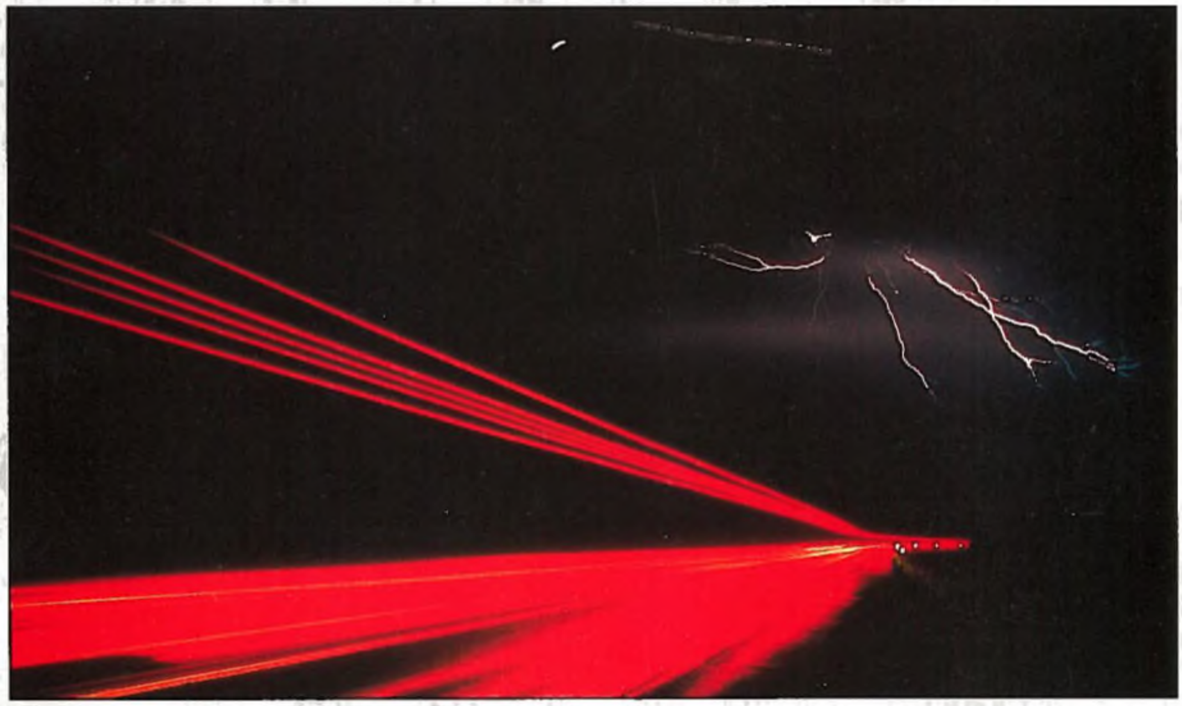
ENVIRONMENT ASSESSMENT TECHNICAL REPORTS

Scanning the Global Environment: A framework and methodology for integrated environmental reporting and assessment

R. J. Swart and J. A. Bakkes (eds.)
L. W. Niessen, J. Rotmans, H. J. M. de Vries and R. Weterings



Stephen Graham, UNEP/SELECT

UNEP/EAP.TR/95-01
RIVM/402001002
1995

rivm
research for
man and environment

UNEP

NATIONAL INSTITUTE OF PUBLIC HEALTH AND THE ENVIRONMENT (RIVM),
BILTHOVEN, THE NETHERLANDS

in co-operation with

ORGANISATION FOR APPLIED SCIENTIFIC RESEARCH (TNO)
CENTRE FOR TECHNOLOGY AND POLICY STUDIES

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This study was commissioned by
the United Nations Environment Programme

For bibliographic and reference purposes, this publication should be referred to as:

UNEP/RIVM 1995
Scanning the global environment: A framework and methodology for integrated environmental reporting and assessment
UNEP/EATR.95-01; RIVM 402001002
Environmental Assessment Sub-Programme, UNEP, Nairobi

ISBN: 92-807-1491-0

FRONT COVER: *Natural and artificial light* by Stephen Graham, USA, from the UNEP International Photographic Competition on the Environment **Focus on Your World**

ABSTRACT

The development and elaboration of strategic environmental policy needs better support. To this end, information should be provided about the past, current and future state of the environment as a function of demographic and socio-economic developments. In this report a framework is sketched for this type of assessments at the regional and global level.

The policy relevance of the global environmental reporting and assessment functions could be improved considerably by introducing three new elements:

1) the application of integrated frameworks and computer models to allow for the analysis of the dynamic linkages between different environmental changes, between environment and development, and for early warning purposes and prognosis;
2) a framework of appropriate indicators related to the pressure on the environment, the state-of-the-environment, the resulting impacts on functions of the environment and the societal response; for these indicators to be policy-relevant appropriate reference values should be selected and developed;
3) networks of experts and expert institutions for assessment and consensus building on key environmental issues.

This report focuses on the first two elements. A framework is proposed, including environmental indicators and models describing the human system, the environmental system and their interactions. This framework is integrative in the sense that integrated models are used to link the system components dynamically. Forecasts for early warning purposes can be supported by model-aided development of consistent sets of scenarios. A hierarchical set of indicators is proposed, as much as possible based on the output of regional and global environmental modelling. These indicators can be developed for different geographical levels, different environmental themes and different societal sectors. Consensus building on reference values is necessary for appreciation of reported indicators. The Pressure-State-Impact-Response framework is used as an organizing principle for indicators in the environmental management cycle.

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ACKNOWLEDGEMENTS

The editors gratefully acknowledge all those who have commented on earlier drafts. They especially thank Dr. Veerle Vandeweerd of UNEP and Paul Rump of Environment Canada for their detailed review and constructive suggestions, and Kenneth Barr and Marcel Berk for final editing.

PART I

INTRODUCTION AND FRAMEWORK

CHAPTER 1

BACKGROUND, OBJECTIVES AND KEY ISSUES

1.1 BACKGROUND AND OBJECTIVES OF THIS REPORT

Agenda 21 was adopted at the United Nations Conference on Environment and Development in Rio de Janeiro as the global action plan aiming to achieve sustainable development. To allow decision makers to plan for sustainable development and appraise progress being made towards the objectives of Agenda 21, information on the past, current and future state of the environment as a function of demographic and socio-economic development is essential. Assessments can play a major role in this process by providing:

1. an integrated view on environment and development: integrating environmental and socio-economic issues, and analyzing the impact of driving forces on the services / functions the environment provides;
2. ex ante evaluation of the environmental effects of alternative socio-economic scenarios and broad policy options;
3. an explicit policy-oriented interpretation of available data and scientific knowledge.

This report is intended to explore ways in which integrated reporting and assessment can be based on a systematic, policy-relevant evaluation of the past, current and future state of the environment. "Reporting" here refers to the preparation and distribution of documents and other information about the environment, while "assessment" refers to the appreciation of this information by scientists for supporting policy development, applying their expertise and using appropriate tools.

Current reporting is characterized by an emphasis on data with insufficient policy-relevance, sometimes complemented by evaluations by selected experts. This report deals with the methodological innovation that is necessary to make reporting more systematic, broad-based and policy-relevant. This report is not in the first place meant for the reader who wants to get an impression of the content of integrated assessments. Other publications are in preparation to do just that. Nevertheless, we have included an example from existing material as an appendix.

1.2 OBJECTIVES OF INTEGRATED ENVIRONMENTAL REPORTING AND ASSESSMENT

The international community through United Nations fora such as the General Assembly (GA), the Governing Council of the United Nations Environmental Programme (UNEP-GC), the United Nations Conference of Environment and Development (UNCED), and more recently the Commission on Sustainable Development(CSD) has expressed repeatedly the need:

> **"to keep under review the state of the global environment, enhance understanding of the critical linkages between environment and human activities, identify priorities for international action, flag emerging issues and strengthen national and regional information-handling capacities for sustainable development"** (UNEP,1994).

At present, there is inadequate knowledge on the state of the environment and its linkages with development and socio-economic issues at the global and the regional level. Information necessary to assess the impacts of demographic and developmental trends on environmental processes is often not available or known. Yet, this information is required to identify emerging issues and priorities for collective action in the context of sustainable development at international, regional and national levels. Given the paucity of relevant information, a global reporting and assessment system needs to be primarily targeted at addressing the following question:

> *Which environmental issues and priorities deserve special attention by the international community?*

In order to answer this question, a global reporting and assessment system would have to enable comparison across regions and environmental issues in the broader context of sustainable development. In accordance with the policy life cycle (figure 1-1), the following objectives could therefore be set.

1. Identifying and articulating environmental issues

- Agenda formation, e.g. through the UNEP's Governing Council, CSD. Contribution to the periodic revision of Agenda 21 and related policy plans.
- Raising awareness, e.g. by providing feedback of environmental information to the broader public.

in a coherent fashion. It would support international efforts in the areas of early warning, periodic review, and the identification of emerging issues. Decision makers in national governments and in multilateral organisations would thus be supported in setting priorities.

Evidently, the proposed framework is not yet operational. No appropriate indicators for many environmental themes have been agreed yet, nor are practicable simulation models at the regional or world level always available. However, several integrated modelling techniques and associated sets of indicators for the different elements of the environmental management system are being developed. The strength of these techniques would be greatly enhanced if the efforts in different sectoral areas could be integrated into a comprehensive regional and global reporting and assessment.

This process of integration can be reinforced through global networks of research and monitoring institutions. The efforts under way in the industrialized countries of the OECD should be complemented by parallel and joint efforts in the less-industrialized countries in order to fully acknowledge their special situation, their rich knowledge and different priorities.

1.4 A VISION ON FUTURE OUTPUTS

Developing a framework for comprehensive reporting functions must go hand in hand with creative thinking about potential future profiles for international policy-relevant assessments and reports. To start the discussion, we would like to present some preliminary ideas for consideration.

First, environmental issues needing additional attention by the policy community should be highlighted. Based on an ongoing assessment of environmental trends, the (projected) state of the environment could be compared against reference values selected for each issue (depending on the phase of policy development, this can be one target value or a range of options). Issues and regions for which additional efforts - research, information gathering - are necessary, as well as the level of additional effort needed, could be identified.

Second, global assessment reports could present successes in environmental policy and implementation as illustrations of steps forward that can be made. By presenting successful and promising developments, collective action in the context of sustainable development can be enhanced. In addition, developments in partnerships, international coordination and funding can also be highlighted.

Third, significant trends in environmental pressures could be presented. These trends can be regarded as early warnings for future environmental trends, considering the time lapse between pressures and impacts at the global and regional level and the delay time of societal responses. The time horizon of this analysis could be 10 to 40 years.

Consequently, a global assessment report can have the following elements:

First, it would be based on an integrated analysis of trends in the state of the environment, as a function of demographic and socio-economic developments. Past trends and scenarios for future trends could be analyzed in order to compare the (projected) state of the environment to policy objectives. A relevant time-horizon in the analysis of these trends and scenarios would be 10 years, but it might be wise to include a longer term prognosis (10-25 or even 50-100 years, depending on the issue being considered), in order to allow for delays in societal and natural systems.

Second, the report can, in order to present feedback to governments and international organizations, present an appraisal of agreed international policies. It should also include the results of ex ante evaluations of alternative policy options, in order to identify promising strategic lines for environmental policies during the next ten years period.

In addition, the global report could address more specific target groups by including region specific and issue specific sections and by documents directed to donor communities. In order to support such activities, a well-organized world-wide network of excellent reporting and assessment institutes should be established. Possible directions for the activities of the network components are outlined in the following chapters.

CHAPTER 2

A FRAMEWORK FOR ENVIRONMENTAL REPORTING AND ASSESSMENT

2.1 THE FRAMEWORK

Most of the current regional and global environmental reporting systems are static and statistics-based. Information about the state of the environment is consequently limited to the past and present situation for individual themes. We propose to improve these systems by applying a set of - conceptual and computer - integrated models and associated indicators, supported by a broad network of international experts and expert institutions. We have adopted an *integrated and multidisciplinary framework* to guide the development of a reporting system that recognizes the dynamics of the interactions between human society and the environment at different spatial and temporal levels. We distinguish two main systems: the *human system* and the *environmental system* (figure 2-1). Within these systems we can further distinguish several subsystems . In figure 2-1, the human system is subdivided into a *social subsystem* - including demographics, health, education, equity, emancipation, safety - and an *economic subsystem* - including energy, production, consumption and trade, and stock of human (labour, capital) and natural resources (see Box 2-1 on natural resources). The environmental system is subdivided into the *biotic subsystem* and the *a-biotic compartments* proper: physical and chemical characteristics of soil, air and water. Alternatively, the environmental system could be subdivided according to environmental issues that have their influence across compartments (e.g. climate change, eutrophication, acidification).

From a systems analysis perspective, activities in the human system exert *pressure* upon the environmental system. As a consequence, the characteristics of the *state* of the environment change. This again causes functions of the environment to change: *impacts*[1]. Reacting to these impacts, the human system shows a societal *response*[2].

Figure 2-2 illustrates how 'pressure', 'state', 'impacts' and 'response' are coupled in a dynamic cycle. This generic approach is characteristic of most integrated environmental policy models. Of course, in the real world the interactions are more complicated than the simple sequential representation of figures 2-1 and 2-2, but we believe that the proposed framework can serve the important purpose of structuring and analyzing the most important interactions[3].

RELATING IMPACTS TO FUNCTIONS

In describing the 'impacts' resulting from changes in the 'state' of the environmental system, it is important to relate 'impacts' to specified functions. Where standards and guidelines have been set, a specification of functions has also usually been made. For fresh water systems, for example, a conventional breakdown of functions is: transport, hydropower generation, industrial supply, agricultural supply, fishery, drinking water preparation, recreation, support of ecosystems. Examples of functions of soils are: support of infrastructure, supply of materials, agricultural resource base, support of natural vegetation. Changes in these functions are of more direct importance to policy makers than changes in the physical, chemical or biological characteristics of the different systems.

Indicators are used to communicate information about the elements in the cycle in figure 2-2, their interactions and changes over time. The term 'indicator' refers in this report to a piece of numerical information that is both (1) part of a specific management process and can be related to the objectives of that management process and (2) has been assigned a significance beyond its face value. (Bakkes et al., 1994). Figure 2-3 illustrates how different indicators relate to the elements in the framework depicted in figure 2-1 and the phases of the dynamic cycle. Figure 2-4 shows

[1] The approach chosen here is very similar to the Pressure-State-Response framework as adapted by the OECD. In fact, the 'state' part of the OECD approach is here split in two parts to be able to accommodate information about changes in (impacts on) the functions the environment has for man (function changes). Most integrated models addressing environmental problems make this distinction. Also, for decision makers, functions of the environment are considered to be of more direct interest than the characteristics of environmental media and ecosystems.

[2] In systems analysis terms, 'steering' is also often used. It is replaced here by 'response' to acknowledge that the system under consideration is only partly steerable, as unintended 'autonomous' influences are also part of the response.

[3] 'Response' does not only include (impact-induced) policies, but also socio-economic responses resulting less directly from policy. In the proposed analysis, autonomous and policy-driven responses have to be clearly separated. Also, the one-way direction of the arrows is a simplification of reality. For example, responses can directly affect impacts, such as geo-engineering to counteract the enhanced greenhouse effect or cleansing of polluted soils.

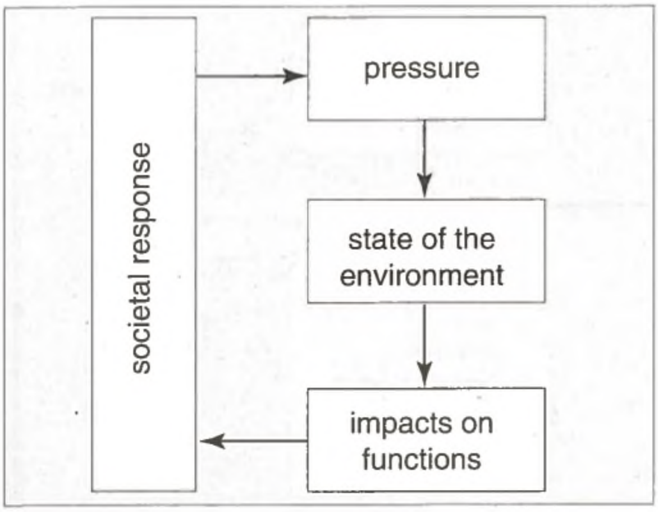


Figure 2-2: The dynamic cycle from a systems analysis perspective

of available knowledge in the light of policy objectives and uncertainties. The assessment can combine a scientific as well as a policy component. A *scientific assessment* describes the current state of scientific knowledge in policy-relevant terms. A *policy assessment* evaluates the effectiveness of established or proposed policies. Assessments can be targeted at a policy audience. The preparation of assessments forms an integral part of the reporting process and an important vehicle towards international consensus-building. This is in contrast with the more traditional assessments prepared by selected expert authors, which were not based on models and consistent forecasts but primarily on the judgement of a fairly limited number of experts about observations.

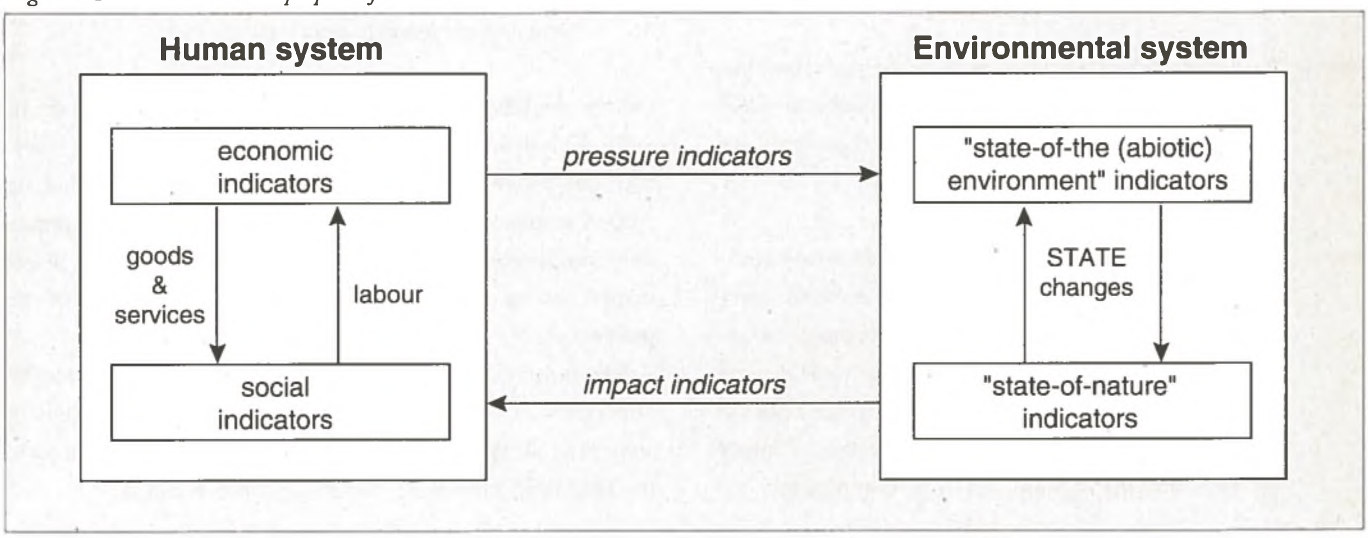
Simulation models can play a key role in the assessment activities. Assessment panels can formulate questions in, say half-yearly meetings. Thereafter, modelling teams (e.g. 3 to 10) could address the questions and report during the following meeting. This procedure has proven to be successful in support of the negotiations on the Long-Range Transboundary Air Pollution agreement in Europe (Hordijk, 1991). Models have been used in this way in a more ad hoc fashion in the proceedings of the Intergovernmental Panel on Climate Change (Swart, 1994). Models will be discussed in more detail in the next section.

The acceptance and impact of the produced reports can be enhanced by specifically facilitating consensus-building processes. In some cases (climate change, stratospheric ozone depletion, biodiversity) regular assessments are being or already have been institutionalized. However, no regular assessment system has yet been established for other important issues such as soil degradation and the quantity and quality of fresh water resources.

Although assessments about different individual environmental issues are essential, we argue that this is not sufficient. To capture the interlinkages between different issues in a coherent framework, a cross-cutting, integrated assessment is required also. But let us start by illustrating a possible structured reporting and assessment methodology for addressing single-issue environmental themes. It could have the following generic steps (based on an example for a river basin by Heij, 1994):

step 1. *definition of theme, system, problem and objectives*: before addressing the issue in detail, a clear definition of the issue has to be elaborated as a basis of further reporting and assessment activities; this includes an initial selection or development of models and associated indicators and reference values based on an evaluation of user demands.

Figure 2-3: Indicators in the proposed framework



2.3 INTERLINKED MODELS AT VARIOUS AGGREGATION LEVELS

Models are tools for organizing knowledge at the proper time/space level. There are several advantages in using models in environmental reporting and assessment. These include:

1) *the dynamic analysis of the interdctions* between the components of the global systems under consideration: the driving forces (e.g. population, industry, technology), the changing state of the environment, the impact on functions of the environment and the societal response to the changes;

2) *the development of forecasts and early warnings*: models allow for extending an analysis in time and space and implicitly show time delays in environmental and social processes and thus may lead to priority setting superior to priority setting without forecasting facilities;

3) *the optimization of monitoring systems*: models can help in optimizing investments in monitoring systems and can generalize patterns on the basis of incomplete data and allow approximations in data-poor environments.

Of these, the first two in particular are relevant to this report's proposals for a policy-oriented reporting and assessment framework; so it is to a discussion of the use of models in reporting and assessment that we shall now turn.

The regular use of models in diagnosis and prognosis of environmental changes is a rather recent phenomenon. In the past, large-scale models addressing - sustainable - development have been biased towards the socio-economic factors, as will be discussed in part II. However, increased awareness and understanding of environmental problems have spurred the development of more sophisticated models of environmental change, which have redressed the balance between the human and environmental systems. Environmental forecasting and assessment is now being applied extensively at the national level in a limited number of industrialized countries, one example being the Netherlands (RIVM, 1992). At the international level, it is being used on a regular basis in support of the negotiations about the Long-Range Transboundary Air Pollution agreement in Europe (Downing et al., 1993). On a more ad hoc basis, models have also been used for assessments in support of the negotiations of the Law of the Sea (Sebenius, 1981), the Montreal Protocol (WMO, 1985), and the Framework Convention on Climate Change (IPCC, 1990). Integrated policy models have been developed by a limited number of organizations that are either funded primarily by national governments, such as RIVM in The Netherlands (e.g. IMAGE) and Battelle in the United States (first and second generation Edmonds & Reilly models), or by international contributions through interested governments and foundations, such as IIASA (RAINS, world food models) and the Stockholm Environment Institute (POLESTAR).

Although a few models used in the analysis of global environment and development issues are already available, they often deal with selected individual environmental themes or focus on a limited set of socio-economic factors. To meet the objectives of integrated environmental assessments in the context of Agenda 21, the application of models within our framework will have to be extended to cover sustainable development strategies in general. It will also have to take full account of the linkages between environmental issues and between environment and socio-economic development at the global and regional levels.

While for some important issues, such as soil degradation, waste and loss of biodiversity, no appropriate models are available, most models that have been developed in the scientific realm are expert models focusing on elements of the causality chain for one particular issue. Sometimes, such models are adapted to serve policy purposes, but they may not be as useful for supporting decision making as those models specifically developed for the purpose (De Rond, 1994).

Furthermore, integrated models capturing the spatial levels between the local and the global remain scarce. In dealing with the issue of sustainable development, one has to take into account the variety of scales in space and time that are involved. Although models describing ecological processes at the level of large-scale vegetation zones or biomes, and at the level of individual species, to analyze the impacts of climate change on ecological systems are available, we do not know of any integrated model that has been developed to capture the important intermediate level of ecosystems. Clearly, we will need to develop purpose-built models adequate to this task. We would therefore propose an approach using a set of mutually supportive simulation models at different levels of scale. And because higher levels of scale usually imply higher levels of generalization, effective interaction between the development and application of modelling tools at different levels will have to be developed to ensure dynamic reporting about the past, current and future state of the environment.

On many issues, it is likely that the dynamic linkages can be explored by high-aggregation level models which, later on, when the relevance of the linkages has been assessed, can be adapted to the low aggregation level.

At the high aggregation level, the focus is on conceptualization and exploration of long-term dynamics. A recent example is the

Box 2-2: Integration across disciplines: levels of reality

From the onset it is important to recognize the social and cultural diversity within the world community. On the one hand, the world appears to be growing into an ever more integrated whole with increasingly shared models (mental representations) of how it is developing. On the other hand, there is a strong feeling that local social, cultural, religious and economic identity and autonomy need to be preserved. The richness of such feelings will have to be respected and used if a sustainable development strategy is to be made effective. One way of putting this into perspective is the acknowledgement that we are dealing with various levels of reality. One may describe the underlying vision as a layered structure with the physical at the bottom and the mental at the top. Each discipline has its own realm of investigation along this axis.

At each level, the nature of human knowledge differs with regard to how it is acquired and how it is framed into concepts and theories. Whereas in physical and engineering sciences the emphasis is on repeated controlled experiments and rather strict falsification procedures, knowledge in the social sciences is inherently of a more hypothetical nature due to its limited feasibility of controlled experiments with its object of study. The relevance of this perspective is that it reminds us that the nature of our models and the way in which their results are interpreted are not, and cannot, be uniform. More specifically, it can be used to:

- allow an explicit expression of various cultural perspectives on global environmental change issues, and
- provide a context for fruitful cooperation between social and natural scientists.

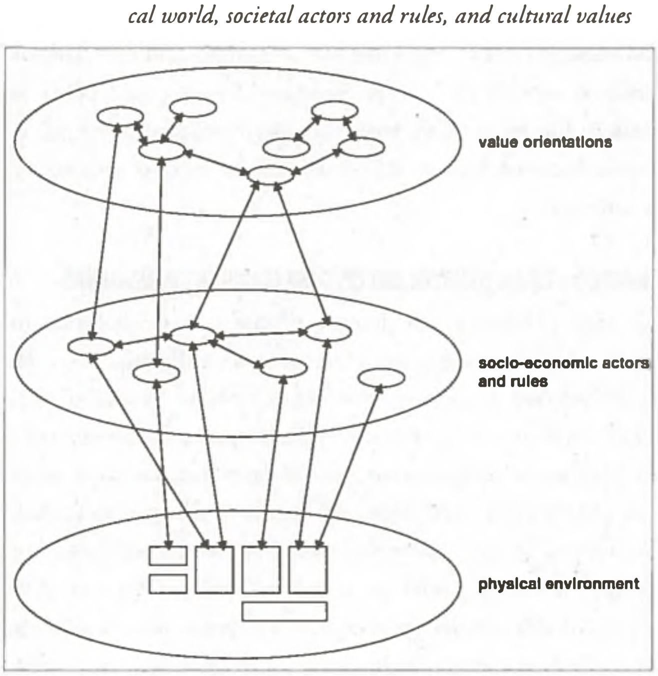
One could think of such a structure as being modelled at three levels (figure 2-6):

- a level describing the reservoirs and flows of the physical environment in which major principles of the physical and engineering sciences (e.g. mass balances) hold;
- a level at which quality and productivity are assessed (e.g. in monetary terms), which in turn are based on behavioural rules (e.g. invest ment decisions) and govern the major changes in the physical level;
- a level at which social and cultural values are represented which in their turn are the major frame of reference within which quality and productivity are evaluated.

How these different levels can be taken into account in systems of indicators is discussed in chapter 3.

The disaggregated approach has clear advantages in dealing with land- and water-related issues. Region-specific information can be used, impact assessments can be worded in fairly concrete terms and policy options can be explored at the proper response level. Since regional and local impacts are often the consequence of actions elsewhere, models can also have parts which are at much higher aggregation levels e.g. in the representation of atmosphere and oceans. Such models can, in turn, be conceived of as meta-models relating to the GCMs (Global Circulation Models). There are also a few drawbacks to a high level of disaggregation: simulations tend to be much more time-consuming and much more data-intensive, even to the extent that additional detail has negative marginal benefits because of lack of reliability and compatibility.

Figure 2-6: Representation of three levels of model realities: the physical world, societal actors and rules, and cultural values



In conclusion, we would argue that integrated models are necessary at the level of the globe, major regions or subregions (like water basins, agro-ecological zones, biomes). They should be complemented, where necessary and possible, by models that are only partially integrated and that capture specific issues in detail.

2.4 FORECASTING AND SCENARIO DEVELOPMENT

Models, as we have seen, can serve an important function in global and regional environmental reporting. In addition to allowing for analysis of cross-linkages between system components, they form the most important tools for the development and analysis of scenarios. Scenarios can then be used for early warning purpos-

Although this is not the explicit subject of this report, we believe thinking about communication between researchers and decision makers *during* rather than *after* the development or models or the preparation of a report is of paramount importance.

Models can enhance communication between researchers and decision makers in various ways: from open-structured policy exercise set-ups to rigidly structured interactive-simulation sessions with potential users of the reports. The scope for creating learning environments has widened with the newly emerging computer hardware and software e.g. networking and multimedia. Visualization tools like innovative purpose-built software can be supportive in making models more transparent. Similarly, interactive decision support software can help to grasp the complexity of feedbacks, overshoots and time-lags. Such tools, in turn, can be called for within a larger learning environment in which participants are using techniques like backcasting and team-building. RIVM's GESPE-project (de Vries et al., 1993) focuses explicitly on this aspect of model use by creating a learning environment to deal with the dynamic complexity and social dilemma structure of the long-term impacts of global greenhouse-gas emissions. Teams representing major countries/regions in the world, are attempting to reach certain strategic goals for their region while being confronted with the long-term consequences.

UNCERTAINTY

The concept of uncertainty plays a key role in integrated assessment modelling, because forecasting the future pressure on, state of, and impact on the Earth's system as well as the societal response to these changes is beset with many uncertainties. In spite of these uncertainties decision makers have to outline environmental policies, because they cannot wait for total understanding and perfect models. In many policy-oriented models the imperfection and non-understandings are hidden. Addressing the issue of uncertainty is important in helping decision makers understand the big gaps in current knowledge. Therefore, it is crucial that uncertainties within integrated assessment models be made explicit and visible.

The concept of uncertainty covers many different cultural notions. Several attempts have been made to classify the different types and sources of uncertainties in models. Granger Morgan and Henrion (1990) distinguish three kinds of uncertainty in models: uncertainty about empirical quantities, uncertainty about the functional form of models and disagreements among experts. An alternative classification is the distinction of Funtowitcz and Ravetz (1989) in technical uncertainties (observations and measurements), methodological uncertainties (the right choice of analytical tools) and epistemological uncertainties (the conception of a phenomenon). For the purposes of this study the various types and sources of uncertainty mentioned above have been arranged in two categories, based on the subdivision of the Earth's system into the human system and the environmental system:

1. *scientific uncertainties*: those uncertainties occurring in the environmental system which arise from the degree of unpredictability of environmental change processes; they may be narrowed as a result of further monitoring, scientific research or more detailed/appropriate modelling;

2. *social and economic uncertainties*: those occurring in the human subsystem which arise from the degree of unpredictability of future geopolitical, socio-economic and demographic evolution and which are inherently 'unknowable' or in practice unpredictable.

Examples of scientific uncertainties include incomplete knowledge of the sources and sinks of chemical substances (gases), caused by lack of measurements, inconsistency of measurements, or deficient knowledge of the key physiological, chemical and biological processes. Illustrative of this is the inadequate understanding of the many feedback responses - both geophysical and biogeochemical - which can amplify (positive feedback) or dampen (negative feedback) the response of the biosphere system (Rotmans and den Elzen, 1993). There is thus a very high degree of inherent uncertainty in the whole complex system. Social and economic uncertainties, on the other hand, refer to processes in the human system, such as socio-economic, demographic and epidemiological developments, which are related to a set of behavioural rules and decisions. These rules and decisions are value-based and a major source of disagreement between experts, so their implementation in models is dependent on the actor's cultural perspective.

Disagreement among scientific experts is an important source of uncertainty in models. Although much disagreement arises simply from different technical interpretations of the same available scientific evidence, it is regularly complicated by the different perspectives people have. Relating the concept of uncertainty to the concept of cultural perspectives we arrive at the concept of perspective based alternative model routes, as a methodology to make uncertainties within the model visible (van Asselt and Rotmans, 1994). Figure 2-7 shows how different types of uncertainty can be related to different types of perspectives.

CHAPTER 3

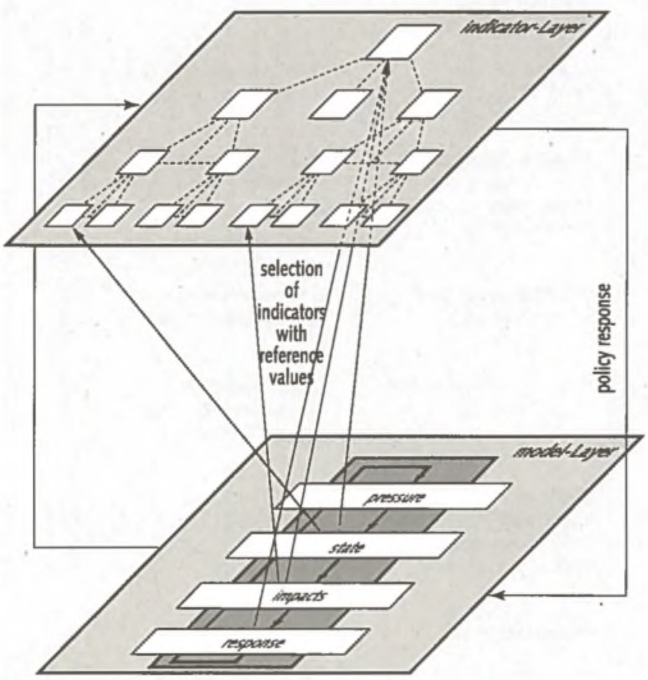
A SET OF INDICATORS

3.1 INTRODUCTION: THE RELATION BETWEEN INDICATORS AND MODELS

While models are important for supporting the analysis of the dynamic interactions of the different aspects of environmental change, indicators serve as the vehicles for communicating the resulting information. The term indicator as used in the context of this publication has already been defined in section 2.1. Paraphrased, the definition means that the comparison of an indicator with an objective or reference provides a signal for action or non-action. Model-based indicators (figure 3-1) are always complemented with information from other sources.

Of the several possible frameworks for developing and organizing environmental indicators, the two-dimensional matrix as applied by OECD (1993) and O'Connor (1994) would seem the most straightforward. The OECD framework places pressure, state and response indicators in columns, and each of 13 issues, such as water resources and acidification, in rows. In a recent Worldbank publication (World Bank, 1995) O'Connor has proposed a tentative adaptation to this matrix. By widening O'Connor's framework to include human and economic subsystems we would have a two-dimensional matrix capable of reporting sustainable development; see table 3-1.

Figure 3-1: The relation between models and indicators



This is further illustrated in figure 3.2 (which is an elaboration of figure 2.3). Each intersection between the human and environmental subsystems and the pressure-state-impact-response management cycle is characterized by an indicator, or, depending on the required level of detail, a hierarchical set of indicators. See 3.3 for an elaboration of this. However, it must be stressed that although this type of organizing framework is very helpful in facilitating comprehensive reporting, it will only provide a static picture because it omits the dynamic linkages between the indicators values.

3.2 CRITERIA FOR SELECTION AND DEVELOPMENT OF INDICATORS

We can distinguish between criteria that apply to indicators as a set, and those that apply to individual indicators. The proposed set of indicators for integrated environmental assessment and reporting should obviously match the framework proposed previously. This will require a balanced coverage of the population, economic, environmental, and ecological subsystems. The set will also have to cover pressures, state, impacts and responses, and allow for the presentation of the information in this form. Finally, the set of indicators should also be capable of measuring progress in attaining the long-term goals of Agenda 21 at the strategic level.

In addition, to meeting these criteria, individual indicators should also:

Be policy relevant

- Indicators should be tailored to the needs of the primary users (CSD, donor agencies, international organisations, national governments, major non-governmental groups etc.).
  Because indicators should be recognizable and understandable for client decision makers, stakeholders in the policy life cycle should be involved in their selection or development.
- Indicators should reflect parameters that are changing or can be changed by human intervention.
- It should be possible to relate the indicators to a target or

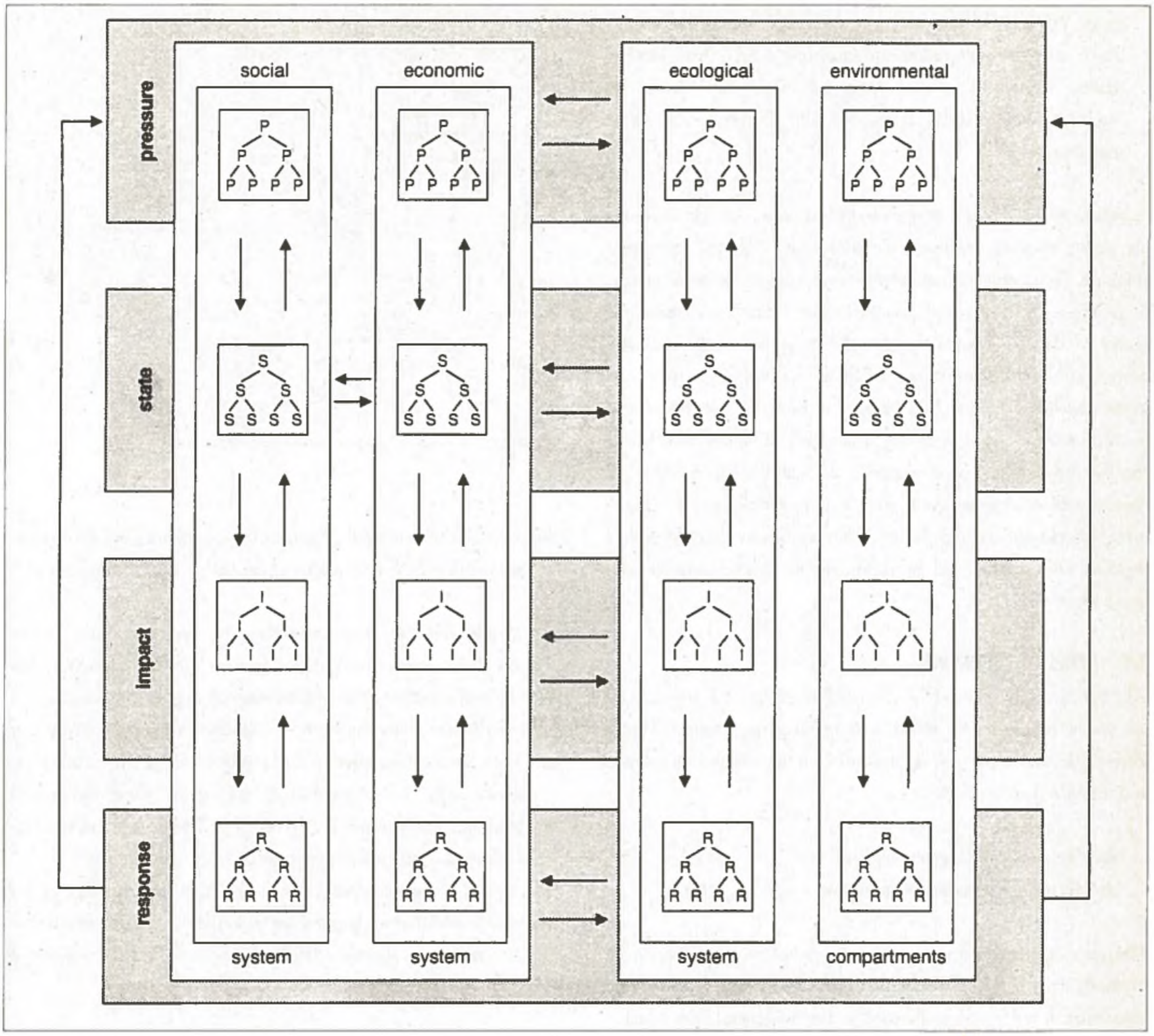


Figure 3-2: Pressure-State-Impact-Response indicators in the proposed framework

other reference value: is the situation getting better or worse and is it acceptable?

- The set of indicators should permit regional priorities to be addressed.

Permit forecasting

- The indicator definition should allow for plausible forecasts based on economic and demographic scenarios and policy options.
- It is important to realize that current knowledge does not allow us to link all indicators dynamically through integrated modelling. Knowledge of existing causal relationships between the human and the environmental system, as well as of relationships between various elements within the environmental subsystem, is limited. Nevertheless, we do think that a gradual transformation of the current system of static indicators into a dynamic system of mutually dependent policy-relevant indicators, is feasible.

Be built on existing environment and policy monitoring systems

- Indicators should be compatible with existing data sources and existing or evolving indicator efforts (e.g. in UNDP, OECD, WHO, World Bank, UNSTAT, World Resources Reports, etc.) as much as possible.
- Although the reporting and assessment described here is different from the regular and frequent monitoring of policy performance at the national level, or in the context of international agreements on specific topics, it should still be able to

Domestic Product (a highly aggregated index) and the socio-economic Human Development Index (a composite index; e.g. UNDP, 1993) would facilitate policy making in the broader context of environment and development. However, the use of aggregate indicators has several disadvantages, among which are the loss of analytical power and the complexity of the link between the resulting index and the real, observed world. An example of the loss of analytical power is the masking of the deterioration of one environmental problem, say greenhouse gas emissions, by the mitigation of another one, e.g. sulphur oxide emissions. In addition, aggregated indices may be relatively insensitive to variations over time.

A further point of possible criticism, especially with regard to indicators, is that the index value and its rate of change are dependent on the scaling and the weighting factors applied. Hope et al. (1992) claim that their national environmental index is largely independent of the origin of the set of weights (within Western Europe, that is). However, since their primary basis for weighting is public opinion and since this could be influenced by the publication of the index values, also with respect to the relative importance of environmental issues, this proposed weighting system does not seem to be satisfactory. Others have used expert judgement or delphi techniques. Another possible solution might be to assign a different basis for weighting such as the difference between the value of the thematic components in the highly aggregated indicator and their target values ('environmental deficit').

Notwithstanding the attractiveness of aggregated indices, separate single-issue indicators are indispensable for a number of reasons (such as specific environmental policies and comparison over time and between different contexts) . If we also note the time required before an aggregated environmental index is developed and accepted, then it is apparent that, irrespective of the state of the art, there will always be a need for a mix of both types of indicators to inform policy development. There is, therefore, a need to develop aggregated or composite indices (level A) at the same time as developing a more theme-oriented set of single-issue indicators (level B).

Level B: single-issue indicators. Possibilities for level B indicators range from selected single parameter indicators to composite indicators. Single indicators are a pars-pro-toto, a surrogate representative for the full issue. The classical example is sulphur dioxide emissions representing the issue of acidification.

Composite thematic indicators are developed by aggregation across substances (e.g. into acid equivalents, or biological oxygen demand), by aggregation across the causality chain, or by aggregation across environmental compartments. Aggregation across the causality chain has the specific purpose of compensating for the natural and societal delays along the pressure-state-impact-response cycle, which may be several human generations.

Traditionally, level B *indicators* are grouped according to specific *themes* or *issues*, e.g. 'economic development' or 'demographics' in the human system, and 'climate change' or 'eutrophication' in the environmental system.

Because all indicators are designed to meet a specific need, they have to be developed with this specific need in mind. This applies equally to levels A and B. Moreover, the choice and role of indicators are dependent on the phase in the policy life cycle of the issue under consideration (Bakkes et al., 1994)[1]. While one type of problem may be served by highly aggregated indicators more detailed indicators may be appropriate for issues in the later phases of policy development and implementation, such as performance monitoring[2]. Sets of indicators, therefore, will evolve along with the user needs.

3.4 REFERENCE VALUES

Reference values are here defined as the desired numerical or nominal values of indicators. Although these values are value-laden and often used for policy making, they need not necessarily be actual policy targets, that is linked to a set of policy measures and to be reached within a defined time-frame. Reference values can, in some cases, be based on a presumed "natural" or "original" state (number of species, concentration levels). Their primary function is to put the descriptive information on pressures, states, impacts and responses communicated through indicators into perspective. Without adequate reference values it is difficult to attach a meaning to changes in pressure, state, impact levels etc. It might even be impossible to discern between those trends that should be valued positively and those that should not. The 'dis-

[1] For instance, the model-based mapping of the exceedence of critical loads for acidifying deposition that is carried out in support of international environmental policy in Europe relates to the vulnerability of forest soils. In preparation of international policies with regard to acidification in Asia, critical loads have also been compiled. The Asian indicator relates to the vulnerability of 14 soil-vegetation combinations, including wet rice fields. While the European and Asian indicator systems use slightly different criteria, they may be used to compare levels at which critical loads are exceeded.

[2] In the profusion of indicator terminology, 'performance indicators' are sometimes understood to be distinct type of indicators. In fact, they are not. However, as it makes more sense to measure the environmental performance of a policy regularly once the issue and the policy have been defined operationally, performance monitoring correlates in practice with the use of the type of indicators that are relatively easy to measure and lend themselves to a straightforward comparison with an established policy objective, or the score of other countries in the region. (For examples, see Adriaanse, 1993 or OECD, 1993.)

what means an environmental objective is to be attained. It should also be noted that *costs of the necessary measures*, which could have featured in the response column, is usually not quantified in international agreements.

3.5 VISUALIZATION

Because of the complexity of integrated assessment models and the information these models produce, it is crucial to use appropriate visualization techniques. Modelling and visualization software for integrated assessment models is being developed. We believe the use of such software will:

- make the models as transparent as possible;
- make the underlying theories as clear as possible;
- increase the quality of models by opening them up to easy inspection by users;
- increase the use of models by decision makers by providing easy-to-use interfaces;
- enable the user to change parameters, variables, functions and scenarios in an interactive manner;
- display uncertainties and complexity of the systems behaviour comprehensibly.

Apart from the traditional and mostly static techniques for visualizing information such as diagrams, graphs, tables and histograms, such software will include innovative techniques that will allow an interactive, comprehensive and dynamic presentation of information.

Various aspects already emphasized in the present report, would ideally be incorporated in the visualisation. These would include:

o development over time;
o comparison with (indicators) reference values;
o insight in delays and cross-linkages in the PSIR cycle;
o understanding of cross-linkages between different issues;
o indication of reliability of the information.

There are different ways of working towards this, all of which have their particular advantages and disadvantages. In an indicator vector, different aspects of the causality chain can be combined into an aggregated index (Rotmans et al., 1994). For instance, the complex problem of stratospheric ozone depletion may ultimately be described by a vector of three indicators: production of CFCs (pressure indicator), change in atmospheric chlorine concentrations (state indicator) and relative change in skin cancer incidence (impact indicator) (den Elzen, 1993).

Visualizing the multi-dimensional components of indices might

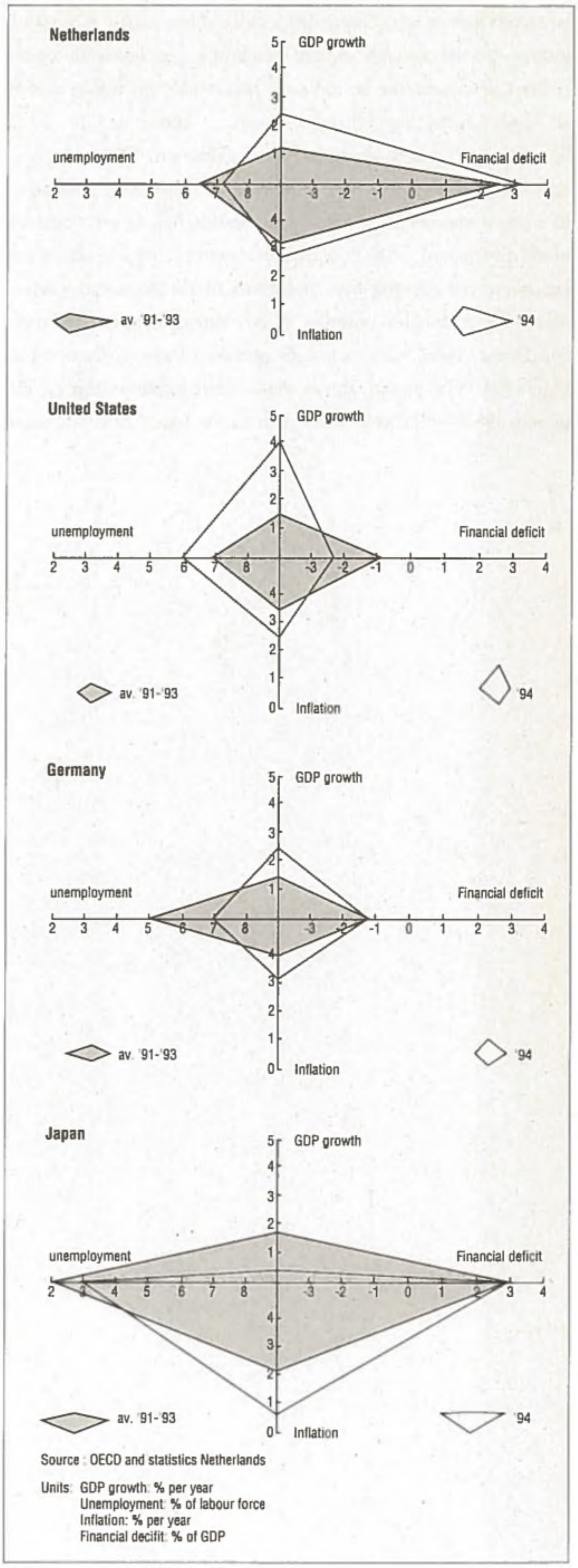


Figure 3-4: An example of a multi-dimensional index: the economic performance of four countries (average 1991 - 1993)

PART II

THE SUBSYSTEMS

CHAPTER 4

MODEL AND DATA REQUIREMENTS

4.1 FEASIBILITY OF AN INTEGRATED MODELLING APPROACH

Within the framework of this report, no comprehensive overview of past and current modelling efforts in the world can be attempted. However, illustrations are given at various levels of aggregation and integration. In this section we briefly describe selected examples of models that attempt a balanced *integration of the environmental and human systems at the global level.*

Models that attempt to set the human and the environmental system on an equal footing are rare. The main wave of global modelling efforts followed the publication of 'Limits to Growth' in the early 70s (Meadows et al., 1974), based on the Forrester/Meadows systems dynamics model[1]. The Mesarovic and Pestel (1974) model addressed regional interdependency and was intended to serve as a policy assessment tool. The Bariloche model (Herrera et al., 1976) added the South's perspective to the discussion, focusing on quality of life and a different global order. Other global models addressed a subset of problems, e.g. MOIRA (Linnemann et al., 1979), focused on food and hunger. The FUGI-model (Kaya et al., 1977), SARU (SARU, 1978) and the United Nations Global Model (Leontief et al., 1977) focused on the world economy, including the problem of resource depletion, which was a key concern in the seventies. However, environmental issues other than resource depletion were addressed in a fairly simplistic fashion.

Few new efforts have been undertaken since this 'first decade of global modelling'. At the Berlin Wissenschaftszentrum, the GLOBUS model, incorporating the economic and political aspects of world development, was developed (Bremer, 1987). The Basic Linked System, developed at IIASA, followed from the MOIRA efforts and described the world's agricultural (trade) system in more detail (e.g. Fisher et al., 1991). All these global models focused on the social and economic components of the human system. Since the seventies the knowledge about, and the political importance of, environmental issues has increased considerably. This has allowed for a more balanced treatment of the human and the environment system in both science and policy. The linkage between environment and sustainable development is now fully recognized in environmental research and modelling. This is reflected in a number of new global modelling efforts complementing the thematic models and integrating their results. Among these is the POLESTAR model of the Stockholm Environment Institute. This includes information on large numbers of components of the human and environmental systems in an information system incorporating scenario features (Raskin et al., 1994). It is being deliberately kept simple. Recently, at RIVM a new effort (TARGETS) has started, which will take into account the latest developments and knowledge from the environmental, information and socio-economic sciences in analyzing the implications of sustainable development in an integrated and dynamic way (Rotmans, et al., 1994).

TARGETS is intended to be used to perform an analysis and assessment on a global scale of the quantitative and qualitative linkages among social and economic processes, biophysical processes and effects on ecosystems and humans from an integrated system dynamics perspective. Common causes, mechanisms and impact of a number of coherent themes, functions and scales are translated in terms of Pressure, State, Impact and Response. The TARGETS-model can be represented as a two-dimensional integration matrix (figure 4-1) in which the vertical "rows" integrate the cause-effect chain of an issue or theme and the horizontal "rows" the integration of cross-linkages and interactions between various pressures, various state-dynamics and various impacts. The time covered by the TARGETS model will span about two centuries starting from 1900, symbolizing the end of the pre-industrial era, until the end of the next century.

4.2 DATA MANAGEMENT FOR INTEGRATED ASSESSMENT AND REPORTING

Data provision is essential if the proposed approach is to be applied in a balanced way to the different regions that make up the world. Moreover, data provision is by far the most resource-consuming element in the reporting process (UNEP, 1993).

One important component of the data demand of integrated assessments relates to the driving forces of environmental change, such as agricultural practices, demographic developments, land

[1] An excellent overview and a critical evaluation of the models developed in the seventies is given by Meadows et al. (1982). We refer the reader to Meadows et al. (1982), and more recently Rotmans et al. (1994), for a discussion of the advantages and limitations of this generation of models.

CHAPTER 5

AN INTEGRATED APPROACH TO THE ENVIRONMENT SYSTEM

5.1 INTRODUCTION

Over the last decades, pressures upon the natural environment have grown rapidly. As a consequence, many stresses on the environment are approaching threshold levels of sustainability or may have already exceeded these. Environmental degradation is already visible around the world, while further degradation due to current and future human activities is expected in the future. These problems are occurring at increasing scale levels. Population growth is an important driving force. From the economic perspective, both wealth - through growth of material production and consumption - and poverty - through inequitable distribution of this wealth - are among the key driving forces. The relationships between these factors and environmental degradation are complex, and will be discussed in chapter 6. In this introduction, we discuss the importance of integration, system delays and the different perspectives on priority issues.

IMPORTANCE OF INTEGRATION

Hitherto, environmental issues have usually been categorized, taking the environmental compartments air, water and land as a starting-point. Monitoring, research, and policy development have followed this thematic approach. In many instances, where easy, cost-effective technological mitigation options have been available, this approach has proven valuable. However, (1) the complexity and interdependency of environmental problems (such as global warming and stratospheric air pollution) require a different approach; (2) more localized, but universal problems (like the degradation of the quality of soil, water and air) are pervading the world; and (3) easy single-issue solutions are becoming less effective. Therefore, a more integrated approach is becoming inevitable. It has already been argued that such integration should not only be across the cause-effect chain, but also across different interacting environmental issues and across the linkages between social, economic and environmental changes. The approach proposed in part I of this report combines:

a) *thematic reporting and assessment*: the current practice of addressing individual environmental problems on an individual basis should be enhanced by structuring a reporting and assessment methodology in such a way that it takes into account the different elements of the environmental (pressure-state-impact-response) management cycle;

b) *global and regional synthesis*: complementary to thematic reporting and assessment, methodologies should be developed to integrate the global and regional social, economic and different environmental changes: multi-impact driving forces, multi-stress impacts and multi-purpose responses.

SYSTEM DELAYS

Crucial characteristics of environmental changes are system delays and accumulation. Many environmental systems have a natural buffer capacity. While stresses pile up and environmental thresholds are approached, impacts are not immediately observed. This type of delay often amplifies existing delays within the human system in responding to changes in the environment, such as the time needed for awareness building, policy formulation and negotiation, implementation of technical or organizational measures and the turnover rate of existing capital stock. Knowledge and forecasting is essential in order to identify environmental problems in time to allow for corrective action. While economic assessment and forecasting is usually limited to the short term and economic indicators have a turnaround time from weeks to years, environmental assessment and forecasting often has to apply time horizons of decades or centuries in order to capture system delays. Different environmental problems have different time horizons, varying from hours (e.g. health effects from local air pollution) to centuries (stratospheric ozone depletion).

DIFFERENT AND CHANGING PERSPECTIVES ON PRIORITIES

It is important to note that also here the different levels of figure 2-6 play a crucial role. At the bottom level - the physical representation of the world - the national and international environmental quality monitoring systems dominate. Information from this level influences - and is also influenced by - the actions and rules of the societal actors (partly captured by models). These rules are changing as a consequence of the developments at the level of cultural values (top of figure 2-6). It is at this level that the debate about how sustainable development should be defined is taking place. Here, different perceptions of the functions of the environment play a vital role. The global and regional reporting systems should be flexible enough to take these different levels and perspectives, and the changes therein, into account. Regional priorities are, among other factors, a function of the phase of economic and demographic development.

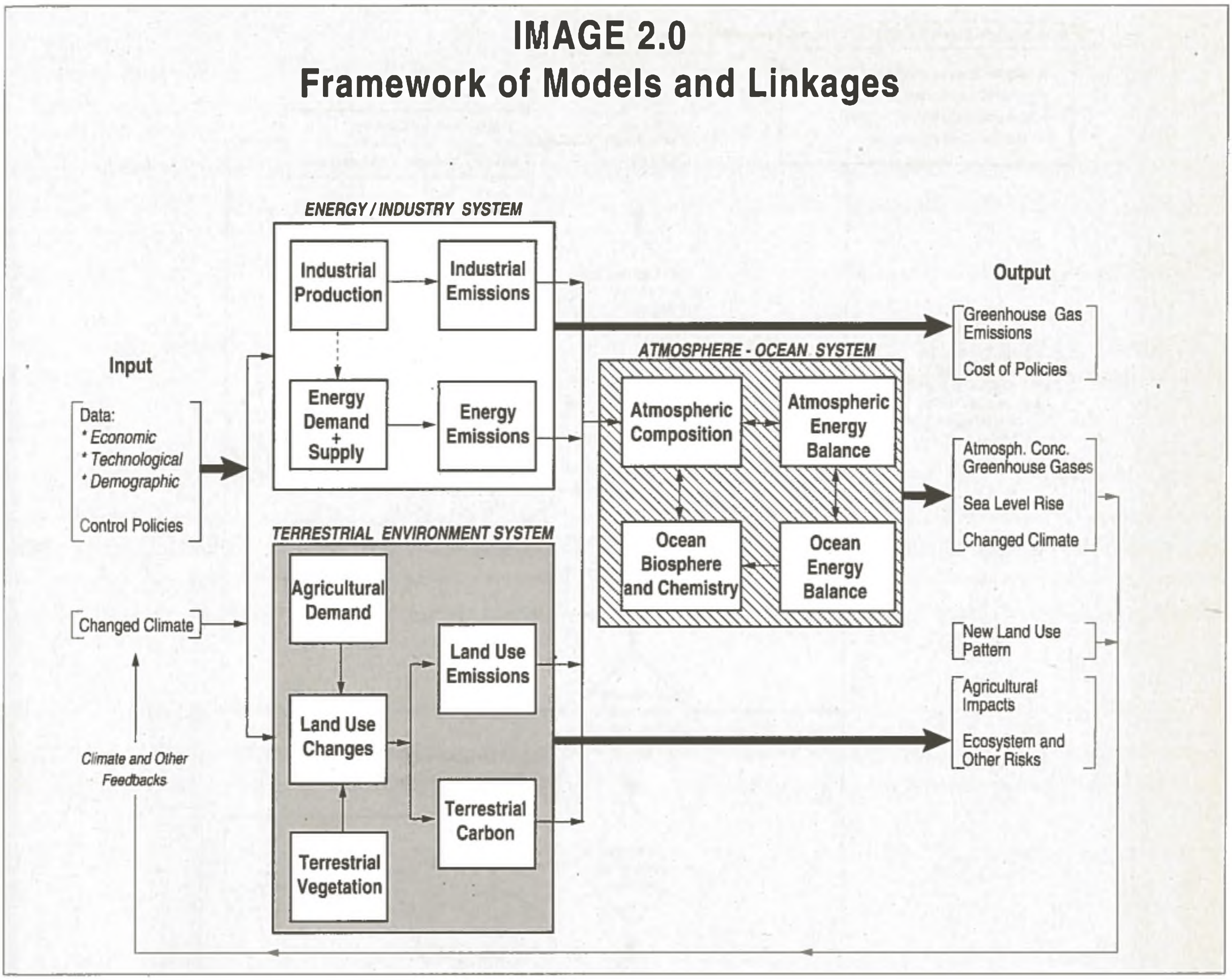


Figure 5-2: The Integrated Model to Assess the Greenhouse Effect (IMAGE)
Integration across the causality chain at the global level (Alcamo et al., 1994)

nerable ecosystems) - *response* (policy feedback) cycle can be recognized in the scheme. The RAINS model is also currently being adapted to support scientific assessment and policy development with respect to acid deposition and air pollution in Southeast Asia and China. These three examples share an integrated approach, which captures basic elements of the different subsystems including driving forces and natural and societal response.

The application of environmental models for regular reporting and assessment activities requires a coordinated effort. This specifically applies to the data used, the data format and the input assumptions. In appendix 2 an example is given of an integrated assessment of the state of the environment in Europe, using two of the above mentioned models (IMAGE and RAINS), with a consistent set of scenarios (Hettelingh et al., 1992). The study described in appendix 2 was supported by a set of separate models and, coordinated, amongst others, in terms of data and input assumptions. In contrast, the CARMEN model, now under development at RIVM, incorporates different models into one integrated framework, currently capturing acidification and eutrophication in Europe (De Haan et al., 1994).

Analysis of the combined impacts of different stress factors can also be supported by models. For example, the MOVE model forecasts what the occurrence probability of selected species is for different environmental scenarios (currently nutrients, acidity and moisture, to be complemented by climate change) (Latour et al., 1993). Figure 5-4a shows a simple representation of the model and figure 5-4b shows an application for the Netherlands, where different shades of grey represent different types of stress on selected plant species.

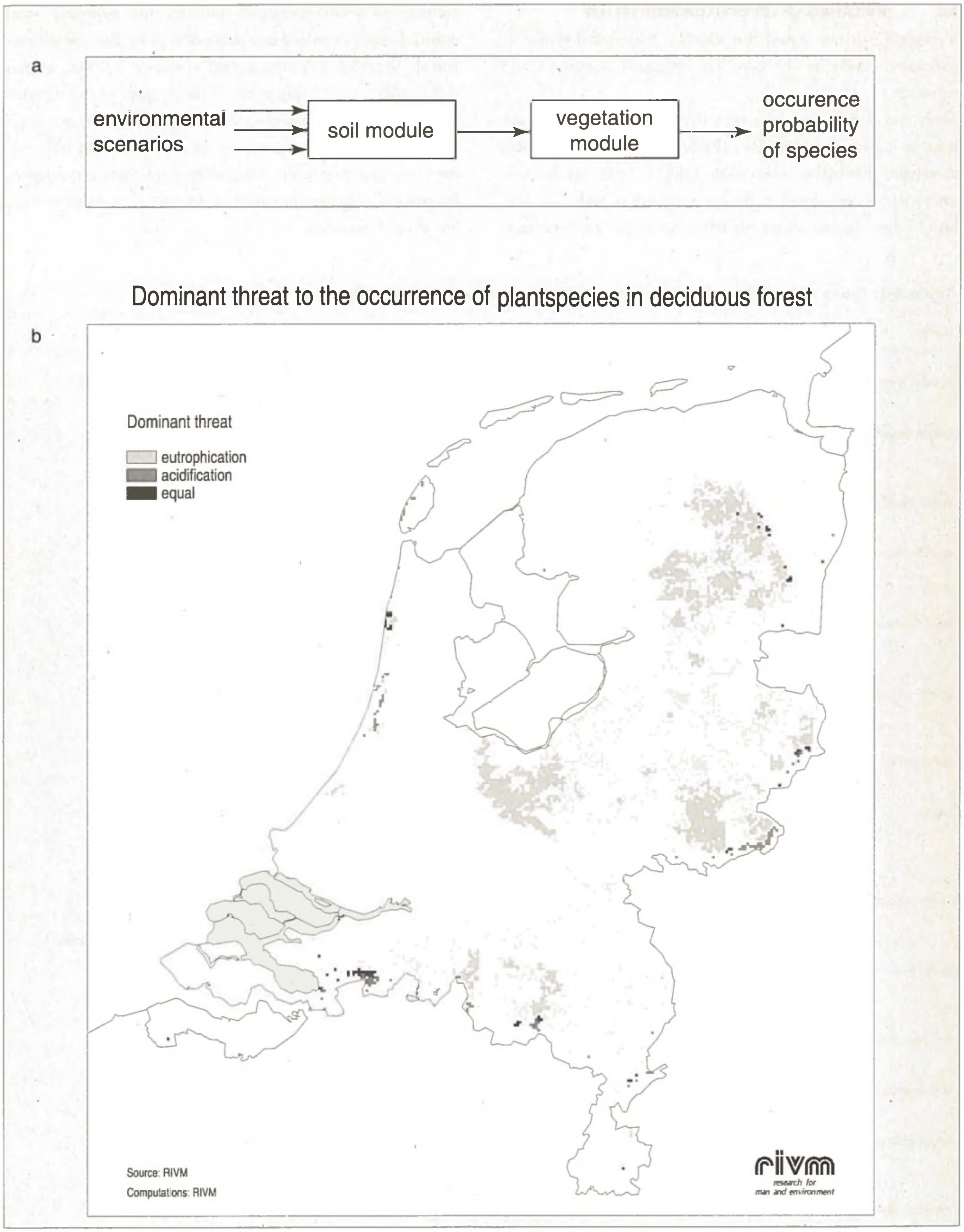


Figure 5-4: Multiple-stress modelling with the MOVE-model
a) simple model structure
b) application for two stress factors in the Netherlands

5.4 TOWARDS REFERENCE VALUES

SUITABILITY OF EXISTING REFERENCE VALUES

In section 3.4 criteria have been formulated for the selection or development of reference values to accompany the indicators. Weterings and Smeets (1994) have compared a sample of existing reference values with these criteria, including the requirement of compatibility with the PSIR approach. They conclude that reference values exist or have been proposed for many environmental themes at the national and sometimes international level. Mostly, these values apply to environmental pressure, notably as emissions targets.

None of the sampled existing reference values meets the criterion that reference values for various environmental issues should ideally be based on an integrative and comprehensive notion of the environmental system. One should bear in mind that formulating separate reference levels for separate environmental issues implies neglecting the interrelations between issues. Since the environmental system is a dynamic system characterized by interdependencies between the subsystems and processes it consists of, neglecting these interrelations may well result in shifting rather than reducing environmental problems. Although some steps towards truly integrated reference values have been taken (Opschoor and Van der Ploeg, 1990; Rees, 1992; Annema et al., 1993; Rotmans et al., 1994), the reference values established - as well as the associated indicators - still remain mainly issue-oriented (see also Box 5-1).

PRAGMATIC POSSIBILITIES

No ready, coherent set of reference values exists. However, it is important to realize that there is an important element of iteration in the development of reference values in policy-oriented reporting. If it is acknowledged that reference values based on an integrative notion of the environment is what is eventually needed, then reference values could be `borrowed' from other contexts in order to prime the reporting and assessment process in a pragmatic way. The text following table 3-1 in section 3.4 gives a broad categorization of possibilities. Obviously, such a pragmatic start would mean that first assessments would use an inconsistent and unconnected set of reference values based on quite different considerations. However, we do believe that even this, when applied throughout the assessment, in addition to the conceptual framework and the model-based linkages, would add considerably to its significance.

Some examples of reference values

Figure 5-5 illustrates an example of the exceedance of critical loads of acidification in Europe calculated by the RAINS-model (figure 5-4). In this RIVM study (Hettelingh , et al, 1992) we can clearly see how deposition levels beyond the critical loads are damaging to ecosystems across Europe.

Figure 5-6 illustrates the use of historical population levels for different indicator species as reference values in a so-called AMOEBA-representation. (Example from RIVM, 1992; see Ten Brink et

Box 5-1: Determining the "Environmental Space" as a basis for reference values

Environmental space (Opschoor, 1987, 1989; Opschoor and Van der Ploeg, 1990; Weterings and Opschoor, 1992, 1994) is a notion that stems from a family of concepts such as: carrying capacity, ecocapacity and ecoscope. These concepts all express the idea that at any given point in time there are limits to the amount of environmental pressure the earth's ecosystems can take without irreversible damage to the systems or the life support processes that they sustain. The notion of environmental space focuses on the environmental functions provided by the biosphere to human society, necessary to sustain economic activities. It covers:

-stocks: the natural renewable and non-renewable resources available to human society, including the capacities to regenerate these resources;
-sinks: the finite capacities to absorb pollution and wastes and to buffer encroachment.

At the metaphoric level, the notion of environmental space seems clear. The initial suggestion it prompts may be to search for the critical levels of environmental pressure beyond which actual environmental systems might become damaged irreversibly and to regard these levels as being the operational boundaries of the environmental space. In practice, however, it soon appears that there is a series of reasons why a purely scientific approach for identifying the boundaries of the environmental space is impossible. In order to arrive at an operational set of boundary conditions, choices of a non- or pre-scientific nature have to be made. Some of these choices have to do with the limited capacity to predict impacts, other choices have to do with the definition of sustainability and with the basic values on the rights of access to (and use of) environmental resources of present and future generations.

One important feature of (the notion of) environmental space is that its magnitude is considered to be dependent on a range of interdependent and time-dependant variables both in the natural and in the societal domain. Consequently, the (notion of) environmental space is not static, nor does it 'freeze' its underlying variables at unique levels (Opschoor and Van der Ploeg, 1990). This also implies that there may be several ways of realizing or maintaining a given volume of environmental space, with improvement in terms of some conditions or variables compensating deteriorations elsewhere or in terms of other variables. In other words: there can be trade-offs. Trade-offs between environmental issues, as well as trade-offs between specific regional parts of the (global) environmental space.

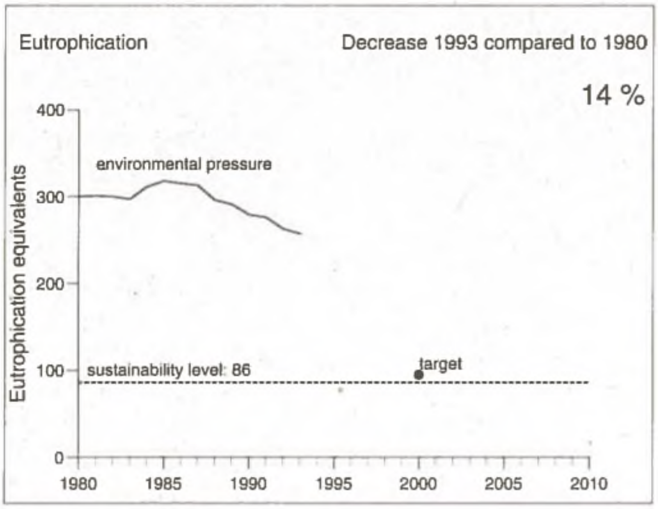


Figure 5-7: Eutrophication in the Netherlands (RIVM, 1993): Example of a policy performance indicator; reference value is derived from policy objective

al. 1991 for methodology.) If the hatched circle segments go outside the reference circle, the species population has increased. In addition, the desired population levels of the indicator species may be shown in the AMOEBA, acknowledging the fact that the desired situation may be different from the historical reference and that for some of the species an increase may not be the desired development.

Figure 5-7 illustrates the application of environmental policy performance indicators in the Netherlands for the problem of eutrophication. Eutrophication equivalents are calculated by a weighted addition of nitrogen and phosphorus loads. The reference value shown is the official policy objective.

These are examples of purpose-designed indicators with associated reference values. They represent indicators for one environmental theme and one element of the causality chain. As such, they show neither interactions with other elements of the causality chain, nor time delays.

CHAPTER 6

THE HUMAN SYSTEM

We saw in part I how the human system can be split into an "economy subsystem" and a "social subsystem" (figure 2-1). In section 6.1 we discuss some of the many perspectives on how the economy system works or ought to work. No attempt has been made to elaborate on any particular approach. In view of the focus of this report, we have tried to maintain an environmental view on economic modelling. Although economics is somewhat outside the scope of the report, it has strong linkages to the environment.
Section 6.2 deals with the social subsystem, in this case limited to a population subsystem. It focuses on a structured approach to two interrelated components of the population subsystem: public health and demographics. Future elaboration and extensions to the population subsystem should also capture elements of the social subsystem other than demography and health, such as social, institutional and cultural issues.

6.1 THE ECONOMIC SUBSYSTEM

INTRODUCTION

One of the key elements in the environmental management cycle is the degree to which economic forces affecting environmental changes can be influenced. Basic data and models for the economic subsystem are developed by such institutions as the World Bank and by regional or national research and policy institutes. These data and tools can be used in the proposed framework to analyze potential future developments, the dynamic interactions between the different subsystems and the options available to mitigate environmental degradation.

In this chapter we first briefly describe the connection between economic development and the use and availability of natural resources. Since our focus is on natural resources, the economic system (e.g. consumption and services, government, capital and labour markets) is only dealt with in so far as it generates the demand and the means for resource exploitation. Second, we present a brief overview of interpretative models. Finally, we discuss indicators of the functioning of the economic system in relation to resource use. The ideas and proposals are derived from RIVM's integrated modelling frameworks (Rotmans et al., 1994; de Vries et al., 1993).

THE ISSUE: ECONOMIC DEVELOPMENT AND NATURAL RESOURCES

The increasing pressure on the regional and global environment is caused not only by the growing population, but also by the ever larger throughput of materials associated with the life-styles of more affluent regions. These larger throughputs are directly associated with increasing human welfare, in the form of dwellings, cars, consumer electronics, roads, schools, hospitals etc. It has also become evident that they cause various undesirable side-effects among which is environmental degradation. Such externalities, as they are called in the economic literature, tend to offset part of the gains in welfare, although both welfare and the perceived loss of welfare through environmental degradation are difficult or even impossible to quantify in unambiguous and noncontroversial terms.

Where parts of the population are marginalized by prevailing social and economic allocations and distribution mechanisms, they may - on perfectly 'rational' grounds - resort to forms of resource exploitation which are unsustainable. Thus, poverty and destitution, it can be argued, lead inexorably to environmental degradation. Thus, it is unavoidable that equity aspects will need to be included in an integrated and dynamic global environmental reporting system.

Trend towards increasing resource productivity

The productivity of resource use has significantly increased over the last decades and centuries, partly in response to rising prices and partly in response to strategic and environmental considerations, but largely due to technological changes. In most nations, over the last 15 years, the amount of energy and minerals required per unit of production has been declining continuously. An exception has been in the use of electricity. Its share in total final energy demand has been rising. This is due to its high exergetic quality and versatility[1]. Another exception are those regions that are in the first stage of industrialization and therefore have experienced a rapid expansion of resource-intensive industrial activity, to some extent as part of a larger restructuring of global industry.

[1] The exergy content is a measure of the ability of energy to deliver power. For low-temperature heat it is about 0.06; for electricity it is 1.0.

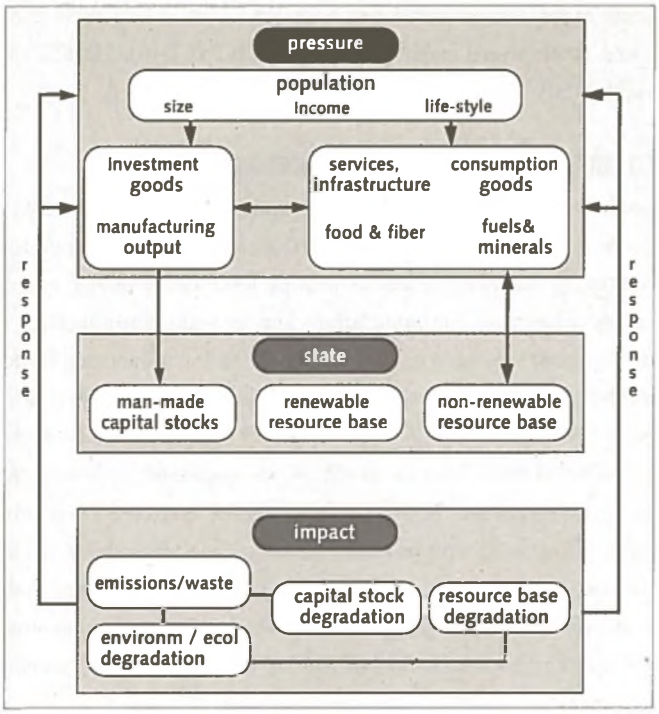


Figure 6-1: Representation of the economic subsystem in the PSIR framework

quences is that modelling such systems at the aggregated world level has quite limited relevance in most areas. Another consequence is that there are no unanimously accepted models to describe these systems.[2]

A representation of the economic-resource system in TARGETS/GESPE is given in figure 6-1. It is an attempt to capture the workings of the economic system by the pressure-state-response cycle, in spite of the inherent difficulties. With population and its various characteristics as the main driving force, economic output is partly used for consumption and partly used to maintain and expand industrial production. *Pressure* can be indicated by investments. No generally accepted rules can be established for the allocation mechanisms, although cultural, political and strategic considerations play an important and often unique role. Within the Targets/GESPE-framework the allocation decisions are made part of interactive simulation c.q. policy exercise. The main *state* variables within this submodel are the man-made capital stocks and the natural capital stocks (renewable and non-renewable resources). To run the economic system, these resources have to be exploited - showing up as flows of food, fibre, fuels and minerals. The effects and *impacts* of sustaining these resource flows can be represented by changes in productivity (e.g. GDP-loss), on welfare or on the quality and productivity of the man-made and natural capital stocks on which the system runs. Finally, autonomous or policy driven changes in investments patterns such as economic instruments, can be regarded as *responses*.

[2] In the TARGETS/GESPE-project, RIVM is trying to cope with this by using explicit actor descriptions based on observations and insights within the region. These projects also aim to embed the simulation models in a learning environment that supports communication about how people are perceiving issues and thus help generate alternative strategies ("policy exercises").(Morecroft and Sterman, 1992).

While international academic discourse about the different schools of thought has been lively for decades, such debate remains largely absent in policy circles. In fact, the recent initiative of the Intergovernmental Panel on Climate Change (IPCC) on the economic implications of climate change strategies (one of the "crosscutting issues" of the newly established Working Group III) is one of the first world-wide policy-oriented assessments. It covers the advantages and disadvantages, possibilities and limitations, and associated specific roles of different types of economic models in support of major policy decisions on the world's economic system.

The role economic models can play in integrated environmental assessment reporting is clearly an important question. Ideally, a fully integrated assessment across the environmental management cycle and across different components of the human and environmental systems would fully acknowledge the role of economic factors. However, the wide variety of views on the role of economics and the choice of methods continue to impede consensus on such an approach. Consequently, for integrated environmental assessment reporting, the emphasis may lie initially on the assessment and forecasting of environmental changes, taking available scenarios of socio-economic driving forces as input. Scenarios by international organizations, such as the World Bank or IPCC could be taken as a starting-point. However, regional expectations and ambitions should eventually be better reflected. At the same time, a debate could be started on how to deepen and broaden the integration of economic factors in integrated environmental assessment reporting. As mentioned above, such a discussion has already been started in the area of climate change; in the preparation of the second assessment report of the third Working Group of IPCC on crosscutting issues, and in the debate about ways of evaluating the effectiveness of policies, as required by the Framework Convention on Climate Change. The costs and economic implications of different response strategies can be estimated, using a variety of methodologies. In integrated environmental assessment reporting this variety of views on costs of environmental strategies may be reflected.

ECONOMIC AND RESOURCE INDICATORS

Over the past decades, a plethora of economic indicators based on

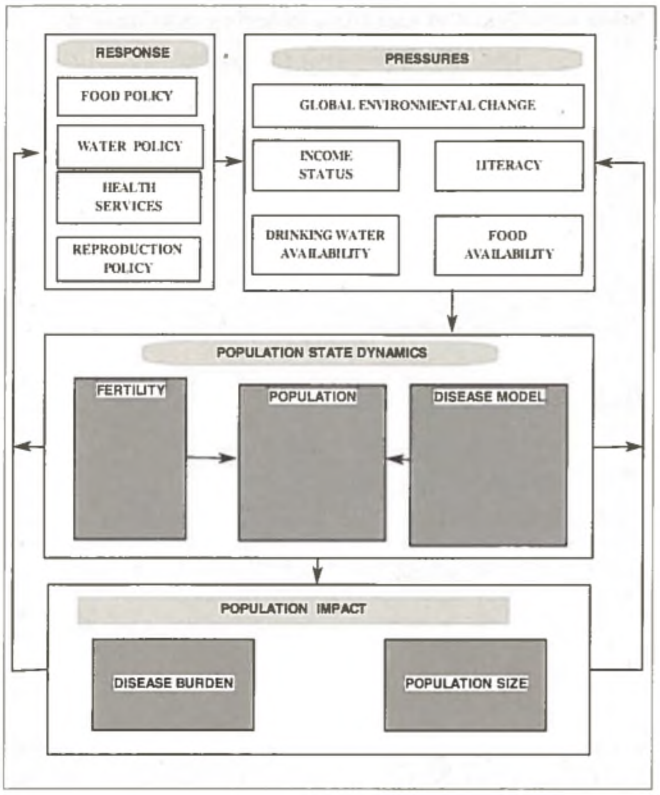


Figure 6-2: The integrated population health simulation model in TARGETS

of competition of diseases and substitution of one disease by another) dynamics taking place within the population. Once validated against historical time series and made internally consistent the modelled dynamics can serve early warning purposes by indicating potential environment-related health problems before they are actually revealed.

The proposed modelling methodology builds upon previously developed models aiming at an integrated health assessment (Niessen and Rotmans, 1993). The overall structure is based on existing international theory (Murray and Chen, 1993 for an overview). It incorporates a dynamic approach to the building up within populations of health assets, such as food supply, health services and health knowledge. It also includes the effectiveness of (public) health services and the delays of exposure and health service effects (De Vries et al., 1993). The disease modelling is based on Anderson and May's model (1993) for infectious disease and on Niessen's (1993) and Bonneux's (1994) for chronic diseases. This kind of disease modelling has so far been primarily applied to national level health problems. This is the first time that these models are being used on a global and regional scale, although some related simplified modelling has been used for static global calculations (World Bank, 1993). Calibration and validation of the model will be based on global and regional population time series as well as time series of total and disease-specific mortality rates (WHO, 1994 and World Bank, 1993).

Figure 6-2 shows a diagram of the components of an interpretative model of the health subsystem as well as illustrating how population and health issues are structured. The integrated modelling approach aggregates the data on the forces driving health as well as those regarding health impacts (i.e. morbidity and mortality levels) also for data on population and health related issues,. At the same time it identifies the gaps in the national and international information systems. The interpretative mathematical model identifies the specific contributions of social, economic and environmental changes to the loss of potential (healthy) life years.

Like the environment, the population health area can also be described according to the pressure (health determinants) - state (population and fertility dynamics) - impacts (morbidity and mortality) - response (public health and socio-economic policies) framework (see figure 4-1). Inputs from other sectors (water, food production, economy and global environmental change) act on the population.

In the TARGETS model, the population projections generated by the population module form the major feedback loop to the other modules; in this way the dynamics of the interplay between population, the environment and development can be described[4]. The integrated disease-specific approach chosen in this model accounts for the simultaneous occurrence of multiple health risks and diseases (Niessen and Rotmans, 1993). This corrects for the major shortcoming in the non-integrated, single-disease approaches used so far (eg. World Bank 1993). Changes in the occurrence of one health risk might affect the occurrence of various other health risks (diseases) at the same time, e.g. through food supply.

Furthermore, changes in one health risk might be nullified by the presence of high risks from other causes like the common childhood diseases in developing countries. This methodological approach is currently being developed further by RIVM in consultation with the Population, Health and Nutrition Department of the World Bank (Niessen, 1995 (in press)).

Pressure

The pressure part consists of a socio-economic force determining

[4] Indirectly, potential global climate change might influence health levels by affecting harvests (Parry, 1994). In some areas the result may be increased desertification and deterioration in crop quality and in other areas there may be a beneficial increase in food production. The global balance of these effects and their consequences on food availability is still unclear.

ted level. These are based on the various stocks and flows of the model. Routine pressure and impact statistics in relation to the health transition level of the population and the level and nature of the epidemiological transition are collected from routine data registries. Presented in time series, these are to be used for historical validation. At the second level, indices can be defined for the four individual PSIR-components as a whole. Most of these indices are already being used in international reporting. At the highest aggregated level an overall population health index can be defined comparable to the UNDP human development index (UNDP, 1993).

Pressure

Risk levels for the population level are expressed in terms of people exposed. Danger thresholds have been defined based on research results usually found in experimental settings. Using the relative risk associated with a particular exposure, one can calculate the population-attributive risk which indicates the proportion of disease incidence that is explained by the level of exposure. At the pressure level, an overall "health risk" index is proposed which adds up the risks related to all determinant categories while weighting for their contribution to the incidence of diseases. The use of a discount rate is possible to correct for the moment in time when disease incidence occurs. No weighting takes place for the age at which disease incidence occurs. Because of the delays involved, this pressure index will provide an early warning signal for potential future health changes.

State

Two state indices are proposed: one related to fertility and one related to population structure. The fertility index expresses the percentage of children born that have been planned: the "planned births ratio". This ratio depends on actual effective contraceptive use and desired family size. There are quite a number of related empirical data sources available from censuses, demographic surveys and family planning programmes. This fertility index demonstrates the potential for fertility change and, hence, the momentum of population growth.

The second proposed index is the dependence ratio. This describes the number of dependents within a population, i.e. those under 15 and those above 65 years of age, as a proportion of the whole population. As this index indicates, the position of the involved population within the demographic transition it will therefore describe the proximity of the population to a possible steady state.

Impacts

Health status assessment at the population level implies a quality-of-life measure. This is expressed in the health expectancy measure. Up until now, a population's health has been measured by its overall life expectancy, stressing the gains in mortality reduction and, hence, gain in absolute life years. Recently (World Bank, 1993), composite quality measures, including those life years spent with disease, have been made operational, making use of internationally available health statistics. Weighting the total years lived for the time spent with and without disease leads to a measure of disability-adjusted-life-years per 1000 persons (the *daly* measure). In calculating this measure the severity of the disease is weighted according to a disability scale that consists of six categories. In this way, time lived with a disability is made comparable with the time lost due to premature mortality. The value of time lived at different ages is captured using an exponential function reflecting the dependence of the young and the elderly on adults. A 3% discount rate is used in the calculation of total lost life years.

Table 6-2: Types of disease categories including co-morbidity categories and dependencies

Examples of single diseases

1. Gastro-enteritis
2. Acute respiratory infections
   and chronic obstructive pulmonary disease (COPD)
3. Malaria
4. Lung cancer
5. Cardio-vascular diseases

Examples of co-existing diseases

6. Cardio-vascular diseases and lung cancer
7. Cardio-vascular diseases and COPD
8. COPD and lung cancer

In most areas of the world, the empirical data are still insufficient to monitor trends in this index based on disability-adjusted-life-years. However, efforts are being made to do this through the central offices for population statistics. The available data on *dalies* are based, again, on modelling i.e. life-table extrapolations and a Delphi-like method (World Bank, 1993).

Response

Customary indicators for this component are the percentages of the available budgets that have been allocated for particular social or health policy areas. Other lower level indicators in relation to social and health regulations are also used (e.g. level of educational requirements). Budgets can be summarized at an aggregated level.

APPENDIX 1

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APPENDIX 2

THE ENVIRONMENT IN EUROPE: INTEGRATED ASSESSMENT MODELLING AT THE REGIONAL LEVEL

As an illustration of the integrative approach presented in this report, the results of integrated assessment modelling at the European level are summarized in this appendix. Scenarios were developed within the framework of the preparation of the European Community's 5th Action Programme on the Environment. Results were partly presented in the report "The Environment in Europe: a Global Perspective" (RIVM,1992). The example is elaborated here, because it is one of the few attempts to arrive at a model-based integrated assessment of a number of environmental problems at a multi-nation level. The assessment is partly integrated through common scenarios for driving forces and a comprehensive treatment of the causal chain.

INTRODUCTION

The study addresses a number of environmental problems in Western and Eastern Europe, that may result from socioeconomic developments at the global, continental and regional level. Through Integrated Assessment Modelling the (potential) global environmental problems related to various trends in energy use, CO_2-emissions and the use of CFC's are described, as well as continental environmental problems due to transboundary air pollution (tropospheric ozone, winter smog, radioactivity and acidification). In addition regional scale problems like soil and groundwater pollution (due to nutrients, pesticides and land fills), erosion, pollution of European rivers and seas and air pollution in cities are addressed. Using RIVM's air transportation models, the effects of emission scenarios on concentrations and depositions were calculated and compared with human health risk standards (WHO) and critical loads for ecosystems.

Although the study presents an integrated analysis of a broad range of environmental problems, this summary necessarily concentrates on two environmental problems: climate change and acidification.

ENVIRONMENTAL PRESSURES

Future implications of environmental policies are described for two contrasting policy scenarios:

* GLOBE I in which current trends in development and environmental policies continue, and which is consistent with the convential wisdom scenario of the EC, the Overall Economic Projections of UN-ECE and the business-as-usual scenarios of the IPCC;
* GLOBE II in which full implementation of best available technologies and policy options in both Western and Eastern Europe is assumed and which is consistent with the accelerated policy scenario of the IPCC.

Table A presents scenario data in GLOBE I and GLOBE II for Western Europe (WE) and Eastern Europe (EE).

The following trends in environmental pressures (emissions) are related to these socioeconomic trends:

Climate change:
Global trends in CO_2-emissions due to fossil fuel combustion for GLOBE I, GLOBE II are presented in figure A. In order to illustrate the effect of any European climate policy three additional scenario's have been considered in which the energy related emissions produced by Europe have been varied. European CO_2-emissions for GLOBE I and GLOBE II and one additional scenario (the implementation of EC Carbon tax) are presented in figure B.

Acidification:
In the GLOBE I scenario emissions of acidifying components decrease in 2010 with respect to 1990 by about 30% (SO_2) and 20% (NO_x); ammonia (NH_3, NH_x) emissions in GLOBE I are expected to increase by about 5% between 1990 and 2010.
In the GLOBE II scenario the extra reductions of SO_2 and NO_x emissions will result in overall decreases in 2010 with respect to 1990 by about 80% (SO_2) and 60% (NO_x); ammonia emissions are expected to decrease by about 40%.

ENVIRONMENTAL STATES AND IMPACTS

Prognoses of the changes in environmental state (atmospheric concentrations, depositions) and of the environmental impacts (temperature rise, ecosystem stress, critical loads) related to these trends in emissions have been obtained through computer models.

Climate change:
By means of RIVM's Integrated Model to Assess the Greenhouse Effect (IMAGE) the CO_2-equivalent concentrations and corre-

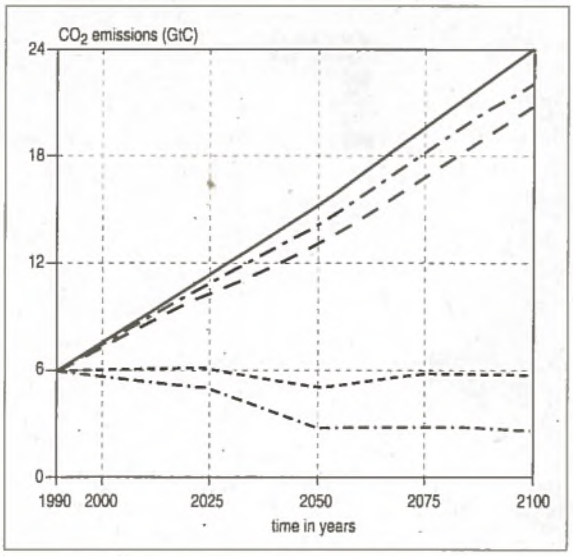

Figure A:
Global CO_2 emissions due to fossil fuel combustion; for GLOBE I, II and three scenario variants

Globe I scenario
EC Ecotax scenario
Europe Globe II scenario + Rest of World Escape Globe I scenario
Europe Escape Globe I scenario + Rest of World Globe II scenario
Globe II scenario

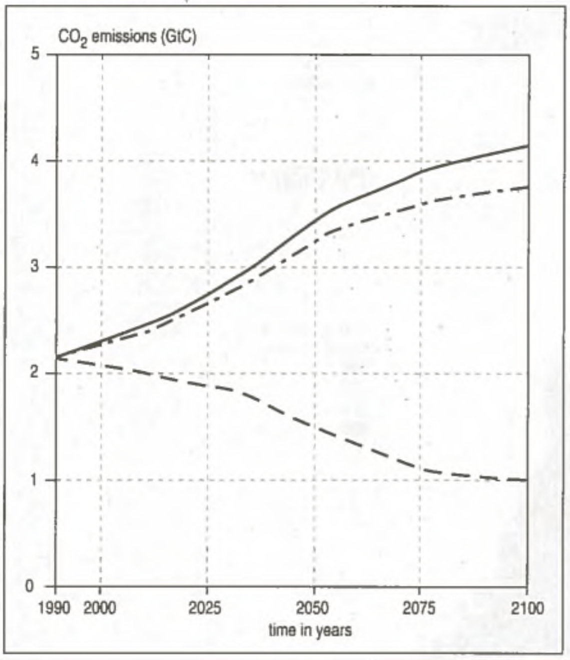

Figure B:
European CO_2 emissions due to fossil fuel combustion; for GLOBE I, II scenarios

Europe Globe I scenario
Europe Ecotax scenario
Europe Globe II scenario

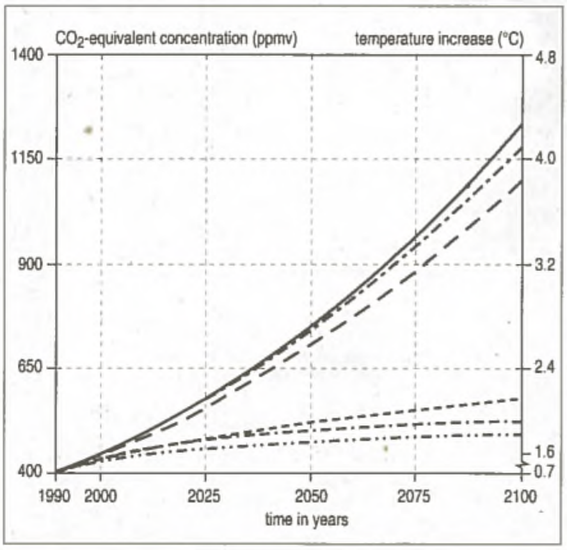

Figure C:
CO_2 equivalent concentrations and corresponding temperature increases for GLOBE I and II senarios and variants

Globe I scenario
EC Ecotax scenario
Europe Globe II scenario + Rest of World Escape Globe I scenario
Europe Escape Globe I scenario + Rest of World Globe II scenario
Globe II scenario
Toronto scenario

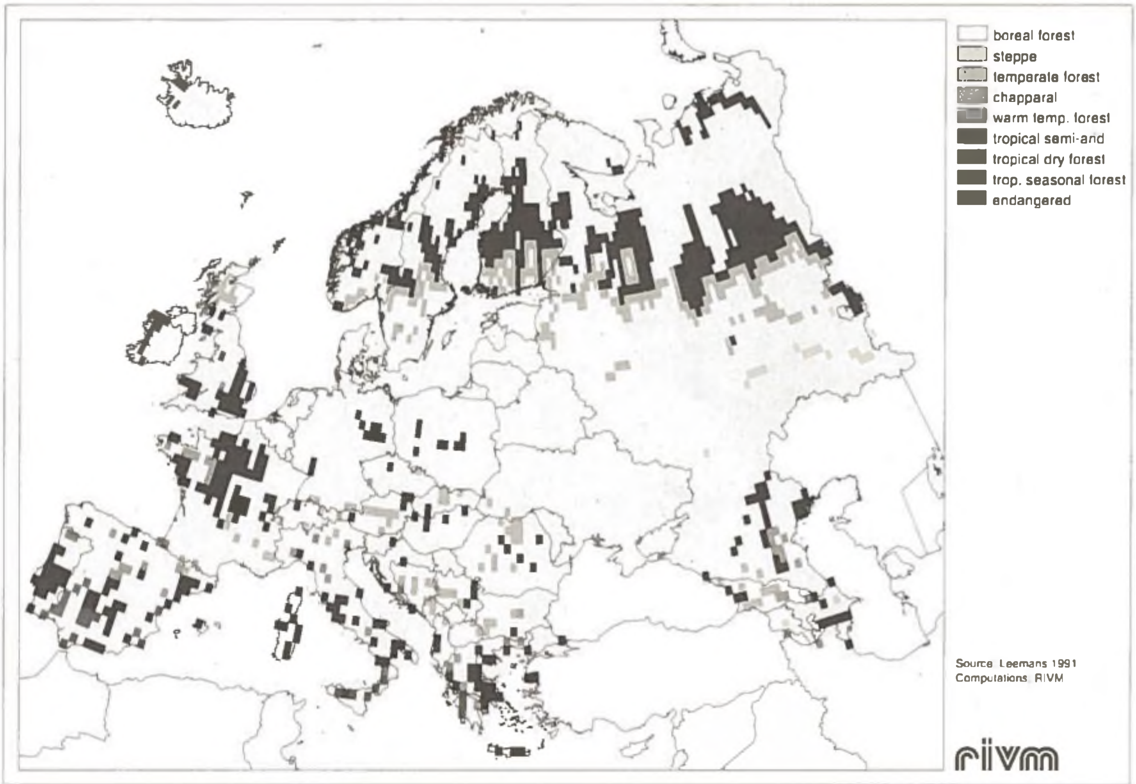

Figure E: Areas in Europe wich will become endangered under a doubling of CO_2, because there is no similar vegetation type available in the surrounding 5080 km

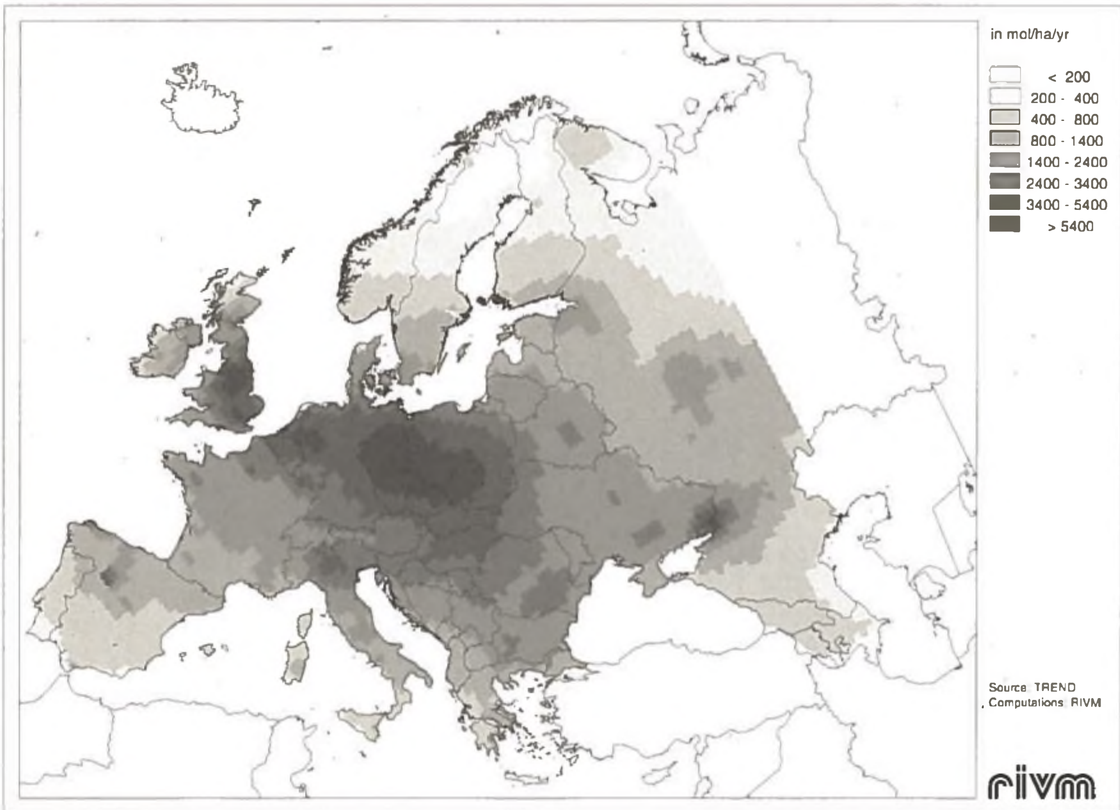

Figure F: Total loads of acidifying compounds in Europe in 1990

Figure H: Exceedances of critical loads of acidifying compounds in Europe, GLOBE I scenario, 2010

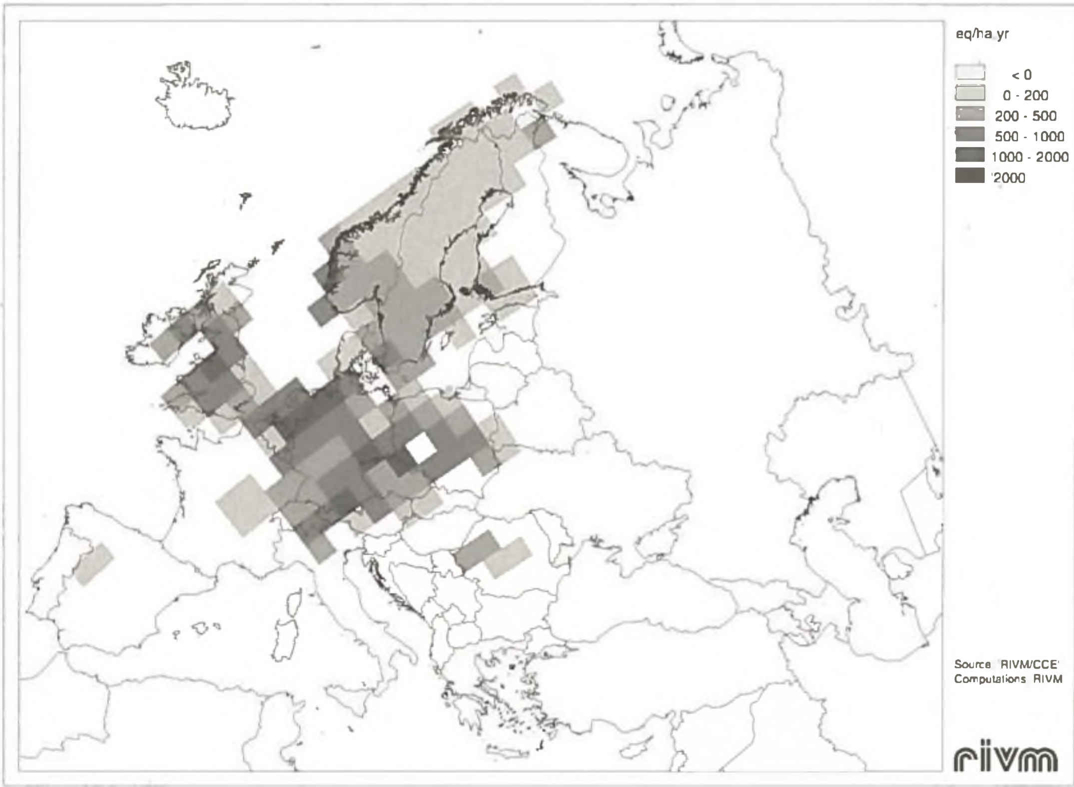

Figure I: Exceedances of critical loads of acidifying compounds in Europe, GLOBE II scenario, 2010

SUMMARY

In summary, in the "The Environment in Europe: a Global Perspective" a first attempt is made to develop an integrated assessment of the past, current and future state of the environment of a continent in the context of global developments. Coordination across the PSIR environmental management cycle was achieved through the application of thematic integrated models, with the emphasis on the environmental system (state of the environment and impacts). Integration across different environmental issues was achieved through the application of the same consistent scenarios for all themes. As such, the study is an improvement over a combination of independent, partial assessments of the national environments. Nevertheless, the study does not yet comply with all the requirements of a fully integrated assessment. The policy-relevancy of the report would have been still greater, if it would have been developed in a broader international network of European experts and institutions. Technically, limited knowledge prevented a full appreciation of interactions between different environmental changes, such as multi-stress impacts. Also, the analysis of the relationship with socio-economic development in general was limited. Nevertheless, we believe that the study provides an excellent example of the feasibility of an integrated environmental assessment at the international level.