STEPS 6 AND 7: ASSESSMENT OF AUTONOMOUS ADJUSTMENTS AND EVALUATION OF ADAPTATION STRATEGIES 8

Impact experiments are usually conducted to evaluate the effects of climate change on an exposure unit in the absence of any responses which might modify these effects. Two broad types of response can be identified: mitigation and adaptation (Figure 5).

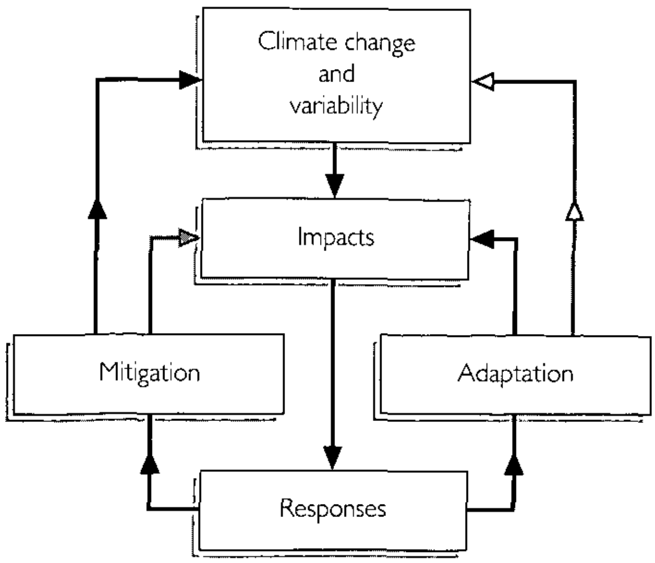
8.1 Mitigation and Adaptation

Mitigation or 'limitation' attempts to deal with the causes of climate change. It achieves this through actions that prevent or retard the increase of atmospheric greenhouse gas (GHG) concentrations, by limiting current and future emissions from sources of GHGs (e.g., fossil fuel combustion, intensive agriculture) and enhancing potential sinks for GHGs (e.g., forests, oceans). In recent years there has been a heavy focus on mitigation as a major strategy for coping with the greenhouse problem. However, it seems likely that realistic policies of mitigation will be unable fully to prevent climate changes, and that alternative adaptive measures are needed.

Adaptation is concerned with responses to both the adverse and positive effects of climate change. It refers to any adjustment, whether passive, reactive or anticipatory, that can respond to anticipated or actual consequences associated with climate change. Many policies of adaptation make good sense in any case, since present-day climatic variability (in the form of extreme climatic events such as droughts and floods) already causes significant damage in different parts of the world. Adaptation to these events can thus help to reduce damage in the short term, regardless of any longer-term changes in climate.

While mitigation and adaptation are complementary responses, as both are needed, the evaluation of mitigation policies is outside the scope of these Guidelines. For more information on this topic, the reader is directed to parallel work by Working Group III of the Intergovernmental Panel on Climate Change.

Figure 5. Pathways of response: mitigation and adaptation. Black lines indicate direct effects or feedbacks; grey lines depict secondary or indirect effects (after Smit, 1993)



Yet the identification and evaluation of adaptation options is an essential component of impact assessment. In this section, a basic distinction is drawn between system responses to climate change that are automatic or built-in (termed autonomous adjustments), and responses that require deliberate policy decisions, described as adaptation strategies. While there are some overlaps between these two types of adaptation, they are allocated separate steps in the assessment framework (Figure 4) in recognition of the different treatment they usually receive in assessment studies.

8.2 Assessment of Autonomous Adjustments

Most ecological, economic or social systems will undergo some natural or spontaneous adjustments in the face of a changing climate. These 'autonomous' adjustments are likely to occur in response both to gradual changes in average climate (which themselves may be barely imperceptible relative to background climatic variability) as well as to more drastic shifts in climate, for example, those associated with a change in dominant atmospheric circulation patterns. What is much less certain, however, is what forms these adjustments will take and what costs they will incur. Clearly, in order to obtain credible estimates of impacts, there is a need to account for these autonomous adjustments in the assessment process (Smit, 1993; Rosenberg, 1992).

Within the broad class of autonomous adjustments it may be instructive to distinguish three groups according to their 'degree of spontaneity': inbuilt, routine and tactical adjustments.

8.2.1 Inbuilt adjustments

Inbuilt adjustments, sometimes referred to as physiological adjustments, are the unconscious or automatic reactions of an exposure unit to a climatic perturbation. Some of these are easy to identify (for example, the automatic response of a plant to drought conditions is to reduce transpiration water loss by closing its stomata), and can be accounted for in models that describe the system. Others are more difficult to detect (for instance, the ability of long-lived organisms such as trees to acclimate to a slowly changing climate). These may require the implementation of some controlled experiments to determine the nature of the adjustment mechanisms (for example, by transplanting tree species between different climatic regimes to investigate the processes of acclimation in a changed environment; see Beuker, 1994).

8.2.2 Routine adjustments

Routine adjustments refer to everyday, conscious responses to variations in climate that are part of the routine operations of a system. For example, as the climate changes, the growing season for crop plants would also change, and crop performance might be improved by shifting the sowing date. In some crop growth models the sowing date is determined by climate (e.g., the start of the rainy season or the disappearance of snow cover), so it is selected automatically to suit the conditions. Here, the model is performing internally an adjustment that a farmer might do instinctively or routinely.

8.2.3 Tactical adjustments

Tactical adjustments imply a level of response over and above the adjustments that are made routinely in the face of climatic variability. Such adjustments might become necessary following a sequence of anomalous climatic events, which indicate a shift in the climate. For example, a run of years with below-average rainfall in a semi-arid region may persuade farmers that cultivation of a drought-resistant crop like sorghum is more reliable than a drought-sensitive crop like maize, in spite of its lower yield capacity than maize in favourable conditions. Adjustments of this type require a behavioural change, but can still be accommodated internally within the system. There are numerous examples of assessments that consider these small-scale, low cost adjustments (e.g., the MINK study, see Box 13; and a study of world food supply, Rosenzweig and Parry, 1994).

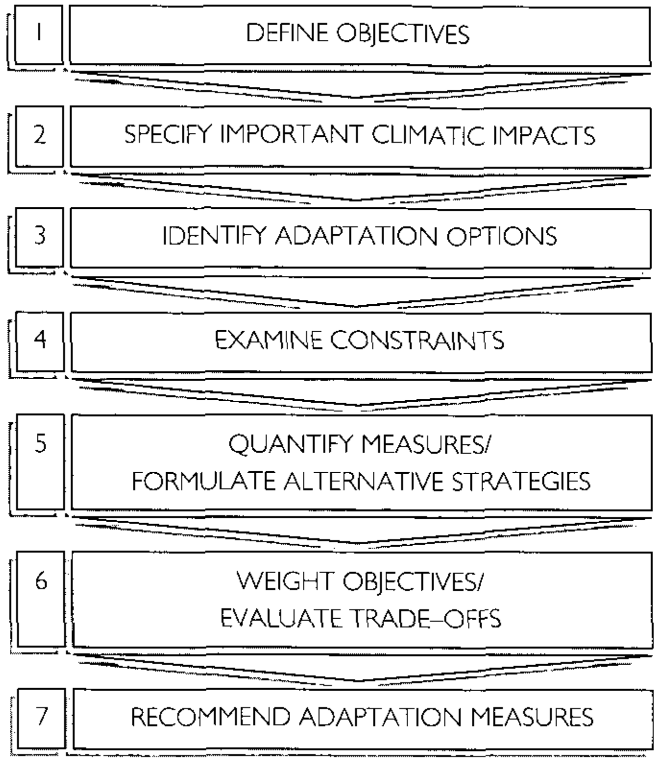
In moving towards a more interventionist type of adjustment, however, the distinction between autonomous adjustments and adaptation starts to become blurred. For instance, it is not always a straightforward task to separate out autonomous tactical adjustments that are directly related to climate change from adjustments that are made to changing external conditions, which are themselves an adaptive response to climate change (such as government assistance to farmers to cope with adverse climatic conditions). The evaluation of these 'exogenous' adaptations is examined in the following section.

8.3 Steps in the Evaluation of an Adaptation Strategy

In this section, types of adaptation are described and procedures presented for identifying, classifying and evaluating available options for decision making. For more information on adaptation strategies, Chapter 6 of the 1990 IPCC Response Strategies report (IPCC, 1991a) provides a good overview of the range of issues and ideas that should be considered in developing a coherent approach. Moreover, several countries (including Australia, Canada, and the USA) are actively pursuing the development of protocols for the assessment of adaptation to climate change.

At present there are no generally accepted procedures for formulating national and regional policies for adaptation to climate change, one of the reasons being that the assessment process involves value judgements, which can be both subjective and controversial. Nevertheless, formal evaluation procedures do exist to address analogous problems as part of the planning process in many developed countries. By drawing on the experiences gained in formulating those planning guidelines, a broad framework for the evaluation of adaptation strategies to cope with climate change can be identified. As with the general framework for assessing climate impacts, the framework for developing adaptation strategies also comprises seven steps (Figure 6).

Figure 6. Development of an adaptation strategy



8.3.1 Defining the objectives

Any analysis of adaptation must be guided by some agreed goals and evaluation principles. It is not sufficient merely to state that adverse impacts should be avoided, reduced or eliminated. Two examples of general *goals* commonly propounded by international institutions and conventions are: (i) the promotion of sustainable development, and (ii) the reduction of vulnerability. However, these are so broad that they are open to many different interpretations, so specific objectives need to be defined that complement the goals.

Objectives are usually derived either from public involvement, from stated public preferences, by legislation, through an interpretation of goals such as those described above, or any combination of these. They represent desired targets which can be evaluated using specified criteria and constraints. Table 2 illustrates three possible objectives that might be selected to achieve each of the two different goals described above, and the evaluation criteria that can be used to measure their success. Most of these are quantitative measures (e.g., income, employment); others like biodiversity can be quantified, but not in economic terms.

A common, shared set of evaluation principles and decision rules is an important aspect of analysis. The scientific and technical part of the climate impact assessment provides most of the information concerning physical effects and direct social and economic impacts on the main resource-dependent sectors. The options to ameliorate or modify the adverse primary impacts all have their own economic, social and environmental benefits and costs. It is not always apparent what these are, since they differ among resource use sectors and the public.

Virtually all forms of cost-benefit analysis follow the basic decision rule that for any action, project, programme or strategy, the benefits must exceed the costs, however they are measured. Benefits are measured relative to a set of desired targets or planning objectives, which reflect a notion of what needs to be achieved. Those objectives can further be quantified by conventional measures of relative worth, termed evaluation criteria (e.g., income, employment, change in habitat acreage, population at risk, etc.). Constraints may also be part of an evaluation framework, defining a set of bounds that are considered acceptable (for example, a 100-year return period event or a minimum habitat size for a species based on per capita water availability).

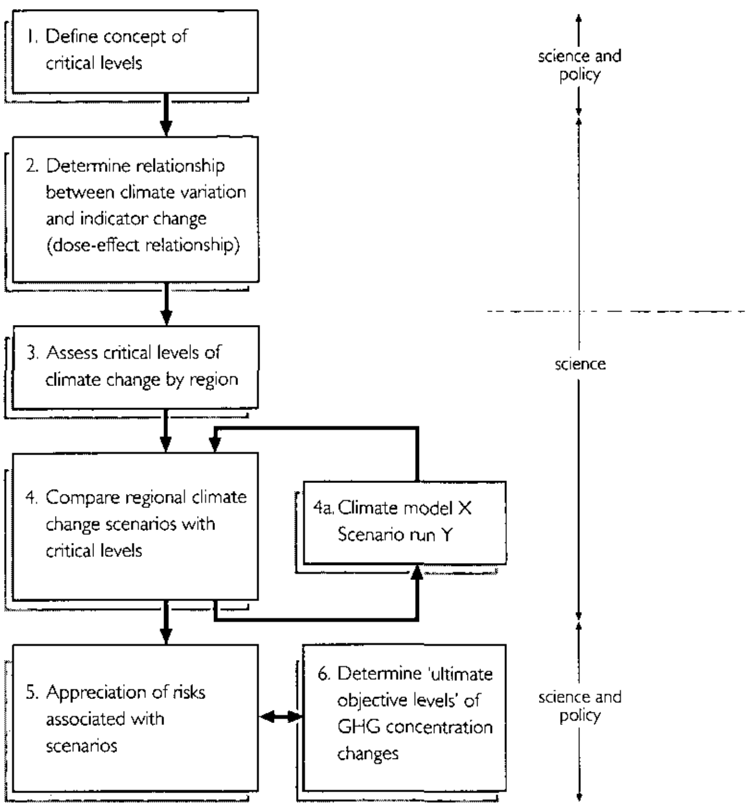
8.3.2 Specifying the climatic impacts of importance

This step involves an assessment, following the methods outlined elsewhere in this report, of the possible impacts of climate variability or change on the exposure unit. Where climatic events are expected that will cause damage, these need to be specified in detail so that the most appropriate adaptation options can be identified. Where beneficial climatic events are anticipated, these should be examined, both in their own right and because they may help to compensate for negative effects. Details include the magnitude and regional extent of an event, its frequency, duration, speed of onset and seasonality (i.e., timing during the year). In the case of long-term climate change, impacts should be considered relative to those that would be expected to occur in the absence of climatic change. Moreover, since there is often great scientific uncertainty attached to projections, it may be useful to express possible changes in terms of the probability of their occurrence and/or as changes in the recurrence frequency of events observed in the historical climatological record.

One general approach for identifying the exposure units at risk from climate variability is vulnerability assessment. Vulnerability can be defined as the degree to which an exposure unit is disrupted or adversely affected as a result of climatic events. It follows that vulnerable systems, activities or regions are likely to be those most in need of planned adaptation.

The approach can be illustrated with reference to a 'common methodology' that has been developed for the national-scale assessment of coastal zone vulnerability to sea level rise (IPCC 1991b, 1994; cf. Box 6). One of the main objectives of the common methodology is to inform national decision makers about the vulnerability of the coastal zone, the possible problems a country may face due to a changing climate and sea level and, if necessary, the types of assistance that are most needed to overcome these problems. The identification of critical levels of vulnerability and critical levels of climate change is likely to be important in the determination of what constitutes 'dangerous' levels of climate change (a term used in Article 2 of the UN Framework Convention on Climate Change). A proposed six step process of determination is outlined in Figure 7.

Figure 7. A six step approach to the ultimate objective of the Climate Convention (after Swart and Vellinga, 1994)



8.3.3 Identifying the adaptation options

The main task of assessment involves the compilation of a detailed list of possible adaptive responses that might be employed to cope with or take advantage of the effects of climate. The list can be compiled by field survey and by interviews with relevant experts, and should consider all practices currently or previously used, possible alternative strategies that have not

Table 2. An example of a multiple criteria evaluation framework, in this case, for water resources management (Stakhiv, 1994)

OVERALL GOAL	SPECIFIC OBJECTIVE	EVALUATION CRITERIA
SUSTAINABLE DEVELOPMENT	1 Regional economic development	Income Employment
	2 Environmental protection	Biodiversity Habitat areas Wetland types
	3 Equity	Distribution of employment Minority opportunities
REDUCE VULNERABILITY	1 Minimize risk	Population at risk Frequency of event
	2 Minimize economic losses	Personal losses Insured losses Public losses
	3 Increase institutional response	Warning time Evacuation time

been used, and newly created or invented strategies. Information is needed on the frequency with which particular actions are taken, in what circumstances and by whom. The effectiveness of different actions, their cost and the reasons for their use or otherwise should also be recorded. It is useful to note here that there are abundant cases to demonstrate that existing policies and practices may actually increase the impacts of present-day climatic variability. For example, agricultural support payments, subsidized insurance and damage cooperation payments may encourage higher risk taking among farmers and increase the total costs to society. These are cases of maladaptation that should be identified at an early stage of assessment. This step also requires a consideration of the likely impact on adaptation strategies of technological change.

Six generic types of behavioural adaptation strategy for coping with negative effects of climate have been identified by Burton *et al.* (1993):

- *Prevention of loss*, involving anticipatory actions to reduce the susceptibility of an exposure unit to the impacts of climate (e.g., controlled coastal zone retreat to protect wetland ecosystems from sea level rise and its related impacts).
- *Tolerating loss*, where adverse impacts are accepted in the short term because they can be absorbed by the exposure unit without long term damage (e.g., a crop mix designed to minimize the maximum loss, to ensure a guaranteed minimum return under the most adverse conditions).
- *Spreading or sharing loss*, where actions distribute the burden of impact over a larger region or population beyond those directly affected by the climatic event (e.g., government disaster relief).
- *Changing use or activity*, involving a switch of activity or resource use from one that is no longer viable following a climatic perturbation to another that is, so as to preserve a community in a region (e.g., by employment in public relief works).
- *Changing location*, where preservation of an activity is considered more important than its location, and migration occurs to areas that are more suitable under the changed climate (e.g., the re-siting of a hydro-electric power utility due to a change in water availability).
- *Restoration*, which aims to restore a system to its original condition following damage or modification due to climate (for example, an historical monument susceptible to flood damage). This is not strictly an adaptation to climate, as the system remains susceptible to subsequent comparable climatic events.

Table 3. Characteristics of selected coping strategies by smallholders for drought in central and eastern Kenya[a] (after Akong'a *et al.*, 1988)

	Effectiveness				Constraints					
Response/ coping strategy	Prevalence	Normal	Moderate drought	Severe drought	Recovery	Labour	Capital	Constraints technology	Education/ information	Land
Subsistence production										
Soil conservation	M–H	M	M	L	0	–	–	–	+	–
Water conservation	L	M	H	L	0	–	–	–	+	–
Irrigation	L	H	H	H?	+	–	+	+	+	+
Multiple farms	L	M	M	L	0	–	+	–	–	+
Inter/relay cropping	H	H	H–L	L	+	–	–	–	+	–
Dry planting	M	H	H	L	0	–	–	+	–	–
Mixed livestock herds	M–H	H	H	M	+	+	–	–	–	+
Dispersed grazing	H	H	H	M	+	+	–	–	–	+
Fodder production[b]	M	H	H	M	+	+	–	+	+	+
Drought-resistant crops	H	M	H	M	+	–	–	+	+	–
Monetary activity										
Local wage labour	M–H	H	H	H	+	+	–	–	+	–
Migrant wage labour	M	H	H	H	–	+	–	–	+	–
Permanent employment	M	H	H	H	+	+	–	–	+	–
Local business	L	M	M	L	0	+	+	–	+	–
Cash crop[c]	M	H	M	L	+	+	+	+	+	+
Sell capital assets	M	H	M	L	–	–	–	–	–	+
Livestock sales	H	H	M–H	M–L	–	–	–	–	+	–
Remittances/donations										
Relatives/friends	M–H	M	H	H	+	–	–	–	–	–
Government and others[d]	M–H	?	H	H	?	–	–	–	+	–
Loans/credits	L	H	H	H	+	–	+	–	+	–

Key:

Prevalence/Effectiveness
H = > 50%/High
M–H = 30–50/Mod. high
M = 15–30/Moderate
L = 0–15/Low

Recovery/Constraints
– = negative, i.e., impedes recovery/is a constraint
+ = positive, i.e., aids recovery/is not a constraint
0 = neutral, i.e., no effect on recovery
? = uncertain or variable

[a] Consensus agreement by authors based on available data. Ratings are intended to be qualitative and relative as no systematic survey data are available. In many cases, these are hypotheses to be verified. [b] Very common in the upper altitudinal zones; almost non-existent in the lower zones. [c] Does not include food crops. Very common in upper zones; rare in lower zones. [d] High in the lower zones; low in the upper zones.

There are, of course, many cases where climate changes can be positive. Here the strategies involve capitalizing on opportunities.

Different criteria can be used for organizing the information. For instance, detailed tables have been used to catalogue traditional adjustment mechanisms for coping with inter-annual climatic variability in self-provisioning societies (Jodha and Mascarenhas, 1985; Akong'a *et al.*, 1988). Table 3 illustrates a classification system for displaying smallholder coping strategies for drought in central and eastern Kenya and a qualitative effectiveness ranking for different measures.

Other methods of cross-tabulation have been employed in formal procedures of resource management. For example, alternative water resource adaptation measures in the United States are commonly analysed according to both the type of measure and its strategic scope. Four groupings of strategy have been identified (Stakhiv, 1993):

- Long range strategies, generally pertinent to issues involving mean changes in climate (e.g., river basin planning, institutional changes for water allocation).
- Tactical strategies, concerned with mid-term considerations of climatic variability (e.g., flood proofing, water conservation measures).
- Contingency strategies, relating to short-term extremes associated with climatic variability (e.g., emergency drought management, flood forecasting).
- Analytical strategies, embracing climatic effects at all scales (e.g., data acquisition, water management modelling).

Numerous options exist for classifying adaptive measures, but generally, regardless of the resource of interest (e.g., forestry, wetlands, agriculture, water) the prospective list should include management measures that reflect:

- Structural/infrastructural measures.
- Legal/legislative changes.
- Institutional/administrative/organizational measures.
- Regulatory measures.
- Education.
- Financial incentives, subsidies.
- Research and development.
- Taxes, tariffs, user fees.
- Market mechanisms.
- Technological changes.

It is worth noting that society in general, and each resource use sector separately, already contends with contemporary climatic variability and the wide range of natural hazards (e.g., floods, droughts, storm surges and hurricanes) and the variety of opportunities (e.g., a benign period of weather; an unbroken 'snow season'; a mild winter) this brings. As a first approximation, it is probably fair to assume that most of the current measures employed in resource management to deal with climatic variability will be equally feasible, even if not comparatively cost-effective, under a different climatic regime. It follows, therefore, that the adaptation measures which ought to be selected now are those which are beneficial for reasons other than climate change and, for the most part, can be justified by current evaluation criteria and decision rules. This is sometimes referred to as the 'no regrets' strategy

8.3.4 Examining the constraints

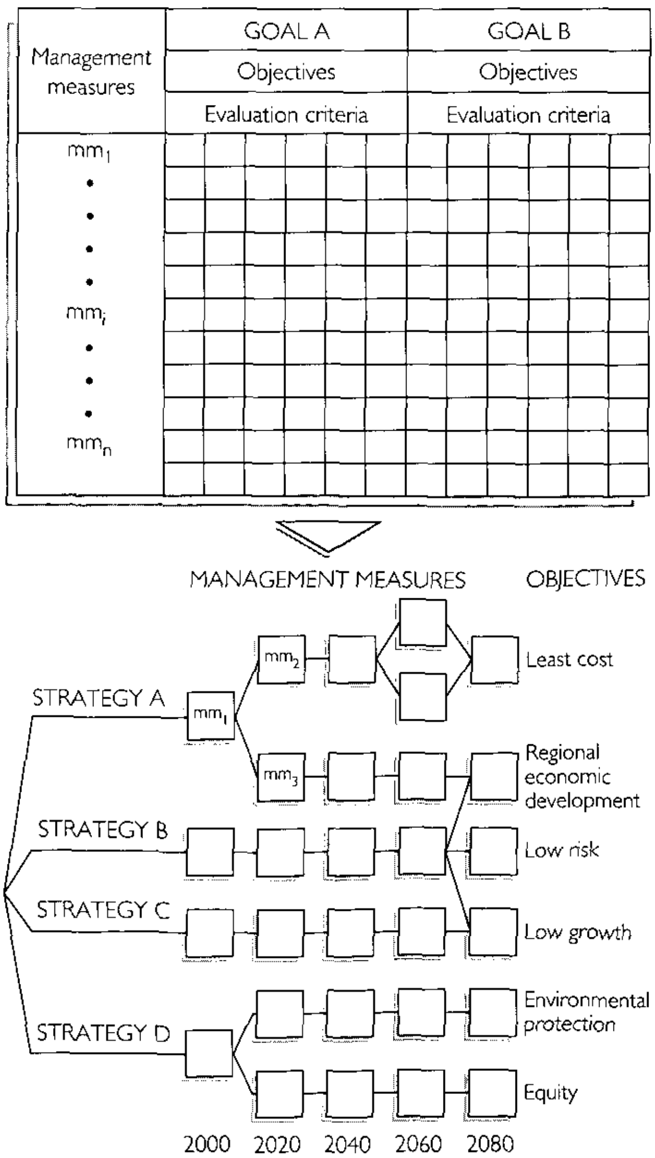
Many of the adaptation options identified in the previous step are likely to be subject to legislation, influenced by prevailing social norms related to religion or custom, or constrained physically (such as the landward retreat from an eroding coast) or biologically (e.g., genetic material for plant breeding to adapt to changing climate). This may encourage, restrict or totally prohibit their use. Thus, it is important to examine closely, possibly in a separate study, what these constraints are and how they might affect the range of feasible choices available.

8.3.5 Quantifying the measures and formulating alternative strategies

The next step is to assess the performance or degree of fulfilment of each management measure with respect to the stated objectives. It may be possible, if appropriate data and analytical tools exist, to use simulation models to test the effectiveness of different measures under different climate scenarios. Historical and documentary evidence, survey material or expert judgement are some other alternative sources of this information. Uncertainty analysis and risk assessment are also considered at this stage (see Section 7.6).

Management measures can be ranked according to their responsiveness to individual objectives and criteria as a way of

Figure 8. Some procedures for strategy formulation—top: multicriteria analysis of individual management measures; bottom: multiobjective strategy formulation.



assessing their robustness, effectiveness and resilience relative to other comparable measures. The second step in such analysis would be to assess the performance of each management measure across all the objectives, recognizing that some of the objectives conflict with one another (e.g., in Table 2, regional economic development often conflicts with environmental protection). This step is a prelude to developing strategies which maximize the level of achievement of some objectives while maintaining baseline levels of progress towards the remaining objectives. In order to assess which options are better suited for certain strategies, multicriteria analysis provides a formal, useful and replicable method of evaluation (Figure 8, top). One of the important aspects to consider at this stage is the quantification of achievable rates of adaptation and their additional costs. The faster the need for adaptation, the more it is likely to cost per annum.

An example of testing the feasibility of one line of adaptation to drought risk in Saskatchewan, Canada is given in Box 12. A more extensive range of adaptations has been tested for the central USA (see Box 13).

8.3.6 Weighting objectives and evaluating trade-offs

The adaptation strategies that emerge from the foregoing analysis each relate to specific objectives (Figure 8, bottom). Even if all objectives are directed to the same general goal, however, it is very likely that many will conflict with one another. This step of the analysis, therefore, is the key evaluation step, where each objective must be weighted according to assigned preferences and then comparisons made between the effectiveness of different strategies in meeting these objectives. For instance, for coastal responses to accelerated sea level rise, there could be a 'pure' retreat option, consisting exclusively of regulatory measures, taxes, incentives and legal and institutional measures spread out over a period of time. Also, a pure protection option might be considered, consisting of structural measures and better organized monitoring, warning and evacuation plans.

The key aspect of this step of evaluation is that all the component measures that comprise a strategy are compared against the same set of objectives and criteria, so that decision makers, policy makers and the public can see the relative range of benefits and costs for each strategy as well as the distribution of impacts among the sectors and population (equity). Only then can trade-offs among objectives and between management measures be undertaken. A wide variety of methods and models are available for such multicriteria analyses (e.g., Goicoechea *et al.*, 1982; Chankong and Haimes, 1983).

A standard impact accounting system for evaluating the effectiveness of different planning strategies is used operationally in federal projects in the United States. This evaluates

BOX 12

CASE STUDY: POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURE IN SASKATCHEWAN, CANADA

Background: the province of Saskatchewan in Canada has about 40 per cent of Canada's farmland and it accounts for about 60 per cent of Canada's wheat production, most of which is exported. About one eighth of internationally traded wheat originates from Saskatchewan.

Problem: to evaluate the possible impacts of future climate change on Saskatchewan agriculture, assuming the same technology and economic circumstances as in the 1980s.

Methods: four different types of predictive model were linked hierarchically: crop growth, farm simulation, input-output and employment models. These provided estimates of regional crop yields, income and economic activity at the farm level, commodity use relationships between sectors of the provincial economy, and provincial employment. The effects of changed climate, described by climatic scenarios, were then traced through from changes in crop yield to effects on regional employment.

Testing of methods/sensitivity: each of the models had been tested and calibrated based on climatic or economic data from recent years. In addition, the sensitivity of the crop growth model to arbitrary changes in climatic input variables was also investigated to ascertain its suitability for evaluating the effects of climate change.

Scenarios: three types of climatic scenario were examined: one historical anomaly scenario (the drought year 1962), one historical analogue scenario (the dry period 1933–37) and one GCM-based 2 x CO_2 scenario. The climatological baseline was 1951–80. Future changes in other environmental and socio-economic factors were not considered.

Impacts: under present climatic conditions, Saskatchewan can expect occasional extreme drought years with wheat yields reduced to as little as one-quarter of normal, with large effects on the agricultural economy and on provincial GDP and large scale losses in employment. Occasional periods of consecutive years with drought can lead to average yield reductions of one-fifth and substantial losses of farm income and employment. Under the GCM-based 2 x CO_2 scenario, with increased growing season temperatures combined with increased precipitation but higher potential evapotranspiration, wheat yields would also decline, by average levels similar in magnitude to an extreme period under present climate, with comparable economic impacts. The frequency of drought or severe drought is estimated to triple relative to the baseline under this scenario.

Adjustments. one potential adaptive response to climate change was tested: the switching of 10 per cent of the cropped area from spring wheat to winter wheat. It was estimated that yield losses in drought years would be significantly lower with such an adaptation, but that the reverse would be true in normal years. Thus this adaptation would be favoured if climate shifted towards warmer and drier conditions in the future.

Source: Williams *et al.* (1988)

BOX 13
CASE STUDY: THE MINK PROJECT
AN INTEGRATED REGIONAL ASSESSMENT

Background: Missouri, Iowa, Nebraska and Kansas (the MINK region) are four adjacent states in the central United States which are dependent on resource sectors known to be sensitive to climate change: agriculture, forestry, water resources and energy. Except for pockets of forestry on the Ozark Plateau of southeast Missouri, and grassland on sand dunes in north central Nebraska, the region is fairly coherent, with flat or rolling topography used predominantly for agriculture.

Problem: to study how climate change might affect the current and future functioning of regional-scale economies.

Method: a number of models were used to evaluate impacts of climate on individual sectors. For agriculture a semi-empirical process model (EPIC) was adopted that simulates crop biomass and yield production, evapotranspiration and irrigation requirements. For forests, a succession model (FORENA) that simulates the annual development of individual trees within a mixed species forest was used. This allows the effects of climate change on both forest growth and species composition to be evaluated. Both EPIC and FORENA were modified to account for the direct effects of CO_2 on photosynthesis and water use. Several approaches were used to estimate regional water resources: changes in evapotranspiration and irrigation requirements were modelled using EPIC. Regional water supply was estimated using empirical relationships between present and past streamflows. Impacts on the energy sector drew on the modelling and interpretations from the other three sectors and on an analysis of how heating and air conditioning requirements are affected by changing temperature. Finally, the economy-wide effects of changes in productivity of the above resource sectors were studied using IMPLAN, a regional input-output model. IMPLAN describes the interaction between 528 industries in the MINK region.

Testing of methods/sensitivity: EPIC was validated against national agricultural statistics (county level) and observed seasonal yields in agronomic experiments for seven crops in the region. Evapotranspiration terms were compared with field observations. FORENA had been validated previously for conditions in the eastern United States, and results were also compared with observed forest behaviour under drought conditions in Missouri. A sensitivity study was conducted on the response of forest biomass to changes in temperature and precipitation. The model coefficients relating inputs and output flows between industries in IMPLAN were computed from regional data for 1982.

Scenarios: a temporal analogue was employed as the climate scenario, specifically the decade 1931–1940 in the MINK region. Overall, this period was one of severe drought—both drier and warmer than average in the region, consistent in sign with GCM projections. These conditions were assumed to occur in the present and also in the year 2030, along with an increase in CO_2 concentration of 100 ppm (to 450 ppm). Four sets of conditions were investigated: (1) the current baseline, which referred to the economic situation in the early 1980s, with 1951–1980 as the climatological baseline; (2) climate change imposed on the current baseline; (3) a baseline description of the economic structure of the region in the future without climate change (including population, economic activity and personal income); and (4) imposition of climate change on the future baseline (including feedbacks between sectors, such as the projected extent of irrigated agriculture given scenarios of future water supply).

Impacts: in the MINK region of 2030 with a climate like that of the 1930s the main results of the study are: (1) Crop production would decrease in all crops except wheat and alfalfa, even accounting for CO_2 effects. However, impacts on agriculture overall would be small given adaptation, though at the margins losses could be considerable (e.g., a shift in irriga-

continued ...

the effects of different plans on a set of four basic objectives or impact categories:

- National economic development (monetary).
- Environmental quality (significant environmental resources and their ecological, cultural and aesthetic attributes).
- Regional economic development (distribution of regional economic activity in terms of regional income and employment).
- Other social effects (including urban and community impacts, life, health and safety factors, displacement, long-term productivity, energy requirements and energy conservation).

All impacts and adaptation measures are evaluated according to these four categories. Selection of preferred strategies thus requires the determination of trade-offs between the categories.

8.3.7 Recommending adaptation measures

The results of the evaluation process should be compiled in a form that provides policy advisers and decision makers with information on the best available adaptation strategies. This should include some indication of the assumptions and uncertainties involved in the evaluation procedure, and the rationale used (e.g., decision rules, key evaluation principles, national and international support, institutional feasibility, technical feasibility) to narrow the choices.

8.4 Points to Consider in Developing an Adaptation Strategy

It may be helpful to note some of the practical requirements involved in conducting an adaptation assessment of the type proposed above. These include: institutional requirements, data requirements, analytical tools and cost.

8.4.1 Institutional requirements

The formal procedures described above, which are routinely and successfully used in a variety of resource management settings in many developed countries, do, however, require an institutional and information infrastructure as prerequisites. This implies that there is an organizational, administrative and legal structure in place that is capable of carrying out the procedures in a uniform

... continued

tion from west to east). (2) Impacts on forestry would not be fully felt by 2030, but in the long term they would be severe. There is little potential for adaptation to the climate change unless the production of wood for biomass fuel makes adaptation economically justifiable. However, forestry is a very small part of the MINK economy. (3) Impacts on water resources would be major and severe. The quality and quantity of surface waters would diminish, water-based recreation would suffer losses and navigation would become uneconomic on the Missouri. Rising costs of water extraction would make agriculture less competitive for surface water and groundwater supplies and would hasten the abandonment of irrigation in the western portions of the region. (4) Only about 20–25 per cent of the region's current energy use would be sensitive to a 1930s-type climate, and any impacts of climate would be eased by adjustments within the energy sector so that the effect on the regional economy would be minor. (5) Unless the climate-induced decline in feedgrain production falls entirely on animal producers in MINK (which would lead to an overall loss to the regional economy of 10 per cent), the regional economic impacts of the climate change would be small. This is because agriculture, while important relative to other regions of the US, is still only a small (and diminishing) part of the MINK economy.

Adaptation: most of the work on adaptation dealt with responses to impacts on crop production. Simulated adjustments included changed planting dates, altered varieties and changed tillage practices. In addition technological advances were assumed in irrigation efficiency and crop drought resistance as well as improvements in a number of crop specific characteristics including harvest index, photosynthetic efficiency and pest management. In economic terms, in the absence of on-farm adjustments and CO_2 enrichment, the analogue climate would reduce the value of 1984–87 crop production in MINK by 17 per cent. The CO_2 effect would reduce the loss to 8 per cent, and on-farm adjustments would reduce it further to 3 per cent. In the forestry sector a number of management options were investigated using the FORENA model (e.g., the suitability of pine plantations and various thinning strategies), but none was considered appropriate as a response to climate change in the region. Rather, barring major public intervention, only reactive measures to forest decline such as salvage cutting were judged likely. Qualitative assessments were made of possible adjustments in water use (e.g., water conservation, a shift of emphasis from navigation to hydropower production, recreation and water supply on the Missouri River) and in energy production and use (e.g., energy-saving water pumping and irrigation practices, improved energy-use efficiency and adoption of new or existing technologies for improving electric conversion efficiency and reducing cooling water requirements).

Policy options: although the MINK study did not seek to provide specific recommendations to policy makers for how to cope with climate change in this region, one important conclusion was that the relevant policy issue at the regional scale is not one of climate change abatement (which can only be dealt with at national and international level), but rather one of optimal adjustment to climate change. An important assumption of the study was that markets play a major role in inducing adjustments needed for adequate response to climate change. However, some important elements are not commonly considered in economic terms (e.g., the quality of aquatic habitats is projected to decline in the MINK region). These should necessarily fall within the ambit of public policy. Moreover, the study also speculated on possible policy shifts, which could have more far-reaching implications for the MINK region (e.g., the removal of subsidies for irrigation agriculture under sharply increased water scarcity or subsidization of plantation forestry as a method of capturing atmospheric carbon and of energy production).

Source: Rosenberg (1993)

and replicable manner. Moreover, some of the analytical tools employed are both sophisticated and resource intensive to develop and operate.

It is clear that some of these prerequisites are likely to be lacking in less developed countries, due to the limited resources available. However, alternative 'low cost' procedures are available that could be applied in many regions. Additional capabilities could then be built up over time, if desired. The framework outlined above is therefore a general one, which is applicable to a wide range of situations and capabilities in different regions.

8.4.2 Data requirements

Data requirements can vary considerably, depending on the scope of the study. Biological and physical information such as climatological, hydrological and agricultural production data, is likely to be more readily available than socio-economic information, though not necessarily in the form required. It is very likely, however, that original socio-economic data will have to be collected as part of the analysis. This can prove to be quite expensive in terms of time, money and human resources, as it may require surveys of the population where adaptive actions are being considered. An alternative is expert judgement, but this should be blended with a knowledge of social values and priorities or there is a danger that local perceptions and understandings may be overlooked in the assessment.

8.4.3 Analytical tools

As has already been indicated, a number of aspects of the analysis can be enhanced with the use of models. These can vary from formalized methods of qualitative assessment (e.g., Delphi analysis of expert judgement) to advanced quantitative assessment models (many of which are described elsewhere in this report). Many of these types of model are available as software packages for a personal computer. However, aside from their cost (which need not be excessive), and the considerable complexity often entailed in linking model inputs and outputs, data availability is likely to impose the greatest constraint on model use in many regions.

8.4.4 Cost

The cost of conducting a study of adaptation to climate change can vary widely. A detailed study can easily cost several hundred thousand US dollars, although useful results can be obtained from small-scale studies costing in the range 50,000 to 100,000 US dollars.

8.4.5 Policy exercises

One possible method of evaluating policy adjustments is the policy exercise. Policy exercises combine elements of a modelling approach with expert judgement, and were originally advocated as a means of improving the interaction between scientists and policy makers. Senior figures in government, industry and finance are encouraged to participate with senior scientists in 'exercises' (often based on the principles of gaming), whereby they are asked to judge appropriate policy responses to a number of given climatic scenarios. Their decisions are then evaluated using impact models (Brewer, 1986; Toth, 1989). The method has been tested in a number of recent climate impact assessments in South-East Asia (Parry *et al.*, 1992).

8.4.6 Sensitization seminars

A less formal method of communicating the important research issues to policy makers is through organized meetings on climate change and its possible effects. If these are targeted at policy makers and other stakeholders, they can be very effective vehicles for influencing attitudes and, ultimately, policy.