IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations

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PREFACE

When the Intergovernmental Panel on Climate Change (IPCC) completed its first Impacts Assessment in 1990 it became clear that much more work was needed if a credible global picture was to be drawn of the potential effects of climate change. In particular, the Assessment revealed how difficult it was to compare impacts in different regions and economic sectors that had been assessed using different methods. A compatible set of methods was needed to yield comparable regional and sectoral impact assessments.

Working Group II of the IPCC therefore established an expert group to develop some guidelines for the assessment of impacts of climate change. The work of this group resulted in the publication in 1992 of an initial report entitled *Preliminary Guidelines for Assessing Impacts of Climate Change* (Carter *et al.*, 1992).

The major objective in producing and distributing that report was to solicit comments and suggestions for an improved set of guidelines that could be tabled and reviewed as part of the IPCC Second Assessment. The present report is the product of that process. It should be considered as a set of technical guidelines for the scientist, which does not seek to prescribe a single preferred method but a range of methods, some of which may be more suitable than others to the task in hand, but which can yield broadly comparable results. The United Nations Environment Programme is currently developing a set of Workbooks, designed to translate the technical procedures outlined here into practical methods of impact and adaptation assessment at the country and sectoral level.

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SUMMARY FOR POLICY MAKERS

Working Group II of IPCC has prepared Guidelines to assess the impacts of potential climate change and to evaluate appropriate adaptations. They reflect current knowledge and will be updated as improved methodologies are developed. The Guidelines outline a study framework which will allow comparable assessments to be made of impacts and adaptations in different regions/geographical areas, economic sectors and countries. The Guidelines are intended to help contracting parties meet, in part, their commitments under Article 4 of the UN Framework Convention on Climate Change.

Impact and adaptation assessments involve several steps:

- Definition of the problem.
- Selection of the methods.
- Testing the method.
- Selection of scenarios.
- Assessment of biophysical and socio-economic impacts.
- Assessment of autonomous adjustments.
- Evaluation of adaptation strategies.

Definition of the problem includes identifying the specific goals of the assessment, the ecosystem(s), economic sector(s) and geographical area(s) of interest, the time horizon(s) of the study, the data needs and the wider context of the work.

The selection of analytical method(s) depends upon the availability of resources, models and data. Impact assessment analyses can range from the qualitative and descriptive to the quantitative and prognostic.

Testing the method(s), including model validation and sensitivity studies, before undertaking the full assessment is necessary to ensure credibility.

Development of the scenarios requires, firstly, the projection of conditions expected to exist over the study period in the absence of climate change and, secondly, the projection of conditions associated with possible future changes in climate.

Assessment of potential impacts on the sector(s) or area(s) of interest involves estimating the differences in environmental and socio-economic conditions projected to occur with and without climate change.

Assessment of autonomous adjustments implies the analysis of responses to climate change that generally occur in an automatic or unconscious manner.

Evaluation of adaptation strategies involves the analysis of different means of reducing damage costs. The methodologies outlined in the Guidelines for analysing adaptation strategies are meant as a tool only to compare alternative adaptation strategies and thereby identify the most suitable strategies for minimizing the effects of climate change were they to occur.

EXECUTIVE SUMMARY

1 Objectives

These Guidelines, which are a further development of those previously published (Carter *et al.* 1992) provide a means for assessing the impacts of potential climate change and of evaluating appropriate adaptations. They reflect current knowledge and will be updated as improved methodologies are developed. They do not aim to prescribe a single preferred method, but provide an analytical outline that comprises a number of steps. A range of methods is identified at each step. Where possible, the merits and drawbacks of different methods are briefly discussed, with some suggestions on their selection and use.

The ultimate purpose of the Guidelines is to enable estimations of impacts and adaptations which will allow comparable assessments to be made for different regions/geographical areas, sectors and countries. The Guidelines are intended to help contracting parties meet, in part, commitments under Article 4 of the UN Framework on Climate Change.

2. Approaches

A general framework for conducting a climate impacts and adaptations assessment contains seven steps:

- Definition of the problem.
- Selection of the method.
- Testing the method.
- Selection of scenarios.
- Assessment of biophysical and socio-economic impacts.
- Assessment of autonomous adjustments.
- Evaluation of adaptation strategies.

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.

3. Step One—Definition of the Problem

This involves identifying the goals of the assessment, the exposure unit of interest, the spatial and temporal scope of the study, the data needs, and the wider context of the work.

3.1 Goals of the Assessment

It is important to be precise about the specific objectives of a study, as these will affect the conduct of the investigation. For example, an assessment of the hydrological impacts of future climatic change in a river catchment would have 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.

3.2 Exposure Unit to be Studied

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

3.3 Study Area

The selection of a study area is guided by the goals of the study and by the constraints on available data. Some options are reasonably well-defined, including governmental units, geographical units, ecological zones, and climatic zones. Other options requiring more subjective selection criteria include sensitive regions and representative units.

3.4 Time Frame

The selection of a time horizon for study is also influenced by the goals of the assessment. For example, in studies of industrial impacts the planning horizons may be 5–10 years, while investigations of tree growth may require a 100-year perspective. However, as the time horizon increases, the ability to accurately project future trends declines rapidly. Most climate projections and scenarios rely on general circulation models (GCMs) which are subject to uncertainties. Projections of socio-economic factors such as population, economic development and technological change need to be made for periods exceeding 15–20 years.

3.5 Data Needs

The availability of data is probably the major limitation in most impact and adaptation assessment studies. The collection of new data is an important element of some studies, particularly for monitoring purposes regarding expected climate changes, but most rely on existing sources. Thus, before embarking on a detailed assessment, it is important to identify the main features of the data requirements, namely the variables for which data are needed, the time period, spatial coverage and resolution of the required data, the sources and format of the data and their quantity and quality, and the data availability, cost and delivery time.

3.6 Wider context of the work

In order to assist policy makers in evaluating the wider significance of an assessment, it is important to place it in the context of similar studies and of the political, economic and social system of the region.

4. Step Two–Selection of the Method

A variety of analytical methods can be adopted ranging 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.

4.1 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 and adaptation assessment, however, experimentation has only a limited application. Clearly it is not possible physically to simulate large-scale systems such as the global climate. Only where the scale of impact is manageable, the exposure unit measurable, and the environment controllable, can experiments be usefully conducted (for example, gas enrichment experiments with plants).

4.2 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 main focus of much recent work has been on impact projections, using an array of mathematical models to extrapolate into the future. 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.

4.2.1 Biophysical Models

Biophysical models may be used to evaluate the physical interactions between climate and an exposure unit. There are two main types: empirical-statistical models and process-based models. Empirical-statistical models are based on the statistical relationships between climate and the exposure unit. Process-based models make use of established physical laws and theories to express the dynamics of the interactions between climate and an exposure unit.

4.2.2 Economic Models

Economic models of several types can be employed to evaluate the implications of first-order impacts for local and regional economies. The main types of models are firm-level (which depict a single firm or enterprise), sectoral (which simulate behaviour within a specific economic sector) and macro-economic (which simulate entire economies).

4.2.3 Integrated Systems Models

Integrated systems models represent an attempt to combine elements of the modelling approaches described above into a comprehensive model of a given regionally- or sectorally- bounded system. Two main approaches to integration can be identified: the aggregate cost-benefit approach, which is more economically orientated, and the regionalized process-based approach, which focuses more on biophysical effects.

4.3 Empirical Analogue Studies

Observations of the interactions of climate and society in a region can be of value in anticipating future impacts. The most common method employed involves the transfer of information from a different time or place to an area of interest to serve as an analogy. Four types of analogy can be identified: historical event analogies, historical trend analogies, regional analogies of present climate and regional analogies of future climate.

4.4 Expert Judgement

A useful method of obtaining a rapid assessment of the state of knowledge concerning the effects of climate on given exposure units is to solicit the judgement and opinions of experts in the field. Literature is reviewed, comparable studies identified, and experience and judgement used in applying all available information to the current problem.

5. Step Three–Testing the Method

Following the selection of the assessment methods, it is important that these are tested in preparation for the main evaluation tasks. Three types of activity may be useful in evaluating the methods: feasibility studies, data acquisition and compilation, and model testing.

5.1 Feasibility Studies

These usually focus on a subset of the study region or sector to be assessed. Such case studies can provide information on the effectiveness of alternative approaches, of models, of data acquisition and monitoring, and of research collaboration.

5.2 Data Acquisition and Compilation

Data must be acquired both to describe the temporal and spatial patterns of climate change and their impacts and to develop, test and calibrate predictive models. Data collection may rely on existing information obtained and compiled from different sources, or require the acquisition of primary data, through survey methods, direct measurement or monitoring.

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 rigorously. 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. Validation involves the comparison of model predictions with real world observations to test model performance. Sensitivity analysis evaluates the effects on model performance of altering its structure, parameter values, or values of its input variables.

6. Step Four–Selection of the Scenarios

Impacts are estimated as the differences between two states: environmental and socio-economic conditions expected to exist over the period of analysis in the absence of climate change and those expected to exist with climate change.

6.1 Establishing the Present Situation

In order to provide reference points with which to compare future projections, three types of 'baseline' conditions need to be specified: the climatological, environmental and socio-economic baselines.

6.1.1 Climatological baseline

The climatological baseline is usually selected according to the following criteria:

- Representativeness of the present-day or recent average climate in the study region.
- Of sufficient duration to encompass a range of climatic variations.
- Covering a period for which data on all climatological variables are abundant, adequately distributed and readily available.
- Including data of sufficient quality for use in evaluating impacts.

It is recommended that the current standard WMO normal period (1961–90) be adopted in assessments where appropriate.

6.1.2 Environmental baseline

The environmental baseline refers to the present state of other, non-climatic environmental factors, that affect the exposure unit. Examples include: groundwater levels, soil pH, extent of wetlands, etc.

6.1.3 Socio-economic baseline

The socio-economic baseline describes the present state of all the non-environmental factors that influence the exposure unit. The factors may be geographical (e.g., land use), technological (e.g., pollution control), managerial (e.g., forest rotation), legislative (e.g., air quality standards), economic (e.g., commodity prices), social (e.g., population), or political (e.g., land tenure). All of these are liable to change in the future, so it is important that baseline conditions of the most relevant factors are noted.

6.2 Time Frame of Projections

A critical consideration for conducting impact experiments is the time horizon over which estimates are to be made. Three elements influence the time horizon selected: the limits of predictability, the compatibility of projections and whether the assessment is continuous or considers discrete points in time.

6.2.1 Limits of predictability

The time horizon selected depends primarily on the goals of the assessment. However, there are obvious limits on the ability to project into the future. Climate projections, since they are a key element of climate impact studies, define one possible outer limit on impact projections. GCM estimates seldom extend beyond about 100 years, due to the uncertainties attached to such long-term projections and to constraints on computational resources. This fixes an outer horizon at about 2100. In many economic assessments on the other hand, projections may not be reliable for more than a few years ahead.

6.2.2 Compatibility of projections

It is important to ensure that future climate, environment and socio-economic projections are mutually consistent over space and time. It is important to be clear about (i) the relative timing of increases in greenhouse gas concentrations and climate change and (ii) the relative timing of a 2 x CO_2 compared to a 2 x CO_2 'equivalent' atmosphere[1]. With regard to the former, there is a lag time of several decades in the response of the climate system to increases in greenhouse gas concentrations. With regard to the latter, a 2 x CO_2 'equivalent' atmosphere occurs earlier than a 2 x CO_2 atmosphere because gases such as CH_4, N_2O, and troposphere O_3 also contribute to radiative forcing.

6.2.3 Point in time or continuous assessment

A distinction can be drawn between considering impacts at discrete points in time in the future and examining continuous or time-dependent impacts. The former are characteristic of many climate impact assessments based on doubled-CO_2 equivalent scenarios. In contrast, transient climatic scenarios allow time-dependent phenomena and dynamic feedback mechanisms to be examined and socio-economic adjustments to be considered.

6.3 Projecting Environmental Trends in the Absence of Climate Change

The development of a baseline describing conditions without climate change is crucial, for it is this baseline against which all projected impacts are measured. It is highly probable that future changes in other environmental factors will occur even in the absence of climate change, which may be of importance for an exposure unit. Examples, as appropriate, include changes in land-use, changes in groundwater level and changes in air, water and soil pollution. Most factors are related to, and projections should be consistent with trends in socio-economic factors. Greenhouse gas concentrations may also change, but these would usually be linked to climate (which is assumed unchanged here).

6.4 Projecting Socio-Economic Trends in the Absence of Climate Change

Global climate change is projected to occur over time periods that are relatively long in socio-economic terms. Over that period it is certain that the economy and society will change, even in the absence of climate change. Official projections exist

[1] A 2 x CO_2 'equivalent' atmosphere is one where the radiative forcing due to changes in all greenhouse gases (CO_2, CH_4, N_2O, O_3, halocarbons) is the same as that of an atmosphere where the concentration of CO_2 has doubled with the concentration of other greenhouse gases remaining unchanged.

for some of these changes, as they are required for planning purposes. These vary in their time horizon from several years (e.g., economic growth, unemployment), through decades (e.g., urbanisation, industrial development, agricultural production), to a century or longer (e.g., population).

6.5 Projecting Future Climate

In order to conduct experiments to assess the impacts of climate change, it is first necessary to obtain a quantitative representation of the changes in climate themselves. No method yet exists of providing confident predictions of future climate. Instead, it is customary to specify a number of plausible future climates. These are referred to as 'climatic scenarios', and they are selected to provide climatic data that are spatially compatible, mutually consistent, freely available or easily derivable, and suitable as inputs to impact models.

There are three basic types of scenario of future climate: synthetic scenarios, analogue scenarios and scenarios from general circulation models.

6.5.1 Synthetic scenarios

A simple method of specifying a future climate is to adjust the baseline climate in a systematic, though essentially arbitrary manner. Adjustments might include, for example, changes in mean annual temperature of ± 1, 2, 3 °C ..., etc. or changes in annual precipitation of ± 5, 10, 15% ... etc. relative to the baseline climate. Adjustments can be made independently or in combination. In this way information can be obtained on:

- *Thresholds or discontinuities* of response that might occur under a given magnitude or rate of change. These may represent levels of change above which the nature of the response alters (e.g., warming may promote plant growth, but very high temperatures cause heat stress).
- *Tolerable climate change,* which refers to the magnitude or rate of climate change that a modelled system can tolerate without major disruptive effects (sometimes termed the 'critical load'). This type of measure is potentially of value for policy, as it can assist in defining specific goals or targets for limiting future climate change.

One of the main drawbacks of the approach is that adjustments to combinations of variables may not to be physically plausible or internally consistent.

6.5.2 Analogue scenarios

Analogue scenarios are constructed by identifying recorded climatic regimes which may serve as analogues for the future climate of a given region. These records can be obtained either from the past (temporal analogues), or from another region at the present (spatial analogues).

Temporal analogues are of two types: those based on past instrumental observations (usually within the last century) and those based on proxy data, using palaeoclimatic indicators such as plant or animal remains and sedimentary deposits (from the more distant past geological records). The main problem with this technique concerns the physical mechanism and boundary conditions that would almost certainly be different between a warmer climate in the past and a future greenhouse-gas induced warming.

Spatial Analogues require the identification of regions today having a climate analogous to the study region in the future. This approach is severely restricted, however, by frequent lack of correspondence between other non-climatic features of two regions that may be important for a given impact sector (e.g. daylength, terrain, soils or economic development.

6.5.3 Scenarios from general circulation models

Three dimensional numerical models of the global climate system (including atmosphere, oceans, biosphere and cryosphere) are the only credible tool currently available for simulating the physical processes that determine global climate. Although simpler models have also been used to simulate the radiative effects of increasing greenhouse gas concentrations, only general circulation models (GCMs), possibly in conjunction with nested regional models, offer the possibility to provide estimates of regional climate change, which are required in impact analysis.

GCMs produce estimates of climatic variables for a regular network of grid points across the globe. Results from about 20 GCMs have been reported to date (e.g., see IPCC, 1990 and 1992). However, these estimates are highly uncertain because of some important weaknesses of GCMs. These include: 1) poor model representation of cloud processes, 2) a coarse spatial resolution (at best employing grid cells of some 250 km horizontal dimension), 3) generalized topography, disregarding some locally important features and 4) a simplified representation of land-atmosphere and ocean-atmosphere interactions. As a result, GCMs are currently unable accurately to reproduce even the seasonal pattern of present-day climate at a regional scale. Thus, GCM outputs represent, at best, broad-scale sets of possible future climatic conditions and should not be regarded as predictions.

GCMs have been used to conduct two types of experiment for estimating future climate: equilibrium-response and transient-forcing experiments. The majority of experiments have been conducted to evaluate the equilibrium response of the global climate to an abrupt increase (commonly, a doubling) of atmospheric concentrations of carbon dioxide. A measure that is widely used in the intercomparison of various GCMs, is the climate sensitivity parameter. This is defined as the global mean equilibrium surface air temperature change that occurs in response to an increase in radiative forcing due to a doubling of atmospheric CO_2 concentration (or equivalent increases in other greenhouse gases). Values of the parameter obtained from climate model simulations generally fall in the range 1.5-4.5°C (IPCC, 1992). Knowledge of the climate sensitivity can be useful in constructing climate change scenarios from GCMs.

Recent work has focused on fashioning more realistic experiments with GCMs, specifically, simulations of the response of climate to a transient forcing. These simulations offer several advantages over equilibrium-response experiments. First, the specifications of the atmospheric perturbation are more realistic, involving a continuous (transient) change over time in GHG concentrations. Second, the representation of the oceans is more realistic, the most recent simulations coupling atmospheric models to dynamical ocean models. Finally, transient simulations provide information on the rate as well as the magnitude of climate change, which is of considerable value for impact studies.

The following types of information are currently available from GCMs for constructing scenarios:

- Outputs from a 'control' simulation, which assumes fixed GHG concentrations, and an 'experiment' which assumes future concentrations. In the case of equilibrium-response experiments, these are values from multiple-year model simulations for the control and 2 x CO_2 (or equivalent increases in other greenhouse gases) equilibrium conditions. Transient-response experiments provide values for the control equilibrium conditions and for each year of the transient model run (e.g., 1990 to 2100).

- Values of surface or near-surface climatic variables for model grid boxes characteristically spaced at intervals of several hundred kilometres around the globe.
- Values of air temperature, precipitation (mean daily rate) and cloud cover, which are commonly supplied for use in impact studies. Data on radiation, windspeed, vapour pressure and other variables are also available from some models.
- Data averaged over a monthly time period. However, daily or hourly values of certain climatic variables, from which the monthly statistics were derived, may also be stored for a number of years within the full simulation periods.

6.6 Projecting Environmental Trends with Climate Change
Changes in environmental conditions not due to climatic factors should already have been incorporated in the development of the environmental trends in the absence of climate changes, the only changes in these trends to be incorporated here are those due solely to climate change. The two factors most commonly required in assessments are greenhouse gas concentrations and sea level rise. Future changes in these are still under discussion, but the estimates reported by the IPCC may serve as a useful basis for constructing scenarios (IPCC, 1990). Other factors that are directly affected by climate (such as river flows, runoff, erosion) would probably require full impact assessments of their own, although some might be incorporated as 'automatic adjustments' in projections.

6.7 Projecting Socio-Economic Trends with Climate Change
The changes in environmental conditions that are attributable solely to climate change serve as inputs to economic models that project the changes in socio-economic conditions due to climate change both within the study area and, where relevant and appropriate, outside it, over the study period. All other changes in socio-economic conditions over the period of analysis are attributable to non-climatic factors and should have been included in the estimation of socio-economic changes in the absence of climate change.

7. Step Five–Assessment of Impacts
Impacts are estimated as the differences over the study period between the environmental and socio-economic conditions projected to exist without climate change and those that are projected with climate change. Assessments may include:

7.1 Qualitative description
The success of this method rests on the experience and interpretive skills of the analyst, especially the analyst's ability to consider all factors of importance and their interrelationships. Formal methods of organizing qualitative information also exist (for example, cross impact analysis).

7.2 Indicators of change
These are particular regions, activities or organisms that are intrinsically sensitive to climate, and which can provide an early or accurate indication of effects due to climate change.

7.3 Compliance to standards
This may provide a reference or an objective against which to measure the impacts of climate change. For example, the effect on water quality could be gauged by reference to current water quality standards.

7.4 Costs and benefits
These should be estimated quantitatively to the extent possible and expressed in economic terms. This approach makes explicit the expectation that a change in resources and resource allocation due to climate change is likely to yield benefits as well as costs. It can also examine the costs or benefits of doing nothing to mitigate potential climate change.

7.5 Geographical analysis
Impacts vary over space, and this pattern of variation is of concern to policy makers operating at regional, national or international scales because these spatial differences may have consequent policy and planning implications. The geographical depiction of the effects of climate change using geographical information systems (GIS) is one method of describing impacts.

7.6 Dealing with uncertainty
Uncertainties pervade all levels of a climate impact assessment, including the projection of future GHG emissions, atmospheric GHG concentrations, changes in climate, their potential impacts and the evaluation of adjustments. There are two methods which attempt to account for these uncertainties: uncertainty analysis and risk analysis.

7.6.1 Uncertainty analysis
Uncertainty analysis comprises a set of techniques for anticipating and preparing for the impacts of uncertain future events. It is used here to describe an analysis of the range of uncertainties encountered in an assessment study.

7.6.2 Risk analysis
Risk analysis deals with uncertainty in terms of the risk of impact. Risk is defined as the product of the probability of an event and its effect on an exposure unit. Since it is extreme events that produce the most significant impacts, there is value in focusing on the changing probability of climatic extremes and of their impacts. Another form of risk analysis, decision analysis, is used to evaluate response strategies to climate change. It can be used to assign likelihoods to different climatic scenarios, identifying those response strategies that would provide the flexibility, at least cost, (minimizing expected annual damages), that best ameliorates the anticipated range of impact.

8 Steps Six and Seven–Assessment of Autonomous Adjustments and Evaluation of Adaptation Strategies
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 and are not already automatic or built into future projections. Two broad types of response can be identified: mitigation and adaptation.

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 emission from sources of GHGs and enhancing potential sinks for GHGs. The evaluation of mitigation policies is outside the scope of these Guidelines.

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. It thus implicitly recognizes that future climate changes will occur and must be accommodated in policy.

8.2 Steps in evaluation of an adaptation strategy

A broad framework for the evaluation of adaptation strategies to cope with climate change can be identified. This comprises the following steps:

- Define the objectives.
- Specify the climatic impacts of importance.
- Identify the adaptation options.
- Examine the constraints.
- Quantify measures and formulate alternative strategies.
- Weight objectives and evaluate trade-offs.
- Recommend adaptation measures.

8.2.1 Defining the objectives

Any analysis of adaptation must be guided by some agreed overall goals and evaluation principles. Two examples of general *goals* commonly propounded are: (i) the promotion of sustainable development, and (ii) the reduction of vulnerability. These are open to various interpretations, however, 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 stated above, or any combination of these.

8.2.2 Specifying the climatic impacts of importance

This step involves an assessment, following the methods outlined elsewhere above, 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.

8.2.3 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 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, as well as possible alternative strategies that have not been used, and newly created or invented strategies.

Six types of strategy for adapting to the effects of climate have been identified:

- *Prevention of loss*, involving anticipatory actions to reduce the susceptibility of an exposure unit to the impacts of climate.
- *Tolerating loss*, where adverse impacts are accepted in the short term because they can be absorbed by the exposure unit without long term damage.
- *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.
- *Changing use or activity*, involving a switch of activity or resource use to adjust to the adverse as well as the positive consequences of climate change.
- *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.
- *Restoration*, which aims to restore a system to its original condition following damage or modification due to climate.

Numerous options exist for classifying adaptive measures, but generally, regardless of the resources of interest (e.g., forestry, wetlands, agriculture, water) the prospective list may include among other management measures:

- Legal
- Financial
- Economic
- Technological
- Public education
- Research and training

8.2.4 Examining the constraints

Many of the adaptation options identified in the previous step are likely to be subject to legislation or be influenced by prevailing social norms, which 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.

8.2.5 Quantifying the measures and formulating alternative strategies

The next step is to assess the performance of each adaptation 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 climatic 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. 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.

8.2.6 Weighting objectives and evaluating trade-offs

This is the key evaluation step, where objectives must be weighted according to assigned preferences and then comparisons made between the effectiveness of different strategies in meeting these objectives. Standard impact accounting systems can be used in the evaluation. For example, a four-category system might consider: (i) national economic development; (ii) environmental quality; (iii) regional economic development; and (iv) other social effects. Selection of preferred strategies then requires the determination of trade-offs between the categories.

8.2.7 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.

9 References

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