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CONCEPTUAL FRAMEWORKS OF ADAPTATION TO CLIMATE CHANGE AND THEIR APPLICABILITY TO HUMAN HEALTH

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Abstract

Anthropogenic climate change will affect the distribution and urgency of health risks around the world. However, the majority of adverse health impacts of climate change can be avoided by implementing suitable adaptation policies. Planned adaptation to the health impacts of climate change comprises a broad range of public health interventions. Most of these measures are not only effective in a changed climate but they also current health risks. Successful planned adaptation depends on an awareness of and information about the problem, on the existence of effective response strategies, and on the availability of the resources, information, and incentives to actually implement them. The main challenges in developing adaptation strategies for human health are to account for the diversity of health impairments, regional conditions and adaptation actors, and for the large uncertainty about future changes in most climate-sensitive health risks.

This report reviews a broad range of 'conceptual frameworks of adaptation' as to their relevance for assessments of planned adaptations to the health impacts of climate change. These frameworks originate from the largely distinct communities concerned with climate change, public health, natural hazards, and risk management. The term 'conceptual framework of adaptation' is used here to denote any representation of concepts that can assist the design and assessment of policy strategies aimed at reducing climate-sensitive health effects. In our review, we distinguish the following categories of conceptual frameworks: typologies of climate change assessments; guidelines for climate change risk assessments; conceptual frameworks for vulnerability and adaptation to climate change; typologies of adaptation measures and adaptive systems; and evaluation frameworks for adaptation strategies.

We fnd that no single approach to adaptation policy assessment can deal with the diversity of climate-sensitive health impairments, regions, and information needs of adaptation actors. Further more, no single conceptual framework addresses all questions that are important in adaptation assessments for human health. However, the review of the diverse set of conceptual frameworks enables us to name the most important guidelines for human health vulnerability and adaptation assessment; to identify those criteria that determine the most suitable approach for assessing adaptation to the health effects of climate change in different decision situations; to evaluate the potential for and urgency of planned adaptation; and to identify key questions for developing and implementing effective adaptation strategies to be addressed in any adaptation assessment for human health.

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Chapter 1

Introduction

Climate is an important environmental factor for human health and well-being. Hence, any major change in climatic conditions is likely to have consequences for human population health. Anthropogenic climate change is likely to increase health risks in most regions of the world. However, societies can avoid many of these impacts by implementing policies that increase their capacity to cope with this new hazard. The development of these policies touches the areas of interest of several scientific communities, including those concerned with public health, adaptation to climate change, natural hazards, and risk management. The present document reviews conceptual frameworks developed by these different communities as to their applicability in national and regional assessments on adaptation to the health impacts of climate change and variability. It contributes to the cCASHh project, a European-wide research project aimed at providing guidance to communities in performing such adaptation assessments.

This introductory chapter summarizes key aspects of the relationship between climatic factors and health outcomes (Section 1.1); presents the main policy responses to reduce the risks of climate change (Section 1.2); discusses the preconditions for planned adaptation to reduce climate-sensitive diseases (Section 1.3); introduces the main categories of 'conceptual frameworks of adaptation' (Section 1.4); gives a short description of the cCASHh project (Section 1.5); and outlines the purpose and scope of this literature review (Section 1.6).

1.1 Climate change and human health

The emission of large amounts of greenhouse gases since the begin of the industrial revolution has significantly altered the energy balance of the Earth. As a result, climate is changing on a global scale and will continue to do so for at least the next decades to come. Human population health is affected by changes in climatic factors both directly (*e.g.,* by increased frequencies of heatwaves) and indirectly (*e.g.,* due to altered ranges of disease vectors). Health problems already prevalent today may become more (or less) urgent, and new health risks may be introduced to currently unaffected regions. For recent overviews of anticipated climate-related health effects in Europe and worldwide, see Kovats et al. (2000a) and McMichael and Githeko (2001), respectively.

Most human and natural systems are sensitive to climatic changes. However, human health differs from other impact domains in various ways. The pathways along which climate change affects human health are often long and complex, and uncertainties accumulate along them. The majority of health impacts are strongly influenced by behavioural factors and by the socioeconomic characteristics of the community such as the overall level of economic development, the state of sanitation and public health systems, and building standards. Since climate is but one of many factors that determine the status of population health, assessing the role of climate in disease occurrence requires careful analysis. In addition, data acquisition is often more difficult in human health than in other impact domains because it usually depends on human co-operation and there is limited scope for controlled experiments.

Not only is human health distinct from other climate-sensitive domains, but anthropogenic climate change is also distinct from other environmental threats to human health. The most important differences are the large spatial scale of the problem, the very long time horizon to be considered, the uncertainty related to future scenarios of climatic hazards, and the complexity of the relationship between climatic factors and health outcomes. Therefore, the prevailing toxicological model of environmental health where a defined exposure to a specific agent causes an adverse health outcome to identifiable exposed populations is often not applicable to climate-sensitive health issues. In this situation, standard procedures for quantitative risk assessment are often less important for assessing climate-health associations than expert judgement, analogue studies, process-based and empirical modelling, and other integrated assessment methods. (For a more detailed discussion of this topic, see Section 3.2.)

1.2 Fundamental options for reducing the risks of climate change

Societies can respond to the threat of anthropogenic climate change by two fundamental mechanisms: mitigation and adaptation. In the terminology of the climate change community, mitigation of climate change refers to actions that limit the amount and rate of climate change by constraining the emissions of greenhouse gases or enhancing their sinks. Adaptation to climate change, in contrast, refers to any actions that are undertaken to avoid, prepare for or respond to the detrimental impacts of observed or anticipated climate change.

Mitigation and adaptation differ significantly in terms of their type of actions, scope, geographical scale, lead time, secondary benefits, equity aspects, and principal actors. Mitigation is the only strategy that can reduce impacts of climate change on all systems and on a global scale. It implements the precautionary principle and the polluter-pays principle, which are widely accepted principles in sustainable development and in international environmental policy. The primacy of mitigation is also acknowledged in the ultimate objective of the UN Framework Convention on Climate Change, which demands the "stabilization of atmospheric greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system". However, mitigation requires international cooperation and takes a long time to become fully effective because of the inherent inertia of the climate system. Adaptation, in contrast, can reduce climate-related risks in human-managed systems on a regional scale, and often with a short lead time. However, its scope is generally limited to specific systems and risk types.

Mitigation and adaptation differ considerably in their information needs. Figure 1.1 presents a stylized picture of the cause-effect chain from greenhouse gas emissions to their eventual health effects. It also shows the accumulation of uncertainty from different sources along that cause-effect chain and the target points for intervention. It can be seen that the development of effective and efficient adaptation policies requires detailed knowledge about the vulnerable system, the climatic and non-climatic stressors that it is exposed to, and how they might change in the future. The design and implementation of mitigation measures, in contrast, does not rely on specific knowledge about future climate change and its impacts.

Adaptation is often distinguished into 'autonomous' and 'planned' adaptation, depending on the level of conscious planning by a specific actor. Planned adaption to climate change comprises any actions undertaken with the intention to reduce adverse impacts, or exploit beneficial impacts, of experienced or anticipated climate change. Obviously, reliable information about future climate change and the associated risks is crucial for anticipatory adaptation.

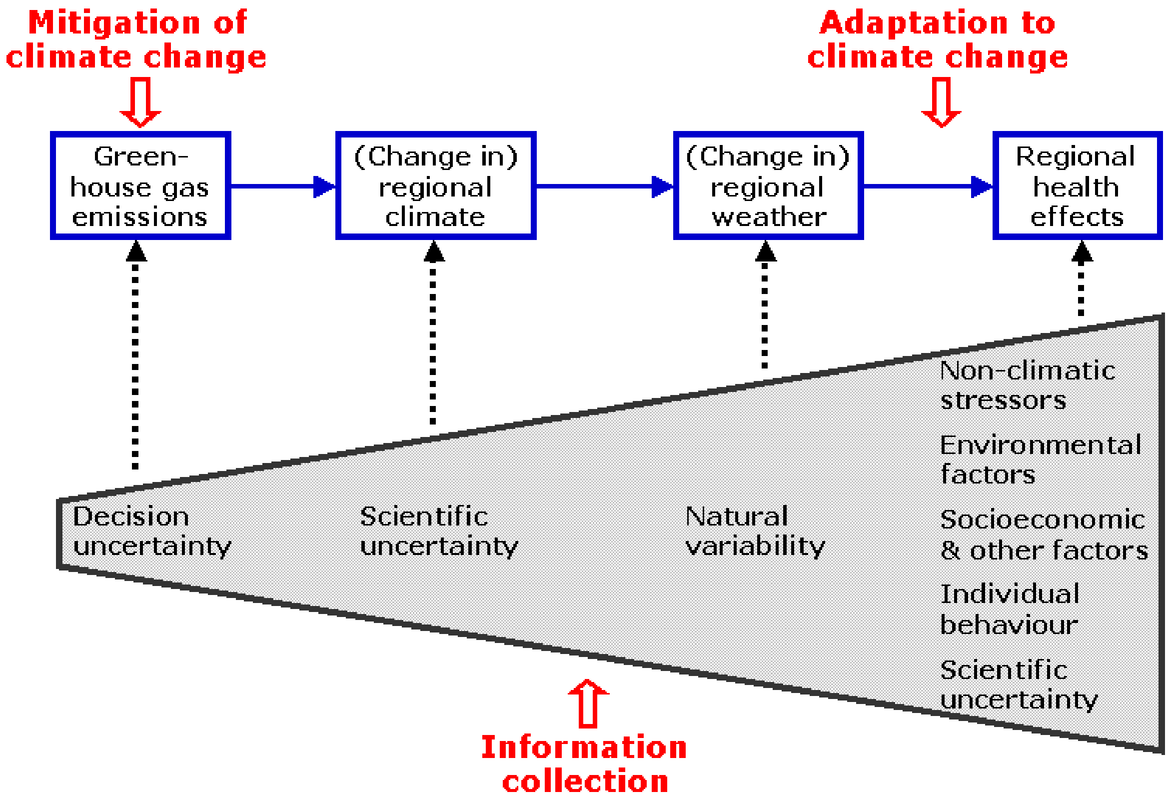


Figure 1.1: Cascade of uncertainties in the assessment of climate impacts on human health. Blue: Simplified causal chain; black: sources of uncertainty; red: fundamental response options. *Source:* adapted from Füssel (2003)

While ‘planned adaptation to climate change’ is triggered by experienced or anticipated climate change, it actually comprises much more than that. Depending on the circumstances, ‘planned adaptation to climate change in human health’ is likely to also comprise issues such as improved adaptation to current climate variability, management of natural resources, sustainable economic development, infrastructure development, and basic health care. As a result, most adaptation measures triggered by anticipated future climate change will also provide benefits under current climate conditions. The relative weights put on the reduction of potential future impacts compared to current risks depends on factors such as the magnitude of current risks, the magnitude of potential future risk changes, the reliability of future risk projections, and the lead time of effective response measures.

1.3 Planned adaptation to the health impacts of climate change

Planned adaptation to the health impacts of climate change comprises a wide range of preventive public health measures. Eventually, behavioural changes, medical interventions, improved infrastructure, or the use of technologies are required to reduce adverse health effects of climate change and variability. The public health sector and other relevant sectors may facilitate these actions by appropriate educational, institutional, legal and other measures. Many measures considered in adapting to future climate change are not new, and most of them also reduce the vulnerability to current climate variability. However, adaptation to climate change may require action by institutions or individuals who have not considered climate an important factor for their decisions in the past.

Successful planned adaptation to climate change to a large extent depends on five preconditions. These elements, and their relationship to adaptation assessment and planning, are as follows:

Availability of effective intervention measures: This element is beyond the control of adaptation policy. For instance, many climate impacts on natural ecosystems cannot be prevented by any conceivable means.

Availability of resources to implement these measures: Adaptation measures will not be implemented if the resources (in a broad sense) for doing so are not available. The relationship between adaptation assessment and this element is ambivalent. On the one hand, an assessment should be based on reasonable assumptions about the resources available for adaptation. On the other hand, the outcomes of the assessments may be used to mobilize additional resources either domestically or internationally.

Awareness of the problem: Adaptation measures will not be implemented if the relevant adaptation actors are not aware that there is (or will be) a problem. Assessing the risks associated with anthropogenic climate change, and raising awareness about them, is the domain of climate impact (or vulnerability) assessment, which is an important component of any adaptation assessment.

Information about these measures: Adaptation measures will not be implemented if the relevant adaptation actors have no information about them. Adaptation policy assessments address this element by suggesting effective intervention measures.

Incentives for actually implementing these measures: Adaptation measures will not be implemented if the relevant adaptation actors have no incentive to do so. Many adaptation measures have immediate benefits to the person or organization implementing them. Other measures may have immediate costs but only delayed, uncertain benefits. Preventive measures implemented by government agencies (including health authorities) may have no direct benefits at all to the organization implementing them. Therefore, an analysis of the incentive structure of the relevant adaption actors is an important component of an adaptation policy assessment, in particular if multiple actors are concerned.

For adaptation to be successful, all five preconditions have to be met to a certain degree. Since the main obstacles to successful adaptation will vary from one context to another, it is important to analyze each of these preconditions. Based on this analysis, scientific and political efforts can then be targeted on those elements that are most in need of improvement.

Adaptation policy assessments for climate change and human health aim to assist health managers in their decisions by identifying policies that reduce, with the least cost, death, disease, disability and human suffering related to climatic stimuli. They do so by combining information about current health issues in a population, future changes in climatic and non-climatic risk factors, the relationship between these risk factors and specific health outcomes, and interventions to reduce climate-sensitive health risks. This task involves the integration of ideas from climate impact and adaptation assessment, disaster risk management, health impact assessment, comparative risk assessment, and effectiveness of intervention studies.

Arguably, the most important challenges for the development of adaptation strategies to climate change in human health are diversity (or heterogeneity) and uncertainty. Let us explore these issues in some more detail:

Diversity of health impairments: The causal pathways linking climatic stimuli with specific health outcomes are very heterogeneous. The most fundamental distinction is the one between direct and indirect health effects of climatic stimuli. However, each of these groups is itself composed of diseases with diverse causal structures. Hence, adaptation assessments for human health need to apply different methodological approaches for different climate-sensitive health impairments.

Diversity of regions: Different regions vary widely as to the availability of data, knowledge, infrastructure, and financial resources for the assessment of vulnerability to climate change and for the implementation of adaptation measures. They also differ with respect to the current levels of climate-sensitive diseases, the characteristic time horizon of decisions, and other factors that are relevant for adaptation. Hence, the choice of the assessment methodology and of the portfolio of potential adaptation measures needs to take into account the specific characteristics of the assessment region.

Diversity of actors: The actors that would implement adaptation measures to reduce the burden of climate-sensitive diseases are a heterogeneous group with widely varying information needs and incentive structures. Hence, the key questions addressed in an adaptation assessments are likely to differ according to the level and institutional background of the main stakeholders addressed.

Uncertainty about future changes in risk levels: Planned adaptation to climate change is, by definition, motivated by the concern about future increases in health risks caused by anthropogenic climate change. However, many projections of relevant changes in climatic stimuli are associated with large uncertainties, including even uncertainties about the direction of change. Large uncertainties may also exist about the relationship between climatic stimuli, non-climatic factors, and disease outcomes. As a result, uncertainties about future risk levels are at the core of any adaptation decision rather than being a nuisance that can be easily neglected.

Diversity across health impairments and regions also applies to the level of uncertainty. The reliability of future risk projections varies widely across health outcomes and regions depending on the specific climatic stimuli involved in the causation of the disease and on the regional availability of data and expertise to produce state-of-the-art scenarios of future risks.

Adaptation assessments for human health, and even more so 'conceptual frameworks' intended to provide guidance to such assessments, need to account for these issues. Otherwise they run the risk of transferring concepts or solutions from a specific context where they *were* appropriate to a new context where they are *not*.

1.4 Conceptual frameworks of adaptation to climate change

Planned adaptation to the health impacts of climate change touches upon issues that have traditionally been discussed in the distinct communities concerned with climate and climate change, public health, disaster risk management, and environmental management. Each of these communities has developed their own approach to assess the problem in order to provide the information needed to guide actions within their specific area of responsibility.

Given the diversity of approaches, methodologies, and terminologies involved, it is important that the participants in an adaptation assessment agree on a common framework that clarifies (at least) the following aspects:

- Aims and objectives of the assessment
- Conceptual model of the relevant system components and processes

- Definitions of relevant concepts and terms
- Choice of the overall methodology

The most suitable choice for some of these aspects will vary across assessments, depending on regional circumstances such as the type of health effects potentially affected by climate change; the current health status of the population; the level of socioeconomic development, including public health infrastructure; the availability of data, technical know-how, and financial resources; and cultural preferences.

We start from the assumption that valuable guidance for individual assessments can be derived by reviewing relevant concepts and approaches from the different communities involved as well as lessons learnt from previous assessments. The most important topics where such advice is warranted are:

- Key factors of the decision situation that determine the framing of an adaptation assessment
- Common steps in an adaptation assessment
- Key concepts and terms (and possible pitfalls in using them)
- Factors that determine the need for, and urgency of, additional policy measures
- Criteria to evaluate the suitability of suggested policy measures

The term 'conceptual framework of adaptation to climate change in public health' is used here to denote any document or other representation of concepts that addresses some or all of the above-mentioned issues. As there are generally many valid perspectives on a complex phenomenon such as climate-sensitive health risks, a multitude of conceptual frameworks may exist, each of which serving a distinct purpose. Conceptual frameworks of adaptation to climate change in public health have been developed to describe, among others, the causal chain linking certain climate and health indicators, the dynamics of the system under consideration, and the structure of the adaptation process. According to this broad definition, the distinction of five preconditions for successful adaptation in Section 1.3 may also be considered a 'conceptual framework for adaptation'. Any 'conceptual framework' that aims to assist adaptation assessments for human health needs to be flexible enough to account for the diversity of decision contexts discussed above. In fact, we consider guidance on the selection of the most suitable approach for vulnerability assessment and adaptation planning in a particular decision context one of the most relevant topics for a 'conceptual framework of adaptation to climate change in human health'. (For additional information about the understanding of a 'conceptual framework of adaptation' in the cCASHh project, see Section 1.6.)

Important ideas of a conceptual framework are often represented graphically, in particular by various kinds of 'box-and-arrows diagrams'. Caution needs to be applied in interpreting these diagrams because the same graphical element may represent very different concepts, depending on the context. For instance, arrows are used to represent the following concepts:

- Information flow (*e.g.,* Figure 3.8)
- Work-flow (*e.g.,* Figure 3.10)
- Causal relationship (*e.g.,* Figure 4.1)
- Other functional relationship (*e.g.,* Figure 4.5.b)
- Temporal sequence (*e.g.,* Figure 4.16)

- Membership in a superset (*e.g.,* Figure 5.1)

Some diagrams use more than one type of arrows to illustrate different kinds of relationships between elements of the respective framework (*e.g.,* Figures 2.2 and 4.3); other diagrams lack an explanation of what the arrows stand for, or they seem to use them inconsistently (*e.g.,* Figures 4.8, 4.15, and 4.16).

1.5 The cCASHh project

The cCASHh (Climate change and adaptation strategies for human health in Europe) project is an interdisciplinary research effort to conduct a pan-European adaptation policy assessment for climate change and human health, and to provide guidance for more detailed national and regional assessments. cCASHh is funded within the Fifth Framework Programme for Research of the European Union and conducted by an international research consortium under the guidance of the World Health Organization (WHO) Regional Office for Europe.

The key objectives of the research in cCASHh, according to its Work Programme, are:

- to identify the vulnerability of European populations to adverse impacts of climate change on human health;
- to review current measures, technologies, policies, and barriers to improve the adaptive capacity of human populations to climate change;
- to identify for European populations the most appropriate measures, technologies and policies, as well as the most effective approaches to implementation, in order to successfully adapt to climate change;
- to estimate the health benefits of specific strategies or combinations of strategies for adaptation for vulnerable populations that are robust under different climate change scenarios; and
- to estimate the health-related ‘costs’ of climate change (associated with the implementation of adaptive measures and due to residual health impacts) and the benefits of adaptation strategies (including co-benefits independent of climate change) for different climate scenarios and adaptation strategies.

Using the terminology of the climate change community, these objectives can be rephrased as follows:

Vulnerability assessment: to provide new knowledge on the vulnerability of population health in Europe to anthropogenic climate change.

Adaptation policy assessment: to combine different sources of knowledge in order to provide recommendations for planned adaptation to climate-sensitive health risks in Europe, in particular by public bodies.

Guidelines for vulnerability and adaptation assessment: to assist national and regional governments in conducting more detailed vulnerability and adaptation assessments within their jurisdiction.

The research in cCASHh focusses on four types of climate-sensitive health effects: temperature-related morbidity and mortality, injuries and illnesses from extreme weather events, vector-borne diseases, and food- and water-borne diseases. The main tools applied are vulnerability assessment, policy analysis, economic analysis and scenario analysis.

1.6 Purpose and scope of this literature review

The cCASHh project is implemented by an international and interdisciplinary group of researchers. Recognizing the need to integrate the different assessment approaches of this diverse team, the project contains a separate (albeit small) Work Package 2, termed 'Elaboration of a conceptual framework of adaptation to climate stimuli in public health'. This literature review is a contribution to that Work Package. Its specific purpose is to identify existing 'conceptual frameworks of adaptation to climate change', and to evaluate their applicability to national and regional adaptation policy assessments of climate change and human health.

We have outlined in Section 1.4 our understanding of the term 'conceptual framework of adaptation'. The description of Work Package 2 provides the following, rather ambitious, objective for the 'conceptual framework of adaptation' to be developed in cCASHh:

> *"This framework will describe the process of adaptation in the human health sector, specifying relationships and feedback between climatic stimuli, sensitivity and vulnerability of human population and interconnected systems, short term and autonomous ways of adaptation, initial impacts, long-term or strategic adaptations and net residual impacts. [...] These conceptualizations of the processes, sequences and interconnections commonly provide the framework or structure for empirical analysis and for numerical impact assessment modelling."*

While no single 'framework' can fulfill all these purposes at the same time, the cited text indicates that guidance is sought on the following issues:

- the process of adaptation;
- causal relationships between key phenomena;
- the conceptualization of key terms;
- typologies of adaptation measures; and
- the structure of quantitative impact and adaptation assessments.

Responding to these needs, this review considers several categories of 'conceptual frameworks of adaptation', each of which will be discussed in a separate chapter. The types of frameworks reviewed, and the questions addressed by them, are as follows:

Chapter 2: Typologies of climate change assessments

How can climate change assessments be categorized?

Chapter 3: Guidelines for climate change assessments

Which steps are involved in an assessing vulnerability to climate change and developing effective adaptation strategies, and how should these steps be implemented?

Chapter 4: Conceptual frameworks for vulnerability and adaptation

Which system components and/or analytical concepts are important to assess adaptation, and how are they related?

Chapter 5: Typologies of adaptation

How can adaptation measures and adaptive systems be categorized?

Chapter 6: Evaluation frameworks for adaptation strategies

How can the quality of adaptation be assessed?

In each chapter, the health-specific frameworks are discussed first, and the generic ones afterwards. The reviews of the more important frameworks in the Chapters 3 and 4 are further structured as follows, wherever applicable:

- Purpose
- Content
- Application
- Evaluation
- Applicability to climate change and human health

It shall be emphasized that all conceptual frameworks are evaluated here exclusively as to their applicability for adaptation policy assessments of climate change and human health. Hence, an evaluation as 'unsuitable' shall only be interpreted to the effect that a specific framework is of limited applicability in the context of cCASHh and similar assessments. In particular, it does *not* suggest that the framework is regarded as useless for the purpose for which it was originally developed.

This literature review is based on a broad range of sources from a variety of disciplines. The search strategy comprised the following main tasks:

- Systematic review of the literature cited in the relevant chapters of the IPCC Third Assessment Report (Ahmad and Warrick, 2001; McMichael and Githeko, 2001; Smit and Pilifosova, 2001), in pertinent publications of the WHO (WHO, 1996a, 1997a, 1999a, 2002a; Kovats et al., 2000b) and in other key publications (*e.g.,* Klein and Nicholls, 1999; Klein et al., 1999; Smit et al., 2000).
- Keyword searches in bibliographic databases and in internet-based search engines.
- Systematic review of relevant journals in the fields of climate change and public health.
- Recommendations from key scholars in relevant fields.

Chapter 2

Typologies of climate change assessments

A typology of climate change assessments provides a framework for the classification of assessments according to criteria such as their purpose, methodological foundation, level of detail, etc. This chapter presents the most important typologies for climate change assessments, discusses their relevance for human health, and characterizes the cCASHh project according to these schemes.

2.1 Analytical function

Climate change adaptation assessments can be distinguished according to their analytical function, as illustrated in Figure 2.1. A *positive* (or descriptive) adaptation assessment, as part of a climate impact or vulnerability assessment, aims at predicting what adaptations are *likely*, and what their aggregate effects are, in order to better estimate the residual impacts of climate change. A *normative* adaptation assessment, as part of an adaptation policy assessment, addresses the question what planned adaptations are *recommended*. To this end, it compares the effects of specific planned adaptations against a baseline of autonomous adaptations.

Both types of adaptation assessments are relevant for human health. Whereas positive adaptation assessments contribute to the realistic estimation of the future burden of disease attributable to global climate change, normative adaptation assessments aim at identifying strategies that reduce the burden of disease under given restrictions, such as resource availability. The cCASHh project clearly falls into the second category.

2.2 Generations of climate change assessment

In their review of the evolution of climate change assessments, Füssel and Klein (2002) have refined the classification of climate change assessments presented in Section 2.1. They distinguish several generations of climate change assessments according to the decision context in which the results are mainly applied. These generations of assessments, and their respective policy purposes, are as follows:

Climate impact assessment: Specification of long-term targets for the mitigation of global climate change and identification of additional research needs.

Most of the assessments carried out in the past were climate impact assessments, the goal of which has been defined by the Intergovernmental Panel on Climate Change (IPCC) as “identifying and

	Adaptation as part of IMPACT ASSESSMENT	Adaptation as part of POLICY EVALUATION
Analytical Function	Positive	Normative
Purpose	Predict, Estimate Likelihood	Evaluate, Prescribe
Central Question	What Adaptations are Likely?	What Adaptations are Recommended?
UNFCCC Article	Art. 2. are the impacts likely to be dangerous for ecosystems, food production and sustainable economic development?	Art. 4. which measures should be formulated and implemented to facilitate adequate adaptation?

Figure 2.1: Different purposes of adaptation assessment. *Source:* Smit et al. (1999)

evaluating the detrimental and beneficial consequences of climate change on natural and human systems" (McCarthy et al., 2001). Climate impact assessments focus on the incremental effects of anthropogenic climate change. They bring attention to the anticipated effects of climate change and assess the potential for constraining them by mitigating the magnitude and rate of anthropogenic climate change.

Climate vulnerability assessment: Identification of regions or communities that are particularly vulnerable to climate change in order to prioritize the allocation of resources at the national or international level.

Vulnerability assessments, as understood in the context of climate change, integrate the results of impact assessments in a wider context. They achieve this by

- assessing global climate change together with other stressors to a system, such as natural climate variability and socioeconomic factors;
- taking into account the uncertainty about the future development of external stress factors and the system under consideration;
- evaluating the impacts, including their distribution, in terms of their importance for human societies; and
- considering likely adaptations to changing climatic conditions and their potential to reduce adverse impacts.

An important aspect of vulnerability assessments is that they integrate the natural and the social sciences. Most vulnerability assessments also integrate non-scientific knowledge by involving relevant stakeholders. However, the main focus is still a descriptive one, namely to assess the magnitude and likelihood of adverse consequences of climate change, and potentially other aspects of global change, on a system or society. Vulnerability assessments may be further distinguished into first- and second-generation vulnerability assessments, depending on the level of consideration of the adaptive capacity of the vulnerable system.

Adaptation policy assessment: Design and implementation of adaptation strategies for specific regions and/or sectors.

Adaptation policy assessments have an explicit normative purpose. They aim at recommending adaptation policies that reduce the vulnerability of a specific system to climatic stressors. This purpose requires close interaction with relevant stakeholders, consideration of wider policy goals, and explicit consideration of the uncertainties in projections of regional climate change and its impacts. Since the evaluation of complex policies under conditions of substantial uncertainty can never be done on a purely objective basis, adaptation policy assessments always include a normative component.

Figure 2.2 illustrates important aspects of the framework developed by Füssel and Klein (2002). The diagram provides a visual glossary of key concepts and terms in climate change assessments that is consistent with their definitions in the IPCC Third Assessment Report. Different colours are used to represent the evolution of conceptual thinking about vulnerability and adaptation in the climate change community. They refer to the successive inclusion of new elements and relationships in different generations of vulnerability assessments.

Figure 2.3 applies this framework to human health, including the four diseases addressed in cCASHh. The main difference between the general framework in Figure 2.2 and the health-specific frameworks in Figure 2.3 is that the 'Vulnerability' box is missing in the latter frameworks. The standard use of the term 'vulnerability' differs significantly between the climate change and the public health communities due to the different focus of their respective interest. Hence, this term should only be used with considerable caution across the two communities.

An important aspect of adaptation highlighted in Figure 2.3 is the broad range of potential adaptation measures, as represented by the multitude of bold dotted arrows starting from the 'Implementation' box within the 'Adaptation' box. Taking heat stress as an example, these arrows may represent the ability of adaptation measures to reduce any of four determinants of the impacts of climate change on human health:

- **exposure** to heat stress (*e.g.,* through the provision of cool environments),
- **sensitivity** to heat stress (*e.g.,* through advice on adequate drinking behaviour),
- **impacts** of heat stress (*e.g.,* through provision of better health care to those still affected), and
- **non-climatic risk factors** (*e.g.,* through measures that temporarily reduce urban air pollution).

2.3 Methodological approaches to adaptation policy assessment

The User's Guidebook to the UNDP–GEF Adaptation Policy Assessment (UNDP, 2003, see also Section 3.6) recommends four approaches to adaptation assessment:

Climate hazard approach: Analyze possible outcomes from a specific climate hazard

Vulnerability-based approach: Determine likelihood that current or desired vulnerability may be affected by future climate hazards

Policy analysis approach: Investigate the efficacy of an existing or proposed policy in light of a changing exposure or sensitivity

Adaptive capacity approach: Analyze the barriers to adaptation and propose how they can be overcome

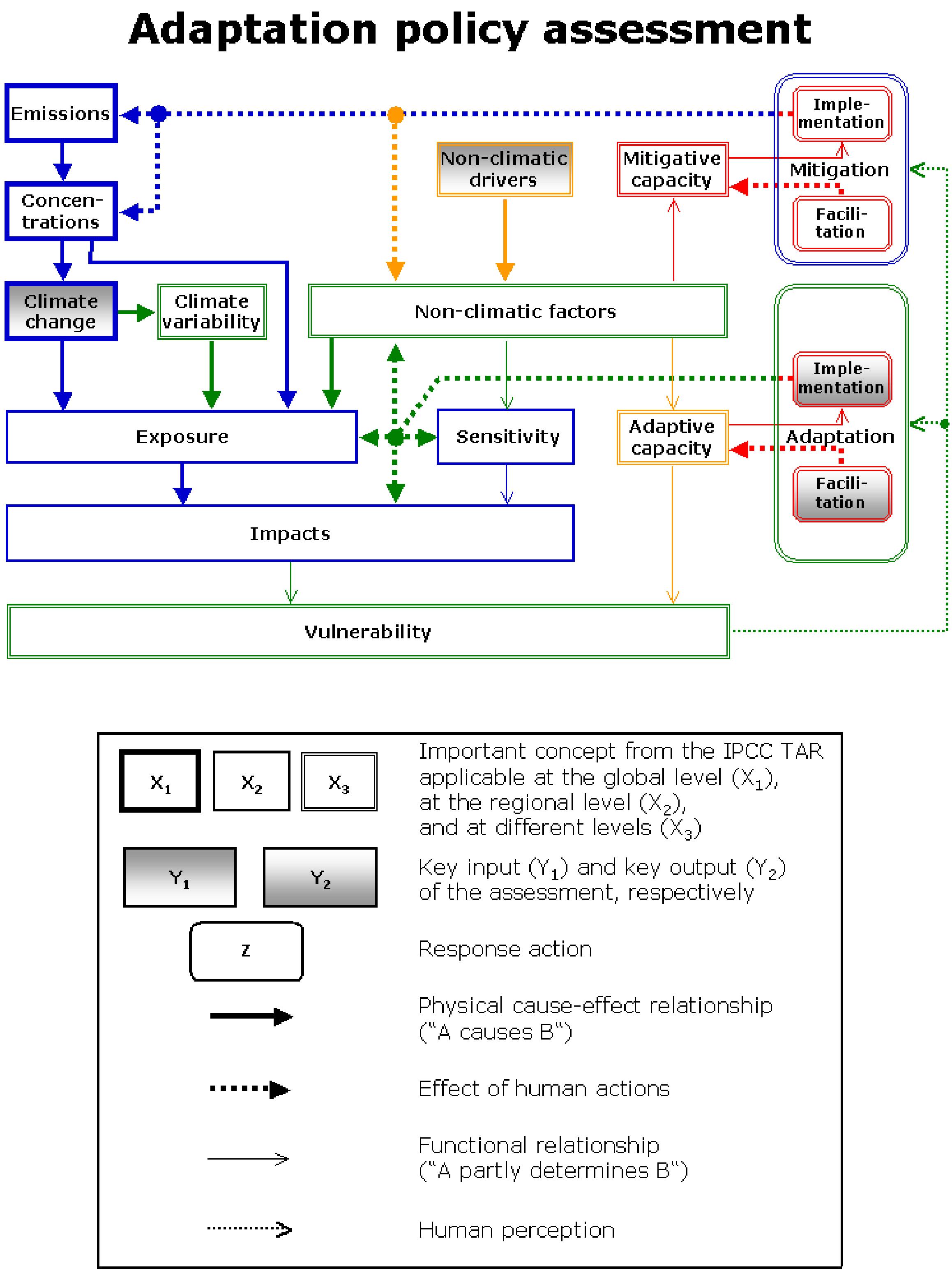


Figure 2.2: Conceptual framework for adaptation policy assessment. The colours refer to different generations of vulnerability assessments: blue: impact assessment; green: first-generation vulnerability assessment; yellow: second-generation vulnerability assessment; red: adaptation policy assessment. *Source:* Füssel and Klein (2002)

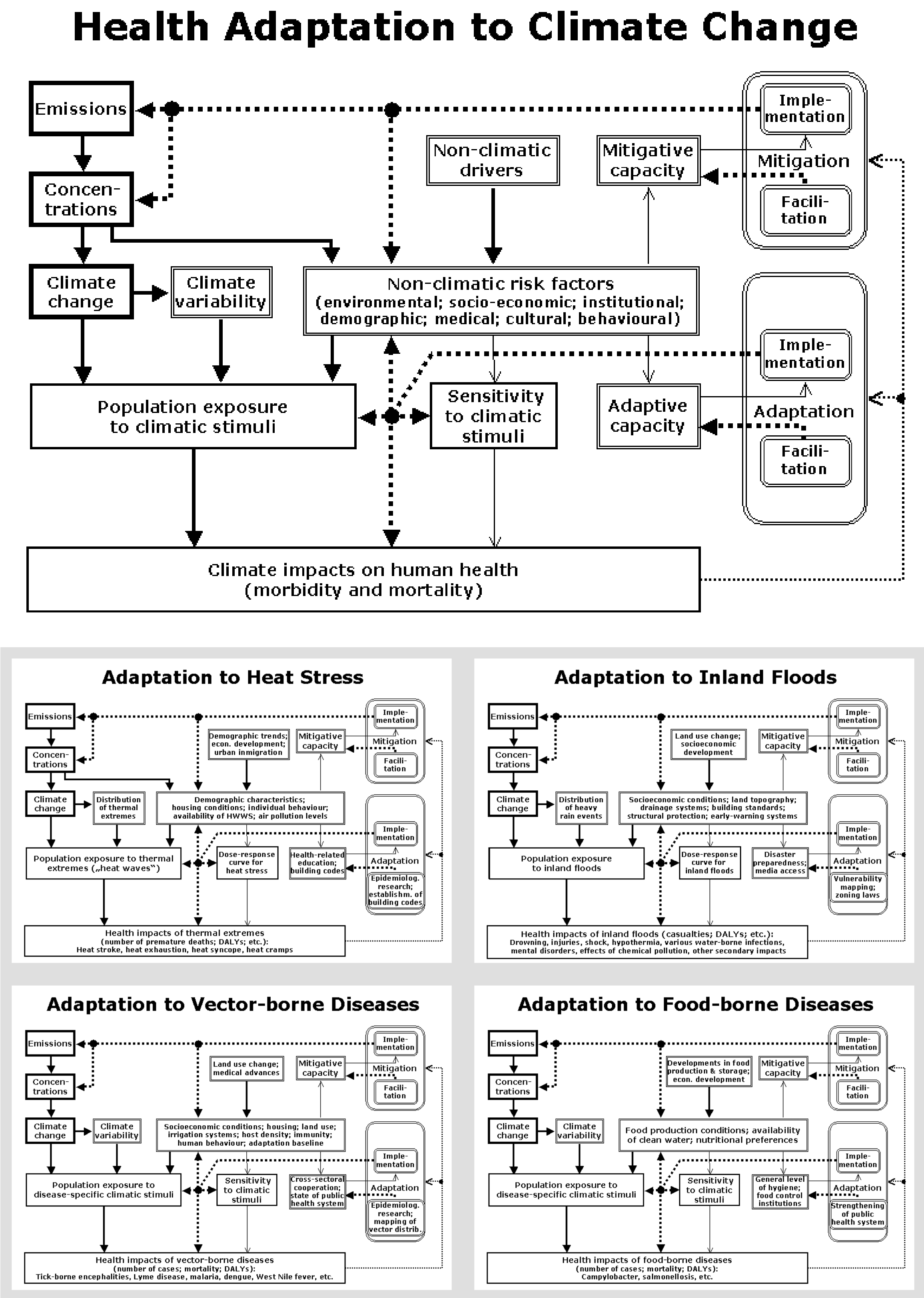


Figure 2.3: Conceptual frameworks for adaptation to the health effects of climate change. *Top:* Generic framework; *Bottom:* Application to the four different diseases addressed in cCASHh. *Source:* Füssel et al. (2004)

Each of these approaches focuses on a different aspect of the decision context: on a specific stressor to a system, on the vulnerable system itself, on a specific policy decision, and on barriers to implement certain changes, respectively. Hence, the choice of a particular method has direct implications for the level of effort associated with certain aspects of the adaptation assessment. The climate hazard approach, for instance, requires significant efforts to develop future climate scenarios whereas other approaches call for a deeper understanding of socioeconomic aspects of current vulnerability.

The documentation of the Adaptation Policy Framework emphasizes that the different methods are complementary and can be used separately or together. The following 'checklist' is provided to determine the efficacy of using the first two approaches in an assessment (Jones and Mearns, 2003):

Method	**Natural hazard**	**Vulnerability**
Hazard characte-rization	Ranges of uncertainty, described by climate scenarios and/or characterization of hazard under climate change well-calibrated.	Ranges of uncertainty, described by climate scenarios and/or characterization of hazard under climate change *not* well-calibrated.
Drivers of change	Main drivers known and understood	Many drivers with multiple uncertainties
Structure	Chain of consequences understood	Multiple pathways and feedbacks

An important aspect not mentioned in this table is the time horizon of adaptation decisions. The longer the lifetime of a decision, the more important it is usually to include information about future climate scenarios in addition to current vulnerabilities.

2.4 Level of assessment

Klein and Nicholls (1999) distinguish three different levels of coastal zone vulnerability assessment according to their complexity and resource requirements:

Screening assessments focus on the biophysical determinants of vulnerability. They assess the sensitivity of the coastline to sea-level rise and relate it to the expected exposure level. As a result, screening assessments identify those regions whose biophysical characteristics suggest that they are potentially vulnerable and that a more detailed vulnerability assessment is warranted.

Vulnerability assessments constitute a more comprehensive analysis of potentially vulnerable regions. They include explicit assessments of biogeophysical effects, socioeconomic impacts, and the potential for adaptation.

Planning assessments provide the foundation for detailed sectoral planning in regions identified as vulnerable to sea-level rise. They evaluate potential adaptation measures, recommend a specific adaptation strategy, and integrate it in a wider policy context.

In each impact domain, vulnerability assessments will be conducted at different levels depending on the availability of previous data and knowledge, the amount of resources, and other factors. However, the three levels of assessments proposed for coastal zones are not directly applicable to human health because of important differences between the two domains. These differences are related to the basic unit of analysis, the possibility to separate biophysical and social impacts, the number and complexity of causal pathways, the predictability of changes in relevant climatic factors, and the type of adaptation measures.

Kovats et al. (2003b) suggest to distinguish three levels of adaptation assessment for human health based on the amount of new data collected, and of new analysis performed. These assessments were denoted as ‘basic assessment’, ‘more comprehensive assessment’, and ‘even more comprehensive assessment’. For the WHO European region investigated in cCASHh, a basic assessment already exists (Kovats et al., 2000a). The assessments performed in the cCASHh project would be classified into one of the two ‘more comprehensive assessment’ categories, depending on the specific region and disease.

2.5 Conceptual framework for integrated assessments

Rothman and Robinson (1997) propose a conceptual framework within which individual integrated assessment studies, and the practice of integrated assessment of climate change as a whole, can be placed and evaluated. This framework comprises eight categories, whereby the first six refer to the level of integration, and the latter two to the policy usefulness of the assessment:

1. Vertical integration (along the cause-effect chain)
2. Horizontal integration (across sectoral and regional boundaries)
3. Consideration of feedbacks and dynamics
4. Consideration of autonomous and purposeful human adaptation
5. Recognition of multiple baselines
6. Integration of quantitative and qualitative knowledge
7. Consideration of the policy context in which the analysis is used
8. Involvement of stakeholders

These categories are not only used to *categorize* assessments but also to *evaluate* them. Competing criteria (such as the tractability of results) and other constraints (such as the availability of time and financial resources) are mentioned in the text but not included in the conceptual framework.

Adaptation assessments are a specific type of integrated assessments of climate change. The eight categories proposed above can provide useful guidance for the design and the evaluation of adaptation assessments, including those intended to reduce climate-related health risks.

2.6 Other classification schemes

Other criteria for the classification of adaptation assessments proposed in the pertinent literature include the following ones (Smit and Pilifosova, 2001):

- methodological foundation;
- degree of stakeholder involvement;
- ability to address uncertainties;
- resource requirements; and

- comprehensiveness.

All of these criteria are relevant for human health adaptation assessment. A detailed discussion of these criteria in the context of the cCASHh project is, however, beyond the scope of this literature review.

Chapter 3

Guidelines for climate change assessments

This chapter reviews existing guidelines for climate change assessments. These guidelines usually describe the assessment process in a step-by-step manner. Many of them also provide techniques and tools to accomplish each step. Their main purpose is to help assessors at varying levels of experience to conduct high-quality assessments, and to enhance the comparability of results across regions and/or sectors.

The guidelines reviewed here refer to a broad range of climate impact and adaptation assessments. They cover all analytical functions, generations, methodological approaches, and levels of climate change assessment described in Chapter 2. We start with two health-specific frameworks, followed by generic guidelines that apply a hazards-based approach (also known as the 'standard approach') to climate change assessment, followed by various guidelines that include strong vulnerability-based components.

3.1 National Health Impact and Adaptation Assessment Framework

Purpose

Health Canada has developed an initial 'National Health Impact and Adaptation Assessment Framework' (Health Canada, 2002). This framework aims at assisting national governments and government agencies to conduct a comprehensive health impact assessment of climate change, and to develop response strategies. The framework is considered to be applicable in regions at all stages of economic development. Based on this framework, the WHO, in collaboration with Health Canada, the WMO, and UNEP, has published a report on 'Methods of assessing human health vulnerability and public health adaptation to climate change' (Kovats et al., 2003b). This report aims at providing flexible instructions for moving through the steps of the risk assessment and management process and enable the valid comparison of assessment results across countries. The results of health impact assessments conducted according to the WHO–Health Canada Framework shall be used to meet the obligations of countries to report on their vulnerability to climate change in National Communications under Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), and to facilitate effective adaptation to the adverse health effects of climate change.

Content

The WHO–Health Canada Framework is based on a bottom-up approach to risk management that starts from current health risks and their determinants. The initial version of the framework distinguishes

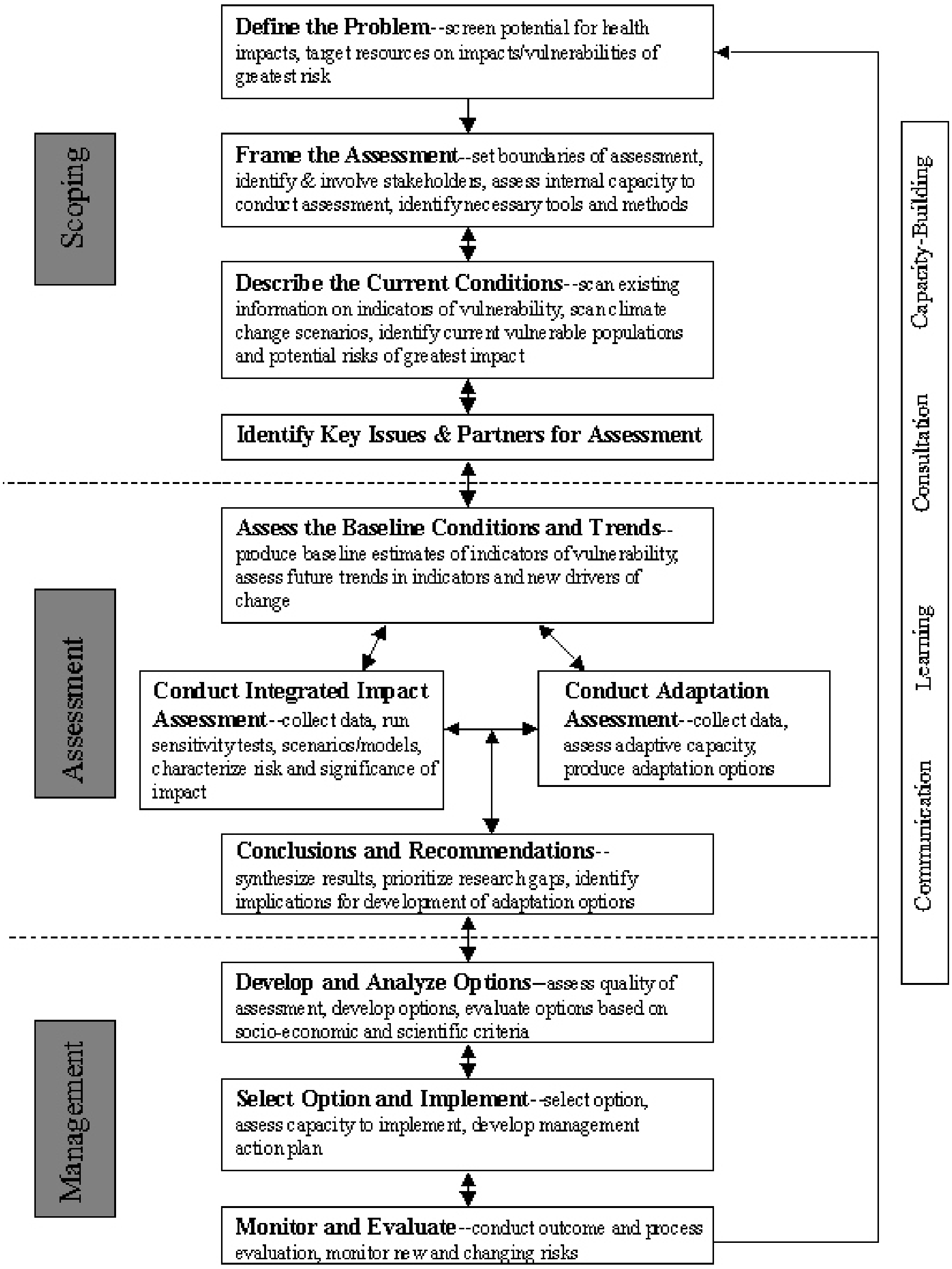


Figure 3.1: National Health Impact and Adaptation Assessment Framework. *Source:* Health Canada (2002)

three phases: scoping, assessment, and management. Each phase is further divided into several steps (see Figure 3.1). The framework emphasizes the importance of stakeholder involvement throughout the assessment process as well as the cyclical nature of risk management.

Application

The development of the WHO–Health Canada Framework has been informed by various national health impact assessments. However, the framework has yet to be applied in national assessments.

Evaluation

Owing to its late publication date, the final framework (Kovats et al., 2003b) could not be considered in this literature review. This brief review refers instead to the preliminary framework (Health Canada, 2002).

The WHO–Health Canada Framework is targeted specifically at the needs of national and regional government agencies in assessing the health risks associated with global climate change, and in adapting to them. It provides a useful structure for such assessments. However, two aspects require further consideration. First, the framework seems to inadequately deal with the dynamic aspects of the climate change problem. The transient change of climatic risk factors, and the uncertainties associated with future climate projections, call for a prioritization of response measures according to their urgency. Hence, the question *when* to adapt requires about as much attention as the question *how* to adapt. (For a more detailed analysis of the various factors that affect the appropriate timing of adaptations, see Section 5.8.) Second, the framework makes a sharp distinction between the scientific and the political evaluation of potential adaptation measures. Whereas the former is considered a part of risk assessment, the latter is only done in the risk management phase. This separation may lead to considerable efforts being devoted to the development of adaptation strategies that are not politically acceptable. Close interaction between risk assessors and political stakeholders, as suggested in the framework, should enable the consideration of political preferences earlier in the process.

Applicability to climate change and human health

The WHO–Health Canada Framework is the single most important guidance for national and regional adaptation policy assessments of climate change and human health, as performed in cCASHh.

3.2 Environmental Health Risk Assessment

Environmental health risk assessment is a particular type of risk assessment. This section starts with a brief introduction to the main concepts and terms used in risk assessment and management, followed by a discussion of the concept of exposure in the context of anthropogenic climate change. These reflections then provide the basis for the specific discussion of environmental health risk assessment.

Introduction to risk management

Risk assessment denotes the process of quantitatively or qualitatively estimating the potential impact of exposure to a chemical, physical, microbiological or other hazard on a specified system (the 'exposure unit') under a specific set of conditions. The term 'risk' refers both to the magnitude of the impact and to its likelihood or frequency. Risk assessments are undertaken for a variety of exposure units, including humans, ecosystems, settlements, built infrastructure, and economic sectors. The results of risk assessments are used by risk managers as an important source of information in their decisions on constraining these risks.

The key characteristics and assumptions underlying risk assessments can be summarized as follows:

- The direct exposure of a receptor to one or more stressors causes certain harmful effects.

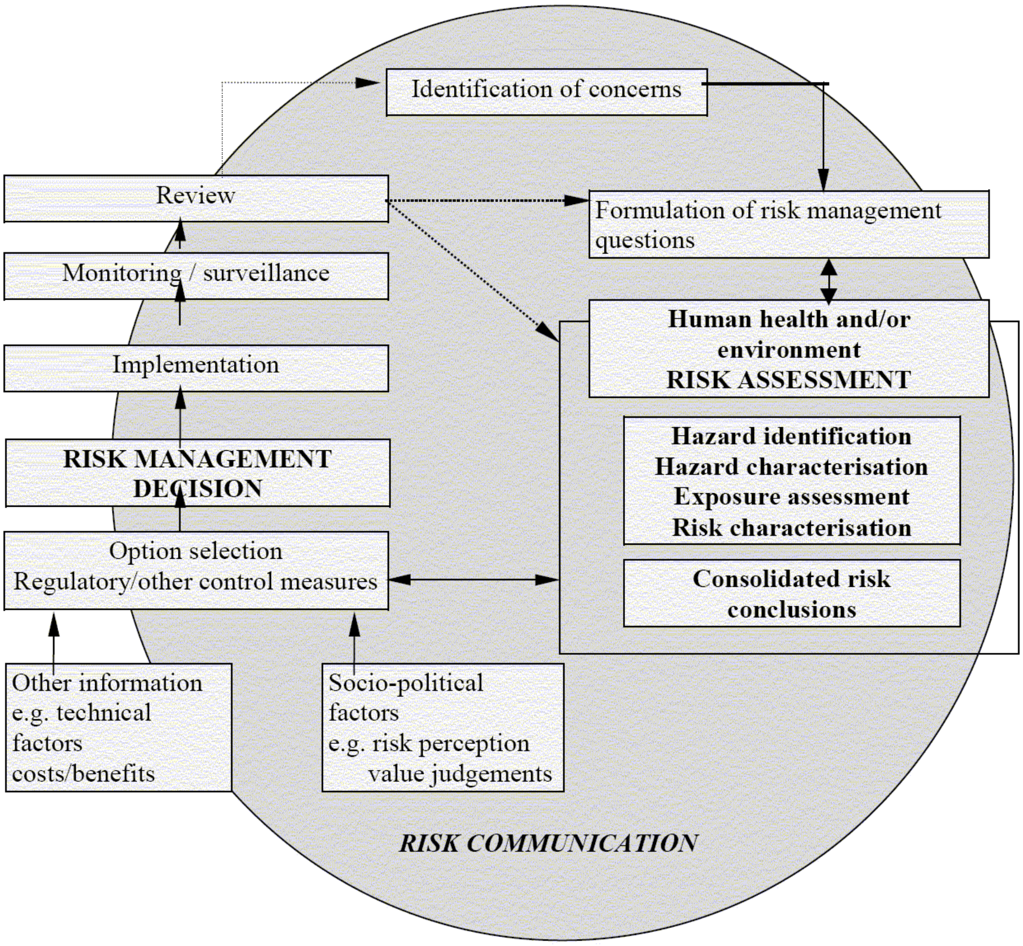
- Risks are characterized by integrating the exposure profile and the stressor-response profile, giving full consideration to relevant uncertainties.
- The acceptability of the assessed risks, and of risk control strategies, are evaluated according to the needs, issues, and concerns of relevant stakeholders.
- Stakeholders are involved throughout the process to ensure that the risk assessment addresses a broad range of concerns, that the context in which the assessment will be used is appropriately taken into account, and that the technical aspects of risk are balanced with moral and social considerations that often accompany issues of risk management.

Various organizations have developed guidelines (or 'standards') for risk assessment. These standards often use different terms to refer to the same process and, in some cases, the same terms refer to different processes. The terminology used by the WHO, FAO, WTO, and the European Commission's Directorate-General for Public Health and Consumer Protection uses 'risk analysis' as the umbrella term that comprises risk assessment, risk management, and risk communication (see Figure 3.2.a). In contrast, the terminology used by the US Environmental Protection Agency, the UK Health and Safety Executive, the Canadian Standards on Risk Management, and many others uses 'risk management' as the umbrella term that comprises risk analysis, risk evaluation, and risk control (see Figure 3.2.b). Hence, there is considerable risk (*sic!*) of misunderstanding when the above-mentioned terms are used outside their original context (for details, see McNab, 2001).

Regardless of the specific words used, published risk management frameworks contain very similar components and concepts. The major stages of risk governance are consistently described as

- scoping of the issue;
- scientific analysis of risks;
- communication of risks between assessors and stakeholders;
- evaluation of the risks by decision-makers;
- development and evaluation of risk-reducing policies;
- implementation of these policies; and
- review of their efficacy.

Risk management frameworks have been applied in a wide variety of contexts where an existing or new activity is expected to have negative impacts on valued exposure units, including 'classical' quantitative risk assessment in environmental health. There have also been several attempts to apply risk management approaches to climate change-related issues. One example is the integrated program *Climate Change Adaptation through Integrated Risk Reduction (CCAIRR)*, which addresses the reduction of climate-related risks in different Pacific island states through integrated approaches to local disaster risk management (Hay, 2002). Another example is the framework presented by Jones (2001), which is specifically designed to manage the propagation of uncertainties from climate change scenarios through a sequence of biophysical and socioeconomic climate impacts on individual exposure units.



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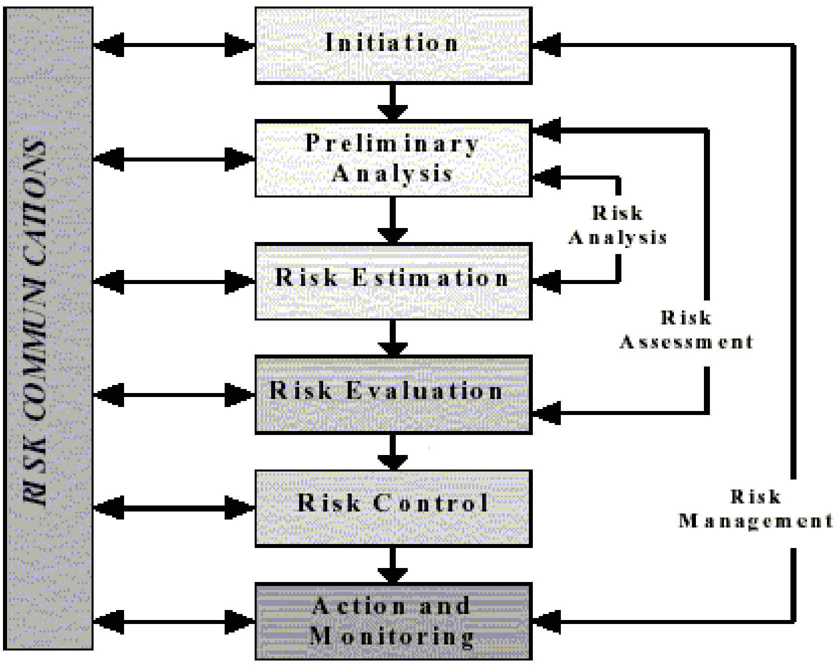


(b)

Figure 3.2: Two frameworks for structuring the process of risk governance. *Sources:* (a) European Commission (2000); (b) Canadian Standards Association (1997)

The concept of exposure in the context of global climate change

'Exposure' is a central concept in risk assessment and environmental epidemiology. It thus seems appropriate to provide some reflections on its operationalization in climate change assessments for human health. Risk assessment is concerned with situations where adverse impacts are potentially caused by the exposure of a vulnerable system (the 'exposure unit') to some external hazard. In an environmental health context, the hazards concerned are typically chemical, physical, or biological agents, and the exposure may be defined on an individual or population level.

The exposure of an exposure unit to a hazard takes place in a spatial and temporal continuum. The exposure of a small exposure unit to a discrete, short-term hazard event can often be described by a scalar value, which allows to describe the effects of that type of hazard in terms of a simple exposure-response relationship. For instance, the impacts of a wind-storm or an earthquake on a building are largely determined by the maximum wind velocity or by the rating on the Richter scale, respectively. For many environmental health problems, the exposure may also be described by a scalar value, such as the cumulative intake of a persistent toxic substance. It is more difficult to define the exposure of an exposure unit to a multi-dimensional, spatially heterogeneous and temporally extended hazard such as anthropogenic climate change. This task becomes even more difficult if the risk assessment is concerned with future hazard scenarios fraught with considerable uncertainty.

The problem of operationalizing the exposure to the hazard 'anthropogenic climate change'. shall be illustrated by discussing two 'extreme' choices. In the first choice, exposure to climate change is defined in terms of a globally aggregated indicator, for instance the change in global mean temperature compared to some baseline period. This definition is easily quantifiable, thus enabling the development of probabilistic future exposure scenarios. It is also universally applicable to all countries, which allows a comparison of their relative vulnerability to anthropogenic climate change. However, a globally aggregated indicator provides little information for regional assessments of health impacts from future climate change (*i.e.,* for the exposure–response relationship) due to the large uncertainty how it translates to the regional level. In the second choice, exposure to climate change is defined as the transient change of the means, variances, and higher statistical moments of a multitude of climate variables at the local level. Whilst this multi-dimensional, dynamic hazard definition would provide ample information for health impact assessments, it is practically impossible to develop future exposure scenarios using such a complex definition that adequately reflect the uncertainties involved in regional climate modelling. In addition, the ability to fully use this data might be limited by the availability of relevant epidemiological data.

The most suitable definition of the 'exposure to anthropogenic climate change' in terms of the variables involved, the choice of the spatial and temporal unit of analysis, and the consideration of dynamic aspects depends on the specific health outcome concerned. It is largely determined by the type of climatic hazard involved in the causation of a specific disease. Climatic hazards with relevance for health include long-term climate means, seasonal to decadal anomalies (*e.g.,* El Niño events), single weather events (*e.g.,* hurricanes and flash floods), and even chains of specific events (*e.g.,* hot, dry summers with brief periods of unseasonably cool temperatures are thought to be favourable for the transmission of West Nile virus in the USA). It also depends on the length and complexity of the causal chain linking the hazard with the health outcome. Climatic hazards may have either a direct effect on human health (such as in the case of heat-related stress) or an indirect effect (such as in the case of vector-borne diseases).

The 'traditional' concept of exposure applies most easily to direct health effects of discrete weather events. However, a scalar description of exposure may still be insufficient. For instance, the health impact of a heat-wave on a specific population depends on the length of the heat-wave as well as the temperature level, in particular nocturnal temperatures. If more complex associations between climatic factors and human health are concerned, such as for West Nile fever, it may be very difficult to define the climatic hazard in such a way that reliable future scenarios of the hazard can be developed for quantitative risk assessment.

Purpose

'Environmental health risk assessment' denotes a specific type of risk assessment. It refers to the assessment of individual or population health risks associated with a particular environmental hazard. Many organizations have developed guidelines for (environmental) health risk assessment. In particular, various countries have established standards for health risk assessments as part of a mandatory environmental impact assessment for a proposed activity, development, or policy.

The term 'health risk assessment' is now often narrowly used in public health to quantify and extrapolate the exposure-response relationship to new exposure scenarios, or to describe a formal risk assessment that follows a specific set of guidelines. However, health risk assessments can be either quantitative or qualitative, and there are different legitimate approaches, depending on the particular issue of concern.

Content

The different guidelines and glossaries for health risk assessment agree fairly well as to their content. The standard process for risk assessment in environmental and occupational epidemiology consists of the following four steps (Nurminen et al., 1999):

Hazard identification: assesses the available evidence of the potential for a risk agent to cause harmful health effects in exposed populations.

Dose-response assessment: models the relation between exposure to an identified hazard at different dose levels and the disease risk it induces.

Exposure assessment: describes the exposure patterns and processes, estimates the intensity and duration of exposure, as well as the characteristics and numbers of persons actually or potentially exposed.

Risk characterization: estimates the health consequences of different exposure scenarios (*e.g.,* a business-as-usual scenario and one or more alternative scenarios).

These four steps were first formalized by the US National Research Council, who developed a framework for assessing the health risks associated with chemicals in the environment (National Research Council, 1983). Analogous to general risk assessment, different terminologies are used internationally to describe the components of environmental health risk assessment. Figure 3.3 compares the terminologies of various widely applied frameworks.

We illustrate the process of environmental health risk assessment using the Australian framework as an example (Department of Health and Ageing, 2002). Figure 3.4.a illustrates the sequence of steps in this framework, which includes a separate first step denoted as 'Issue identification'. Figure 3.4.b shows how risk assessment is related to the broader task of risk management.

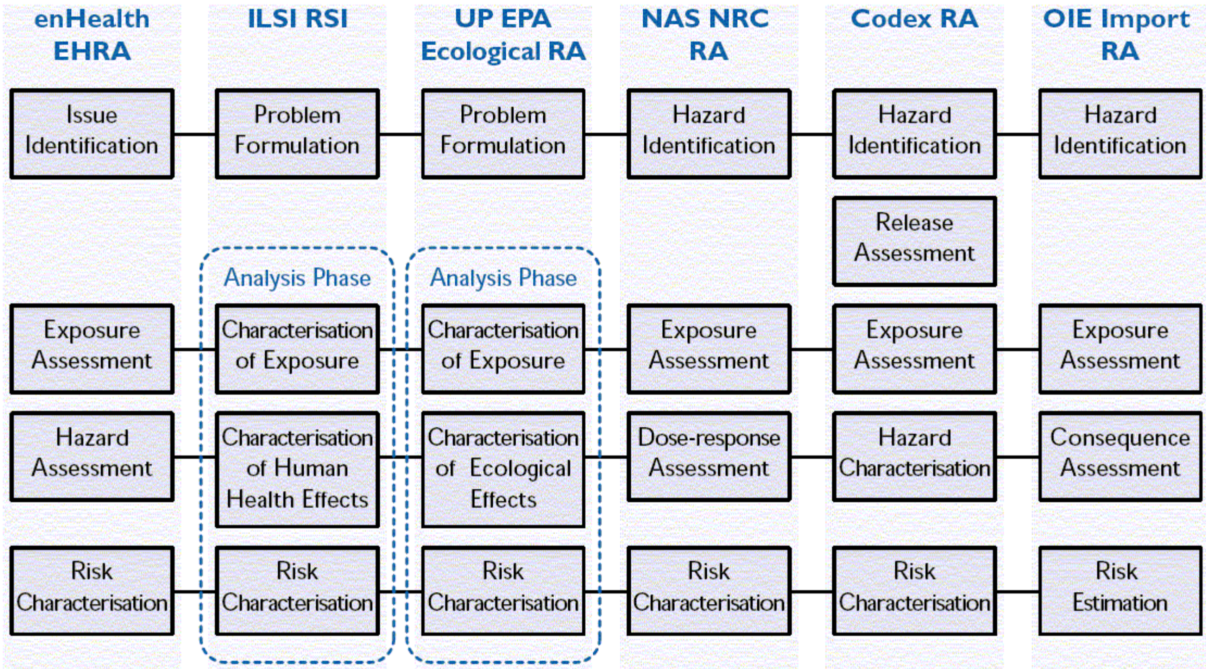


Figure 3.3: Different terminologies used in health risk assessment. *Source:* Department of Health and Ageing (2002)

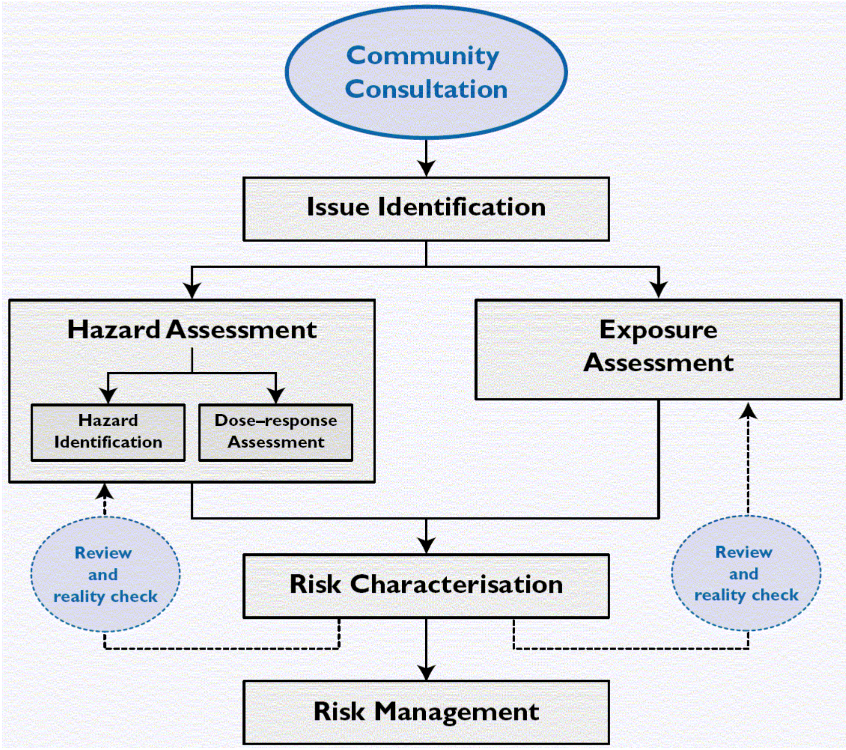
Application

Health risk assessment has been successfully applied to assess and constrain the risks to human health associated with a variety of natural, economic, technical, and human hazards. Most of these assessments were part of a mandatory environmental impact assessment for a proposed development project, activity, or policy. Such assessments are typically characterized by a limited spatial scope and by a discrete set of hazards considered. One may argue that the assessment of 'Health Effects of Climate Change in the UK' (Department of Health, 2001) loosely followed the framework for environmental health impact assessment. However, no explicit mention of this framework was made in the report.

Applicability to climate change and human health

Anthropogenic climate change differs from other environmental health hazards in terms of the large spatial scale of the problem, the long time horizon to be considered, the complexity of the climatic hazard, the complexity of the relationship between climatic factors and health outcomes, and the uncertainty about future hazards scenarios. There are few empirical precedents for anticipated climate change, and the applicability of data from historical or geographical analogues is also limited. As a result, the quantitative assessment of health risks from future climate change is often hampered by the lack of reliable scenarios for relevant climatic variables, the lack of epidemiological data on the relationship between climate exposure and health effects, and/or difficulties to project important non-climatic 'confounding' factors.

Patz and Balbus (1996) review the methods available for assessing public health vulnerability to global climate change. They identify the complexity and uncertainty of the stressor as the main factors that distinguish global climate change risk assessment from conventional health risk assessment. For indirect health effects mediated through ecosystem changes where simple dose-response relationships are less



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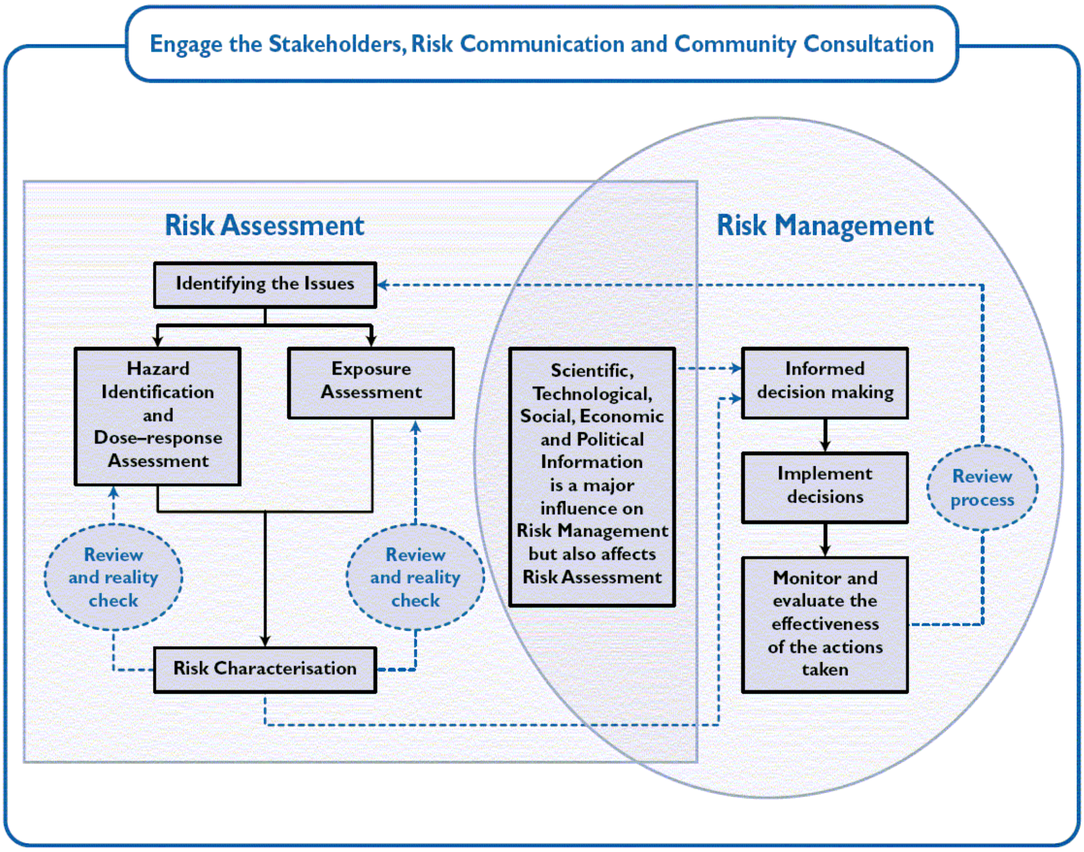


(b)

Figure 3.4: Australian framework for health risk assessment. (a) Steps in risk assessment; (b) Relationship of risk assessment and risk management. *Source:* Department of Health and Ageing (2002)

meaningful, they suggest to use a systems-based ecological framework that integrates climatic, natural, economic, and demographic factors.

Bernard and Ebi (2001) review the applicability of risk assessment frameworks to assess the effects of climate change on human health. They argue that the existence of multiple, interrelated causes for disease and of various feedback mechanisms often limits the predictability of the health outcome and even the ability to estimate the degree of uncertainty. As a result, the traditional four-step approach to risk assessment often cannot be applied to climate change-related assessments despite the importance of many of its goals and principles. The most common alternative methods mentioned are expert judgement, spatial and temporal analogue studies, process-based and empirical modelling, and other integrated assessment methods. In particular, the application of an ecosocial framework for epidemiology is suggested as an alternative to traditional quantitative risk assessment. This framework would apply a social-ecologic system perspective rather than the traditional epidemiologic focus on proximate, individual-level risk factors.

The conclusion that the prevailing toxicological model of environmental health is often not applicable to climate-sensitive health issues, in particular for indirect effects of climate stimuli, is shared by several authors who have investigated the applicability of classical risk assessment approaches to the health effects of anthropogenic climate change (McMichael, 1993; Patz and Balbus, 1996; Haines and McMichael, 1997; Bernard and Ebi, 2001). There are nevertheless important lessons to be learnt from traditional environmental health risk management for adaption to climate change, including the importance of a continuous and effective dialogue with affected stakeholders and of an explicit consideration of uncertainties in the analysis.

3.3 IPCC Technical Guidelines

Purpose

The IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations (Carter et al., 1994) constitute the first comprehensive approach for guiding impact and adaptation assessments. They have been developed by a team of 48 authors and 26 reviewers. An expanded and illustrated form of the Technical Guidelines was later published in book form (Parry and Carter, 1998).

The Technical Guidelines aim at structuring climate impact and adaptation assessments, and at guiding through the various methods that can be used to assess the impacts from, and adaptations to, climatic changes. The goal of climate impact and adaptation assessments, as understood here, is to estimate the impacts of future climate change, and to evaluate the array of potential adaptations to such impacts. Specifically, the Technical Guidelines shall enable countries to fulfill their commitments under Article 12 (National Communications) and Article 4 of the UNFCCC. The Technical Guidelines are intended to be applicable in different sectors and geographical regions, and in countries at different levels of economic development. However, most of the examples presented in Parry and Carter (1998) refer to climate impacts on natural ecosystems and agriculture. The intended audience includes non-expert scientists.

Content

The Technical Guidelines propose a seven-step analytical framework for climate impact assessment, which is illustrated in Figure 3.5.a. The last step, which refers to the development of a strategy for (planned) adaptation, is further divided into seven steps (see Figure 3.5.b). In their concluding chapter,

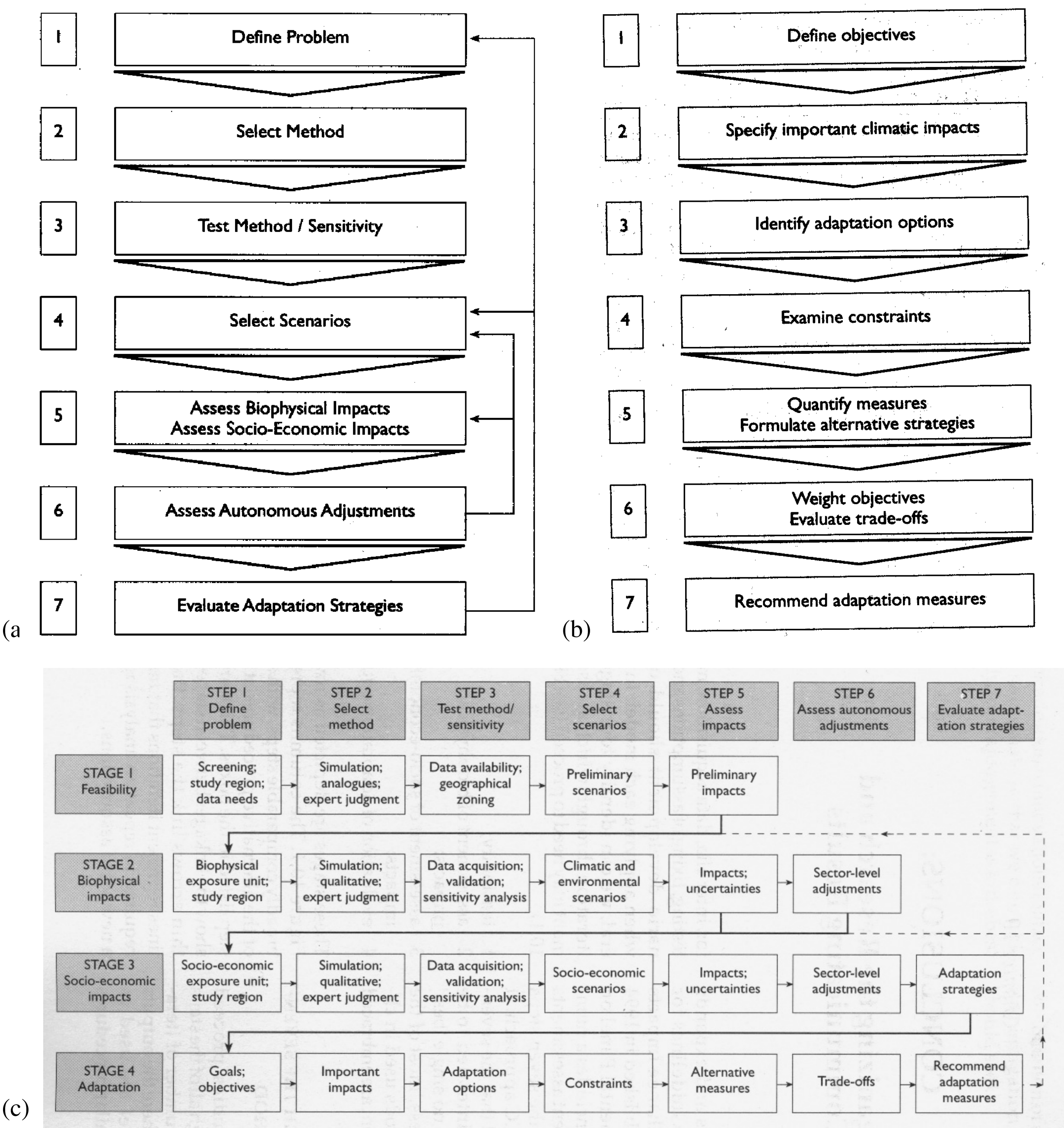


Figure 3.5: Assessment framework of the IPCC Technical Guidelines. (a) Seven steps of impact assessment; (b) Seven steps of adaptation assessment; (c) Four stage method for conducting impact and adaptation assessments. *Sources:* Carter et al. (1994); Parry and Carter (1998)

the Technical Guidelines propose a staged approach to impact and adaptation assessments (see Figure 3.5.c). According to this approach, the steps of impact assessment are repeated three times to assess the feasibility of the study, the biophysical impacts, and the socioeconomic impacts, respectively. During these three stages, only limited attention is paid to adaptation. Finally, the seven steps of adaptation assessment are carried out.

Application

The IPCC Technical Guidelines have provided guidance for many country studies that assessed the vulnerability of various climate-sensitive sectors to anthropogenic climate change. However, the Technical Guidelines were not followed literally in most cases due to the lack of data, models, and/or financial resources. The same holds for the UNEP Handbook (Feenstra et al., 1998) and for the guidelines for the US Country Studies Program (Benioff et al., 1996), both of which are presented below.

Evaluation

There are two main policy purposes for adaptation assessment, as discussed in Section 2.1 and Section 2.2. Whereas the Technical Guidelines describe well the structure of an adaptation assessment as part of an *impact* assessment, they are less applicable to guide *adaptation policy* assessments. The main weaknesses of the Technical Guidelines with respect to adaptation policy assessments are as follows:

First, adaptation needs in the Technical Guidelines follow exclusively from the impacts projected for certain future climate scenarios. As a result, adaptation is restricted to the *incremental* effects of climate change. This narrow interpretation is consistent with the initial UNFCCC definition of adaptation to climate change. However, we already emphasized in Section 1.2 that the practice of adaptation to climate change needs to consider much more than just future climate change. Many communities, in particular in developing countries, are already vulnerable to current climate variability. For them, it is particularly important that measures aimed at reducing the risks of future climate change are also effective to reduce current risk levels. Therefore, adaptation policy assessments need to consider vulnerability to future climate change along with current climate variability, and integrate response strategies with other policy objectives such as sustainable economic development and natural resource management. For a vivid critique of the UNFCCC definition of climate change, see Pielke Jr. (2003).

Second, the adaptation assessment in the Technical Guidelines is contingent on quantitative results from the impact assessment. As a result, the Technical Guidelines provide little guidance to countries, in particular in the developing world, that lack the data, models, expertise, or resources required to conduct quantitative impact assessments. They are also of limited help if the uncertainty about future climate change is too large to make reliable projections about the impacts associated with it. For instance, if climate change may cause significant health impacts in a particular region but their eventual occurrence is highly uncertain, improved monitoring and surveillance may be highly effective adaptation mechanisms. However, such generic policies are not necessarily identified through the top-down to adaptation approach proposed in the Technical Guidelines .

Klein et al. (1999) have assessed the applicability of the Technical Guidelines for coastal zone management. Their main criticism refers to the following points:

- little guidance on involving stakeholders;
- strong reliance on GCM-based climate scenarios;
- little consideration of current and future climate variability;
- little consideration of non-climatic stressors;
- little consideration of adaptive capacity and the social determinants of vulnerability;
- little consideration of the planning and implementation of adaptation measures;

- little consideration of non-technical (*i.e.,* economic, legal, institutional) aspects of adaptation; and
- little consideration of post-implementation evaluation.

Burton et al. (2002) have assessed the applicability of the 'standard approach' to impact and adaptation assessment (*i.e.,* the IPCC Technical Guidelines, the UNEP Handbook, and the USCSP Guidebook), for adaptation policy assessments in different climate-sensitive sectors. Their evaluation largely agrees with Klein et al. (1999). A common experience made in many country studies applying the 'standard approach' was that an overwhelming part of the time and funds has been devoted to the selection of climate scenarios and to the assessment of first–order impacts whereas insufficient time was left to fully develop the adaptation component of the study. Five explanations why the standard approach has not yielded useful results for the purposes of adaptation policy design (in developing countries) are suggested:

1. Practitioners in developing countries are concerned with more pressing immediate and short-term issues than designing adaptation measures for some future time to an uncertain future climate in an unknown socioeconomic context.
2. Climate scenarios from general circulation models are not sufficiently precise in terms of spatial scale for most adaptation assessments. In addition, they do not cover well many climate indicators that are important for adaptation decisions, such as the duration of sequences of weather conditions, changes in extreme events, and combinations of different variables,
3. The impact assessments are designed to consider only adaptation options, measures, or strategies that are covered by the —predominantly biophysical— impact models.
4. Where adaptation has been incorporated, it has been on the basis of —generally unrealistically optimistic— assumptions about the adoption of possible measures that have not been based on knowledge of the adaptive capacity of the region and of the adaptation process itself.
5. Because the standard approach has been developed for the purpose of understanding (residual) impacts it pays less attention to the policy context of adaptation or to the key actors or stakeholders involved.

Applicability to climate change and human health

The development of the Technical Guidelines was heavily influenced by the experiences of various modelling groups who combined GCM-based climate scenarios with biophysical climate impact models to project the impacts of climate change on food production, natural ecosystems, and freshwater hydrology. Their applicability to different impact domains depends, in particular, on the availability of simulation models covering the relationship between climatic factors, other relevant influence factors, and the considered impact domain; and of reliable projections for future changes in the relevant climatic (and non-climatic) risk factors.

Health impacts are addressed in the Technical Guidelines but the focus is cursorily and on scenario-driven modelling. The applicability of the Technical Guidelines for national assessments of climate-related health impacts was briefly reviewed in Kovats et al. (2003a). The review concludes that the guidelines focus on biophysical impacts for which large-scale models are readily available. In contrast, they have limited use for assessing impacts on socioeconomic or human systems, and for designing adaptive measures.

Many of the above-mentioned criticisms of Klein et al. (1999) and Burton et al. (2002) are valid in the context of human health. As mentioned earlier, quantitative assessments of the future health risks posed by anthropogenic climate change are often not possible because appropriate models or data are not available at all, or not at the appropriate scale level (Bernard and Ebi, 2001). This constraint is even more important for adaptation policy assessments than for climate impact assessments because the former are usually conducted at finer spatial scales. Any climate impact and adaptation assessment for human health should therefore include an assessment of the confidence in each of the projected health impacts (McMichael et al., 2001). Interestingly, none of the health impact assessments reviewed in Kovats et al. (2003a) included an explicit uncertainty assessment.

3.4 UNEP Handbook

Purpose

The UNEP Handbook on Methods for Impact Assessment and Adaptation Strategies (Feenstra et al., 1998) was designed to assist countries in conducting climate change impact and adaptation assessments, predominantly as inputs to the National Communications as required by the UNFCCC. It is the result of the intensive collaboration of a large international team of authors and external reviewers.

Content

The UNEP Handbook elaborates the IPCC Technical Guidelines (see Section 3.3) by presenting and discussing a broad range of approaches that might be used for addressing the question *"What does climate change mean to us?"* and, to a lesser extent, *"What might be done about it?"*. It consists of two parts: The generic part deals with the framing of the assessment, the development of socioeconomic and climate change scenarios, integrated assessment, and adaptation. The sectoral part discusses methods for impact and adaptation assessment in nine sectors, including human health. Similar to the IPCC Technical Guidelines, the UNEP Handbook is the result of the collaboration of a large international team of authors and external reviewers.

The chapter on adaptation (Burton et al., 1998) discusses important theoretical aspects of adaptation and presents specific methods for the assessment of adaptation measures. It does not refer specifically to the seven-step approach for adaptation assessment proposed in the IPCC Technical Guidelines.

The chapter on health (Balbus et al., 1998) provides guidance for each step of the impact assessment. However, due to the limited experience with climate impact assessments for human health available at that time, the chapter primarily suggests an approach to impact assessment for human health rather than reviewing applied methods. This proposed approach closely follows the IPCC Technical Guidelines:

- Selection of health impacts, populations, and regions to be considered.
- Selection of methods (*e.g.,* conceptual models, empirical studies, and numerical models).
- Selection of climate change, socioeconomic, and demographic scenarios.
- Assessment of health effects (including uncertainty analysis).
- Assessment of autonomous adaptation.
- Assessment of planned adaptation (considering also current health problems).

A basic consideration of the health chapter is the uncertainty that surrounds predictions of future states of human health. The sudden and unpredictable emergence of major health problems such as AIDS is cited as an example that current knowledge is often insufficient to reliably identify future health risks. Policies that aim at reducing particularly uncertain future health risks should be designed in such a way as to reduce current health risks as well. The section on planned adaptation in the health sector does not contain a specific procedural framework.

Application

The UNEP Handbook elaborates the IPCC Technical Guidelines for the most important impact sectors, including human health. As a result, country studies following the IPCC Technical Guidelines have generally considered the additional guidance provided by the UNEP Handbook .

Evaluation

Four country case studies were carried out within the UNEP project "Country Case Studies on Climate Change Impacts and Adaptations Assessment" funded by the Global Environmental Facility (GEF). Reviews of these country studies emphasize the importance of adopting a flexible approach to the assessment of climate change impacts and adaptations (O'Brien, 2000; Kovats et al., 2003a). Critical issues identified were the reliance on data and models that may not be available, in particular in many developing countries. The 100-year time frame for climate change projections, which is relevant for decisions on spatial planning, coastal zone development and some infrastructure projects, was seen as having little practical relevance for health-related adaptation measures.

Clear limitations of the scenario-driven approach to the quantitative assessment of future health impacts were identified in the case of complex climate-disease relationships. McMichael et al. (2001) come to similar conclusions in their brief review of methods for climate impact assessments in human health. In contrast, the UK National Assessment (Department of Health, 2001) was more successful in basing its (often quantitative) estimates on elaborated climate scenarios provided by the UK Climate Impacts Programme (UKCIP).

Applicability to climate change and human health

The fact that the UNEP Handbook contains a separate chapter on human health underlines the assumption that its methodology, which is primarily based on model-based, quantitative assessments, can be applied to assess impacts of, and adaptations to, climate change on human health. However, a more detailed analysis of the health chapter reveals that the potential for quantitative impact and adaptation assessments is very limited for human health. As a result, the UNEP Handbook cannot provide specific guidance for climate adaptation assessments for human health.

3.5 USCSP Guidebook

Purpose

The US Country Studies Program (USCSP) provides developing countries and countries with economies in transition with financial and technical assistance in:

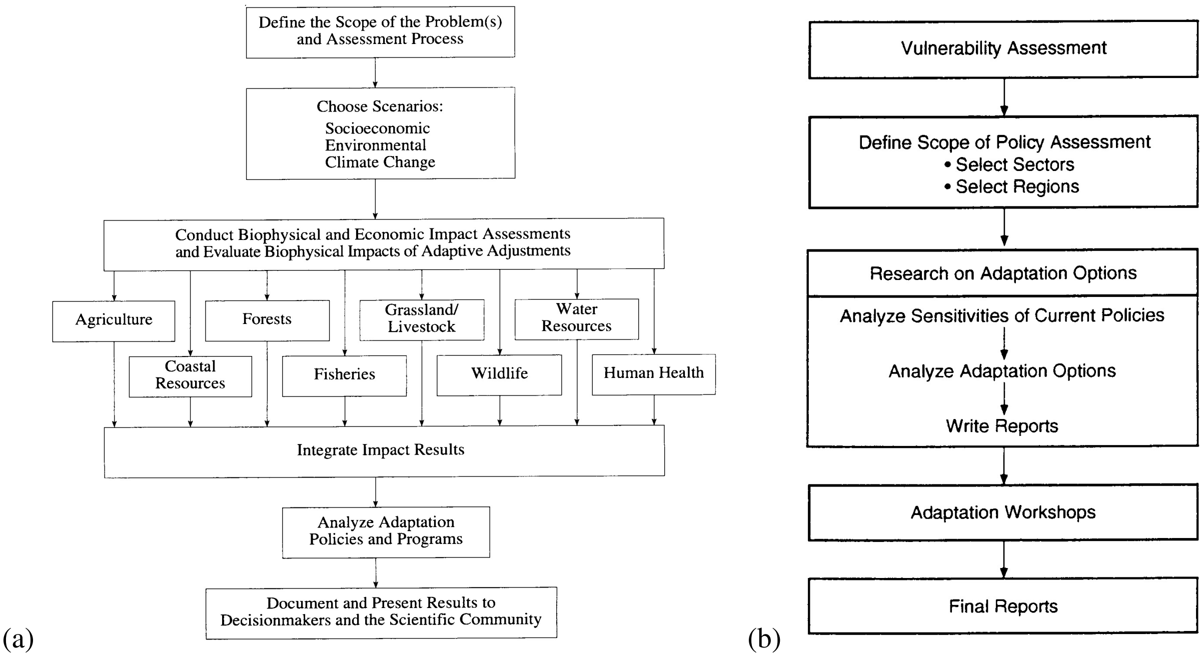


Figure 3.6: Assessment framework of the US Country Studies Program. (a) Approach to climate change vulnerability and adaptation assessments; (b) Adaptation assessment steps. *Source:* Benioff et al. (1996)

- preparing inventories of their emissions and sinks of greenhouse gases (GHGs);
- identifying and evaluating options for controlling GHG emissions and for increasing GHG emissions sinks;
- assessing their vulnerability to climate change and approaches for adapting to such change; and
- developing national action plans for responding to climate change.

The US Country Studies Management Team has prepared a guidebook (U.S. Country Studies Program, 1994; Benioff et al., 1996) to assist countries receiving US support for the analysis of vulnerability to the impacts of global climate change and the evaluation of adaptation measures. The aim of this guidebook is to assist countries in making decisions about the scope and methods for their vulnerability and adaptation assessments, and to provide them with guidance and step-by-step instructions on each of the basic elements of vulnerability and adaptation assessments. The guidebook was explicitly designed to be used in tandem with the IPCC Technical Guidelines. It was developed by a team of authors and has undergone peer review by international experts.

Content

Figure 3.6 shows the USCSP approach to vulnerability and adaptation assessment (left) and to adaptation assessment (right). The actual assessment starts with the development of scenarios for climate, socioeconomic, and environmental conditions. The use of GCM results is regarded as the primary method for developing future climate scenarios but other methods are also encouraged. The biophysical assessment consists of two parts: an impact assessment that uses empirical-statistical or simulation approaches to develop projections of the biological and physical effects of the various climate scenarios and a so-called technical adaptation assessment. The term 'technical adaptation' is used to describe reactive adaptations that can be considered by the models or other approaches applied in the biophysical assessment (*e.g.,* by changing crop planting cycles in response to experienced climate change).

The USCSP Guidebook emphasizes the importance of involving stakeholders throughout the assessment, for instance by establishing an advisory committee and by conducting science-policy workshops. It is recommended that the adaptation assessment be conducted in parallel with the vulnerability assessments in order to prevent resource or time constraints in the final phase of an assessment.

A vulnerability and adaptation assessment, as conceptualized by the USCSP Guidebook, includes an adaptation policy assessment that thoroughly analyzes anticipatory adaptation options to climate change in a manner useful to policy makers. The main tasks of this assessment are

- to analyze the effectiveness of current policies in coping with climate change;
- to analyze the costs and benefits of alternative policies to anticipate the effects of climate change;
- to identify which policies are most in need of immediate implementation; and
- to involve policy-makers in the assessment.

The right panel of Figure 3.6 shows the steps involved in an adaptation policy assessment. Specific decision tools recommended and made available through the USCSP are the use of a decision matrix and of multicriteria objective analysis by means of a so-called Adaptation Strategy Evaluator. The use of quantitative measures for successful adaptation is crucial for applying these methods. In addition, stakeholders must specify various policy objectives, and their relative weights, quantitatively. The USCSP also provides guidance for conducting adaptation policy workshops.

The original USCSP Guidebook (U.S. Country Studies Program, 1994) focussed on the sectors agriculture and forestry, water resources, and coastal zones. The book version of the USCSP Guidelines (Benioff et al., 1996) also includes a chapter on human health vulnerability assessment. Recognizing the limited knowledge about the relationship between climatic factors and human health, a bottom-up approach is recommended for human health. The vulnerability assessment would thus start from current public health issues and assess their sensitivity to climate changes. It is recommended to integrate the results of vulnerability assessments from other sectors, whenever available, because human health integrates many aspects of the socioeconomic and biophysical living conditions. The section on adaptation in the chapter on human health consists merely of a list of various adaptation options.

Application

The US Country Studies Program has been providing technical and financial support to 56 developing countries and countries with economies in transition to assist them in conducting climate change studies. These studies have enabled the participating countries to develop inventories of their anthropogenic emissions of greenhouse gases, to assess their vulnerabilities to climate change, and to evaluate response strategies for mitigating and adapting to climate change.

In a first phase of the USCSP denoted as the Vulnerability and Adaptation Program, 49 countries conducted assessments of the vulnerability of their climate-sensitive resources, and 12 of them also addressed adaptation in ore or more sectors (U.S. Country Studies Program, 1999). Only very few countries addressed human health in their vulnerability assessments, and none of those assessments considered adaptation (Smith and Lazo, 2001).

In a second phase of the USCSP following the Vulnerability and Adaptation Program, the Supporting National Action Plans Program assisted countries with developing climate change action plans that integrate the findings of their USCSP country study into a comprehensive national policy response to the problem of climate change, which generally includes a portfolio of mitigation and adaptation measures. Seven of the 18 countries participating in the second phase of the USCSP examined how adaptation responses could be incorporated into national climate change actions plans whereas the other countries focused on mitigation actions.

Most USCSP country studies focus on agriculture and forestry, coastal zones, and the water sector. Only two countries completed an assessment of human health vulnerability, and only one country considered potential adaptation measures (U.S. Country Studies Program, 1999). The assessment of health effects in the USCSP was limited largely by the lack of relevant data. In addition, most countries addressed by the USCSP have already insufficient resources available for public health to adequately deal with current health risks. Costly adaptations to partially uncertain climatic changes in the future are thus unlikely to become a high priority issue unless they have benefits in the short term as well.

Evaluation

The USCSP Guidebook provides a generally applicable method for conducting vulnerability and adaptation assessments that has been applied across a wide range of countries and sectors. These applications have been reviewed by various authors (Smith et al., 1996; U.S. Country Studies Program, 1999; Smith and Lazo, 2001). Evaluations of the USCSP Guidebook for *adaptation* assessments largely agree with those of the IPCC Technical Guidelines and the UNEP Handbook (see Sections 3.3 and 3.4, respectively). Smith and Lazo (2001) note, in particular, that the studies were generally limited to an analysis of first-order biophysical effects, and there were only some limited studies of adaptation.

A main reason for the limited consideration of adaptation in the USCSP was the uncertainty about future climate change, particularly at the regional scale. This fact reemphasizes the importance of using assessment methods that can deal with various levels of uncertainty. and of designing adaptation policies that are effective under different plausible climate scenarios. Adaptation measures that strengthen the overall resilience of a system to external shocks may be justified even under high degrees of uncertainty about future changes in regional climate. Another major obstacle to adaptation assessment were difficulties in estimating the benefits and the costs of adaptation. These difficulties are related to the uncertainty about future changes in climate and socioeconomic conditions as well as to the unfamiliarity of the assessors with many of the proposed response measures. Case studies from analogous regions, where available, may be an important source of information about the costs and benefits of specific adaptation measures.

Applicability to climate change and human health

The broad structure that the USCSP has provided for adaptation policy assessment can also be applied to human health. However, there is little specific guidance available for health adaptation assessments.

3.6 UNDP–GEF Adaptation Policy Framework

Purpose

The United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have initiated a process to develop a so-called adaptation policy framework (APF). The APF project aims to strengthen adaptive capacity of human systems, in multiple sectors, to all climate-related threats. This is done by providing guidance to developing countries for conducting adaptation policy assessments that help them to integrate adaptation to climate change into sustainable development plans, and to link longer-term climate change to current problems caused by climate variability (UNDP, 2003).

The APF is specifically designed to assist developing parties in the implementation of Decision 11/CP.1 ("Initial guidance on policies, programme priorities and eligibility criteria to the operating entity or entities of the financial mechanism") made at the first Conference of the Parties to the United Nations Framework Convention on Climate Change in 1995. This decision establishes a three-stage process for the financial support of adaptation to climate change by developing parties. The APF addresses Stage II Adaptation, which comprises "Measures … taken to prepare for adaptation". Projects emerging from the application of the APF are expected to be eligible for funding under Stage III Adaptation.

Content

Starting point for the APF initiative was the experience gained from the initial National Communications to the UNFCCC, and from country studies applying the 'standard' hazards-based approach to impact and vulnerability assessment that treatment of adaptation has rarely gone beyond the listing of potential adaptation options. The APF builds on a framework published in Burton et al. (2002).

Key innovations of the APF, compared to methods previously used in vulnerability and adaptation studies, are as follows:

- It treats policy as the overarching purpose (and vulnerability as subordinate to it).
- It starts by assessing current vulnerabilities, including the effectiveness of adaptation to recent climate experiences.
- It links adaptation to climate change with adaptation to current climate variability and extremes.
- It integrates climate adaptation into sustainable development plans.
- It emphasizes the importance of using a stakeholder-led approach.

The five-step approach to the UNDP-GEF framework is depicted in Figure 3.7. This framework will be complemented by a number of supporting papers, including technical support papers for each step of the framework.

Application

The APF is being tested within the context of the regional GEF project *Capacity Building for Stage II Adaptation in Central America, Cuba and Mexico*.

Evaluation

The APF focuses on reducing the vulnerability of communities in developing countries to climatic stimuli independent of their attribution. A particular emphasis of the APF is the integration of adaptation measures with existing natural hazard reduction and disaster prevention programmes. Given the specific

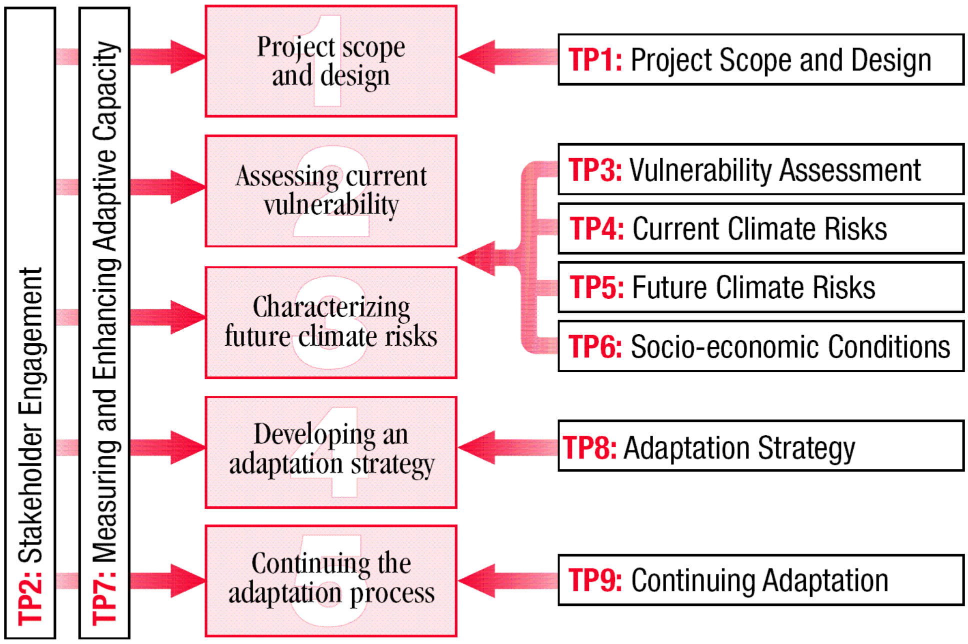


Figure 3.7: Outline of the Adaptation Policy Framework process. *Source:* UNDP (2003)

circumstances in developing countries, the APF encourages to use current vulnerability to climatic stimuli rather than GCM-based climate scenarios as the starting point of the analysis. However, the natural hazards approach is still regarded as appropriate under certain circumstances.

There are several reasons for these changes, compared to the 'standard approach' to climate impact and adaptation assessment proposed in the IPCC Technical Guidelines. First, the urgent needs of present populations in developing countries results in a focus on actions that also have short-term benefits. Second, many developing countries lack the data, skills and other resources that are required to properly utilize GCM-based climate change scenarios. Third, adaptation assessments that are solely based on GCM-based climate scenarios are likely to miss those aspects of climate change, and their consequences, that are not reliably modelled by current GCMs.

Applicability to climate change and human health

The key difference between the 'standard approach' to climate impact and adaptation assessment and the vulnerability-based approach largely favoured in the UNDP-GEF Adaptation Policy Framework is the larger emphasis of the latter on current climate-related risks compared to expected changes thereof caused by future climate change. The appropriateness of each of the two approaches depends on a multitude of factors, including the current level of climate-related threats, the time horizon of the adaptation options considered, and the availability and relevance of GCM-based climate change scenarios for a specific impact domain. In adaptation policy assessments for human health, preference for one or the other approach is contingent on the specific health effect and the study region. For instance, an assessment of health risks from extreme weather events in an already affected region should start with a thorough analysis of current vulnerability. In contrast, assessments of future risks from vector-borne diseases that are not currently prevalent in a region call for the use of climate change scenarios as a crucial input to assess the likelihood of such changes. The APF regards the hazards-based approach and the vulnerability-based approach as complementary rather than as mutually exclusive.

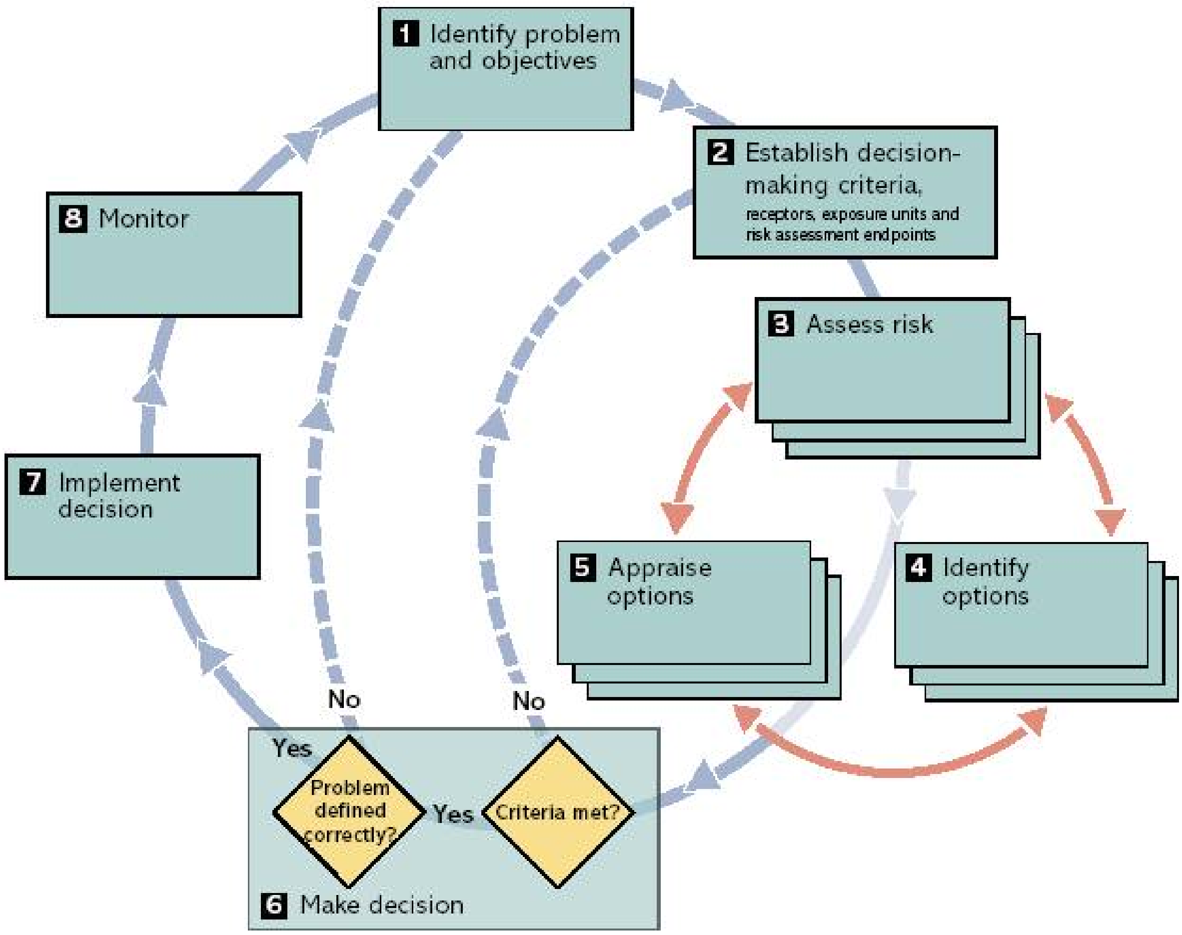


Figure 3.8: UKCIP framework to support decision-making in the face of climate change risk. *Source:* Willows and Connell (2003)

3.7 UKCIP Framework for Climate Adaptation

Purpose

The United Kingdom Climate Impacts Programme (UKCIP) has published a technical report on climate adaptation that is based on a risk management approach (Willows and Connell, 2003). The overall objective of this report is to provide guidance that helps decision-makers and their advisors to take account of the risk and uncertainty associated with climate variability and change, and to identify and appraise measures to reduce the impact or exploit the opportunities presented by future climate (*i.e.,* to facilitate good adaptation). The framework aims to be applicable to climate-sensitive decisions by private and public decision-makers from all relevant sectors in the United Kingdom, and at various levels of decision-making from the project to the policy level.

Content

Figure 3.8 illustrates the UKCIP Framework for adaptation decision-making. The adaptation process is split up into eight key stages, some of which are tiered. The framework is based on a risk management approach. It deals, however, extensively with situations where large uncertainties prevent the application of traditional risk assessment techniques. Key characteristics of the UKCIP Framework are that it is *circular*, allowing the performance of decisions taken to be reviewed, and decisions revisited through time; it is *iterative*, allowing the problem, decision-making criteria, risk assessment and options to be refined prior to any decision being implemented; and certain stages within the framework are *tiered*, allowing the decision-maker to undertake screening, evaluation and priorization of climate risks and adaptation options before moving on to more detailed risk assessments and options appraisals.

The report describing the UKCIP Framework (Willows and Connell, 2003) consists of three main parts. Part 1 lays out the eight stages of the decision-making framework, provides guidance on its use, and recommends tools and techniques that may be applied at each stage. Part 2 provides framework-supporting material that will be needed by those unfamiliar with aspects of risk assessment in general, or risk-based climate change assessment in particular. An appendix presents, among others, an illustrative application of the framework to a climate-sensitive decision about forest management.

Application

The UKCIP Framework was initially developed in the context of four case studies on the Environment Agency's Water Resources Strategy, the Thames Coastal Defence Strategy, the Arun-Adur coastal defences, and forestry policy in Wales. Additional decision-making examples concerning a National Park management plan, building regulations and a local development plan were examined in its further development. The framework in its final form has not been applied so far.

Evaluation

The UKCIP Framework provides comprehensive and detailed guidance on climate adaptation decision-making. The wide range of potentially climate-sensitive issues is structured well, relevant questions to be answered are provided for each stage of decision-making, and potentially useful methods and tools are presented. The framework was designed to be applied in the UK. Hence, it silently assumes a certain level of economic resources, scientific knowledge, data availability, and a rational decision-making culture. These requirements are expected to be met by and large in other democratic industrialized countries but not necessarily in other countries.

An important assumption in the UKCIP Framework is that a decision-maker has already identified a pending decision as potentially sensitive to climate change. Therefore, the framework does not provide specific guidance on raising awareness of the issue of climate change among stakeholders who are not yet aware of its potential relevance for them.

Applicability to climate change and human health

None of the examples in the UKCIP report refers explicitly to climate impacts on human health. Nevertheless, the UKCIP Framework appears largely applicable, and indeed highly relevant, for adaptations to reduce climate-related health risks. Among others, it provides a structured framework for adaptation decision-making, classifies decisions according to the relative importance of climatic and non-climatic factors (see Section 5.5), and presents criteria for assessing the importance of planned adaptation to climate change, including the risk associated with adapting too early, too late, or inappropriately.

The framework in its present form applies best when decisions are pending. This means that the decision-makers and relevant exposure units are clearly identified, the decision-makers are already aware of the potential relevance of climate change for their decision, and they are actively seeking guidance on good adaptation. These conditions are not necessarily met in the context of a national adaptation assessment for human health. In this case, it will generally be necessary to include an awareness raising (or kick-off) phase in which climate-sensitive health issues are screened, and potentially affected decision-makers are identified and engaged in discussions about the relevance of climate change for their field of responsibility (see the five preconditions for successful adaptation presented in Section 1.3).

3.8 Coastal adaptation framework

Purpose

Klein et al. (1999) present a 'coastal adaptation framework' that aims to overcome several deficiencies identified in the UNEP Handbook chapter on coastal zones (see Section 3.4). Whilst the UNEP Handbook addressed adaptation to climate change primarily in the context of climate *impact* assessments, the coastal adaptation framework focusses on policy-driven *adaptation* assessments.

Content

The coastal adaptation framework distinguishes various successive steps in the adaptation process, based on case studies for successful coastal adaptations from the Netherlands, the UK, and Japan:

1. Information collection and awareness raising
2. Planning and design
3. Implementation
4. Monitoring and post-implementation evaluation

The first two steps are linked to the three different levels of coastal zone vulnerability assessments (see Section 2.4): Screening and vulnerability assessments are regarded as an important contribution to *information collection and awareness raising* whereas the results of planning assessments provide input for the *planning and design* phase.

Figure 3.9 illustrates the coastal adaptation framework. This diagram combines a conceptual model of the adaptation process (inside the shaded box) with a conceptual framework for climate impacts (outside the shaded box).

Applicability to climate change and human health

Key components of the coastal adaptation framework are applicable for public health as well. However, there are now more elaborated adaptation frameworks available that either address human population health specifically (*e.g.,* the WHO framework presented in Section 3.1) or that have been designed to apply to various climate-sensitive sectors (*e.g.,* the UKCIP framework presented in Section 3.7).

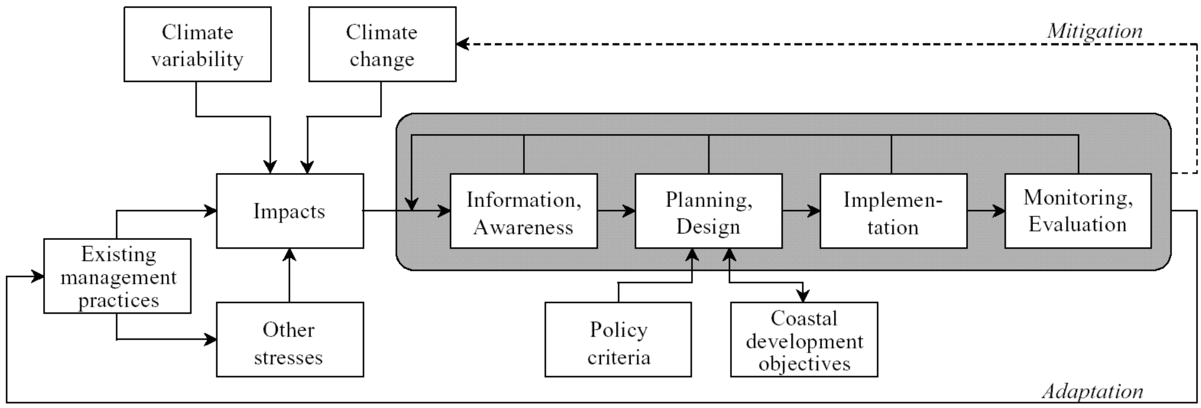


Figure 3.9: Conceptual framework for coastal adaptation. *Source:* Klein et al. (1999)

3.9 Framework for analyzing the need for adaptation

Smith (1997) presents a framework for determining the urgency of anticipatory adaptation to climate change. Figure 3.10 illustrates the process for the priorization of adaptation measures. This framework is meant to be applicable across various climate-sensitive sectors. However, it focusses on managers of climate-sensitive natural resources, such as water resources or coastal zones. Human health is explicitly mentioned as an impact domain where anticipatory adaptation is difficult due to particularly large uncertainties about future risks.

In summary, this framework does not provide specific guidance to climate adaptation assessments for human health. More elaborated decision frameworks are now available for this purpose, as reviewed in this chapter.

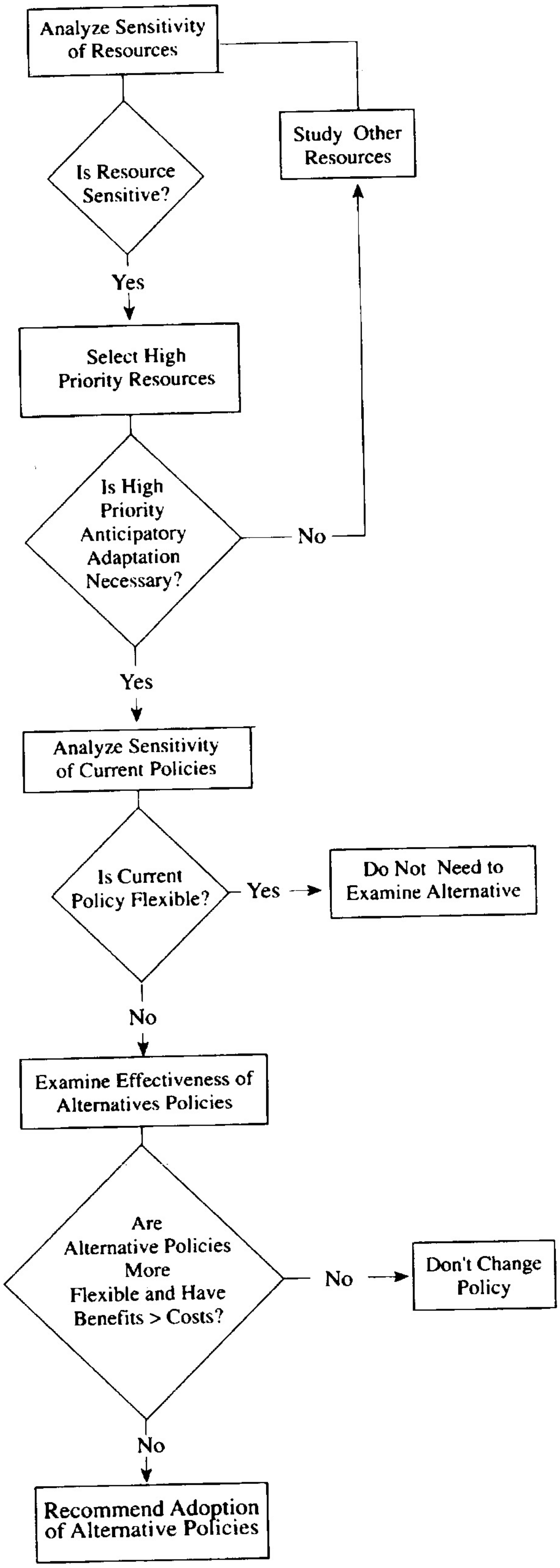


Figure 3.10: Process for analyzing the need for adaptation. *Source:* Smith (1997)

Chapter 4

Conceptual frameworks for vulnerability and adaptation

In this chapter, we review a variety of conceptual frameworks for vulnerability and adaptation, *i.e.,* of mental models that are considered relevant for adapting to climate change. These frameworks originate from such diverse contexts as environmental epidemiology, climate change assessment, coastal zone management, and vulnerability assessment. The common theme among all frameworks is that each of them aims to provide guidance for vulnerability and adaptation assessment by defining key concepts and their causal relationships, by indicating which system components need to be considered, and/or by identifying suitable intervention points for adaptation.

Some of the frameworks considered in this chapter are related to each other. This is particularly true for the three health-specific frameworks reviewed in the first three sections. These frameworks are nevertheless reviewed separately because this allows a more specific discussion of their suitability for climate change adaptation assessment.

4.1 DPSEEA framework

Purpose

The DPSEEA framework (or 'health and environment cause and effect framework') is a hierarchical model linking measurable indicators to environmentally caused diseases. It also displays the various levels of actions that can be undertaken to reduce environmental health impacts. The framework was designed to support decision-making on actions to reduce the burden of disease by describing environmental health problems from their root causes to the health effects, and by identifying areas for intervention (WHO, 1997a; Corvalan et al., 1999).

WHO (2001) state the following aims for the monitoring of climate change and health indicators based on a suitable conceptual framework such as DPSEEA:

- Detect early health impacts of climate change
- Improve quantitative analysis of the relationships between climate and health
- Improve analysis of vulnerability to climate change

- Assist in prediction of future health impacts of climate change, and validation of predictions
- Assess effectiveness of adaptation strategies
- Promote better research
- Inform policy makers and the public

The qualitative model provided by the DPSEEA framework can be developed further into a qualitative one if numerical functions are ascribed to the linkages between the various positions. The resulting quantitative model, or 'causal web' (see Section 4.2), may then serve as a basis for environmental burden of disease assessments (see Section 4.3).

Content

The DPSEEA framework divides the causal pathway of environmental health problems into several stages by distinguishing the following categories of indicators:

D Driving force (anthropogenic)
P Pressure (on the environment)
S State (of the environment)
$\mathbf{E_1}$ Exposure (of humans; *i.e.,* interaction between the environment and humans)
$\mathbf{E_2}$ Effect (in humans)
A Action

Figure 4.1 shows the generic form of the DPSEEA framework. In its simplest form, it represents a causal chain where one element from each level is linked to one element from the next level. In many cases, however, multiple linkages between different levels have to be considered. Figure 4.2 presents an adoption of the DPSEEA framework to climate change impacts on human health.

The DPSEEA framework was developed by the WHO (WHO, 1996b, 1997a,b, 1999a). It is based on the DPSEA framework (Kjellström and Corvalan, 1995), which, in turn, is based on the PSR (pressure-state-response) model (OECD, 1993). In the context of children's environmental health, the DPSEEA framework has been further developed into the MEME (Multiple Exposure, Multiple Effects) model, which emphasizes the multiple links between exposures and health effects (WHO, 2002b).

Application

The DPSEEA framework is widely applied in environmental health. It was, for instance, chosen as the basis for the development of a core set of environmental health indicators in Australia (enHealth Council, 2002). For compilations of environmental health indicators according to the DPSEEA framework, see WHO (1999b); Environment Canada (2001); Eyles and Furgal (2000); Prüss et al. (2001). The DPSEEA framework has also been adopted in proposals for monitoring health impacts of climate change (Corvalan, 2001; WHO, 2001).

Evaluation

Environmental health is concerned with the investigation of health effects caused by environmental hazards and with the development of response strategies to reduce these effects. The focus has traditionally

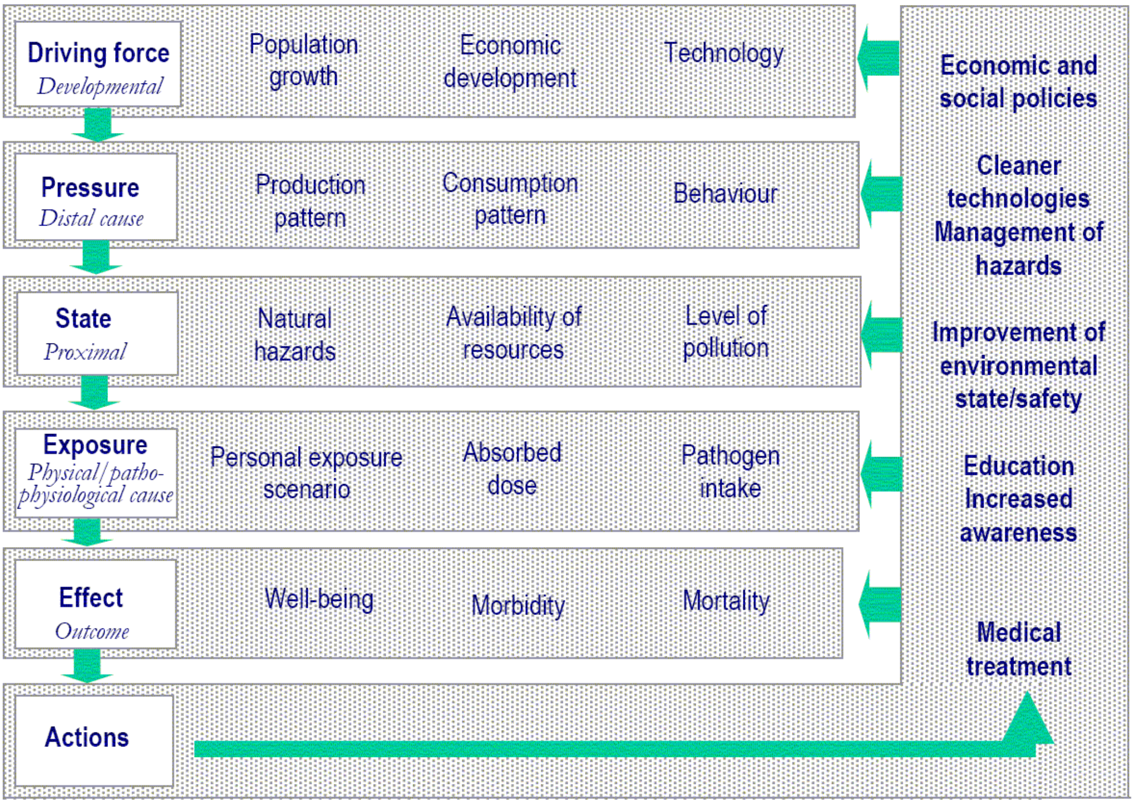


Figure 4.1: DPSEEA framework for environmental health. *Source:* WHO (1996b)

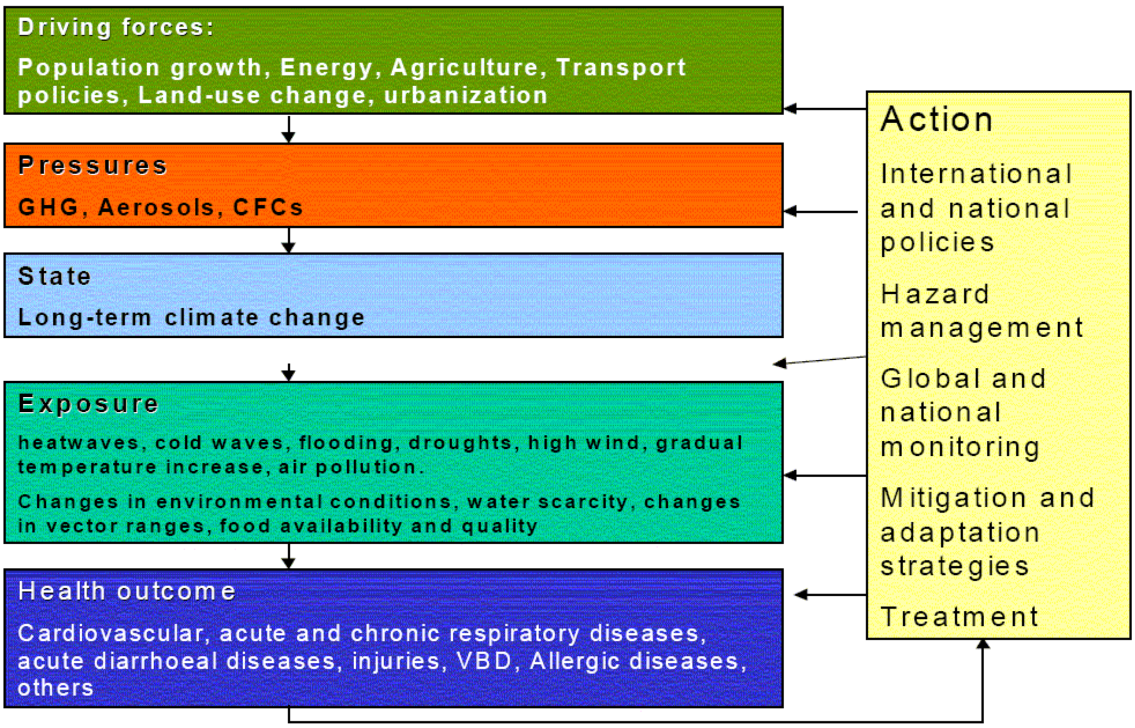


Figure 4.2: Adoption of the DPSEEA framework to climate change impacts on human health. *Source:* WHO (2001)

been on the exposure of humans to chemical, biological, or physical stressors. In these cases, the link between the exposure to an environmental hazard and its health effects can generally be described by a simple dose-response relationship.

The various stages of the DPSEEA framework form a logical causal chain that reflects this conventional linear approach to environmental health. A review of the DPSEEA framework by the WHO concludes that it is less well applicable to non-local hazards and physical risks (WHO, 1999a):

> *"[T]he DPSEEA framework works well for risks associated with environmental pollution, where the chain from driving force to source activity and thence to health effect via emissions and exposure is evident. [. . .] It is less appropriate, however, in the case of physical risks, as presented by natural hazards (e.g. flooding) or technology (e.g. traffic accidents), where the concept of 'pressure' is less meaningful. Nor can it easily be applied in full to those environmental hazards, such as famine, which affect health more by omission than commission. Like other aspects of environmental health indicators, therefore, the DPSEEA framework should be seen as an aid, not a straight-jacket; it needs to be adapted and modified according to circumstance."*

There are two major challenges to the application of an indicator framework (such as DPSEEA) in the context of global climate change. First, a conceptual framework for health-related indicators should ideally be able to consider all factors that affect the causation of a disease on a population level. However, the causal pathways along which anthropogenic climate change may affect human health are very diverse (see Figure 4.8). Some health effects occur as a direct consequence of a person being exposed to climatic stimuli (*e.g.,* heat-waves) whereas others are the consequence of a complex interaction of climatic, ecological, and social factors (*e.g.,* vector-borne diseases). As a result, the choice of suitable indicators for monitoring climate impacts on disease levels depends crucially on the aetiology of the particular disease considered. Second, the causation of climate-sensitive diseases often involves complex interactions between climatic and non-climatic risk factors, calling for consideration of non-climatic 'confounding' factors and their long-term dynamics.

The adoption of the DPSEEA framework shown in Figure 4.2 illustrates both the principal applicability of the DPSEEA framework to the health effects of climate change and its limitations. The original DPSEEA framework is extended by dividing the 'Exposure' indicators into meteorological indicators and climate-sensitive environmental conditions, such as river flows, ecosystem parameters, vector ranges, and crop production levels. While this approach is consistent with the causal structure of many indirect climate effects on health, it still does not address changes in important non-climatic determinants of disease. This is particularly problematic in the context of adaptation assessment because interventions concerned with increasing the adaptive capacity of communities cannot be adequately represented in this adoption of the DPSEEA framework.

Summarizing this discussion, the DPSEEA framework was developed to represent the typical causal pathway in environmental health problems, where human exposure to a chemical, biological, or physical agent directly causes adverse health effects. It is less well suited to represent the complex and diverse causal web that links climatic, environmental, and social factors to human health. To be useful for the identification and monitoring of climate-health indicators and for the development of response strategies to climate change, the DPSEEA framework would have to be extended in a flexible way to include intermediate ecological indicators and relevant non-climatic 'confounding' factors.

4.2 Causal webs and the hierarchy of causes

Purpose and Content

A causal web represents a hierarchical cause-to-effect model that comprises relationships among risk factors, and between risk factors and disease outcomes. Causal webs aim at facilitating the comparative quantification of health risks. They were developed by MacMahon et al. (1960) on the background of increasing knowledge about the multifactorial aetiology of many diseases to replace the then prevalent notion of ‘chains of causation’.

A causal web can be expanded to include the interactions between causal parameters. If the relative risk of disease from all causes and for all exposure levels is known, a causal web provides a framework for the calculation of the attributable and avoidable burden of disease (*cf.* Section 4.3) by the statistical techniques of multivariate analysis (Murray and Lopez, 1999; Murray et al., 2003).

The term ‘causal web’ is now often used more narrowly to denote a ‘hierarchy of causes’ that distinguishes three layers of risk factors: distal, proximal, and direct (physiological) causes. Distal causes operate through proximal and direct causes on the disease outcome in a cascade of causal interferences. The more proximal a cause is to a disease outcome, the more direct analytical relationship is expected with the health outcome.

Application

Causal webs and the hierarchy of causes have been widely applied in environmental health. Figure 4.3 shows an illustrative causal web that models the health effects of chronic exposure to lead. Causal webs have also been applied to the health effects of global climate change. The causal web depicted in Figure 4.4 modifies the standard hierarchy of causes to better represent the effects of climate change on infectious diseases.

In the context of environmental health, distal causes generally refer to socioeconomic driving forces for environmental change measured at the national or regional level; proximal causes describe the level of a health hazard in the local environment; and direct causes refer to the exposure of individuals to that hazard. The three levels of health hazards and the outcome level of the ‘hierarchy of causes’ framework have also been identified with the PSEE layers of the DPSEEA framework, as can be seen by comparison of Figures 4.1 and 4.3.

Evaluation

Causal webs, understood in a broad sense, can principally be used to represent the aetiology of any health problem. Prüss et al. (2001) suggest that they are better suited for representing the complexity of multiple interacting disease factors than more rigid indicator frameworks such as DPSEEA. The causal web in Figure 4.5, for instance, shows the relationship between climate, various social and biophysical risk factors, and malaria risk. Such a conceptual model is particularly suitable for identifying relevant components of the disease system and entry points for interventions.

Krieger (1994) evaluate the concept of the causal web, and the assumptions that it is built on from a methodological perspective. Their main criticism is the absence of any discussion of the theory shaping the model of the ‘web’. Whilst the causal web provides a framework for the classification of disease factors and methods for the quantitative analysis of their relationships, the pertinent literature does not

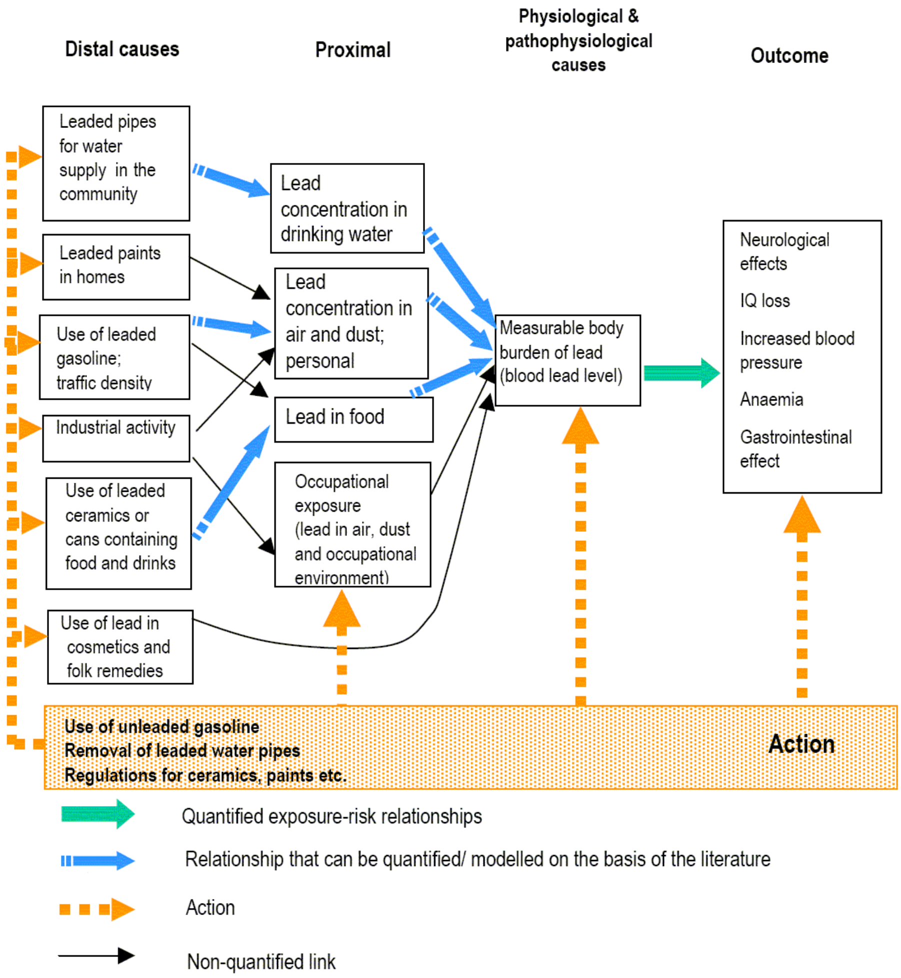


Figure 4.3: Causal web for chronic exposure to lead. *Source:* Prüss-Üstün et al. (2003)

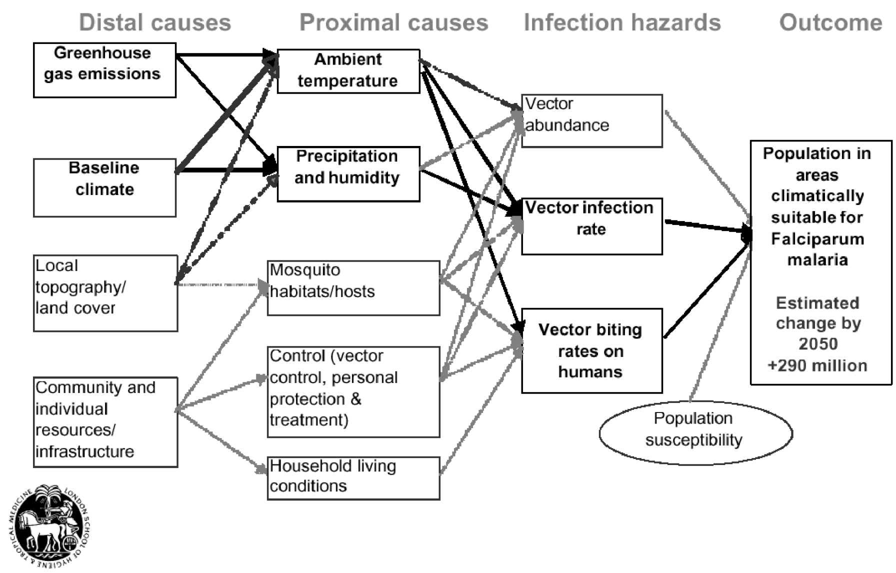


Figure 4.4: Causal web for the effects of climate change on infectious diseases. *Source:* Kay et al. (2000)

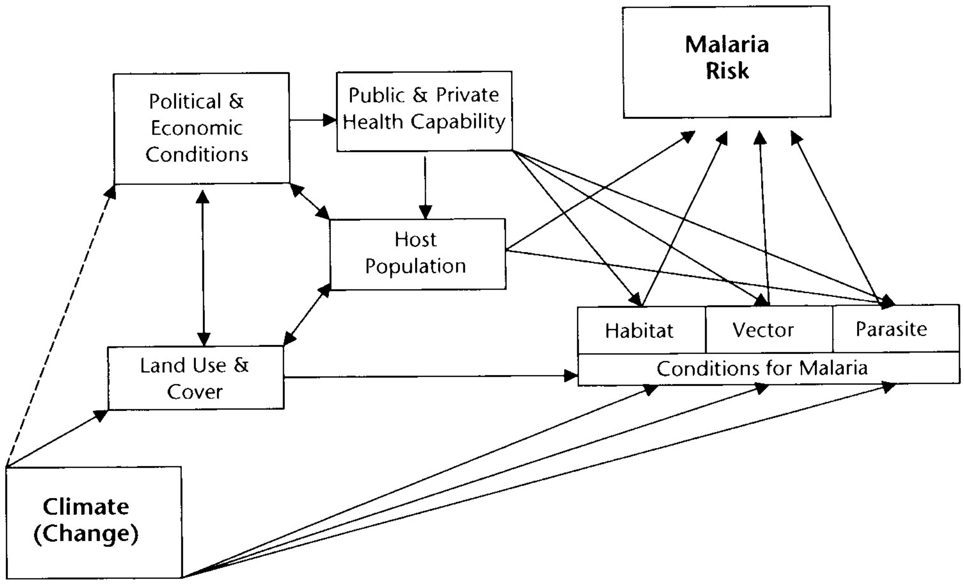


Figure 4.5: Conceptual model for the influence of climate change on malaria risk. *Source:* Casman and Dowlatabadi (2002)

provide any specific advice as to how one might elucidate the elements of such a web in the first place. They also argue that the web of causation relies upon a framework of biomedical individualism that does not distinguish between determinants of disease in individuals and in populations, or 'the causes of cases' from 'the causes of incidence'. The first interpretation highlights individual susceptibility and focusses on interventions aimed at high-risk individuals whereas the latter highlights population characteristics and the need to shift disease levels in the entire population. In an attempt to better integrate biological and social understandings of current and changing population patterns of health and disease, an ecosocial framework is proposed for developing epidemiologic theory that would encourage the use of contextual or multi-level analysis.

Applicability to climate change and human health

Causal webs can principally be used to represent the aetiology of any health problem, including climate-sensitive ones. However, they do not adequately distinguish the hazardous agents from the environmental and host factors that moderate the effects of human exposure to these agents. For instance, the causal web shown in Figure 4.4 does not distinguish between anthropogenic causal factors of a disease (such as greenhouse gas emissions) and natural baseline conditions (such as baseline climate and local topography), both of which are categorized as 'distal causes'. The distinction between the two is not only of theoretical interest but has also important consequences for the modelling approach and for the design of intervention strategies.

The narrower interpretation of causal webs as a classification of causal factors into distal, proximal, and direct causes is not always well suited for representing the complexity of climate-sensitive health effects. In particular, it may easily oversee those societal characteristics that determine the adaptive capacity of a community to climate change and variability. If this typology is nevertheless applied, the classification of a particular risk factor may depend on the type of health effect considered. For instance, 'ambient temperature' is a *proximal* cause for vector-borne diseases but it would be considered a *direct* cause for heat stress.

4.3 Burden of Disease assessment

Purpose

Burden of Disease (BoD) assessments strive to provide a quantitative answer to the question, *"How big is this particular health problem?"*. They do this by establishing an appropriate measure of health status (*e.g.,* disability-adjusted life years, or DALYs), and determining how much ill-health can be attributed to particular risk factors. An important category of BoD assessment is comparative risk assessment, where the contributions of different risk factors to the current burden of disease at the population level are systematically evaluated in order to provide an empirical basis for priority-setting in health policy.

Content

Two fundamental concepts underlying BoD assessments are 'attributable burden' and 'avoidable burden' of disease. They were developed to quantify the disease levels caused by human exposure to particular risk factors, and to estimate the effects that reductions in the population exposure to these risk factors would have. Classically, the *attributable* burden is defined as the burden of disease in a population that would be eliminated in the absence of the exposure to a specific risk factor (assuming that 'zero exposure' goes along with minimum risk). If complete elimination of the risk factor seems unrealistic, the *avoidable* burden is defined as the reduction in the burden of disease if the exposure to a risk factor is reduced to an alternative (or 'counterfactual') distribution that involves a partial reduction of current exposure levels. Four types of distributions of exposure are used as counterfactuals: theoretical, plausible, feasible, and cost-effective minimum risk.

Murray and Lopez (1999) argue that this classical definition is too restrictive when there is a time lag between the exposure to a risk factor and the health effect. They generalized the concept by explicitly including the time dimension, defining the *attributable* burden as "the reduction in the *current or future* burden of disease in a population if the past exposure to a risk factor had been equal to some counterfactual distribution", and the *avoidable* burden as "the reduction in the *future* burden of disease if the current or future exposure to a risk factor is reduced to a counterfactual distribution". Murray et al. (2003) note that "while attributable burden is easier to measure and more certain, avoidable burden is more useful for policy purposes". They also suggest that their discussion of time-lagged health effects "would motivate reporting the estimates of avoidable burden in multiple ways including both snapshots (for example annual) and cumulative estimates as well as over short and long time frames."

Application

The concepts of attributable and avoidable burden have been applied to a large variety of risk factors, including climate change and human health (*e.g.,* Kay et al., 2000; Kovats et al., 2003b). Figure 4.6 illustrates how they can be applied to climate-sensitive diseases under different greenhouse-gas stabilization scenarios.

The most prominent example of a BoD assessment is the Global Burden of Disease (GBD) project initiated by the World Bank and the WHO. This project periodically assesses the available evidence to quantify the burden of disease and injury, its causes in terms of risk factors and broader health determinants, and the likely burden in the future attributable to a variety of major risk factors (Murray and Lopez, 1996; Murray et al., 2001). The data are broken down by age, sex, and region. Since 2000, the GBD exercise includes climate change as one of the risk factors investigated (Kay et al., 2000, Annex 6.7).

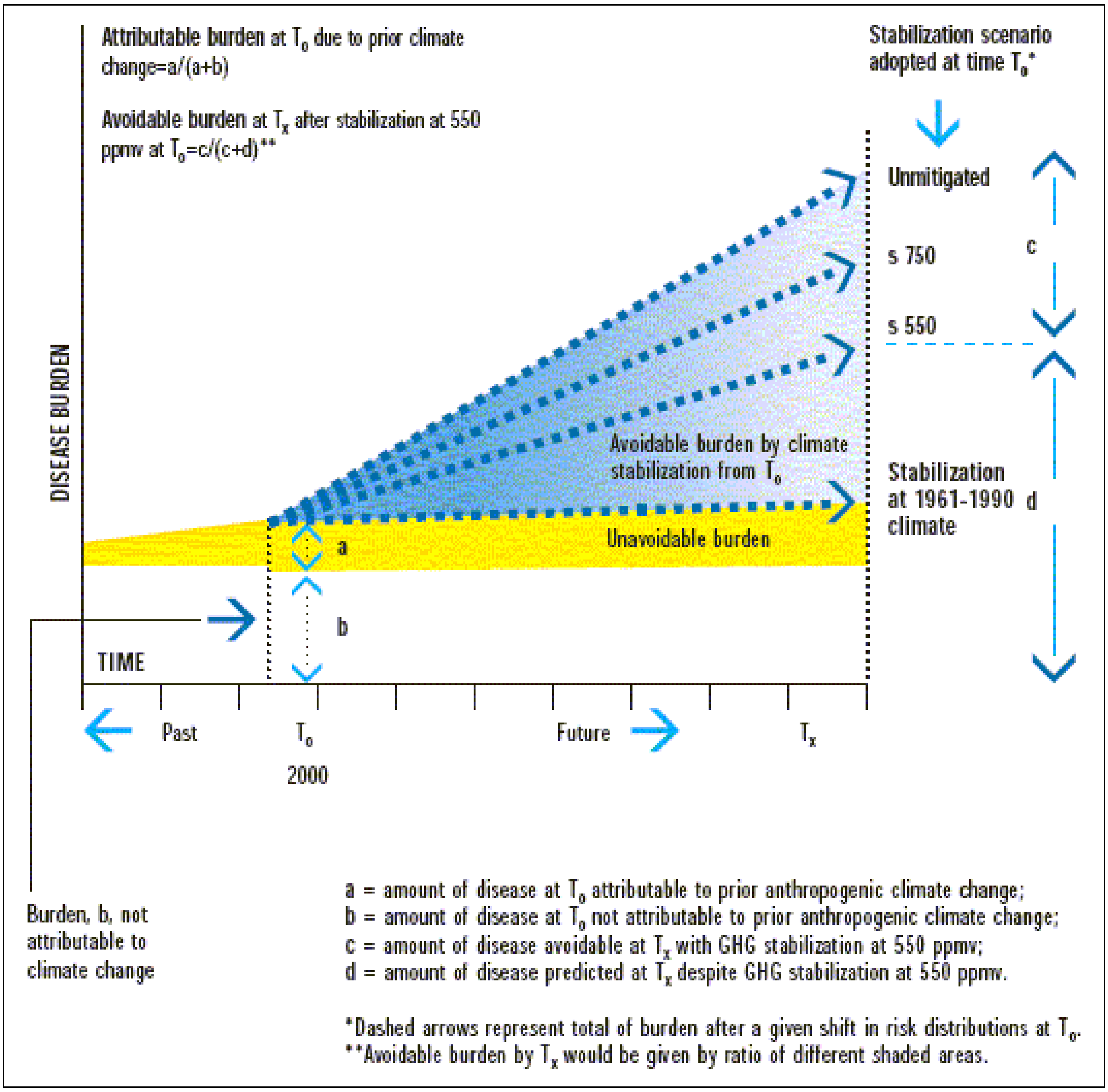


Figure 4.6: Application of definitions from Burden of Disease assessment to climate change. *Source:* Kovats et al. (2003b)

Applicability to climate change and human health

The applicability of BoD concepts to anthropogenic climate change was reviewed by a group of experts in Kay et al. (2000, Annex 5.3). The most important methodological questions raised were

- the definition and classification of the risk factor (*e.g.,* climate change *vs.* climate variability);
- the choice of alternative (counterfactual) scenarios and their time-frames;
- the consideration of secondary effects of interventions;
- the strength of evidence in different parts of the causal web; and
- the appropriate geographical resolution.

Interestingly, the recommendations on how to deal with these issues differed significantly depending on the type and context of assessment. In all but one instance, different recommendations were made for "within the GBD assessment" and "outside the GBD assessment".

The concepts of attributable and avoidable burden of disease can, in principle, be applied in climate *impact* assessments aimed to support mitigation policy. However, the attribution of certain health effects to anthropogenic climate change may be difficult in practice due to natural climate variability and the complexity of the climate-health relationship. In particular, this attribution is *not* possible for single weather events because the separation of anthropogenic climate change from natural climate variability can only be done at a higher aggregation level. Independent of these empirical challenges, the 'classical' concept of avoidable burden of disease is *not* applicable in *adaptation* policy assessments due to the lack of a counterfactual scenario of exposure.

Below we discuss the validity of key assumptions underlying BoD assessment, and of possible modifications to the original concepts of 'attributable burden' and 'avoidable burden' in the context of climate change and human health.

Quantification of hazard and exposure: The concepts of attributable and avoidable burden of disease are based on the comparison of the health effects associated with at least two different population distributions of exposure to a specific health hazard. Typically, one of them is the current distribution and the other a lower counterfactual distribution. We have already argued in Section 3.2 that the concept of 'exposure' cannot be straightforwardly applied to indirect health effects of climatic stimuli, which are caused by changes in climate-sensitive ecological systems (*e.g.,* disease vectors) rather than by the direct exposure of humans to hazardous conditions. We have also noted that the development of quantitative future exposure scenarios is difficult for a complex, multi-dimensional, uncertain hazard such as anthropogenic climate change. Hence, a BoD assessment is more feasible for direct effects of clearly defined climatic stressors (*e.g.,* heat-waves) than for indirect effects of complex climatic characteristics.

Monotonicity of the dose-effect relationship: Whilst most risk factors investigated in burden of disease assessments exhibit a monotonic dose-effect relationship where 'zero exposure' corresponds to 'theoretical minimum risk', this is not necessarily the case for climate change. For instance, studies on the relationship between ambient temperature and mortality have generally identified a J-shaped relationship where mortality increases at temperatures below *and* above a population-dependent optimal temperature range (Martens and McMichael, 2002). The initial effects of anthropogenic climate change may thus be beneficial in some regions where reductions in winter mortality outweigh increases in summer mortality.

Non-monotonic dose-effect relationships are often the consequence of the combination of monotonic but opposed dose-effect relationships between one risk factor and different health impairments. For instance, ambient temperature is positively related to heat-related stresses (*e.g.,* dehydration) but negatively related to cold-related stresses (*e.g.,* frostbites). Non-monotonic dose-effect relationships have also been observed for other risk factors (*e.g.,* alcohol consumption). They require considerable caution in the choice of counterfactuals and in the aggregation, presentation and interpretation of burden of disease estimates for different diseases in order to prevent unsupported policy conclusions.

Time horizon: Attributable and avoidable burden of disease are originally defined for specific *points* in time. However, this conceptualization is not well suited in a climate change context due to the very long time scales involved in global climate change, and in the mitigation of its causes. Consistency and compatibility across scenarios in climate impact and mitigation assessments can be achieved if attributable and avoidable burden of disease are defined *cumulatively* over an identical period of time, as suggested by Murray et al. (2003). Attributable burden is then defined as the difference in the burden of disease between a business-as-usual climate change scenario and a counterfactual that represents theoretical minimum risk (*i.e.,* a constant baseline climate), whereas the avoidable burden refers to the difference between the business-as-usual scenario and a counterfactual that represents feasible minimum risk (*e.g.,* a greenhouse-gas stabilization scenario). In the absence of discounting of future health effects, the cumulative attributable burden refers to the sum of the blue and yellow area in Figure 4.6, whereas the cumulative avoidable burden refers to the blue area or some fraction thereof, depending on the stabilization scenario. Various implications of a cumulative definition of the burden of disease, including methodological issues related to the choice of different time horizons and discounting schemes, are discussed in Murray et al. (2003).

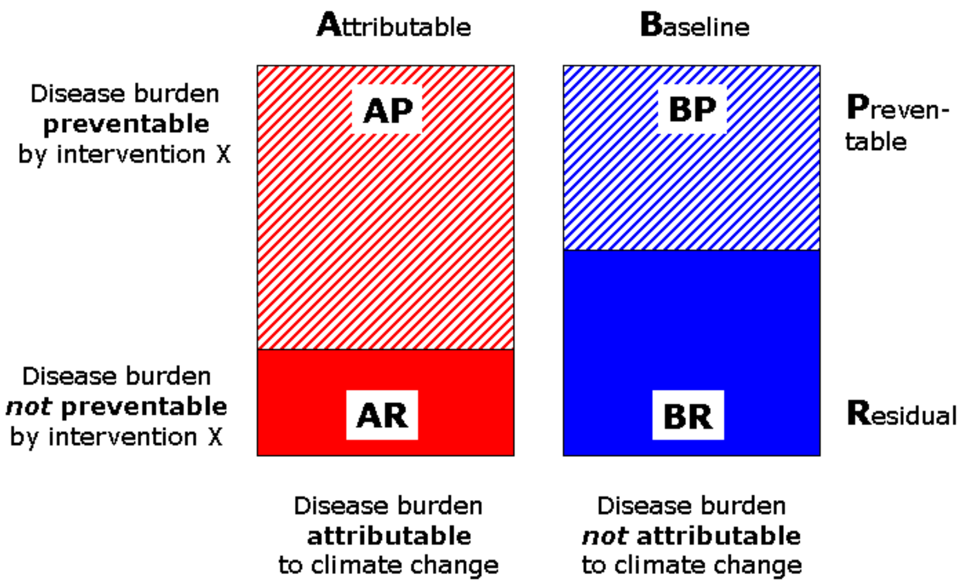
In the remainder of this section, we discuss an extension of the BoD terminology that allows to describe relevant fractions of the disease burden in climate change *adaptation* assessments.

Existence of a counterfactual exposure scenario: Interventions in environmental health typically aim at reducing the burden of disease by limiting population exposure to the underlying health hazard(s). In the context of global climate change, this concept is denoted as *mitigation* of climate change. *Adaptation* to climate change, in contrast, comprises a wide range of interventions that aim to reduce adverse health effects *without* reducing the level of climate change. Since adaptation to climate change does not lead to a counterfactual distribution of exposure to the health hazard 'global climate change', the original definitions of attributable and avoidable burden of disease are not applicable in adaptation assessments.

In this situation, one can either refrain from using the BoD concept in the context of adaptation to climate change or come up with an adapted terminology. This terminology would need to account for the fact that most interventions motivated by future climate change will also prevent current disease burden that is *not* attributable to climate change. Proponents of the first strategy emphasize that the term 'avoidable disease burden' has an established meaning in epidemiology that should not be changed. The prioritization of interventions in an adaptation policy assessment should instead be done using the tools and terms of intervention analysis. Proponents of the second strategy argue that the term 'avoidable disease burden' (or a similar term) is likely to be used anyhow by non-specialists in the context of adaptation to climate change. Consequently, scientists should develop a terminology for communicating the residual health impacts and the expected health benefits of specific interventions under different climate change scenarios that is both consistent and intuitively understandable by decision-makers.

In Figure 4.7, we propose a terminology for different fractions of disease burden that is suitable for both types of climate change adaptation assessments distinguished in Section 2.1. By using the term 'preventable burden' instead of 'avoidable burden' to describe the benefits of adaptation measures, this terminology does not alter established technical definitions, thus minimizing the risk of misunderstanding. The various boxes in Figure 4.7 represent different fractions of the burden of disease whereby the temporal dimension is not explicitly shown. The red and blue stacks refer to the burden of disease attributable and not attributable to climate change, respectively, whereby the latter is termed 'baseline burden'. In this hypothetical example, about half of the total burden of disease is attributable to climate change. The hatched and solid areas refer to the burden of disease preventable and not preventable by an intervention X, respectively, whereby the latter is termed 'residual burden'. In this example, about three quarters of the disease burden attributable to climate change and about half of the baseline burden are preventable by this particular intervention.

We will now illustrate an application of the proposed methodology using heat-waves. This example refers to a hypothetical community in Europe that is already affected by heat-waves, and that considers the implementation of a weather watch and warning system as the proposed intervention 'X'. Such warning systems can reduce adverse health effects of heat-waves independently of their attribution. The



AP	preventable attributable burden
AR	residual attributable burden
BP	preventable baseline burden
BR	residual baseline burden
$A = AP + AR$	(total) attributable burden
$B = BP + BR$	(total) baseline burden
$P = AP + BP$	(total) preventable burden
$R = AR + BR$	(total) residual burden
$T = A + B = P + R$	total disease burden

Figure 4.7: Proposed terminology for describing different fractions of the burden of climate-sensitive diseases in climate change adaptation assessments

disease burden in this population caused by heat-waves in the baseline climate without the intervention is denoted as 'total baseline burden' (B). Anthropogenic climate change is expected to increase both the frequency and severity of heat-waves. The 'total disease burden' (T) for a specific future climate scenario without the intervention can be estimated using analogue techniques or mathematical modelling. The 'total attributable burden' for the respective climate change scenario can then be determined as the difference between the total disease burden and the total baseline burden ($A = T - B$). Estimates of the reduction in disease burden for different climate states following the intervention can, in principle, be obtained from effectiveness of intervention studies. Extrapolation of these results to the baseline climate and the climate change scenario results in estimates of the 'preventable baseline burden' (BP) and the 'total preventable burden' (P), respectively. (We do not want to discuss here the empirical difficulties of transferring effectiveness of intervention results from one population to another that may differ in terms of climate characteristics, housing conditions, and other socioeconomic factors.) From this information, it is further possible to estimate the 'attributable preventable burden' ($AP = P - BP$), the 'residual baseline burden' ($BR = B - BP$), the 'total residual burden' ($R = T - P$), and the 'residual attributable burden' ($AR = R - BR$). An important issue to consider here is the degree of uncertainty associated with the different estimates. In general, uncertainty is larger for assessments of (future) attributable burden than for the baseline burden, and for assessments of either preventable or residual burden than for their sum.

The proposed terminology can be applied in all types of climate impact and adaptation assessments identified in Chapter 2:

- Climate impact assessments in support of mitigation policy aim at determining the additional disease burden due to climate change for different mitigation and adaptation scenarios. This information is represented by the 'total attributable burden' (A; without adaptation) and the 'residual attributable burden' (AR; with adaptation), respectively.
- Adaptation assessments as part of a climate vulnerability assessment aim at determining the 'preventable attributable burden' (AP), which allows more realistic estimates of the 'residual attributable burden' (AR).
- Adaptation assessments undertaken to support adaptation planning aim primarily at estimating the 'total preventable burden' ($P = AP + BP$), which is independent from the burden attributable to climate change ($A = AP + AR$). If the baseline burden of a particular disease is relatively large and an intervention also reduces the baseline burden, the total preventable burden may even exceed the total attributable burden (*i.e.,* $AP + BP > AP + AR$).

  Even though the main outcome of an adaptation policy assessment is the 'total preventable burden' (or total adaptation benefit) for different adaptation scenarios, the different levels of uncertainty associated with its two components often call for their separate assessment. Uncertainty is typically much larger for the 'preventable attributable burden' (or primary adaptation benefit), which is contingent on the selected future climate scenario, than for the 'preventable baseline burden' (or secondary adaptation benefit). Therefore, interventions that were originally designed to reduce the disease burden of *future* climate change (*i.e.,* to have a large *primary* adaptation benefit) may in practice have to be evaluated primarily by their ability to reduce the *current* disease burden (*i.e.,* by having a large *secondary* adaptation benefit) if estimates of the primary adaptation benefit are too uncertain to motivate costly action.

Summarizing the discussion above, it turns out that minor adjustments are sufficient for making the concepts of attributable and avoidable burden principally applicable to climate impact assessments. Their practical applicability may, however, be limited by insufficient knowledge about future climate change and the associated changes in regional health risks. The existing conceptualization of attributable and avoidable burden cannot be applied in adaptation assessments. An alternative terminology was proposed that distinguishes four different categories of disease burden for each choice of climate scenario and adaptation strategy, and that can be applied in all types of adaptation assessments for climate change.

4.4 Framework of the US health impacts assessments

Purpose

The *National Assessment of the Potential Consequences of Climate Variability and Change for the United States* (US National Assessment) contained one component devoted to the potential health impacts of climate change. The five categories of health problems assessed in the US National Assessment included the four categories investigated in cCASHh (*cf.* Section 1.5) and, additionally, air pollution-related health effects. The assessment involved a search for and qualitative expert judgement review of data on the links between climatic factors and population health. It identified vulnerable populations, adaptation strategies, research needs, and data gaps (Bernard and Ebi, 2001).

The scope of the US health impacts assessment was defined by the following framework of questions (Patz et al., 2000):

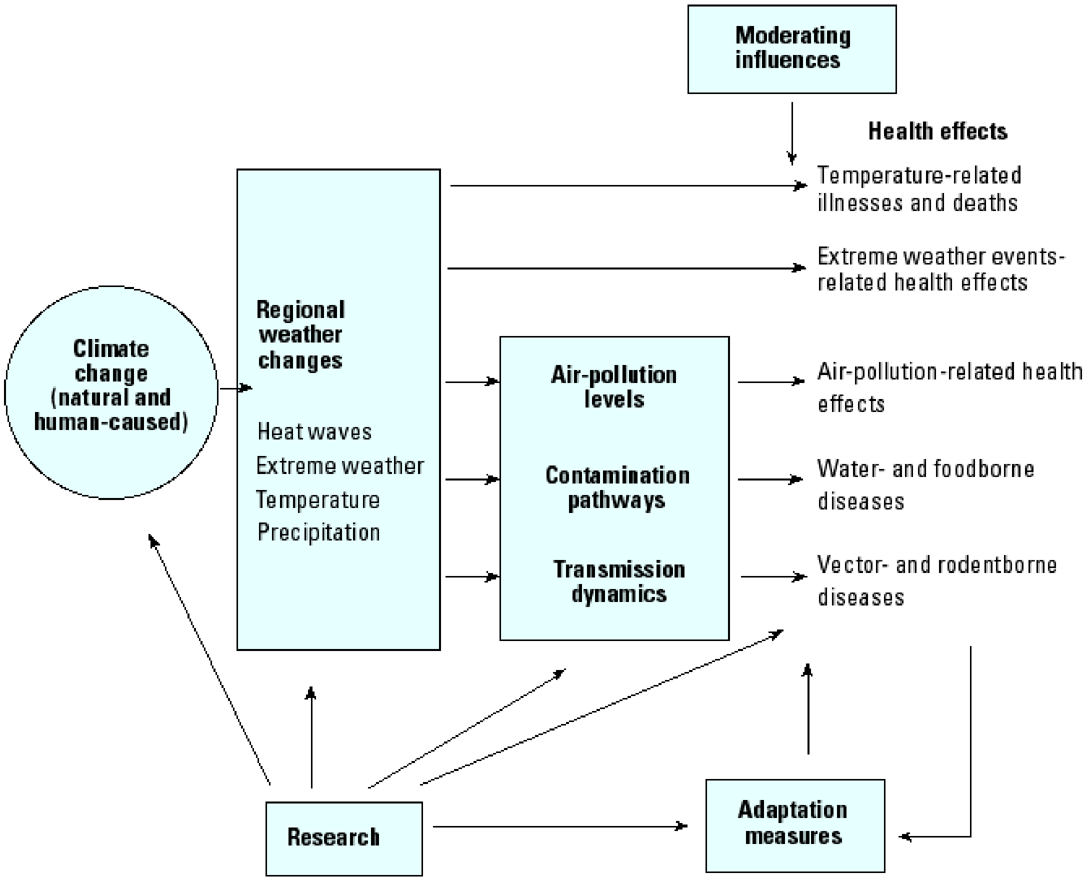


Figure 4.8: Conceptual framework for climate change impacts on human health. *Source:* Patz et al. (2000)

1. What is the current status of the nation's health, and what are current stresses on its health?
2. How might climate variability and change affect the country's health and existing or predicted stresses on health?
3. What is the country's capacity to adapt to climate change; for example, through modifications of the health infrastructure or by adopting specific adaptive measures?
4. What essential knowledge gaps must be filled to fully understand the possible impacts of climate variability and change on human health?

The first two questions focus on the assessment of current and future risks. The third question focusses on risk management options. The fourth question was intended to identify key remaining research gaps that limit the ability to answer the previous questions. Analogous questions were posed to assessors for all other sectors (Scheraga and Furlow, 2001).

Content

Figure 4.8 shows the generic framework that was applied in the Health Sector assessment of the US National Assessment (Patz et al., 2000). The core of this framework consists of a causal diagram that can be summarized as follows: Global climate change causes changes in the regional climate, manifested as changes in the frequency, magnitude and distribution of weather patterns; these climatic changes, in turn, alter disease risks in the exposed population, either directly or by affecting ecological or chemical processes. Additional boxes and arrows suggest that the exposure-effect relationship is moderated by non-climatic factors, and that it may be influenced by adaptation measures.

Application

The generic framework depicted in Figure 4.8 forms the basis for the frameworks developed for each category of health effects investigated in the US National Assessment. These disease-specific frameworks, which are shown in Figures 4.9–4.12, were then used to guide the qualitative assessment of potential health impacts of climate change, and its implications for health management and further research.

Scheraga and Furlow (2001) note that the state of knowledge about potential consequences of climate change was not sufficient to support any modelling in the Health Sector assessment, in contrast to most other sectors addressed in the US National Assessment. Instead, expert judgement and existing peer-reviewed studies were used to provide qualitative insights to stakeholders. Hence, the actual assessment used the climate change projections developed specifically for the National Assessment only qualitatively, and the associated socioeconomic projections were not used at all (Bernard and Ebi, 2001). However, it should be noted that the assessment of the *Health Effects of Climate Change in the UK* (Department of Health, 2001) used a variety of techniques to come up with quantitative estimates for the health impacts from global climate change, wherever possible. This fact raises some doubt whether the exclusive focus on qualitative methods in the health sector assessment was exclusively motivated by scientific reasons.

Evaluation

The generic framework presented in Figure 4.8 presents the main causal pathways along which climate change might influence human health. However, it is too crude to provide specific guidance for adaptation assessments. In addition, parts of that framework are difficult to interpret since the diagram combines the graphical elements in an inconsistent way. For instance, it is not clear why some elements of the diagram are depicted in rectangular boxes, others in circles, and others without such a border. Given the diversity of graphical elements used, it is confusing that the same symbols are used to represent risk factors (*e.g.,* air-pollution levels) and human actions (*e.g.,* adaptation measures). The use of arrows in the diagram is also inconsistent. Whilst most of the horizontal arrows seem to represent a cause-effect relationship, others do not fit into this interpretation. It is, for instance, difficult to conceive how research could cause, or otherwise influence, regional weather changes.

Similar problems are associated with the disease-specific causal diagrams: Some arrows seem to miss completely. For instance, 'vector longevity' is not linked to any other component in Figure 4.11, and the 'survival, persistence, and reproduction of microbial agents' is not affected by 'local and regional weather changes' in Figure 4.12. 'Adaptation measures' do not affect any of the determinants of 'disease transmission dynamics' in Figure 4.11, and they have no influence at all in Figure 4.12. It is also not clear what the arrows originating from 'research' in the various diagrams mean.

In summary, the conceptual frameworks applied in the US health impacts assessment denote important elements to be considered in climate change impact and adaptation assessments. However, the purpose of the various framework diagrams is not well defined, they neglect some important relationships, and they contain many inconsistencies. Whilst the various frameworks may be used to initiate thinking about the relationship between climatic factors and health effects in an adaptation assessment, they should be interpreted with considerable care due to their serious deficiencies.

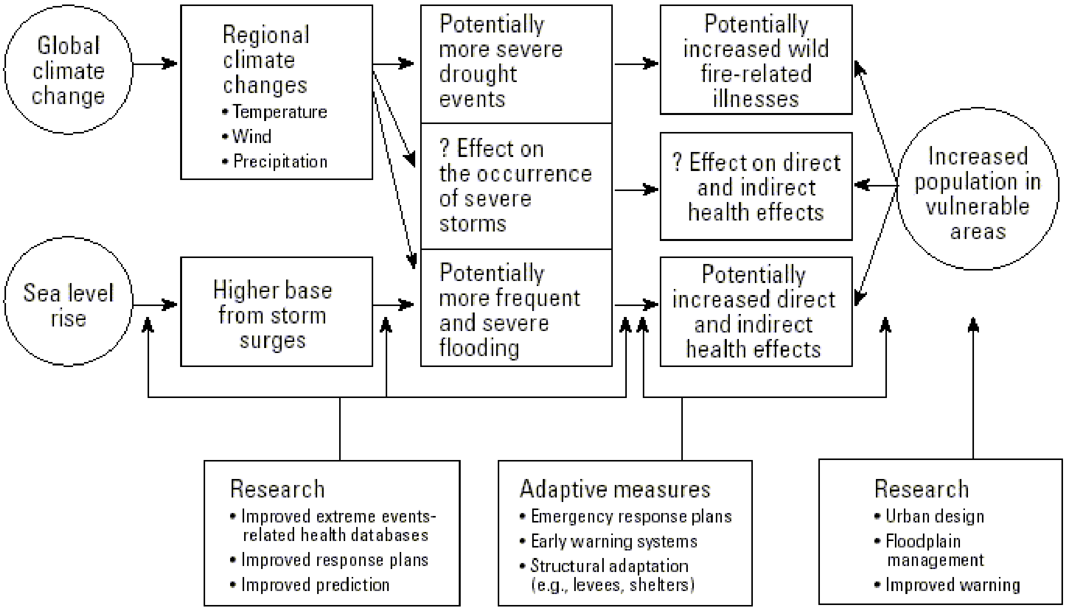


Figure 4.9: Conceptual framework for climate change impacts on extreme weather events-related health effects. *Source:* Greenough et al. (2001)

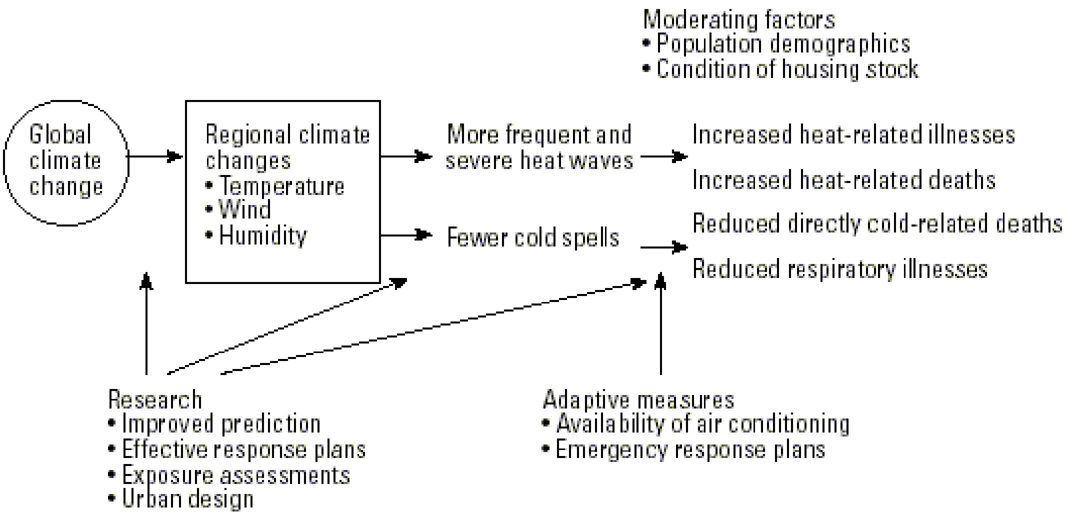


Figure 4.10: Conceptual framework for climate change impacts on temperature-related illness. *Source:* McGeehin and Mirabelli (2001)

4.5 Conceptual framework for coastal zone vulnerability assessment

Purpose

Klein and Nicholls (1999) have developed a 'conceptual framework for coastal vulnerability assessment'. This framework is largely independent of the coastal adaptation framework that the same authors have developed together with an additional co-author (Klein et al., 1999, see Section 3.8). The main purpose of the framework reviewed here is to clarify the interaction of the natural and socioeconomic determinants of vulnerability to sea-level rise in coastal zones. It does not address the assessment process itself.

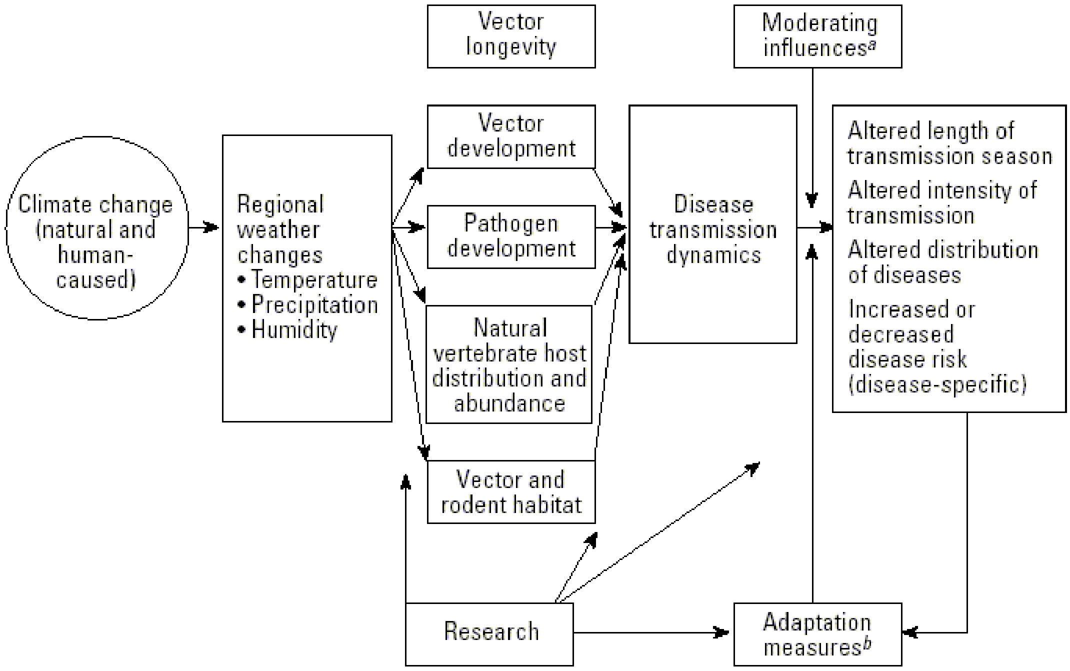


Figure 4.11: Conceptual framework for climate change impacts on vector- and rodent-borne diseases. *Source:* Gubler et al. (2001)

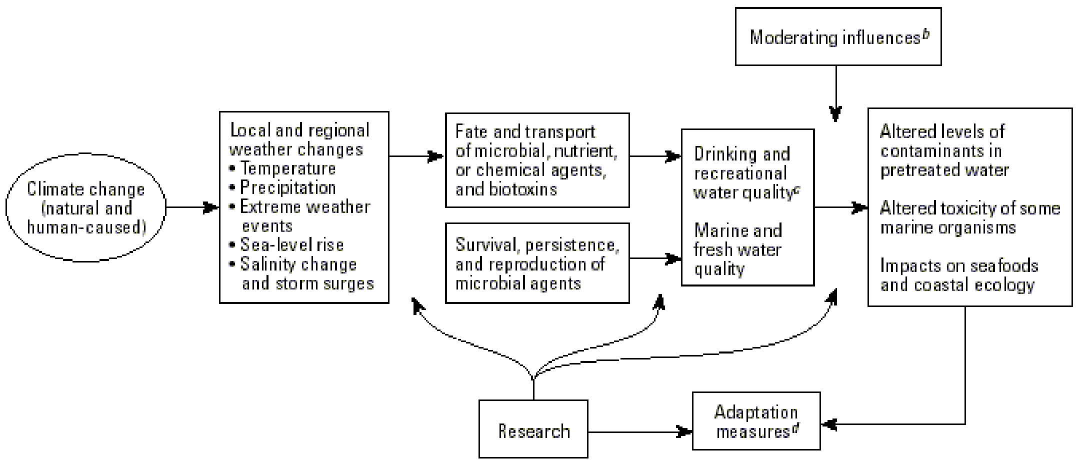


Figure 4.12: Conceptual framework for climate change impacts on water- and food-borne diseases. *Source:* Rose et al. (2001)

Content

The conceptual framework for coastal zone vulnerability is depicted in Figure 4.13. It clearly distinguishes between relevant characteristics of the *natural system* and those of the *socioeconomic system*, using a similar structure to describe the two subsystems. Most importantly, the framework illustrates how the (residual) impacts of sea-level rise on the socioeconomic system depend on the level of biogeophysical effects as well as society's ability to prevent or cope with them.

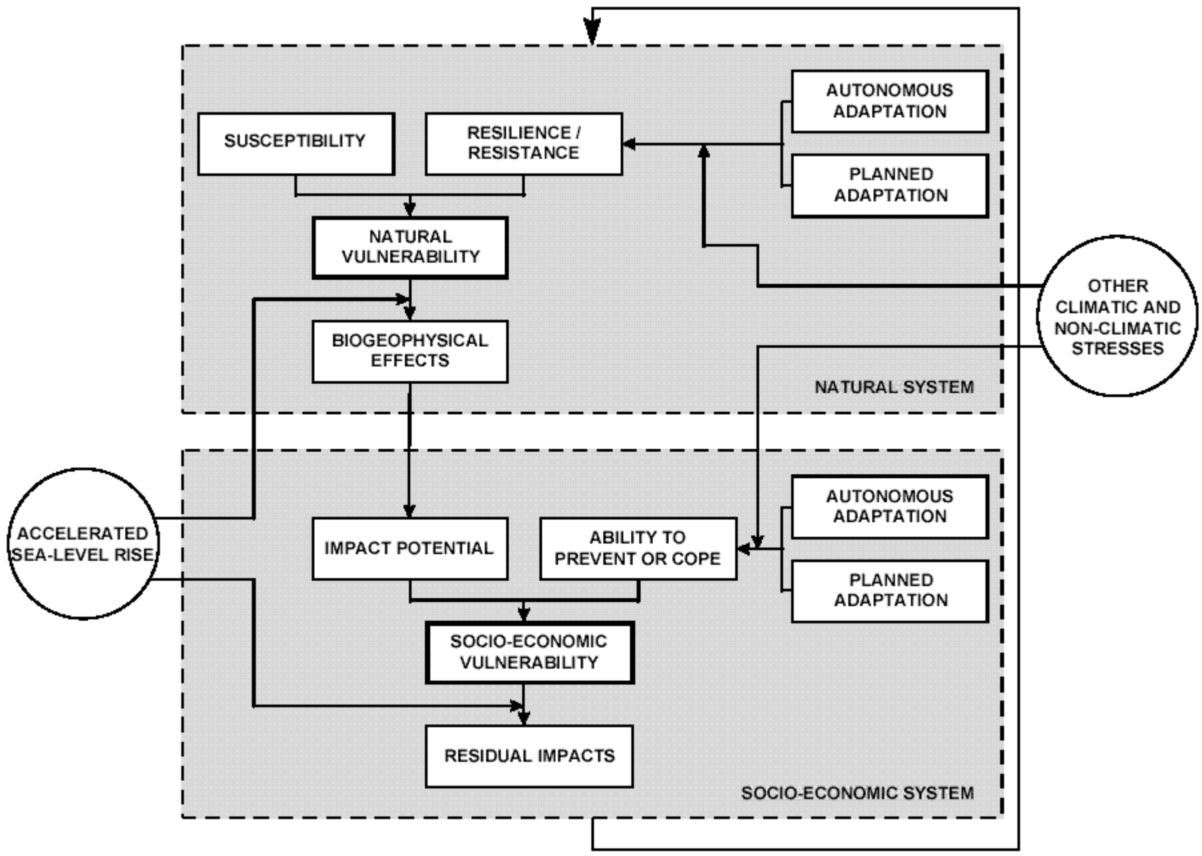


Figure 4.13: Conceptual framework for coastal zone vulnerability assessment. *Source:* Klein and Nicholls (1999)

Application

The main purpose of the present framework was to change the thinking about societal response options to climate change and sea-level rise rather than to be directly applied in adaptation assessments. A highly simplified version of that framework was used to assess vulnerability to sea-level rise in Pacific island countries (de Wet, 1999).

Evaluation

The conceptual framework shown in Figure 4.13 has substantially influenced the thinking about the vulnerability of coastal zones to accelerated sea-level rise. It emphasizes, in particular, the importance of planned adaptations for reducing the potential effects of anthropogenic climate change and sea-level rise on coastal zones. However, some aspects of the diagram are less consistent than others. It is, for instance, difficult to interpret the term 'planned adaptation' in the context of the natural system.

Applicability to climate change and human health

The coastal zone vulnerability framework emphasizes the potential for human agency in shaping the impacts of sea-level rise, which has been underestimated in early climate change assessments for the coastal zone, The research community addressing climate change effects on human health, in contrast, is already well aware of the importance of human behaviour for climate-sensitive disease risks. In addition, the distinction between the natural system and the socioeconomic system is less relevant for the health impacts of climate change, which affect humans primarily in their capacity as biological entities. Therefore, the present framework does not offer substantial new knowledge or guidance for the design of adaption strategies to climate change in human health.

4.6 SUST vulnerability framework

Purpose

The Research and Assessment Systems for Sustainability Program (SUST) at Harvard University developed a conceptual framework for designing place-based vulnerability assessments of coupled human-environment systems with diverse and complex linkages (Turner II et al., 2003a). The SUST framework builds on an earlier framework that became known as the Airlie House framework (Research and Assessment Systems for Sustainability Program, 2001). According to its documentation, it seems to have an analytical as well as a normative purpose:

> *"this framework [...] provides a general framing of vulnerability; the specific variables and relationships to be studied, and the methods for studying them, will vary from case to case. [...] The framework aims to make vulnerability analysis consistent with the concerns of sustainability and global environmental change science. [...] The framework is not explanatory but provides the broad classes of components and linkages that comprise a coupled system's vulnerability to hazards." (Turner II et al., 2003a)*

Content

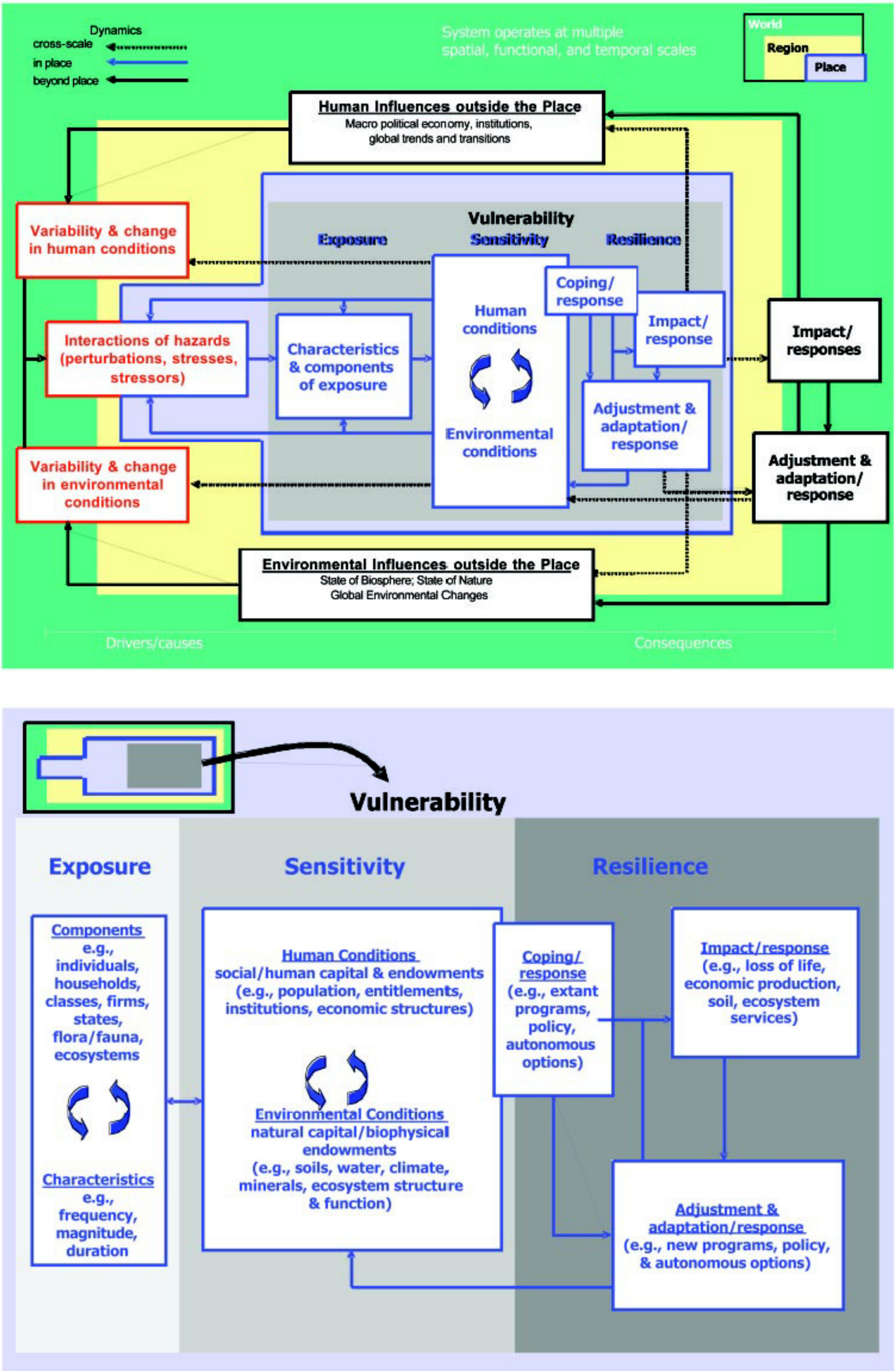
The SUST framework combines and transcends two archetypal reduced-form models that have informed vulnerability analysis: the risk-hazard and pressure-and-release models. Figure 4.14.a shows the overall SUST vulnerability framework, and Figure 4.14.b presents a more detailed picture of the components of vulnerability. The framework emphasizes that place-based vulnerability analysis needs to consider multiple scales (*i.e.,* processes and hazards at local, regional, and global scales), and that it needs to analyze the coupled human-environment system in an integrated rather than reductionist manner.

Application

The SUST vulnerability framework has been applied within the SUST program from which it originates. Turner II et al. (2003b), a companion paper to Turner II et al. (2003a), describe three vulnerability case studies analyzing the overall vulnerability of selected regions whose economies are dominated by primary sector activities (*i.e.,* agriculture, fishing and hunting). Turner II et al. (2003b) claim that these case studies apply the SUST framework yet without providing substantial reference to it.

Evaluation

The main message of the SUST framework: that human and biophysical vulnerability are linked, and that place-based vulnerability is contingent on factors and stressors beyond the study region, is clearly



(a)

(b)

Figure 4.14: SUST vulnerability framework. (a) Full framework; (b) Detailed framework. *Source:* Turner II et al. (2003a)

important in the context of climate change and human health. However, some details of the SUST framework limit its applicability in a climate change context. First, Figure 4.14.a does not show the human causation of ‘global environmental changes’, which is particularly important in the context of global climate change. Hence, the mitigation of climate change is not reflected as a response option in this framework. Second, the framework diagram presents a static snapshot of the determinants of vulnerability. In contrast, key concepts for assessing vulnerability to global climate change, such as adaptive capacity, can only be meaningfully defined from a dynamic perspective. Third, the framework shows ‘human conditions’ only in the ‘sensitivity’ part of the grey ‘vulnerability box’. However, they are also important determinants of the ‘resilience’ of human-environment systems, as is reflected in the concepts of ‘adaptive capacity’ (in the context of climate change) and ‘coping capacity’ (in vulnerability research in general). Finally, the ‘resilience’ part of the ‘vulnerability box’ appears to be inconsistent. It is not clear why ‘impacts’ are seen as ‘responses’, and why they are regarded as determinants of ‘resilience’. Also, the meaning of the overlap of the ‘coping/response’ box with other elements of the framework is not clear.

In summary, the SUST framework illustrates some important ideas for place-specific ‘all stressors, all sectors’ vulnerability assessments. However, it does not seem to be able to provide specific guidance for vulnerability and adaptation assessments of the health impacts of climate change.

4.7 Other frameworks

In this section, several less important frameworks for climate adaptation are briefly reviewed.

Conceptual framework for vulnerability and adaptation in human health

Figure 4.15 shows a conceptual framework that presents key terms from the IPCC Third Assessment Report, and aims to link them to the domain of climate-sensitive health impacts. However, the accompanying text in Kovats et al. (2003b) does not provide specific information on the interpretation of the framework. Due to the lack of specificity, this framework does not appear to provide substantial guidance for assessing human health adaptation to climate change.

Causal pies

The causal pie model, which was developed by Rothman (1976), is used to describe the aetiology of multi-causal diseases at the level of individuals. It helps clarify how multiple causes contribute to disease occurrence by distinguishing and visualizing different types of causal factors.

Causal pies provide a generic framework to analyze multi-causal health problems. However, the framework is deterministic, it addresses only binary disease outcomes, and the classification of causal factors into sufficient, necessary, and component causes is rather coarse. The causal relationship between climatic factors and health effects is generally complex and indirect. Most climate-sensitive health effects need to be described at the population rather than the individual level. Since causal pies do not enable a quantitative analysis of the relevant cause-effect relationships at the population level, they are not well suited for detailed assessments of adaptation to climate change.

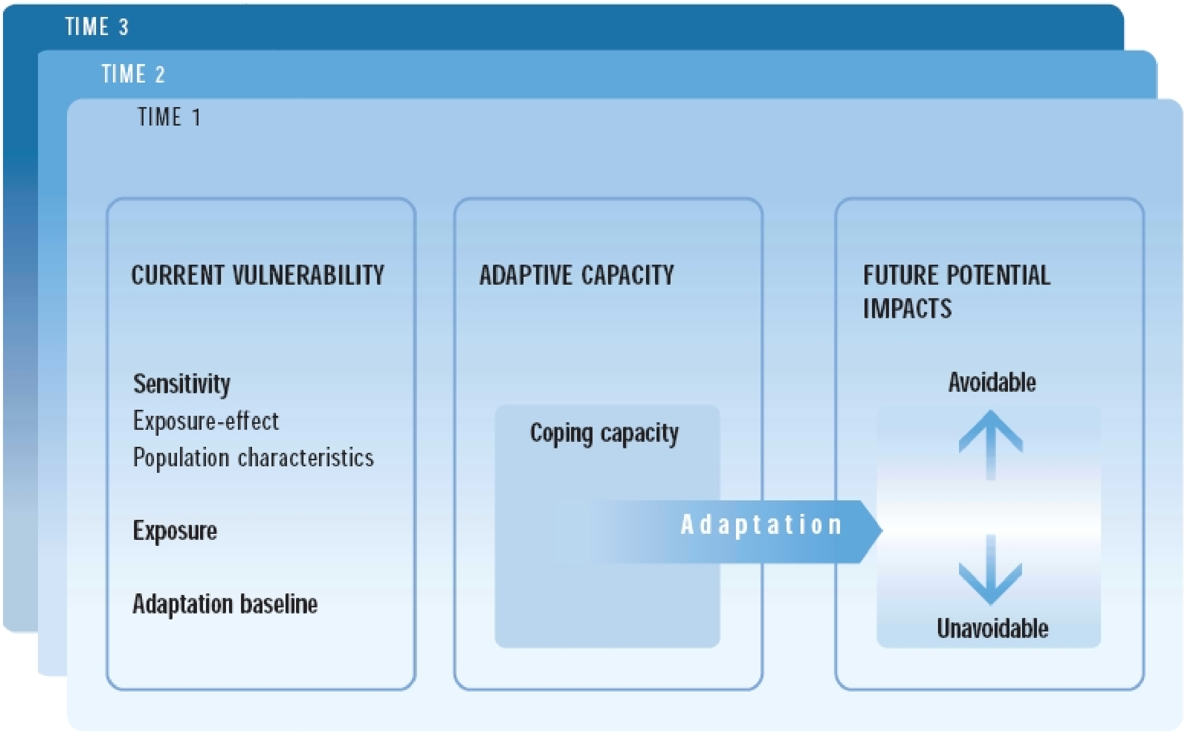


Figure 4.15: Conceptual framework for vulnerability and adaptation in human health. *Source:* Kovats et al. (2003b)

Framework for adaptation assessment

Klein (1998) has developed a framework that aims to clarify different categories of adaptation measures, and how they are related to different concepts of 'climate impacts'. Kovats et al. (2000b) have adapted this generic framework to climate impacts on human health.

The two closely related frameworks are depicted in Figure 4.16. Both of them show different stressors as well as different types of climate impacts and adaptation measures that are connected in a cyclical way by various arrows. The main points to be conveyed by these diagrams seem to be that different 'categories' of climate impacts are potentially relevant in climate change assessments; that different 'categories' of adaptation are potentially relevant in climate change assessments; and that a full climate vulnerability assessment requires different tiers of climate impact and adaptation assessment.

A more detailed review of the two frameworks is difficult because it is not clear how the various graphical elements in the diagrams depicted in Figure 4.16 relate to specific concepts and their relationships in reality. In particular, the same graphical elements are used to represent different concepts (*e.g.*, there is no distinction between actual and hypothetical effects of climate change); the arrows represent vastly different relationships between elements (*e.g.*, causal as well as temporal relationships); and the meaning of the 'feedback arrow' is not explained at all. (Do 'residual impacts' *cause* climate change?) As a result, neither of the two frameworks appears particularly helpful for climate impact or adaptation assessments in human health.

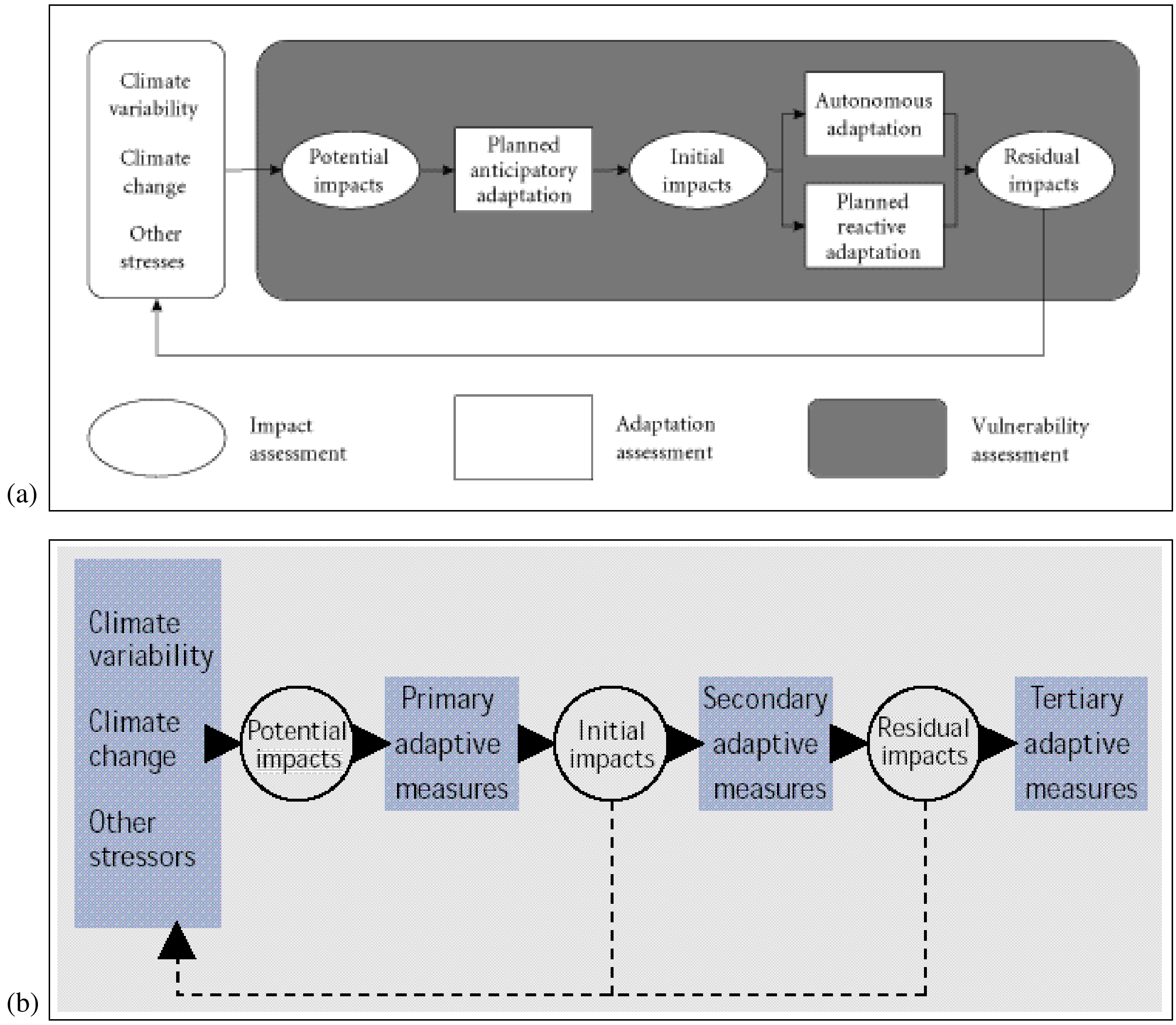


Figure 4.16: Two frameworks for vulnerability and adaptation assessment. (a) Generic framework; (b) Health-specific framework. *Sources:* Klein (1998); Kovats et al. (2000b)

CCAIRR adaptation framework

Figure 4.17 shows two conceptual frameworks applied in the program *Climate Change Adaptation through Integrated Risk Reduction* (CCAIRR). This programme uses risk management approaches to help prioritize and implement a variety of measures aimed at the reduction of climate-related risks addresses (Hay, 2002). The framework in Figure 4.17.a shows a cause-effect chain where human activities affect the climate system, potential impacts and the risk of occurrence of disasters. It also distinguishes three options for risk reduction targeted at different elements of that chain. The explanatory text leaves some questions unanswered. For instance, the distinction between those adaptation measures that may reduce ‘hazards and potential impacts’ and others that reduce the ‘risks of occurrence’ is not explained.

The framework in Figure 4.17.b mixes a simple cause-effect framework with a typology of adaptation options (see Section 5). The diagram shows that adaptation can be both reactive and anticipatory, both independent (or autonomous) and planned, and that interventions can be targeted at different points of the cause-effect chain. The combination of the causal model and the categorization of adaptation options is done in a somewhat unstructured way. The various types of adaptations are merely listed, and their difference is not reflected in the links between the elements of the framework.

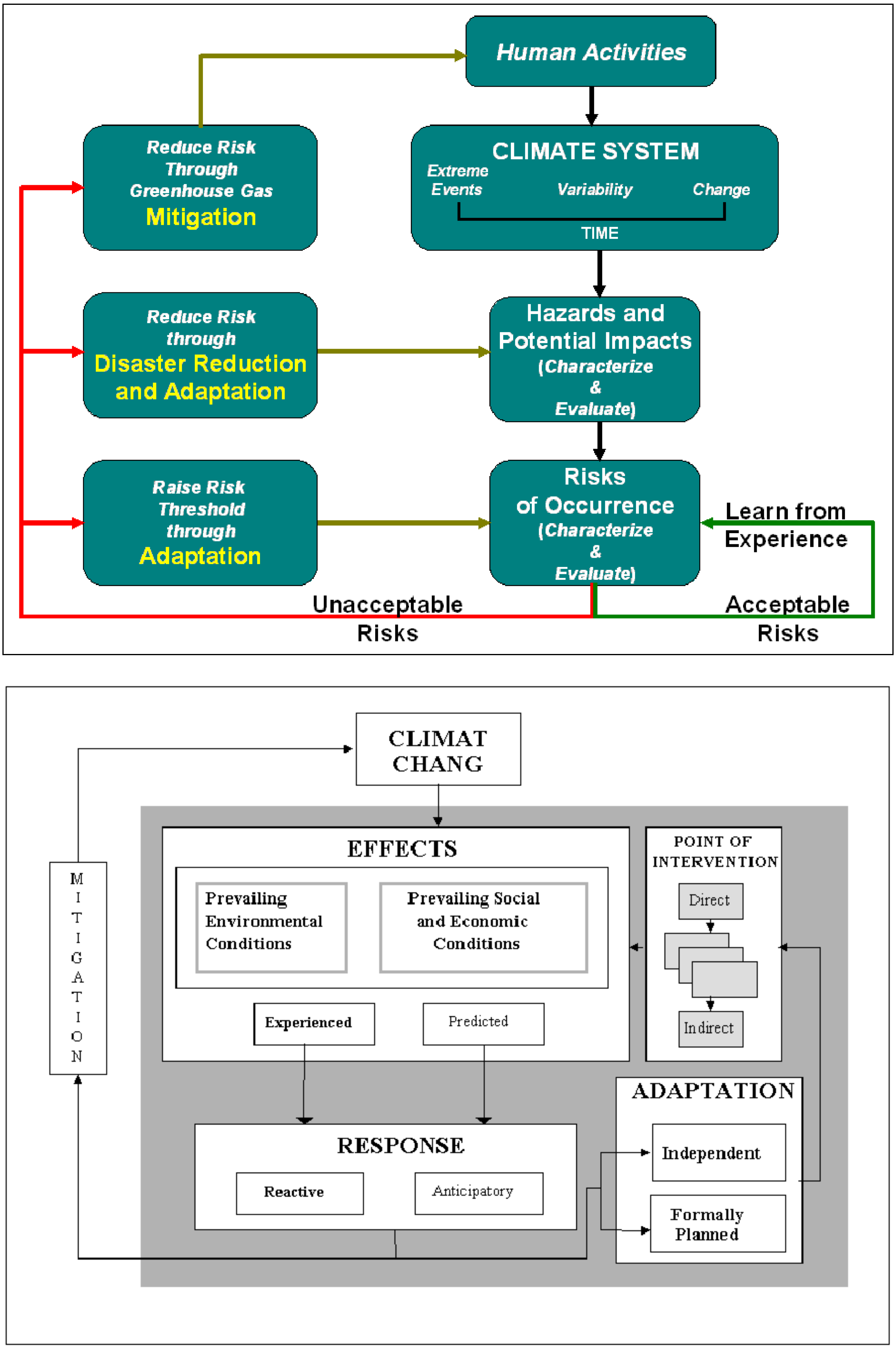


Figure 4.17: Two conceptual frameworks for adaptation applied in CCAIRR. *Source:* Hay (2002)

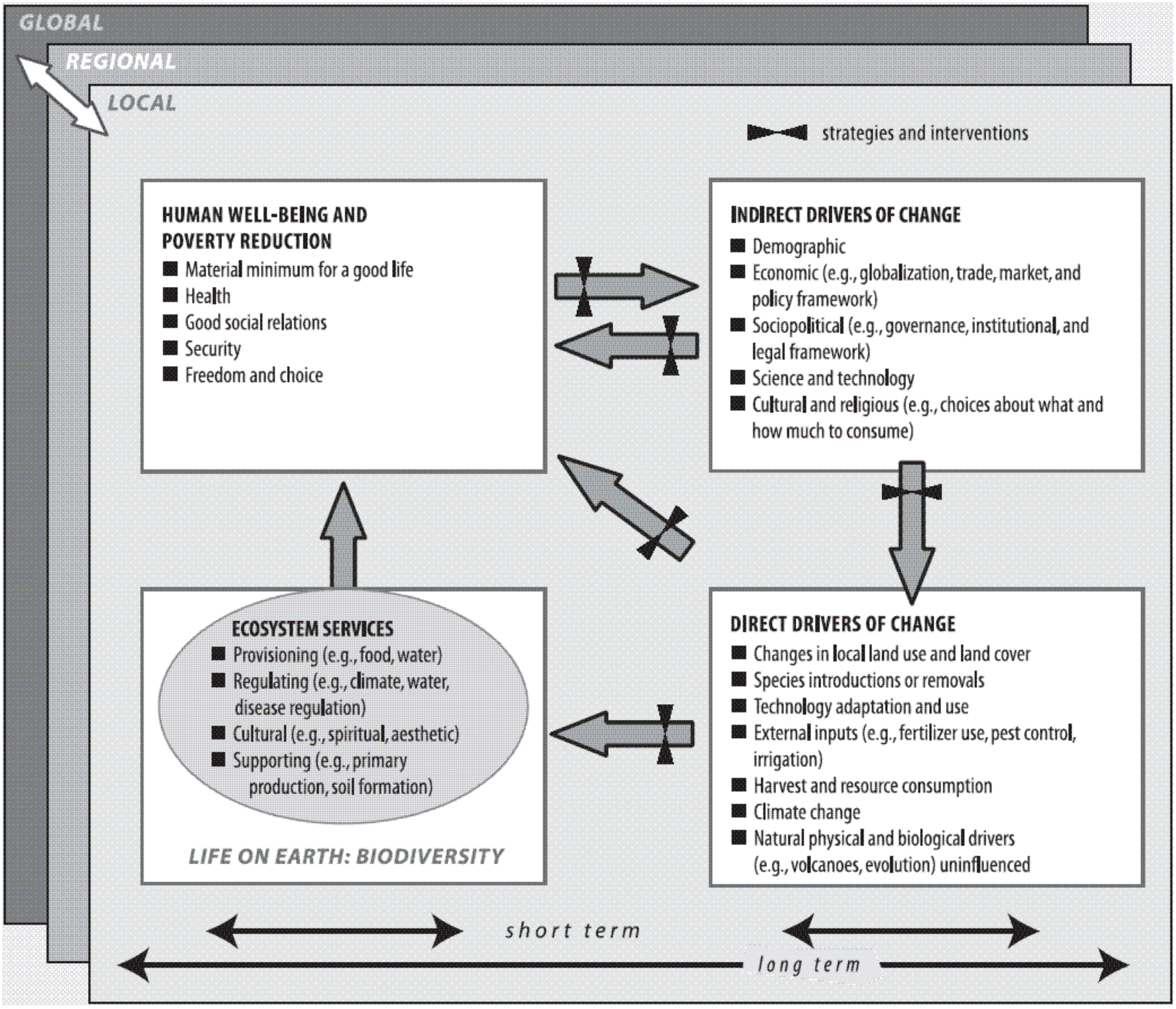


Figure 4.18: Conceptual framework for the Millennium Ecosystem Assessment. *Source:* Millennium Ecosystem Assessment (2003)

In summary, neither of the two frameworks is able to provide substantial guidance for adaptation assessments to climate change in human health.

Conceptual framework for the Millennium Ecosystem Assessment

The Millennium Ecosystem Assessment (MEA) is a global effort to analyze on a global, regional, and local scale the state of ecosystems, their capacity to provide goods and services, the multiple stresses that they are facing, and the potential for human actions to protect ecosystem goods and services by moderating these stresses (Ahmed and Reid, 2002; Gewin, 2002).

Figure 4.18 presents the conceptual framework applied in the MEA. The diagram outlines the major issues that are addressed in the MEA and their interrelationships. It cannot, of course, portray the complexity of these interactions in their respective temporal and spatial domains. The main messages of the MEA conceptual framework are as follows:

- Human wellbeing depends, among others, on a broad range of ecosystems services.

- The causal structure involving human wellbeing, indirect and direct drivers of ecosystem change, and ecosystem services is a closed loop that allows for feedbacks within the system.
- The relationships between different elements of the framework are amenable to human interventions that can alter the dynamics of the system.

The MEA has many things in common with the climate assessments compiled by the IPCC. The two assessments share the aim to provide policy-relevant information to policymakers; the universal importance of their respective subjects of investigation (ecosystems and climate, respectively) for humankind; the combination of knowledge from the natural and social sciences with other sources of knowledge; and the consideration of issues at widely varying spatial levels. The main difference is that the IPCC focusses on a specific *driver* (*i.e.,* climate change) whereas the MEA focusses on a specific *system* involved in the causal path (*i.e.,* ecosystems). As a result of this specific focus, the MEA framework cannot generally be applied to assessments of climate change impacts on human health.

Chapter 5

Typologies of adaptation

Adaptation involves an adjustment in something (*i.e.,* the system of interest, activity, sector, community, or region) to something (*e.g.,* climatic stimuli). As adaptation to climate change and variability has been subjected to more intensive inquiry, analysts have seen the need to distinguish different types, and to characterize important attributes of adaptation.

This section presents an overview of typologies that are used to characterize health interventions and other adaptation measures to climate change, the adaptive system, and/or the decision context for adaptation. As usual, we start with the health-specific typologies. However, in contrast to previous chapters, we merely *present* the various typologies rather than *reviewing* them in detail.

5.1 Stage of prevention

The classical categorization of preventive measures in public health distinguishes primary, secondary and tertiary prevention. In some cases, primordial (or pre-primary) prevention is included as an additional category. This classification is done according to the timing of an intervention measure, referring either to the stage of the disease in an individual or the stage of an epidemic in a population. The individual-level interpretation is generally used in classical epidemiology where primary, secondary and tertiary prevention are defined as measures that are directed toward the susceptible, sub-clinical and clinical stage of a disease, respectively (Gerstman, 1998). The population-level distinction is more common in the area of climate change and human health (Patz, 1996; Kovats et al., 2000b; McMichael and Kovats, 2000).

The following definitions reflect the population-level understanding for categorizing preventive measures in the context of climate change (Kovats et al., 2000b):

Primordial (or pre-primary) prevention: Measures that remove the root cause of the health problem by mitigating climate change itself.

Primary prevention: Intervention to prevent the occurrence of a disease by either reducing the exposure to climate-related hazards or the susceptibility to them.

Secondary prevention: Measures to detect climate-related changes in the population health profile early, and to take specific targeted action.

Tertiary prevention: Effective response to actual illness or disease to prevent serious long-term health deterioration.

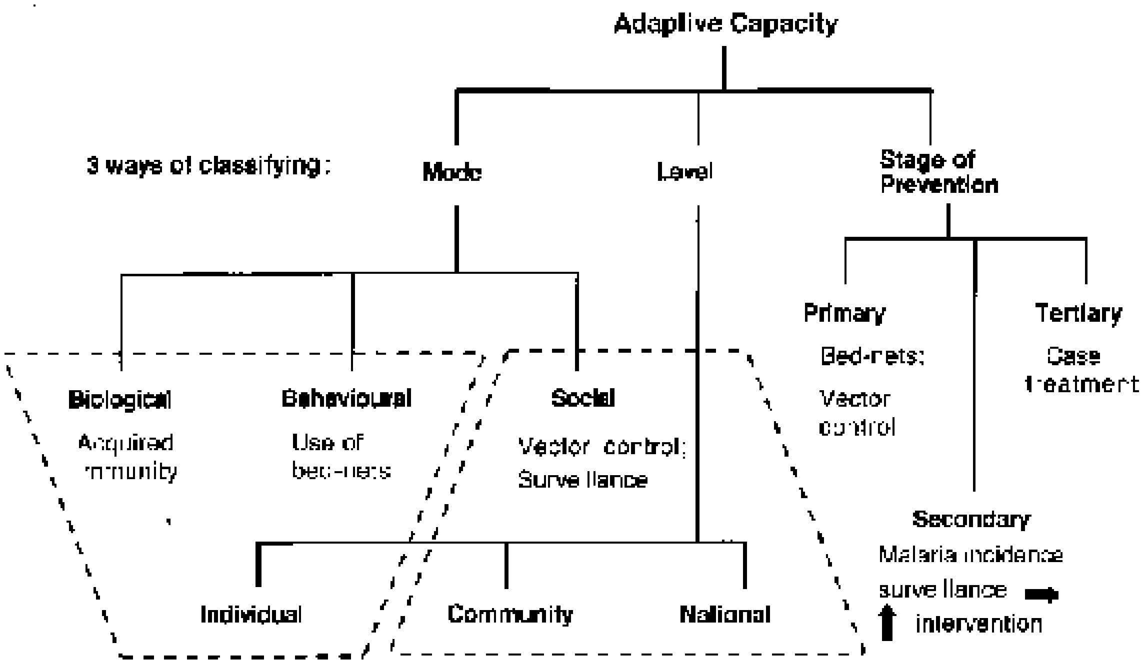


Figure 5.1: Categorizations of adaptation strategies for human health. *Source:* McMichael and Kovats (2000)

5.2 Types of public health interventions

Balbus et al. (1998) distinguish the following general types of planned adaptations to climate change in public health:

- Surveillance and monitoring
- Infrastructure development
- Ecosystem intervention
- Public education
- Technological and engineering strategies
- Medical interventions

In a related classification by McMichael and Githeko (2001), legislative measures are listed as an additional category.

5.3 Classification of adaptation strategies for human health

McMichael and Kovats (2000) classify adaptation measures in the public health sector according to their mode, level, and stage of prevention. For an illustration, see Figure 5.1.

General Differentiating Concept orAttribute	Examples of Terms Used		
Purposefulness	Autonomous	↔	Planned
	Spontaneous	↔	Purposeful
	Automatic	↔	Intentional
	Natural	↔	Policy
	Passive	↔	Active
			Strategic
Timing	Anticipatory	↔	Responsive
	Proactive	↔	Reactive
	Ex ante	↔	*Ex post*
Temporal Scope	Short term	↔	Long term
	Tactical	↔	Strategic
	Instantaneous	↔	Cumulative
	Contingency		
	Routine		
Spatial Scope	Localized	↔	Widespread
Function/Effects	Retreat - Accommodate - Protect Prevent - Tolerate - Spread - Change - Restore		
Form	Structural - Legal - Institutional - Regulatory - Financial - Technological		
Performance	Cost - Effectiveness - Efficiency - Implementability - Equity		

Figure 5.2: Dimensions of adaptation. *Source:* Smit et al. (1999)

5.4 Dimensions of adaptation

Smit et al. (1999) characterize adaptation responses according to seven differentiating attributes, as shown in Figure 5.2. Similar typologies have been developed for specific impact domains. For instance, Smit and Skinner (2002) categorize adaptation options in agriculture according to the following criteria: intent and purposefulness, timing and duration, scale and responsibility, and form.

5.5 Categories of adaptation decisions

The UKCIP framework for adaptation decision-making (Willows and Connell, 2003, *cf.* Section 3.7) provides a simple typology of climate-sensitive decisions. This typology distinguishes three categories of adaptation decisions based on the actual and assumed importance of climatic and non-climatic factors:

Climate adaptation decisions are directly driven by the need to reduce or otherwise manage known or anticipated climate risks. Climate and climate change are often an acknowledged part of a decision-maker's initial problem. Examples include fluvial and coastal flood defence, and disaster management for extreme weather events.

Climate-influenced decisions are decisions which are not primarily about managing present climate variability or directly driven by a recognized need to adapt to future climate change, but whose outcomes may nevertheless be affected by climate change. Examples include control programmes for vector-borne diseases and many decisions related to long-term investments.

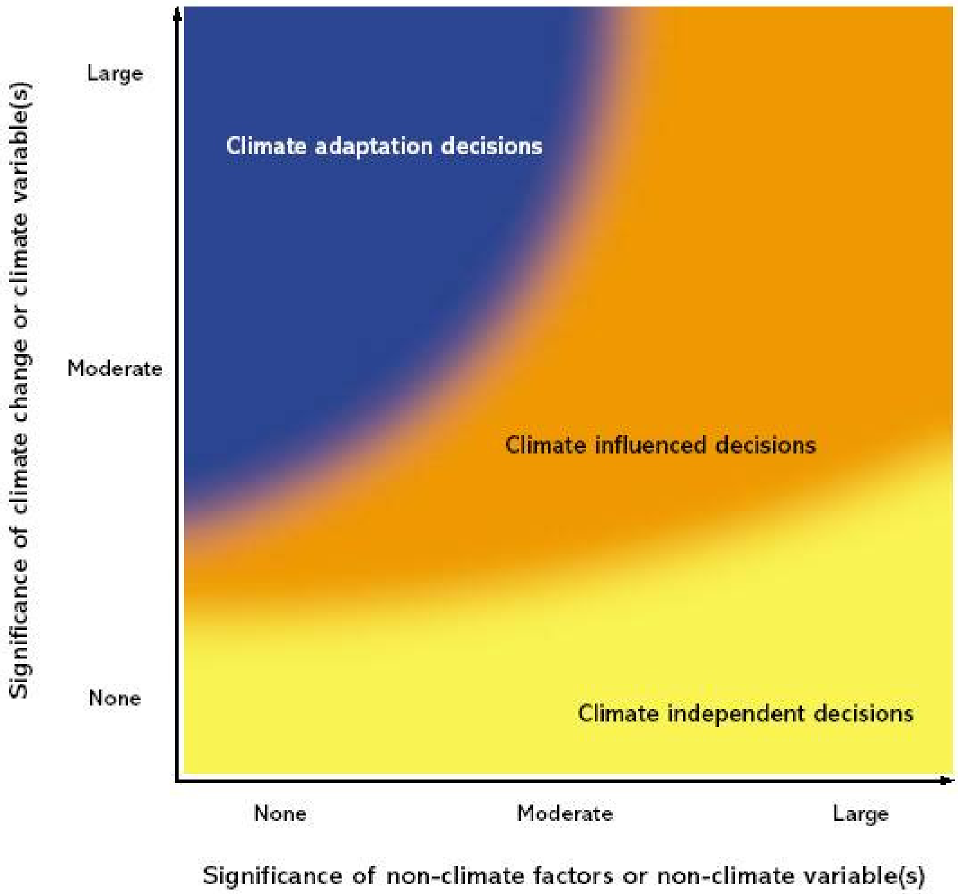


Figure 5.3: UKCIP typology of adaptation decisions. *Source:* Willows and Connell (2003)

Climate adaptation constraining decisions are decisions which are made independently of climatic concerns but which lead to actions that constrain the ability to successfully adapt to climate change. Such decisions are often termed 'maladaptation' in the IPCC context. Examples include the construction of long-lived assets, such as housing developments, in areas vulnerable to increased risk of fluvial and coastal flooding.

Figure 5.3 distinguishes the first two types of climate-sensitive decisions from climate-insensitive decisions, based on the importance of climatic and non-climatic factors. Climate adaptation constraining decisions are not shown in this diagram. They are characterized by the fact that the *actual* importance of climatic factors for a decision is underestimated by the decision-maker.

The distinction between the three types of climate-sensitive decisions has important implications for the most suitable approach to adaptation decision support. For instance, the applicability of quantitative models for adaptation assessment generally decreases from the first to the third category whereas the importance of awareness-raising among affected decision-makers typically increases. Consideration of the three types of climate-sensitive decisions and their specific decision-support needs is an important factor for effective adaptation to climate change and variability in public health.

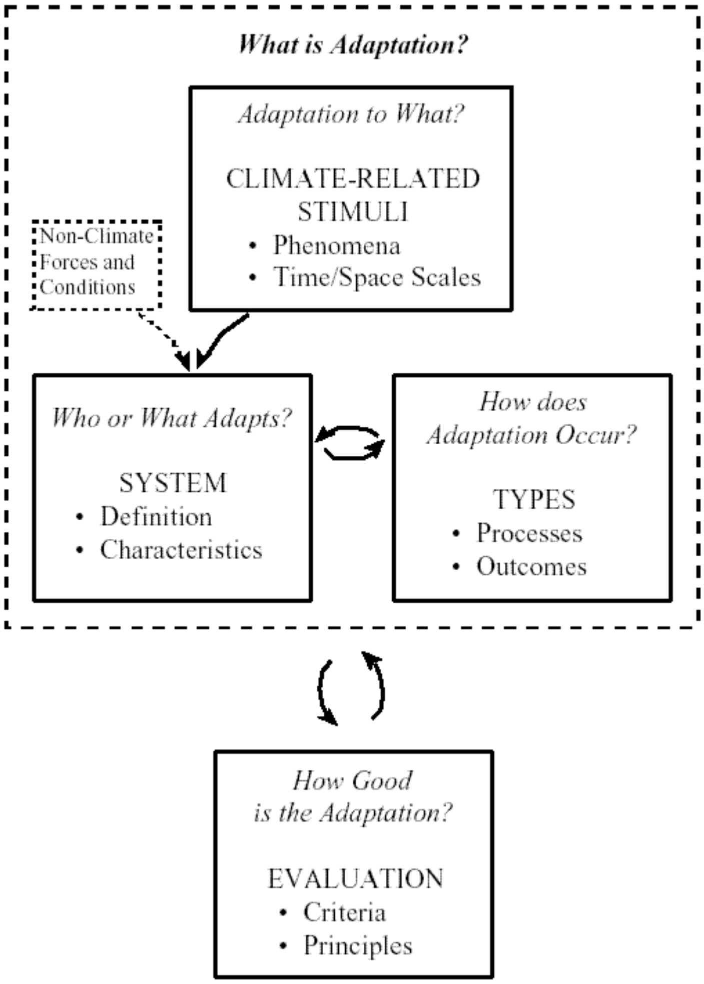


Figure 5.4: Anatomy of adaptation to climate change and variability. *Source:* Smit et al. (2000)

5.6 Anatomy of adaptation

Smit et al. (2000), based on Smithers and Smit (1997), developed a so-called 'anatomy of adaptations', which is depicted in Figure 5.4. This conceptual framework allows for a systematic description and analysis of adaptations to climate change according to four fundamental questions. These questions, and selected criteria relevant in that context, are as follows:

Climatic disturbances: *Adaptation to what?*

- Primary *vs.* synoptic *vs.* compound *vs.* proxy climate variable (see Burton, 1997)
- Average climate *vs.* variability around norms *vs.* isolated extreme events
- Predictability
- Rate of change
- Spatial characteristics

System characteristics: *Who or what is effected, and who adapts?*

- Natural *vs.* socioeconomic *vs.* coupled system

- Spatial scale
- Temporal scale

Adaptive responses: *How does adaptation occur?*

- Autonomous *vs.* planned
- Reactive *vs.* concurrent *vs.* anticipatory
- Tactical *vs.* strategic *vs.* structural
- Technological *vs.* economic/financial *vs.* legal/administrative *vs.* institutional *vs.* social/behavioural

Evaluation criteria: *How good is the adaptation?*

For an overview of suggested evaluation criteria, see Section 6.

5.7 Portraits of adaptation

Reilly and Schimmelpfennig (2000) developed a conceptual framework for characterizing climate-sensitive systems according to six fundamental characteristics that shape their adaptation to climate change:

1. Short-run autonomous flexibility
2. Short-run non-autonomous flexibility
3. Knowledge and capacity to undertake short-run actions
4. Long-run autonomous flexibility
5. Long-run non-autonomous flexibility
6. Knowledge and capacity to plan for and undertake long-run actions

Based on a discretization of these factors, and excluding implausible combinations, 10 'portraits' of adaptation to long-term climate change were identified (see Table 5.1). These portraits have important implications for research strategies and adaptation policy. In particular, they determine

- when the rate of climate change matters;
- what research approaches can be useful (*e.g.,* cross-section analysis, time-series analysis, or structured modelling);
- what strategies would be most useful for assisting adaptation; and
- how system characteristics can lead to differential impacts of climate change across individuals, regions, or other adaptive systems

A discussion of these system portraits sheds light on the adaptability of climate-sensitive systems and suggests how greater adaptability can be fostered depending on which portrait best represents a system. The theoretical discussion is supplemented with examples from crop agriculture, forest and biodiversity loss, water reservoir and flood control, coastal property, and outdoor recreation.

Portrait	Short-run, Auton. Flexibility	Short-run, non-auton. Flexibility	Knowledge for SR flexibility	Long-run, auton. Flexibility	Long-run, non-auton. Flexibility	Knowledgé for LR flexbility
I.1	Y	*	#	*	*	#
II.1	N	Y	Y	Y	*	#
II.2	N	Y	Y	N	*	#
III.1	N	Y	N	N	*	#
III.2	N	Y	N	Y	Y	Y
III.3	N	Y	N	N	Y	Y
IV.1	N	N	#	Y	*	*
IV.2	N	N	#	N	Y	Y
IV.3	N	N	#	N	Y	N
V.1	N	N	#	N	N	#

Table 5.1: Ten system response portraits of adaptation defined in terms of knowledge, flexibility, and time frame. Y: present; N: not present; */#: additional outcomes excluded due to simplifying assumptions. *Source:* Reilly and Schimmelpfennig (2000)

Even though population health is not among the 'systems' considered explicitly in Reilly and Schimmelpfennig (2000), their typology of adaptation is highly relevant for designing adaptation aimed at minimizing adverse health effects of climate change. Climate-sensitive health effects cover many of the 10 portraits, depending on the relative importance of long-term climate change and short-term weather variability, the availability of and knowledge about effective response measures, the degree of knowledge and preparedness required for effective action, and the lead time and adjustment costs of adaptive measures. The scale at which adaptation measures need to be implemented, the most important actors involved, and the availability of knowledge and other resources also differs across regions and health outcomes. Given this diversity, the distinction between different 'portraits' of adaptation helps to assess the potential of autonomous and planned adaptation, to identify the most important knowledge gaps and appropriate research strategies, and to increase adaptability most effectively.

5.8 Framework for prioritizing anticipatory adaptation

The timing of adaptation is a particularly difficult decision because it involves balancing two significant but highly uncertain risks. Delaying adaptation often allows to better target a measure (and thus to avoid the misallocation of scarce resources) as a result of improved knowledge about climate change and its impacts but it may involve adverse impacts that could have been avoided by earlier action. Various authors have investigated this decision problem and come up with criteria for the priorization of adaptation measures (Smit and Lenhart, 1996; Smith, 1997; Fankhauser et al., 1999). There is general agreement that the following criteria indicate conditions that are favourable for anticipatory adaptation:

- Net benefits across the plausible range of climate scenarios ('no/low regrets')
- Addresses decisions with long-term effects or measures with a long lead time
- Addresses irreversible or catastrophic impacts
- Addresses systems that are sensitive to rapidly changing climate parameters (primarily extreme weather)

- Reverses trends that reduce future adaptability

The question how to prioritize research and action on climate change adaptation for different systems is also addressed in some detail by Reilly and Schimmelpfennig (2000) in their discussion of the different 'portraits' of adaptation (*cf.* Section 5.7).

Chapter 6

Evaluation frameworks for adaptation strategies

An important task in any risk assessment is the establishment of criteria to evaluate how 'good' a particular risk management strategy is. The three main groups of criteria by which risk management decisions can be taken are utility-based, rights-based, and technology-based criteria (Morgan and Henrion, 1990).

The assessment of adaptation to the health effects of climate change, as a specific form of risk management, also requires the establishment of evaluation criteria. Such criteria may be related to the expected outcome of a proposed adaptation strategy as well as to the process of adaptation, and they may comprise quantitative as well as qualitative indicators. The choice of a set of decision criteria and of their respective weights is ultimately a normative decision. There is, for instance, no universal rule for comparing the economic costs of an intervention with its expected health benefits or for trading equity aspects against efficiency aspects.

This chapter gives an overview about the criteria and decision frameworks that have been suggested to evaluate how 'good' health interventions and other adaptation measures are. As usual, the health-specific frameworks are presented first.

6.1 WHO principles for environmental health actions

The WHO has established the following basic principles for environmental health actions (WHO, 2000):

- Equity
- Intersectorality
- Polluter-pays principle
- Precautionary principle
- Subsidiarity
- Sustainability

The full 'conceptual framework' from which these principles were derived is portrayed in Figure 6.1. This framework is not further discussed here due to the lack of an explanatory text in the original publication.

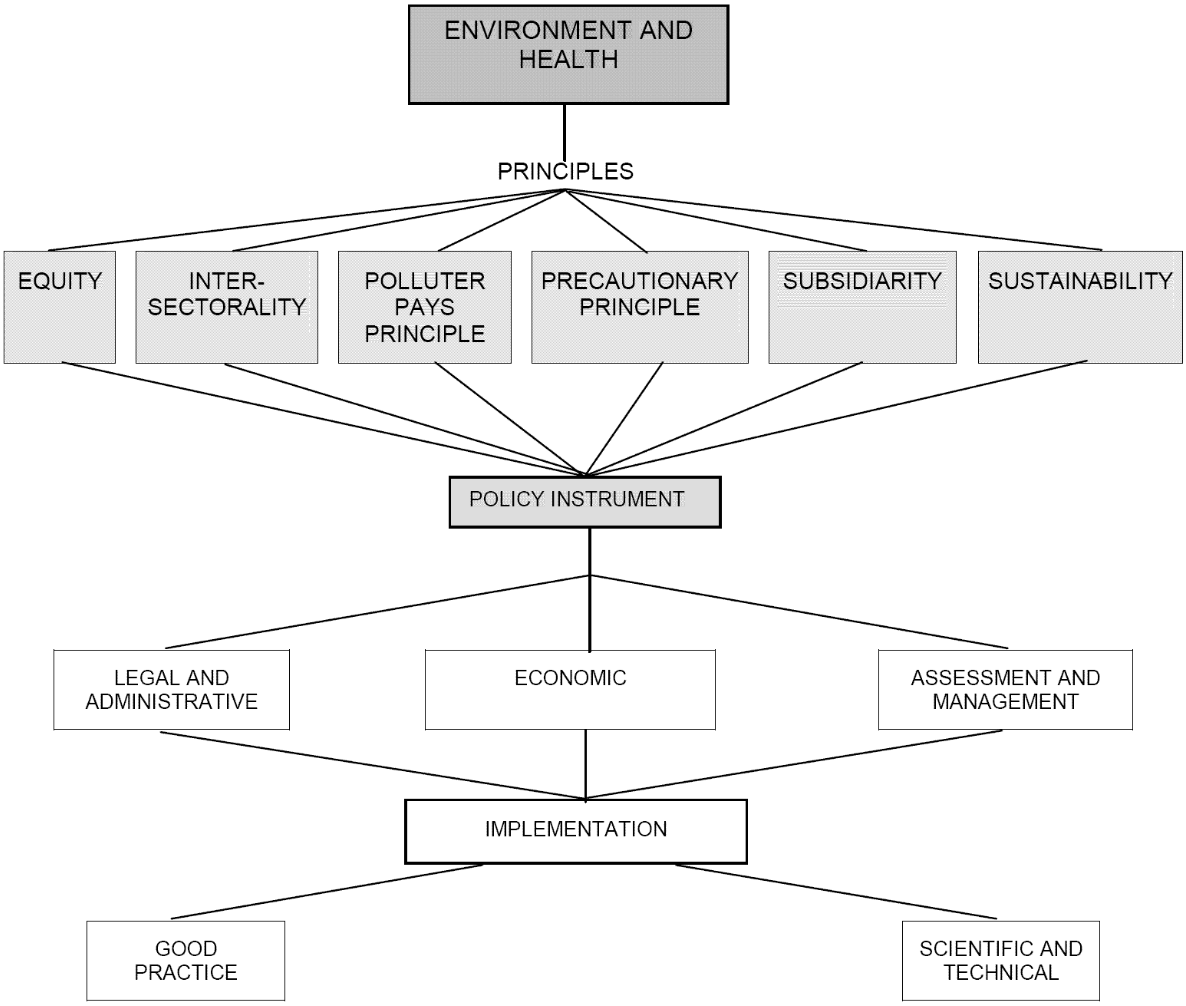


Figure 6.1: Conceptual framework for environment and health actions established by the WHO. *Source:* Schiller and Sonnenberg (2001)

6.2 WHO strategic policy directions

The WHO's global cabinet adopted the following strategic policy directions (Button, 2000):

- Reducing the burden of excess mortality and disability, especially that suffered by poor and marginalized populations.
- Reducing the risk factors associated with major causes of disease and the key threats to human health that arise from environmental, economic, social and behavioural causes.
- Developing health systems which are managed to ensure equitable health outcomes and cost-effectiveness; responsiveness to people's legitimate needs, are financially and procedurally fair; and encourage public involvement.
- Promoting an effective health dimension to social, economic, and development policy.

6.3 RE-AIM framework

Glasgow et al. (1999) propose the RE-AIM model as a framework for evaluating the overall population-based impact of a public health intervention. The RE-AIM framework distinguishes five factors, or 'dimensions of quality':

Reach: Proportion of the target population (within a specific setting or organization) that participates in the intervention.

Efficacy: Success rate of the intervention if implemented as intended; includes positive and negative outcomes on physiological endpoints and on participant satisfaction.

Adoption: Proportion of (relevant) settings and organizations that adopt the intervention.

Implementation: Extent to which the intervention is implemented as intended in representative real-world settings, as opposed to controlled research settings.

Maintenance: Extent to which a program is sustained over time.

Starting point for the development of the RE-AIM framework was the recognition that the results of clinical studies have only limited significance for the eventual public health impact of an intervention. Clinical studies are typically conducted under optimal conditions, involving homogeneous and motivated patients and well-educated health personnel. These studies, focussing on the reach and efficacy of an intervention, need to be complemented by an analysis of the adoption, implementation and maintenance of an intervention to account for the various constraints and confounders found in real-world situations.

The RE-AIM framework is particularly relevant for health interventions that aim at wide-scale dissemination in community settings, including interventions that require behavioural changes by the patient or the health personnel. While only a limited number of health adaptations to climate change fall into this category, the broader message of the RE-AIM framework is still valid in this context: that consideration of the setting in which public health interventions are applied in the real world is of crucial importance for their success.

6.4 Other health-specific evaluation criteria

McMichael and Kovats (2000) list the following criteria for 'good' adaptation in the health sector:

- Cost-effectiveness
- Equity (within populations and intertemporal)
- Political acceptability
- Integration with more general policy goals and existing local needs

de Francisco (2002) presents a comparison of various priority-setting approaches for health *research*, including:

- Burden of disease
- Cost-effectiveness of interventions
- Effect on equity and social justice
- Ethical, political, social, and cultural acceptability
- Feasibility in terms of human resources, funding, and facilities
- Probability of finding a solution

We regard the consideration of these approaches as relevant during the scoping phase of an adaptation policy assessment when the priority areas for a more detailed assessment are determined.

6.5 Generic evaluation criteria

Smit et al. (2000) lists the following evaluation criteria for adaptation measures:

- Net benefits
- Efficiency
- Implementability
- Flexibility (degree of scenario independence)
- Compatibility with other local priorities
- Urgency
- Risk level
- Environmental sustainability
- Public acceptability
- Behavioural flexibility

Downing et al. (2001) highlight the following issues to be considered in the design and evaluation of adaptation measures:

- Stakeholders and their interests
- Resilience and effectiveness
- Strategic responses
- Timing
- Economic evaluation
- Constraints

6.6 Decision-analytical frameworks

The following decision-analytical frameworks are most often applied in adaptation assessments (Ahmad and Warrick, 2001):

- Decision analysis
- Cost-benefit analysis
- Cost-effectiveness analysis
- Multi-criteria methods
- Policy-exercise approach

Burton et al. (1998) provide tools for the use of these frameworks in different impact domains, including human health. However, the applicability of quantitative tools in the health sector is generally limited due to the large uncertainties associated with projections of future health impacts from climate change.

6.7 Fundamental principles for designing adaptation policy

Scheraga and Grambsch (1998) suggest nine fundamental principles that should be considered when designing adaptation policy:

1. The effects of climate change vary by region.
2. The effects of climate change may vary across demographic groups.
3. Climate change poses risks and opportunities.
4. The effects of climate change must be considered in the context of multiple stressors and factors.
5. Adaptation comes at a cost.
6. Adaptive responses vary in effectiveness.
7. The systemic nature of climate impacts (and their uncertainty) complicates the development of adaptation policy.
8. Maladaptation can result in negative effects that are as serious as the climate-induced effects being avoided.
9. Many opportunities for adaptation make sense whether or not the effects of climate change are realized.

These principles do not constitute an evaluation framework for adaptation in a narrow sense. However, they can serve as a useful checklist for the design of climate change adaptation assessments in many impact domains, including human population health.

Chapter 7

Summary and Conclusions

In this chapter, we summarize the main lessons from the reviews of conceptual frameworks, and we discuss their implications for the design and assessment of adaptation strategies aimed at reducing climate-sensitive health effects.

7.1 Lessons from the reviews of individual frameworks

Chapter 2 reviewed the major typologies of climate change adaptation assessments. Adaptation assessments can be classified, among others, according to their analytical approach and policy purpose (Sections 2.1 and 2.2), their methodological approach (Section 2.3), and their level and comprehensiveness (Section 2.4).

Chapter 3 reviewed the major guidelines for health risk assessment and for climate change impact, vulnerability, and adaptation assessment. Most guidelines employ one of two fundamental methodological approaches: the hazard-driven (also known as scenario-driven or top-down) approach, which starts from scenarios for climatic hazards, and the vulnerability-driven (also known as bottom-up) approach, which starts from current health risks.

The Health Impact and Adaptation Assessment Framework developed by the WHO and Health Canada (Section 3.1) is the single most important guidance document for climate change adaptation assessment for human health. It could not be reviewed in detail here due to its late publication date. Based on the preliminary review, an important limitation of this framework seems to be the insufficient consideration of the dynamic aspects of climate change. Hence, little guidance is provided for addressing the important question *when* to adapt, *i.e.,* how to prioritize different adaptation options under resource constraints.

Environmental health risk assessment is concerned with assessing the risks to population health associated with specific environmental risk factors (Section 3.2). Adaptation policy assessment for human health can be regarded as a specific type of environmental health risk assessment, which itself is a subcategory of risk assessment. The application of 'classical' approaches from risk management in adaptation policy assessments for human health faces several methodological and practical difficulties. Most importantly, the applicability of the prevailing toxicological model of environmental health to climate-sensitive health issues varies across climate-sensitive health impairments. This model is most easily applicable for the direct health impacts of local exposure to specific climatic stimuli, such as the health effects of heat-waves. It is least applicable to the indirect health impacts of complex climatic stimuli that strongly interact with non-climatic factors, such as many vector-borne diseases. An important practical impediment to the application of quantitative risk assessment approaches in climate change adaptation assessments are large uncertainties about future exposure scenarios. In general, uncertainties in future climate scenarios are larger for precipitation and wind speed than for temperature, for extreme events than for mean values, and for local characteristics than for average values referring to large geographical regions. Of course, the level of uncertainties also depends on the data, expertise and resources available in a particular region for developing state-of-the-art regional climate change scenarios.

The IPCC Technical Guidelines (Section 3.3) are the most important document that describes the hazards-driven approach to climate impact and adaptation assessment. They have also served as the starting point for the development of the UNEP Handbook (Section 3.4) and the USCSP Guidebook (Section 3.5). In the hazards-driven approach, adaptation needs are exclusively defined by the outcome of the climate impact assessment. However, the 'classical' climate impact assessment, which aims to determine the incremental impacts of anthropogenic climate change, is primarily designed according to the needs of mitigation policy rather than those of adaptation policy. Since hazards-driven approaches do not adequately consider the current level of climate risks, the interaction of climatic and non-climatic risk factors, and the uncertainties in climate impact projections at the scale relevant for adaptation decision-making, they need to be combined with vulnerability-driven approaches in order to produce useful recommendations for adaptation policy.

The UNDP-GEF Adaptation Policy Framework (Section 3.6) focusses on the current adaptation needs of developing countries. It proposes a flexible combination of hazards-driven and vulnerability-driven approaches yet with a strong focus on the latter. The most suitable mixture of these two approaches in an adaptation policy assessment for human health varies across health issues and regions. Key factors that determine their relative importance are the current level of climate-sensitive diseases; the complexity of the causal web linking climatic risk factors with specific diseases; the type and predictability of relevant climatic hazards; the time horizon of adaptation decisions; the expected importance of future risk changes (within that time horizon); and the availability of resources for the assessment in terms of data, expertise, time, and money. Hazards-driven approaches are most valuable if adaptation decisions have a long life time and/or lead time, and if expected increases in risk levels are significant compared to current risks, if the reliability of future risk projections is high.

The UKCIP framework (Section 3.7) applies a risk management approach to adaptation decision-making. It is most useful when decisions that are potentially sensitive to global climate change have already been identified by the relevant decision-maker. Large-scale adaptation policy assessments for an impact domain as diverse as human population health would need to include an additional screening phase that identifies potential risks from anthropogenic climate change in the considered region and raises awareness of the issue among relevant stakeholders.

Two other adaptation frameworks (Sections 3.8 and 3.9) either cannot provide specific guidance for human health adaptation policy assessment, or they have been succeeded by more suitable frameworks since their publication.

Chapter 4 reviewed a variety of conceptual frameworks for vulnerability and adaptation to climate change.

The DPSEEA framework (Section 4.1) is a hierarchical model for categorizing environmental health indicators, and for identifying suitable intervention points. It is based on the classical toxicological model for environmental health, which limits its application to non-local and complex environmental hazards such as anthropogenic climate change. The review concluded that applications of the DPSEEA framework to different climate-sensitive health issues would need to extended it flexibly, often including ecological indicators and non-climatic 'confounding' factors.

The 'hierarchy of causes' (or causal web) model (Section 4.2) is another hierarchical model for structuring the risk factors for specific diseases according to their spatial scale and 'proximity' to the health outcome. Similar to the DPSEEA framework, the hierarchy of causes model would need to be extended flexibly to adequately represent the causal structure of different climate-sensitive health impairments.

Burden of Disease assessments (Section 4.3) strive to quantify the amount of ill-health caused by a particular risk factor, and the expected reduction in disease burden that could be achieved by reducing human exposure to this risk factor. Application of the burden of disease approach to the risk factor 'anthropogenic climate change' raises a variety of methodological and practical issues regarding the quantification of the risk factor, the choice of the time horizon, and the consideration of uncertainties. Once again, the difficulties are larger for indirect than for direct health effects of climate change. Our review focussed on the applicability of the concepts of 'attributable burden' and 'avoidable burden' in the context of anthropogenic climate change. We concluded that these two concepts can be applied with minor adjustments to climate change *impact* assessments aiming to support the development of *mitigation* policy. The classical concept of avoidable burden, however, cannot be applied to *adaptation* assessments due to the lack of a counterfactual scenario of exposure. We proposed a terminology that distinguishes four types of disease burden according to two *independent* factors: whether the burden is attributable to anthropogenic climate change, and whether it can be reduced by a specific intervention. This terminology was then applied to describe the relevant fractions of disease risk in all types of climate impact and adaptation assessments distinguished in Chapter 2.

Reviews of various other conceptual frameworks (Sections 4.4–4.7) concluded that these frameworks cannot provide substantial guidance for human health adaptation assessments due to a variety of reasons.

Chapter 5 presented various frameworks for categorizing adaptation measures, adaptive systems, and/or adaptation decision situations according to a wide range of criteria. Some of these typologies are specific to human health whereas others have a more general scope. Three of the generic frameworks are considered particularly relevant for designing adaptation strategies to the health impacts of climate change.

The 'anatomy of adaptation' (Section 5.6) formulates four questions about adaptation and uses them to discuss key concepts of adaptation in a broad range of decision contexts.

The 'portraits of adaptation' framework (Section 5.7) uses six characteristics of an adaptive system as the basis for the distinction of ten 'portraits of adaptation'. Each of these portraits is then discussed as to its implications for the development of adaptation strategies and for priority research needs. Adaptation to the health effects of climate change covers many of these portraits, depending on the particular disease and region considered. The consideration of the specific circumstances of an adaptation context, as facilitated by the 'portraits of adaptation' framework, is thus highly relevant for the development of effective adaptation strategies for human health.

A framework for analyzing the urgency of adaptation actions (Section 5.8) presents the most important criteria for balancing the risks associated with early action and late action, respectively. This framework, which synthesizes the results from several publications on the priorization of adaptation actions, is highly relevant for human health.

Chapter 6 presented various frameworks for evaluating how 'good' a particular adaptation strategy is, and for identifying recommended strategies. All frameworks include criteria related to the expected outcome of a proposed measure (*e.g.,* the expected magnitude and distribution of health benefits and costs). Some of them also specify criteria referring to the process of adaptation (*e.g.,* on participation and decision-making procedures). The selection of a particular set of decision criteria is ultimately a normative decision that cannot to be made by scientists alone.

7.2 Implications for the design and assessment of adaptation strategies for human health

In Section 1.3, we have listed five fundamental preconditions for successful planned adaptation. We have further argued that uncertainty about future changes in risk levels and diversity across health impairments, regions, and adaptation actors are the main challenges faced by adaptation policy assessments for human health. In the light of this discussion, we draw the following conclusions from our review of conceptual frameworks:

Assessment guidelines: A variety of guidelines have been developed to guide climate change vulnerability and adaptation assessment. The most important guidance document for adaptation policy assessment in human health is the WHO–Health Canada Framework (Kovats et al., 2003b, see Section 3.1).

Preconditions for successful adaptation: None of the guidelines addresses all five preconditions for successful planned adaptation. The ‘portraits of adaptation’ framework (Reilly and Schimmelpfennig, 2000, see Section 5.7) is the most comprehensive framework for distinguishing different adaptation contexts according to their adaptation and research needs.

Methodological approaches: The two fundamental methodological approaches to adaptation assessment are the hazards-driven and the vulnerability-driven approach. The importance of these two approaches in a specific assessment is largely defined by the expected magnitude of (additional) risks attributable to climate change compared to baseline risks during the time horizon of relevant adaptation decisions. The relative magnitude of these risks varies largely across health effects and regions, with important implications for adaptation assessment and planning. None of the health-specific frameworks discusses this issue comprehensively. The best coverage of this topic can be found in the UNDP–GEF Adaptation Policy Framework (UNDP, 2003, see Section 3.6).

Implications of uncertainty: Uncertainty about future changes in health risks varies significantly across climate-sensitive health issues and regions, depending on the complexity of the causal web linking climate and disease, the availability of projections for relevant climatic and non-climatic risk factors, the availability of relevant epidemiological data on the cause-effect relationship, and the availability of resources for the assessment. This variation has important implications for the choice of quantitative or qualitative assessment methods, and for the design of adaptation strategies. None of the health-specific frameworks considers this issue comprehensively. The best coverage of this topic can be found in the UKCIP Framework (Willows and Connell, 2003, see Section 3.7).

Urgency of adaptation: As a result of resource constraints, health managers typically need to prioritize adaptation measures based on their urgency. None of the guidelines addresses this topic comprehensively. The ‘rules to guide adaptation decisions’ (Fankhauser et al., 1999, see Section 5.8) are the single most important source of information about criteria that determine the urgency of adaptation.

Key questions for adaptation: The 'anatomy of adaptation' (Smit et al., 2000, see Section 5.6) formulates four key questions for designing and assessing adaptation strategies, and the 'portraits of adaptation' framework asks six questions about the adaptive system for prioritizing adaptation and research needs. None of the health-specific frameworks uses these (or other) sets of 'key questions' as a starting point for formulating key questions for planned adaptation in human health.

We suggest that the development of adaptation strategies for a particular health issue in a specific region should be guided by the following questions:

1. *How significant is the expected increase in the particular health risk due to global climate change, compared to current risk levels?*

   The answer to this question largely determines the need for a detailed analysis of a particular health issue: The larger the potential increase in health risk, the more efforts should be put into the detailed analysis of the issue.

2. *How familiar is the population with the particular health issue, and with its effective control?*

   The answer to this question largely determines the need for *new* preventive measures: The less familiar a population is with a particular health risk, or the less effective it is controlled currently, the more important are additional intervention measures to control the risk now and in the future.

3. *How reliable are projections for future risk changes at the scale of potential adaptation measures?*

   The answer to this question largely determines the specificity with which interventions can be designed to reduce a particular health risk: If knowledge about future changes in regional health risk is reliable, specific adaptation measures can be implemented already now. However, if regional increases in health risks are less certain, a generic adaptation strategy (focussing on improved monitoring, surveillance, research etc.) will generally be more appropriate.

4. *How large are the risks (in terms of additional costs) of acting early compared to the risks (in terms of additional disease burden) of acting late?*

   The answer to this question largely determines the need for acting now: The lower the expected reduction in adaptation costs due to additional information in the future and the higher the health risks in the near future, the more important it is to act now rather than later.

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