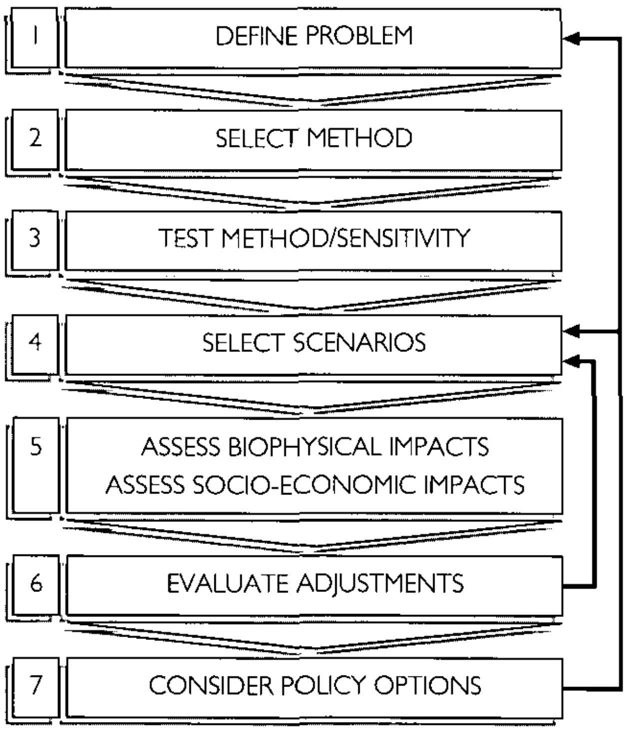
METHODS OF ASSESSMENT 3

A general framework for conducting a climate impact assessment is shown in Figure 4. In consists of seven main steps of analysis. The first five steps can be regarded as common to most assessments. Steps 6 and 7 are included in fewer studies. The steps are consecutive (single arrows in Figure 4), but the framework also allows for the redefinition and repetition of some steps (double arrows). At each step, a range of study methods is available. These are described and evaluated in the following sections. For reasons of brevity, however, only the essence of each method is introduced, along with references to sources of further information.

Figure 4. Seven steps of climate impact assessmnent



3.1 Definition of the Problem

A necessary first step in undertaking a climate impact assessment is to define precisely the nature and scope of the problem to be investigated. This usually involves identifying the goals of the assessment, the sector(s) of interest, the spatial and temporal scope of the study, the data needs, and the wider context of the work.

3.1.1 Goals of the assessment

Some general reasons for conducting an assessment were outlined in Section 2.1. Once the general objectives are defined, the specific goals of the study may be addressed, as these will affect the conduct of the investigation. To illustrate, an assessment of the future hydrological impacts of climatic change in a river catchment has quite different requirements for data and expertise if the goal is to estimate the capacity for power generation, than if it is to predict changes in agricultural income as a result of changes in the availability of water for irrigation.

3.1.2 Sector to be studied

The sector to be assessed is likely to determine, to a large degree, the type of researchers who will conduct the assessment, the methods that can be employed and the data required. Studies can focus on a single sector of activity (e.g., agriculture, forestry, energy production or water resources), several sectors in parallel but separately, or several sectors interactively.

3.1.3 Study area

The selection of a study area is likely to be guided by the goals of the study and by the constraints on available data. Options include:

- Administrative units (e.g., district, town, province, nation), for which most economic and social data are available and at which level most policy decisions are made.
- Geographical units (e.g., river catchment, plain, mountain range, lake region), which are useful integrating units for considering multi-sectoral impacts of climate change.
- Ecological zones (e.g., moorland, savannah, forest, wetland), which are often selected for considering issues of conservation or land resource evaluation.
- Climatic zones (e.g., desert, monsoon zone, rain shadow area), which are sometimes selected because of the unique features and activities associated with the climatic regime.
- Sensitive regions (e.g., ecotones, tree lines, coastal zones, ecological niches, marginal communities), which may be selected because of their inherent sensitivity to external forcing such as climate change, and where changes in climate are likely to be felt first and with the greatest effect.
- Representative units, which may be chosen according to any of the above criteria, but in addition are selected to be representative of that regional type and thus amenable to generalization. For instance, a single river catchment may serve as a useful integrating unit for considering impacts of climate on water resources, agriculture, forestry, recreation, natural vegetation, soil erosion and hydroelectric power generation. Information from this type of study may then be applicable to other similar catchments in a region.

3.1.4 Time frame

The selection of a time horizon for study is also governed, in the main, by the goals of the assessment. For example, in studies of industrial impacts the planning horizons may be 5-10 years, investigations of tree growth may require a 100-year perspective, while considerations of nuclear waste disposal must accommodate time spans of well over 1000 years. However, as the time horizon increases, so the ability to project future trends declines rapidly. Most climate projections rely on general circulation models, and are subject to great uncertainties over all projection periods. The only prediction horizon of proven reliability is that provided by weather forecast models extending for days or, at most, weeks into the future. In general, few credible projections of socio-economic factors such as population, economic development and technological change can be made for periods beyond 15—20 years into the future.

3.1.5 Data needs
The availability of data is a limitation in many impact studies. The collection of new data is an important element of some studies, but most rely on existing sources (an important source of bias in some studies). Thus, before embarking on a detailed assessment, it is important to identify the main features of the data requirements, namely:

- Types of data required
- Time period, spatial coverage and resolution
- Sources and format of the data
- Quantity and quality of the data
- Availability, cost and delivery time

3.1.6 Wider context of the work
Although the goals of the research may be quite specific, it is still important to place the study in context, with respect to:

- Similar or parallel studies that have been completed or are in progress
- The political, economic and social system of the study region
- Other social, economic and environmental changes occurring in the study region

Consideration of these aspects may assist policy makers in evaluating the wider significance of individual studies.

3.2 Selection of the Method
A variety of analytical methods can be adopted in climate impact assessment. These range from qualitative descriptive studies, through more diagnostic and semi-quantitative assessments to quantitative and prognostic analyses. Any single impact assessment may contain elements of one or more of these types. Four general methods can be identified: experimentation, impact projections, empirical analogue studies and expert judgement.

3.2.1 Experimentation
In the physical sciences, a standard method of testing hypotheses or of evaluating processes of cause and effect is through direct experimentation. In the context of climate impact assessment, however, experimentation has only a limited application. Clearly it is not possible physically to simulate large-scale systems such as the global climate, nor is it feasible to conduct controlled experiments to observe interactions involving climate and human-related activities. Only where the scale of impact is manageable, the exposure unit measurable, and the environment controllable, can experiments be usefully conducted.

Up to now most attention in this area has been on observing the behaviour of plant species under controlled conditions of climate and atmospheric composition (e.g., see Strain and Cure, 1985). In the field such experiments have mainly comprised gas enrichment studies, employing gas releases in the open air, or in open or closed chambers including greenhouses. The former experiments are more realistic, but are less amenable to control. The chamber experiments allow for climatic as well as gas control, but the chambers may introduce a new set of limiting conditions which would not occur in reality. The greatest level of control is achievable in the laboratory, where processes can be studied in more detail and can employ more sophisticated analyses.

The primary gases studied have been carbon dioxide, sulphur dioxide and ozone, all of which are expected to play a interactive role with climate in future plant growth and productivity. Both temperature and water relations have also been regulated, to simulate possible future climatic conditions. To date, there have been experiments with agricultural plants (both annual and perennial crops), crop pests and diseases (often in conjunction with host plants), trees (usually saplings, but also some mature species), and natural vegetation species and communities (where aspects of competition can be studied).

There are other sectors in which experimentation may yield useful information for assessing impacts of climatic change. For instance, building materials and design are continually being refined and tested to account for environmental influences and for energy-saving. Information from these tests may provide clues as to the performance of such materials, assuming they were widely employed in the future, under altered climatic conditions.

The information obtained from experiments, while useful in its own right, is also invaluable for calibrating models which are to be used in projecting impacts of climatic change (see below).

3.2.2 Impact projections
One of the major goals of climate impact assessment, especially concerning aspects of future climatic change, is the prediction of future impacts. A growing number of model projections have become available on how global climate may change in the future as a result of increases in GHG concentrations (e.g., see IPCC, 1990a; 1992a). These results, along with scientific and public concerns about their possible implications, have mobilised policy-makers to demand quantitative assessments of the likely impacts within the time horizons and regional constraints of their jurisdiction.

Thus, a main focus of much recent work has been on impact projections, using an array of mathematical models to extrapolate into the future. In order to distinguish them from 'climate models', which are used to project future climate, the term 'impact model' has now received wide currency.

Some of the specific procedures for projecting future impacts are described in Section 3.4. Here, the major classes of predictive models and approaches are described. It is convenient, in categorising impact models, to follow the hierarchical structure of interactions that was introduced in Section 2.3.1. First-order effects of climate are usually assessed using biophysical models, second- and higher-order effects using a range of biophysical, economic and qualitative models. Finally, attempts have also been made at comprehensive assessments using integrated systems models.

3.2.2.1 Biophysical models
Biophysical models are used to evaluate the physical interactions between climate and an exposure unit. There are two main types: empirical-statistical models and simulation models. The use of these in evaluating future impacts is probably best documented for the agricultural sector (e.g., see WMO, 1985) and the hydrological aspects of water resources (e.g., WMO, 1988) but the principles can readily be extended to other sectors.

Empirical-statistical models are based on the statistical relationships between climate and the exposure unit. They range from simple indices of suitability or potential (e.g., identifying the temperature thresholds defining the ice-free period on important shipping routes), through univariate regression models used for prediction (e.g., using air temperature to predict