STEP 3: TESTING THE METHOD

5

Following the selection of the assessment methods, it is important that these are thoroughly tested in preparation for the main evaluation tasks. There are many examples of studies where inadequate preparation has resulted in long delays in obtaining results. Moreover, this step provides an opportunity to refine goals and evaluate constraints that may have been overlooked (for example, in selecting 'off the shelf' models). Three types of analysis may be useful in evaluating the methods: feasibility studies, data acquisition and compilation, and model testing.

5.1 Feasibility Studies

One way of testing some or all of the methods, is to conduct a feasibility or pilot study. This usually focuses on a subset of the study region or sector to be assessed. Case studies such as these can provide information on the effectiveness of alternative approaches, of models, of data acquisition and monitoring, and of research collaboration.

Feasibility studies are most commonly adopted as a preliminary stage of large multidisciplinary and multisectoral research projects. Here, effective planning and scheduling of research relies on the assurance that different research tasks can be undertaken promptly and efficiently. Several approaches can be suggested for conducting feasibility studies:

- Evaluation of available information.
- Qualitative screening analysis.
- Preliminary scenarios.
- Geographical zoning.
- Microcosm studies.
- Response surfaces.
- Analogue studies.

5.1.1 Evaluation of available information

The importance of identifying the main data requirements in an impact assessment has already been stressed in Section 3.5. In addition, a review of the published literature should always be undertaken, to provide a background understanding of the study region, system or activity being investigated, to examine parallel or related studies that have been completed, to obtain new ideas on methods, to locate new sources of data, and to identify possible research collaborators.

5.1.2 Qualitative screening analysis

Assuming that the general sector or sectors of interest have already been identified, a useful first step in defining the specific exposure units to be studied is to conduct a climatic vulnerability analysis (e.g., Downing, 1992; Scott, 1993). This is a qualitative screening procedure which classifies climate vulnerability in a matrix format. Different exposure units within the sector(s) are entered on one axis, classified, for instance, by type or by scale. On the other axis some effects of climate are categorized, for example, by type of climatic event, by possible future climate changes, or by a combination of these. Qualitative ratings are then assigned to each cell in the matrix, indicating both the likely size of the effect and its probability of occurrence. These estimates can be made using whatever information there is available, i.e., from previous studies, expert opinion, literature review or simple quantitative assessments (see below). An example is presented of a vulnerability rating for human settlements in Table 1.

In this way, an impression can be gained of the relative vulnerability of different exposure units to variations in climate at different scales. This may then assist in selecting appropriate exposure units for closer examination, the geographical scale of analysis, the time frame of the study and hence the projection horizon for different scenarios and the types of assessment tools that are appropriate for conducting assessments (including models, survey methods, visualization tools and decision support systems). However, caution should be exercised in interpreting too much from a preliminary assessment of this kind, and this type of procedure should not be regarded as a substitute for an in-depth assessment.

5.1.3 Preliminary scenarios

The qualitative screening procedure is a useful device for identifying the important climatic variables, the region of interest and the projection horizon that are needed in constructing climatic, environmental and socio-economic scenarios. While the devel-

Table 1. Hypothetical example of a qualitative screening analysis to assess the vulnerability of human settlements to climatic variations (after Scott, 1993)

	CLIMATE VULNERABILITY RATING (Examples)			
Settlement	Drought effects on agriculture	Drought effects on water supply	Flooding effects on buildings	Rural-urban migration
Villages < 500 people	1, U	2, U	4, L	2, L
Market towns, 500-1000 people	2, U	2, U	4, L	2, U
City A	4, U	3, U	2, L	1, L

Ratings: 1 = Large or very important; 5 = Trivial; L = Likely; U = Unlikely opment of detailed scenarios can be a time-consuming exercise, preliminary large scale projections can usually be made from information in the literature. For example, it may be possible to derive central, upper and lower estimate projections of trends in measures such as population, GNP, income, employment, energy demand, food demand, GHG concentrations, temperature and precipitation (e.g., see Box 3, on page 19). Simple scenarios of this kind could be very useful in conducting simple assessments of the type described below.

5.1.4 Geographical zoning

In many impact assessments, the geographical scope of the study is already pre-determined (e.g., focusing on an administrative region or a physiographic feature such as a river catchment). Even so, selection of an appropriate study region can pose some problems. First, the region should be relevant to the exposure unit. Second, it should provide adequate data, expertise and conditions for carrying out the assessment. Third, within its bounds, the exposure unit should exhibit measurable sensitivity to climatic variations. Fourth, it should provide representative results that can, if necessary, be extrapolated to a larger region.

One method of targeting appropriate areas for study is to use simple, large area geographical zonation. This has been widely used in assessing agricultural impacts, but is potentially applicable in other sectors. It involves the calculation of simple bioclimatic indices, which combine information on climate, soils and topography into measures of suitability for crops, trees or natural vegetation. Some of the more sophisticated measures can indicate plant biomass or even crop yield potential. Examples include Köppen's climatic classification (Köppen, 1931), Holdridge Life Zones (Holdridge, 1947), or the FAO Agro-Ecological Zones (FAO, 1978)

Where these have been mapped for both present-day climate and possible future climate changes, it is possible to identify those zones or regions where there is likely to be a high sensitivity of a particular exposure unit to climate change. For example, it could indicate zones where new species could be cultivated or regions where species may be threatened. These areas can then be targeted for more detailed analysis (e.g., using simulation models, village surveys or field experiments). Alternatively, zoning may simply serve as a classification method for selecting representative sites for further study.

5.1.5 Microcosm case studies

In studies where there is likely to be a heavy reliance on a specific type of analysis (e.g., model-based, experimental, survey-based) or where data requirements are uncertain, it can be instructive to conduct a small scale pilot study under conditions representative of those anticipated in the main study. These 'microcosm' case studies allow different analysis tools to be selected, tested and evaluated. In addition, they can assist in identifying the personnel required to carry out research. They also offer researchers some experience in addressing problems they are likely to encounter in the main project. For instance, in a project on regional tourism, a representative tourist resort might be chosen as a pilot case study, or for a study of coping strategies for drought in an agriculturally-based, rural subsistence economy, a representative village might be selected for a pilot survey and analysis.

5.1.6 Response surfaces

A growing number of detailed climate impact studies are being reported for different sectors and from many regions of the world. While these frequently make use of sophisticated analytical methods or models, their results can often be summarized more simply, using generalized response surfaces. For example, hydrological models may have been applied to different points in a river catchment and run for different climate change scenarios. The hydrological responses can be complex, but it may still be possible to separate out the most important responses to climate as simple empirical relationships (for example relating river discharge to monthly precipitation).

Where simple relationships of this kind can be identified from previous studies, there may then be an opportunity to apply them to similar regions in the new study, to provide a preliminary assessment of possible responses to climate change. The use of response surfaces in studying system sensitivities to climate change is discussed further in Box 5 on page 22.

5.1.7 Analogue studies

Another method of obtaining a rapid evaluation of the likely climate sensitivity of an exposure unit is to identify analogues of possible future conditions. These have already been discussed in the context of a full impact assessment (Section 4.3)—here they are used as a screening device. These might be regional analogues, where the present-day climate and its effects on an exposure unit are thought to be comparable to possible future conditions in the study region. This is an attractive device for illustrating the possible extent of future climate change, as well as offering useful information on the conditions experienced under the analogue climate. Alternatively, they could be temporal analogues, which identify climatic events and their impacts in the past as analogues of events which could occur again in the future, possibly with an altered frequency under a changed climate.

5.2 Data Acquisition and Compilation

An essential element in all climate impact assessment studies is the acquisition and compilation of data. Quantitative data are required both to describe the temporal and spatial patterns of climatic events and their impacts and to develop, calibrate and test predictive models. Four main types of data collection can be identified: empirical compilation, objective survey, targeted measurement and monitoring.

Empirical compilation of evidence (both quantitative and qualitative) from disparate sources is the mainstay of most historical analysis of past climate-society interactions. The data are pieced together to produce a chronology of events, which can then be used to test hypotheses about the effects of past climate (e.g., see Parry, 1978), or simply as a qualitative description of past events (e.g., see Lamb, 1977; Pfister, 1984; Grove, 1988; Mikami 1992).

Objective survey utilizes established procedures to collect data from contemporary sources (the information itself may relate to the present or the past). Such survey material may represent either a subset of a population (e.g., a sample of plant species at randomly selected locations within given ecological zones, to be related to climate at the same localities) or the complete population (e.g., a regional register of all reported illnesses during a given period that can be related to extreme weather conditions). The tools employed in data acquisition include use of government statistical sources, different methods of questionnaire survey and biological survey techniques. The types of studies reliant on this kind of information include most social impact assessments (Farhar-Pilgrim, 1985), studies of perception (Whyte, 1985), and studies of biophysical impacts where quantitative data are lacking (e.g., of village-level drought effects on agriculture; Akong'a *et al.*, 1988; Gadgil *et al.*, 1988).

Targeted measurement refers to the gathering of unique data from experiments where data and knowledge about vital processes or interactions are lacking. This type of measurement is especially important in considering the combined effects of future changes in climate and other environmental factors, combinations which have never before been observed. In many cases these data offer the only opportunity for testing predictive models (for example, observations of the effects of enhanced atmospheric CO_2 on plant growth).

Monitoring is a valuable source of information for climate impact assessment. Consistent and continuous collection of important data at selected locations is the only reliable method of detecting trends in climate itself, or in its effects. In most cases, impact studies make use of long-term data from other sources (e.g., observed climatological data, remotely-sensed data). However, in some projects monitoring may form the central theme of research. In these, it is important to consider aspects such as site selection, multiple-uses of single sites, design of measurements and their analysis. It should be noted that there are numerous national and international monitoring programmes, including one initiated by the IPCC (WG II). It is important that results from such programmes be made available to impact researchers for assessment studies.

Impact assessments are often hampered by the failure to assemble appropriate data for a given task. This can be due to many causes, including a failure to locate where data are held, bureaucratic delays in the release of data, particularly across national boundaries, and the high cost of obtaining some types of information. This problem is particularly relevant in developing countries.

Where existing data are concerned, government offices often hold valuable data for impact assessment, although the custodians of such data may not be aware of its special relevance. In many cases, data held by the central statistical office of a country is often limited in its subject matter and regional coverage, and researchers may need to access data archived in departmental or regional offices. In some cases, national or regional data may be more easily accessible from international organizations, The UNEP GEMS 'Harmonization of Environmental Monitoring' disk is a useful guide to data banks held by various organizations. Some important international sources of data are listed in Appendix 4. Other potentially valuable sources of longitudinal data are in private organizations such as ornithological or botanical societies.

The quality of data should always be checked, both in terms of its level of accuracy and its consistency over time. Measuring equipment may deteriorate or be replaced and observation procedures or sites often change over time, requiring corrections to maintain consistency.

5.3 Model Testing

The testing of predictive models is, arguably, the most critical stage of an impact assessment. Most studies rely almost exclusively on the use of models to estimate future impacts. Thus, it is crucial for the credibility of the research that model performance is tested as rigorously as possible. Standard procedures should be used to evaluate models, but these may need to be modified to accommodate climate change. Two main procedures are recommended—validation and sensitivity analysis—and these should always precede more formal impact assessment.

Validation involves the comparison of model predictions with real world observations to test model performance. The validation procedures adopted depend to some extent on the type of model being tested. For example, the validity of a simple regression model of the relationship between temperature and grass yield should necessarily be tested on data from additional years not used in the regression. Here, the success of the model is judged by its outputs, namely the ability to predict grass yield. Conversely, a process-based model might estimate grass yield based on basic growth processes, which are affected by climate, including temperature. Here, the different internal components of the model (such as plant development and water use) as well as final yield each need to be compared with measurements.

One problem often encountered in applying process-based models in less developed countries (LDCs) is that the models, while extensively validated in the data-rich developed world, are found to be ill-suited or poorly calibrated for use under the different conditions often experienced in LDCs. A lack or paucity of data for validation may mean that a data-demanding model cannot be used under these circumstances and that a model less dependent on detailed data may be more appropriate.

Climate change introduces some additional problems for validation, since there may be little local data that can be used to test the behaviour of a modelled system in conditions resembling those in the future. Process-based models ought, in theory, to be widely applicable (see Section 4.2.1), and anyway should be tested in a range of environments. There are fewer grounds, however, for extrapolating the relationships in empirical-statistical models or in most economic models outside the range of condition for which they were developed. The use of regional analogies of future climate is one possible method of addressing certain aspects of this problem (see Section 4.3.4).

Sensitivity analysis evaluates the effects on model performance of altering the model's structure, parameter values, or values of its input variables. Extending these principles to climatic change requires that the climatic input variables to a model be altered systematically to represent the range of climatic conditions likely to occur in a region. In this way, information can be obtained on:

- The sensitivity of the outputs to changes in the inputs. This can be instructive, for example, in assessing the confidence limits surrounding model estimates arising from uncertainties in the parameter values (e.g., see Buck *et al.*, forthcoming).
- Model robustness, (i.e., the ability of the model to behave realistically under different input specifications, and the circumstances under which it may behave unrealistically).
- The full range of potential model application (including its transferability from one climatic region to another, and the range of climatic inputs that can be accommodated).

Sensitivity analysis, which is a model testing procedure, should be distinguished from the use of synthetic scenarios (cf. Section 6.5.1), which explicitly seeks to explore system behaviour under given variations in climate. For a useful introduction to sensitivity analysis in ecological modelling see Swartzman and Kaluzny, 1987.

It is worth noting here that while predictive models offer the most promising means of obtaining estimates of possible future impacts of climate change, in some sectors these are not yet sufficiently developed to be used for this purpose. Where the systems are complex and/or poorly understood (e.g., marine ecosystems), considerable efforts are still required to obtain an understanding even of variations in the present-day system. Only after such basic research is completed can meaningful projections be made in the future.