broadly and the FAO AEZ system for more specific characterization. There are also various national systems in use. For example, Kenya's system of agroclimatic zones divides the country into seven regions based on the ratio of mean annual rainfall to mean annual potential evapotranspiration and nine regions based on mean annual temperature (Kenya Soil Survey, 1982). The IARCs have been very active in agroclimatic and, by incorporating soils and other data, agroecological characterization, both of regions and of the growing environments of specific crops (e.g. Carter, 1987). Young (1987) lists some major agroclimatic surveys of countries and regions. Of course, there is no reason why collectors should adopt one of the standard agroclimatic classification systems. Given the raw data from the meteorological stations in a target region, multivariate analyses may be used to define climatically homogeneous areas (Chapter 15).

An important use of climate data is in the timing of collecting (see Box 9.2). Accounts of the phenology of wild species in the literature, herbarium label data, germplasm passport data, published information on sowing and harvesting times and so on will be important for this, but may need to be interpreted on the basis of climate data and fine-tuned on the basis of the actual weather at the time of collecting. Thus, if it is known from the literature and other records what is the most appropriate time for collecting seeds in a given area, a comparison of the climate of that area with that of a nearby target area from which there are no phenological data should make it possible to decide at least the order in which the two areas should be visited. A 5 °C fall in mean annual temperature, for example, as will generally occur with a 1000 m gain in altitude, may delay crop maturity by three to four weeks. It is sometimes useful to plot species phenological data, e.g. peak flowering

Box 9.2
The timing of seed collecting: a case-study

Kiambi (1992) discusses the collecting of seeds of *Tamarindus indica* in Kenya. Much of Kenya is characterized by a bimodal rainfall pattern. Some tree species flower during one or the other, some during both, though there may be genetic differences in populations flowering at different times of the year. *Tamarindus*, however, has only one reproductive cycle per year, normally flowering towards the end of the long rains or just after. This normally means April–May, depending on the year. The time from flowering to seed maturation is four to six months, depending largely on temperature. The peak *Tamarindus* seed collecting season in Kenya is thus between August (lower altitudes) and mid-November (higher altitudes).

time or time of harvest, against such parameters as latitude (which controls photoperiod), altitude or mean annual temperature for a range of sites or years. On the issue of time of harvest, a note of caution is necessary. The harvest time of safflower in southeast China was communicated to a prospective collector as being May. On the spot, it turned out that this was the time when the petals, which are used for medicinal purposes, were harvested, and not the seeds. Similar misunderstandings may occur when collecting tuber crops.

A major determinant of plant growth and flowering is rainfall (except for species of permanently wet areas). Knowledge of when the rainy season(s) normally starts and ends is crucial in the preliminary planning of collecting, but long-term climate averages may not be a particularly useful indication of exactly the best time to visit an area in any given year. Source(s) of up-to-the-minute information will be necessary, which may include both official weather reports and the direct testimony of people who are in the target area or have only recently left it. FAO runs a Global Information and Early Warning System on Food and Agriculture (GIEWS), which assesses weather conditions and crop prospects on a regular basis. Remote sensing of the target area can also be a useful source of real-time phenology information, particularly in semiarid areas, where rainfall is erratic and unpredictable in both space and time (Chapter 15).

It is not just the timing of reproductive events but also their success that is affected by climatic factors. Houle and Filion (1993), for example, present models for predicting cone and viable seed production and seed mass in *Pinus banksiana* on the basis of a number of climatic variables. Such information will be valuable in deciding whether a given year is likely to be a good seed year, and therefore whether collecting should go ahead or be postponed.

Socioeconomic data

Knowing about the human environment in an area is just as important to the germplasm collector (in particular the crop collector) as ecogeographic or climatic information. Human diversity and biodiversity are inextricably linked. Chapter 12 considers this in more detail, and also discusses sources of information on human cultures in general and their relationship with plants in particular. Not all human diversity may be classified as cultural, however. There are also socioeconomic differences both between and within communities. Socioeconomic data sets that may be of relevance to germplasm collectors will include:

- human population data (age and size of settlements, demography, ethnic or linguistic composition, population movements);
- agricultural survey data (farming systems, production of different crops in different areas, size of holdings, type of land tenure, etc.);
- economic indicators (e.g. household income, commodity prices, employment);
- infrastructure (roads, railways, towns, markets, dams, development projects, etc.);
- level of services (education, extension, research, health, financial, etc.).

Such socioeconomic data will be important in predicting the extent and danger of genetic erosion (Chapters 4 and 12). They may also be important in developing an appropriate sampling strategy. For example, collecting crop landraces and/or the indigenous knowledge associated with them might be stratified within different climatic or ecological zones on the basis of socioeconomic group as defined by size of holding, household income or age of settlement. Production data will identify areas that are optimal and areas that are marginal for a crop, which may be due to cultural and socioeconomic as much as agroecological reasons. Again, these could be targeted as distinct strata.

What to look for: scale, accuracy and age

In planning germplasm collecting, maps are generally the most convenient form of display of environmental information. The importance of scale at this stage will depend on the aims of the mission. Relatively small-scale maps (e.g. 1 : 250,000) will be sufficient for most plant collecting programmes aiming to cover a whole country or a relatively large area of a country. Such maps were used in an International Board for Plant Genetic Resources (IBPGR) project to collect forages throughout the Italian island of Sicily, for example. A programme of rice collecting in southern and western Madagascar used the 1 : 500,000 maps issued by the Institut National de Géodesie et Cartographie: four sheets covered the target region. Larger-scale (e.g. 1 : 50,000), more detailed maps will, however, be preferable for missions that are more narrowly targeted, either ecologically or geographically. An example is the collecting of forage material adapted to low rainfall and sandy acidic soils in southern Portugal carried out by the South Australian Department of Agriculture in collaboration with the Portuguese national programme in 1992.

Ideally, only maps at scales of about 1 : 250,000 or larger should be used to determine latitude and longitude in the field (see Chapter 19 for an alternative to reading latitude and longitude off maps). Some road and general touring maps show latitude and longitude lines, which may be an important detail if topographic maps are not available. Also important in such circumstances is that road maps taken into the field should show more than just the main paved roads. Road maps for a given country often differ substantially in the degree of detail they show, and collectors will generally need to journey to relatively out-of-the-way areas.

Maps of rainfall and temperature will generally portray information as contour lines of equal values (called isopleths in general, isohyets and isotherms for rainfall and temperature respectively in particular). This allows the collector to determine a range for any collecting site with respect to each environmental variable (e.g. 250–500 mm mean annual rainfall). A single figure can be arrived at by taking into account the perpendicular distance from the site to the two nearest isopleths, but this may not give a very accurate result. Tables, on the other hand, give accurate information, but only for a specific range of points, usually the larger towns in a region, where meteorological stations are located. The information for the station closest to a given collecting site is often quoted as part of the documentation of the site, along with the distance between the site and the station.

Alternatively, interpolation can be carried out using a number of nearby stations. Interpolation of data from a grid of point sources is a difficult problem and may give inaccurate results in areas of great topographic heterogeneity, where environmental factors will vary widely over short distances. Chapter 15 describes how to derive equal-value contours from point data by hand. Most geographic information system (GIS) packages can carry out such analyses (Chapter 16). A digital terrain model (a quantitative representation of land-form in digital form) can be used to produce climate surfaces predicting temperature and rainfall parameters with good accuracy, and there will be such models for the whole world before too long (Chapter 16). The International Centre for Research in Agroforestry (ICRAF)'s Multipurpose Tree and Shrub Database programme also has a facility for deriving three temperature parameters from latitude, longitude and altitude data, based on a multiple regression model using FAO's FAOCLIM agroclimatic database (Carlowitz *et al.*, 1991).

The age of sources of environmental data can vary greatly. Whether this will be important will depend on the kind of data presented. For example, topographical data will not generally change (unless, for example, large dams are constructed), whereas land use or vegetation maps may relatively quickly become outdated. Road maps may also date very quickly in rapidly developing areas. Older geological and soil maps may use outdated classification systems. A gene-bank sample is a kind of 'time capsule' – a freezing of the otherwise continual process of plant evolution. Given the time frame over which collections are stored and the rate at which the environment can change, it is important that the site data associated with an accession be as relevant as possible to the time at which it was collected. (See Box 9.3 for the effects of possible global climate change.)

Socioeconomic data also need to be as up to date as possible (though historical data can also be of interest) and at a district (tertiary administrative division) level or below. The results of surveys and censuses need to be treated with caution. For example, conventional surveys typically do not capture women's socioeconomic and agricultural roles adequately unless a special effort is made to address their interests, interviewers are present at times when women are free to be interviewed, and the location of the interview encourages women's participation. Hill (1984) is an interesting commentary on the problems associated with official socioeconomic statistics.

Box 9.3
Global climate change and germplasm collecting

The possibility of global climate change presents an important challenge to the plant genetic resources conservation community. Not only may temperatures rise as a result of the 'greenhouse effect', but rainfall may also be affected, and in different ways in different regions. Some climates may be created which have no precedent in the recent history of the earth.

Regions and species that are particularly vulnerable to the complex alterations of climatic patters which many global warming models predict will need to be accorded a high priority by germplasm collecting programmes. Some of these priority areas are (IUCN, 1992; Markham *et al.*, 1993):

1. The high altitudes of mountains at low and middle latitudes: as well as being particularly threatened by the rise in temperatures, these areas are often very high in endemism.
2. Low-lying coastal areas: these may be subject to rising sea levels.
3. Arid and semiarid continental tropical and subtropical areas: as well as temperatures increasing, rainfall in these areas may not only decline overall but also become more unpredictable, with increased frequency of droughts.
4. Wetlands: temporary and shallow freshwater wetlands in particular face the threats of desiccation and increased salinity.
5. Temperate and boreal forests: as tree species will migrate at their own, different paces, in general slower than the northward shift in climatic conditions, some isolated and relic populations are likely to become extinct.

For a review of climate change and plant genetic resources conservation, see also Jackson *et al.* (1990).

Where to look

How much environmental information may be available varies enormously from country to country and sometimes also within countries. Some areas will be covered by little more than a road map, others by a range of large-scale thematic maps. Some may have no meteorological stations, others several. Germplasm collectors thus really have two separate problems. One is to find out whether the maps and other forms of information they require are available. The second is to obtain them, if indeed they exist. These problems may be as acute for a national plant genetic resources programme as for a collector planning to work in a foreign country.

Some sources of information on published maps and other forms of environmental data have already been alluded to. Thus, though there is no single international bibliography on mapping, there are specialized published bibliographies on vegetation, geological and climate maps (see above and Chapter 10). There may also be national bibliographies and catalogues. The crucial reference is Parry and Perkins' (1987) *World Mapping Today*, which provides listings of current topographic and resource mapping on a country-by-country basis and describes the organization and structure of national mapping activities. There are also sections on each of the continents and the world as a whole. Hopkins and Jones (1983) list atlases, gazetteers and bibliographies (in the fields of physical geography, geology, soil, climatology, botany, agriculture, agricultural economics, anthropology, human geography, etc.) on a country and regional basis.

Maps are sometimes published in scientific journals. Wise (1975) lists the more relevant publications. Chapter 13 describes modern methods of searching the literature. There are several bibliographic databases specifically in the field of the environment. For example, the Tropical Agricultural Development Information System (TRADIS) is a bibliographic database developed by LRDC and available at CAB International (CABI), covering non-conventional literature on land resources in tropical countries, from the 1960s onwards. *Geobase*, available on-line via Dialog, covers the worldwide literature on geography, geology, ecology and related disciplines. France's Bureau de Recherches Géologiques et Minières offers both a regular hard-copy *Géocarte Information* service, and an on-line database of earth science maps. The *1993 Directory of Country Environmental Studies* (WRI *et al.*, 1992), 'an annotated bibliography of environmental and natural resources profiles and assessments' mainly covering the period 1987–92, is also available as a database on diskette from the publishers. The bibliographic database *Focus On: Global Change* (Institute for Scientific Information, ISI) may also be of use to collectors. Available on diskette only, it brings together published information from different disciplines on human interaction with the environment, including deforestation, climate change and environmental legislation. Table 9.1. gives relevant bibliographic databases available on CD-ROM.

Table 9.1. CD-ROM bibliographic databases on human interaction with the environment.

Name	Contents	Coverage
Earth Sciences Disc (US Geological Survey (USGS))	(i) Directory of earth science databases; (ii) guide to published geological maps; (iii) citations to materials held in the USGS library	From 1975
On-line Computer Library Center (OCLC) Environment Library	Worldwide coverage of environment-related sources	From 1960s
Environmental Periodical Bibliography	Worldwide collection of bibliographic records on environment issues and research	From 1973

The United Nations Environment Programme (UNEP) Global Environment Information Exchange Network (INFOTERRA) should also be mentioned in the context of information sources. It links users requiring information on, for example, pollution, desertification or environmental law to 155 national focal points, ten regional service centres and over 6000 sources, including bibliographic information sources like CABI. The main tool for accessing the most appropriate source(s) for a given enquiry is the *International Directory of Sources*, which is both a digital database and a hard-copy publication.

Turning now to actually obtaining maps, perhaps the easiest way is in atlas form. A standard global atlas is virtually a necessity for any collecting programme, national, regional or international. Many are available, in many languages, but two have become standards (in English), namely the *Times Atlas of the World* (Comprehensive Edition) and the *National Geographic Atlas of the World* (6th edition). Many national and regional atlases are also available, giving not only topographic but also thematic information of various kinds, for example on agriculture. Federal countries often have atlases on individual states. Details of national atlases and gazetteers are given by Parry and Perkins (1987).

Loose large-scale maps are generally more difficult to obtain than atlases. Both are, however, usually available in national libraries and the libraries of universities and relevant government departments and institutes (see case-study in Box 9.4). Global Resources Information Database (GRID)'s Meta-Database (Chapter 16) includes details of the environmental information holdings (electronic and otherwise) not only of GRID itself, but also of national and other institutions (as of mid-1993, covering Central and South America and Africa). It will clearly not be possible to annotate maps held by libraries or other institutions or take them into the field. With older maps that are out of copyright, it is sometimes possible to make copies of various kinds. Major libraries such as the British Library, for example, run high-quality map-copying services for material in the public domain. Permission from the publisher is needed for material still covered by copyright. However, for the most part collectors will need to purchase maps.

Leaving aside the kind of basic road maps that are available in many general bookshops in large cities the world over, and thus usually present little problem to acquire, maps may be purchased either directly from their publishers (or their agents, the distributors: a list is provided at the end of the chapter) or from map jobbers, companies who are prepared to procure maps from a variety of publishers and pass them on to the user, either in specialized shops or by mail. Publishers of the kind of large-scale topographic, geological and soil maps necessary to germplasm collectors tend to be national government agencies, which will generally have an outlet for the purchase of maps in the capital city. Development agencies also assist countries in publishing mapping. One example among many is the Institut Français de Recherche Scientifique pour le Développement en Coopération (formerly Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM)) and their *Atlas de la Nouvelle Calédonie et Dépendances* (ORSTOM, 1981). Again, details are given in Parry and Perkins (1987). The catalogues of publishers, agents and jobbers are a very important source of information on available maps, quite apart from also usually including an order form and instructions for purchasing. Parry and Perkins (1987) list the more important map jobbers, mainly from Europe and the USA. Some addresses are given at the end of the chapter. The leading map jobber in the world is said to be GeoCenter ILH. Geoscience Resources specialize in geological maps.

Relevant socioeconomic data may be available in published form. For example, there may be a national agricultural bulletin or journal, and a national atlas may have sections on demography and agriculture. Whether this is the case or not, the obvious immediate source is the statistical department of the ministry responsible for agriculture. The records of local extension offices may have more detailed statistics on their district. There may also have been household surveys primarily aimed at sectors other than the agricultural (e.g. health) and conducted by other ministries, which may nevertheless contain relevant socioeconomic data. CABI's *Rural Development Abstracts* and *World Agricultural Economics and Rural Sociology Abstracts* may be useful to the plant germplasm collector looking for published socioeconomic data.

FAO, the IARCs and regional agricultural research organizations can be useful secondary sources of socioeconomic information. Several IARC publications combine socioeconomic and agroecological data for a specific crop. An example is Carter *et al.* (1992), and consideration of the methods of data acquisition used in that study may be helpful. Two main repositories of contemporary information on cassava production in Africa were tapped, the FAO statistics library at FAO headquarters, Rome, and the Economics Section of CIAT's Cassava Program. The actual sources used ranged from the *World Atlas of Agriculture* to more detailed national studies. For example, for Chad, total production for the country in 1982 from the 1984 Statistik des Aulandes, a publication of the German

Box 9.4
Map availability: a case-study

The situation in Kenya can be taken as a fairly typical example. There is a *Catalogue of Maps* available for the country, describing the various maps produced by or available through the Survey of Kenya, the government department responsible for mapping. Parry and Perkins (1987) reproduce much of this information.

The maps listed can be obtained from the Public Map Office in Nairobi, or through the Survey Offices in seven other major cities. Some may also be obtained through a number of agents, both in Kenya and abroad (including GeoCentre and Edward Stanford), and all these are listed with their addresses in the *Catalogue*. The maps listed include relatively small-scale road maps of the whole country, maps of national parks, various thematic maps, series of topographic maps at 1 : 250,000 and 1 : 50,000 and aerial photographs.

Topographic maps and aerial photographs are available for sale only with the permission of the Director of Surveys, for other government departments as for the general public. The *Catalogue* includes an order form. The Survey maintains an Aerial Photographic Library in Nairobi where photographs may be inspected and orders placed.

statistical office, was converted into hectares using typical yields from a 1985 agricultural census in Mali, and for distribution among prefectures older data from a 1972/73 agricultural census were used. For historical data, extensive searches of pre-independence literature were carried out at the Agricultural University of Wageningen, the African Library of Brussels, the African Studies Centre in Leiden, the British Museum and the Food Policy Research Institute at Stanford University.

Conclusions and recommendations

High-quality environmental data are essential for the proper planning and execution of a plant germplasm collecting mission or programme and for the interpretation of data from the characterization and evaluation of the material collected. The quality and type of information available vary greatly, but the more information and the greater the detail which can be obtained, the better. (See Box 9.5 for a case-study.)

Collectors should make an effort to obtain data, preferably in map form, on roads, soils, relief, mean annual rainfall and vegetation in the target area. In addition, if available, data on temperature, geology, land use, protected areas and socioeconomic factors will assist in ensuring the best possible targeting of effort. Land system studies based on remote sensing are a useful further layer of information.

As a bare minimum, collectors will therefore need atlases – one of the standard international atlases plus a national one if available. The problem with these is that they will tend to be at relatively small scales and awkward to take to the field. So, ideally, collecting programmes should also have a full set of 1 : 250,000 or larger-scale maps, and small-scale road maps of the region they cover. For information on the availability of national atlases and of loose large-scale maps, the key reference is Parry and Perkins (1987). There are also more specialized information sources, and some of the more important of these are mentioned in this chapter and in Chapter 10 (e.g. White (1983) on the vegetation and general ecology of Africa). Collecting programmes should have access to the sections relevant to their target regions in these and the other main reference sources, so that an agenda for the acquisition of maps and other environmental data can be planned. The catalogue of the government department responsible for mapping is also a must, if available.

For climate data, if a national climate or agroecological classification study is available, perhaps in a national climate or more general atlas or in a paper published in a scientific journal, the collector will need to have access to it, or at least to one of the international climatic atlases, along with the relevant FAO AEZ study and a general synoptic work on the target region, for example the relevant section in the *World Survey of Climatology* series. For detailed point data on climate, the publications of the national meteorological bureau are the obvious starting-point. Information on these should be obtained from the *INFOCLIMA Catalogue of Climate System Data Sets*. If the data are not easily available from the mainly national sources listed in the *Catalogue*, one or more of the international compilations or databases described in this chapter will need to be obtained.

As for socioeconomic data, it is highly desirable for crop collecting programmes to have access to the latest agricultural census or survey data.

In the first instance, data will need to be procured as hard copy. Some digital data sets have been mentioned, and, if collecting programmes do not have their own GIS technology, there is always the possibility of cooperation with organizations that do. The days are perhaps not far off when collectors will be able to go into the field with a laptop computer containing a full range of digitized topographic, soil, climate, vegetation, etc. maps of the target area in a GIS, perhaps including satellite imagery, with a Global Positioning System (GPS) receiver feeding directly into it. However, until then, collectors will plan their work mainly using conventional maps, and then take some of these into the field to annotate.

What maps and other data on the environment will need to be taken into the field? It is essential to take topographic maps of the specific target area(s) at a scale of about 1 : 250,000 or larger (in multiple copies, ideally, as described in Chapter 19), on which collecting site localities will be marked, plus smaller-scale road maps of the general region to be travelled through. Especially when collecting wild species, it will usually be advantageous, and sometimes essential, to also take along large-scale soil, vegetation, geological and land use maps, in particular the first two. However, these will mostly be used at the stage of mission planning, to identify specific areas to be searched, for example, which could then be

Box 9.5
The mapping requirements of a collecting programme: a case-study

Again taking Kenya as a representative example, what follows is a list of the mapping and other information that a national collecting programme might consider assembling. The Gene-bank of Kenya at Muguga just outside Nairobi actually uses such a collection of sources in planning its collecting:

- 1 : 1,750,000 road maps of the entire country;
- full set of 1 : 250,000 topographic maps;
- selected 1 : 50,000 maps;
- special maps of national parks;
- *Exploratory Soil Map and Agro-climatic Zones Map of Kenya*, at 1 : 1,000,000 (Kenya Soil Survey, 1982);
- 1 : 250,000 map of *Kenya Vegetation* (Trapnell *et al.*, 1966–69), supplemented by the relevant sections of White (1983);
- *Simplified Soil Maps of Kenya* (Siderius, 1979);
- *Farm Management Handbook of Kenya* (Jaetzold and Schmidt, 1983) and *Range Management Handbook of Kenya* (Schwartz *et al.*, 1991), giving district-level climate tables, rainfall maps, agroecological zone maps, soil maps, agricultural (including livestock) statistics and results of Small Farms Survey of 1977.

marked on the topographic maps to be used in the field, and also to develop lists of possible categories for the collecting form descriptors on these subjects. It will rarely be necessary to take raw climatic or socioeconomic data into the field. However, it may be useful to annotate topographic maps with such data, for example the annual rainfall in different areas, or the name(s) of the ethnic group(s) found there.

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Useful addresses

Map jobbers

GeoCenter ILH
Postfach 80 08 30
D-7000
Stuttgart 80
Germany

Edward Stanford Ltd.
12–14 Long Acre
London WC2E 9LP
UK

Geoscience Resources
2990 Anthony Road
Burlington, NC 27215
USA

Distributors

The Marketing
Department
John Bartholomew &
Son Ltd
Duncan Street
Edinburgh EH9 ITA
UK
Road maps (countries, regions and continents) and detailed tourist maps in English

Roger Lascelles
Cartographic and Travel
Publisher
47 York Road
Brentford
Middlesex TW8 OQP
UK
Road maps of Europe, Morocco and Turkey in English

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Schleissheimer Str 371b
D8000, Munich 45
Germany
Road maps of South and Southeast Asia in German

Freytag and Berndt
M. Artaria
1071 Vienna
Austria
European and East African road maps in German

Kummerly & Frey
CH-3001 Bern
Switzerland
Wide range of road maps in German and French

Institut Geographique
National
136, rue de Grenelle
75700 Paris
France
Road and travel maps of Europe and francophone Africa in French

International Travel
Map Productions
PO Box 2290
Vancouver, BC V6B
3W5
Canada
Travel maps of North and South America

Geo Projects
PO Box 113 5294
Beirut
Lebanon
Political/road maps of the Middle East in English

Map Studio
PO Box 4482
Cape Town 8000
South Africa
Political/road maps of southern Africa in English

Runaway Publications
176 South Creek Road
Dee Why, NSW 2099
Australia
Political/road maps of Australia and the Pacific

Others

World Meteorological
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CP 2300
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