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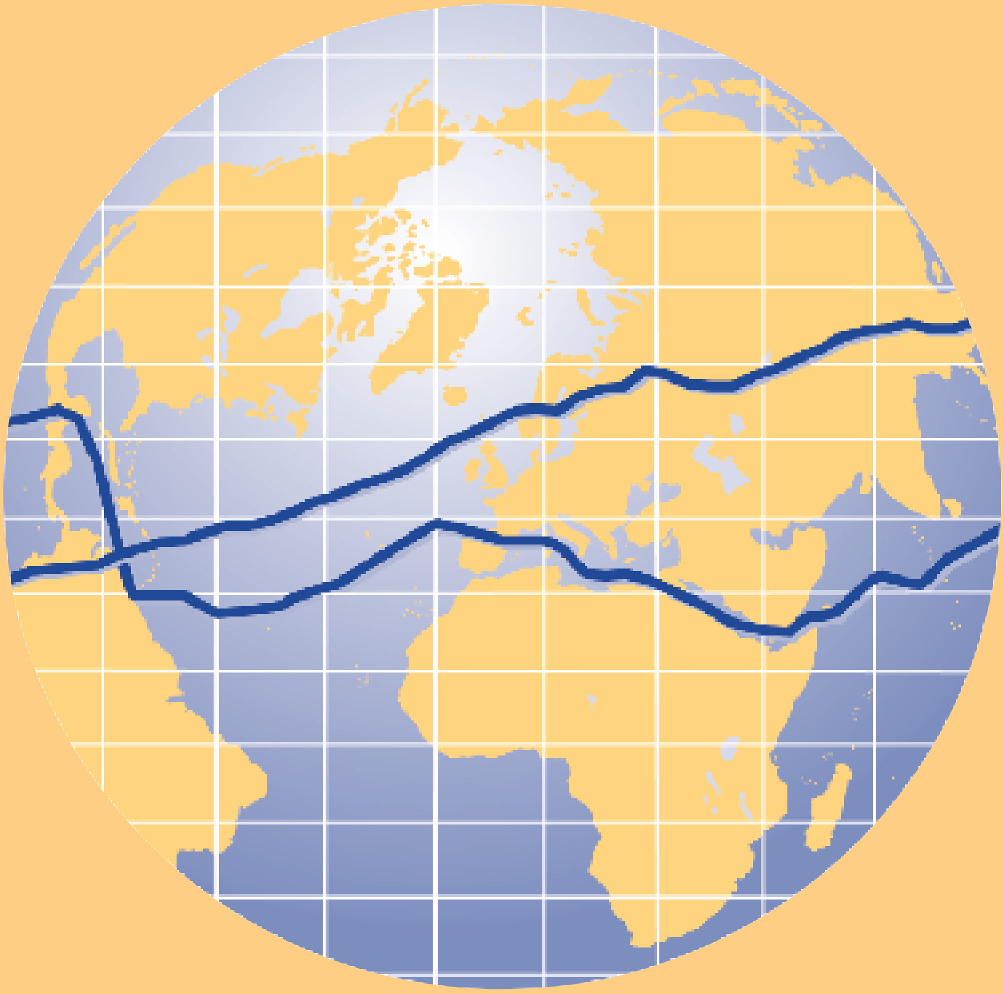
Data Issues of Global Environmental Reporting: Experiences from GEO-2000



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Data issues of global environmental reporting: Experiences from GEO-2000

Jaap van Woerden (ed)

December 1999

with contributions by:
Ruben Mnatskanian, Central European Uyniversity (CEU)
Nickolai Dronin, Moscow State University (MSU)
Choudhury Rudra Charan Mohanty, United Nations Environment Programme (UNEP-EAP-AP)
Ron Witt, United Nations Environment Programme (UNEP/DEIA&EW/GRID-Geneva)
Lászlo Pintér, International Institute for Sustainable Development (IISD)
Fred Langeweg, Jan Bakkes, Guus Velders, Lex Bouwman, Rik Leemans, Ton Bresser, Johannes Bollen, Henk Hilderink, all with the National Institute of Public Health and the Environment (RIVM)

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Division of Environmental Information, Assessment and Early Warning (DEIA&EW)
United Nations Environment Programme (UNEP)
P.O. Box 30552, Nairobi, Kenya
E-mail: Marion.Cheatle@unep.org
Tel: +254 2 623520 (direct)
Fax: +254 2 623944
http://www.unep.org/geo2000.

National Institute of Public Health and the Environment (RIVM)
P.O. Box 1, 3720 BA Bilthoven, The Netherlands
E-mail: Jaap.van.Woerden@rivm.nl
Tel: +31 30 2743346 (direct)
Fax: +31 30 2744427 (direct)
http://www.rivm.nl/env/int/geo

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Foreword

Conceived at the GEO-2 Data Meeting (Budapest, September 1998) and following the request by UNEP for an 'information-architecture' at the Second GEO-2 Drafting Meeting (Brasilia, February 1998), this report summarizes the experiences with core data work for integrated environment assessment at the global level, as derived mainly from the GEO assessments. Lessons from these experiences are put into a wider perspective on data-to-information processes for assessment by means of a pilot analysis of data demand, supply and constraints for several global environmental issues. This has resulted in recommendations to UNEP for improving current data logistics and accommodating critical gaps, in particular for future GEOs. As such, this report does not list or account for in detail all the data and results of the GEO-2000 assessment. The institutional and political data aspects are only touched upon, recognizing that these deserve more attention in future work. Nor does this report address information needed for the development or impacts of possible global scenarios. However, it does try to identify the main data issues involved in practical integrated environment assessment work in an attempt to lay first foundations for a robust and long-term information infrastructure.

This report is printed in black and white, while a coloured version will be available on the internet, via the RIVM website at http://www.rivm.nl/env/int/geo, linked also to UNEP's GEO-2000 web version at http://www.unep.org/geo2000.

Special acknowledgements go to Veerle Vandeweerd and Miriam Schomaker (both formerly with UNEP/DEIA), and all members of the IEA/GEO Data Working Group and the smaller GEO-2000 Data Group.

Marion Cheatle, Nairobi
Jaap van Woerden, Bilthoven

December 1999

Summary

Environmental assessment needs to focus on priority issues, reflecting the policy agenda of priority issues as much as possible. Reliable quantitative assessments can be done only if there is routine collection of data of adequate quality through monitoring systems and surveys. Such ‘core data sets’ need to be further processed to derive policy-relevant, aggregated indicators for major environmental issues. These, in turn, are used for interpretation and final reporting to policy makers, and by them for decision-making.

Although global, harmonized core data sets are improving, expanding and more easily accessible, numerous inconsistencies and shortcomings still exist. Even the straightforward mapping of basic indicators such as current GDP, water consumption and fertilizer use proves difficult. In particular, to date, little information is available for assessment of environmental impacts on human health and natural ecosystems, and of societal responses to and effectiveness of environmental policy actions.

Generic data needs and cross-cutting data issues have been derived from recent global assessment experiences related to the GEO project. These are illustrated with information analyses of a number of environmental issues such as ozone depletion and acidification. Upcoming issues of emission trade and sustainability have been briefly addressed here and information gaps in the causes, impacts, responses and their interlinkages indicated. To enable policy-relevant assessment, it is necessary to fill in the picture on data and information needs and, subsequently, to cooperate in the realization of global observation and survey programmes. Because basic data are often common to many other assessments, UN-wide coordination could and should be(come) more efficient and foster harmonization. An immediate start could be made with the compilation and distribution of ‘no-regret’ indicators and underlying core data sets i.e. those for which it is very obvious that they are needed now and in the future.

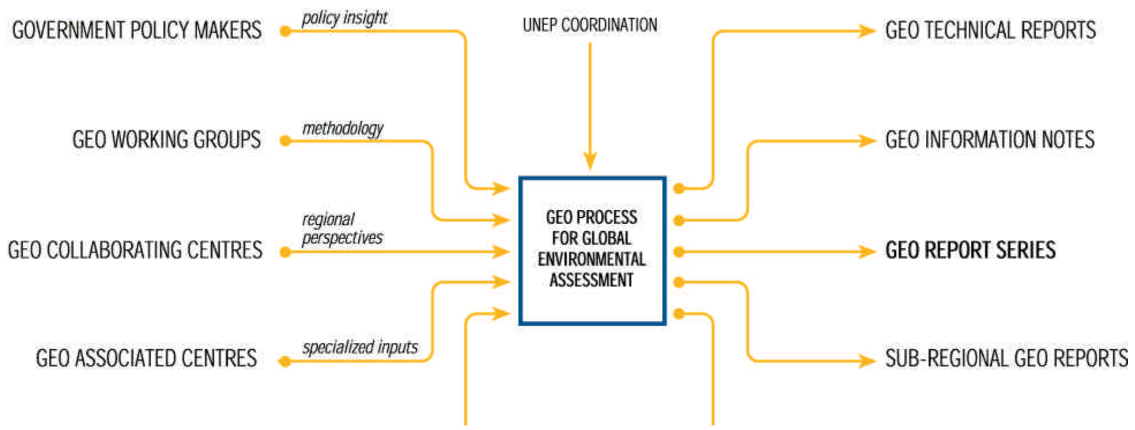
Introduction

The overriding goal of assessment is to link science and policy by providing relevant and easy-to-understand information based on sound scientific knowledge and observations. In principle, existing or emerging environmental problems are assessed by looking at their magnitude, as well as the causes in society and effects on humans and nature. Targets are then set, and instruments formulated and implemented to alleviate the problem at hand. In practice, this iterative process is highly complicated, often irrational and, on the global scale, rather loose. Several assessment structures, such as the DPSIR framework, have been developed to give at least some guidance on and insight into information analysis, data needs and interlinkages (see Figure 1.2). Starting with the broad definition of issues to-be-assessed (e.g. climate change), information and data requirements can be derived, eventually down to the level of time series for country energy use, meteorological station data, subnational population growth, regional trade statistics, gridded land cover patterns etc.

Core data sets thus form the basis for reporting programmes such as GEO. On the basis of huge volumes of country statistics, station measurements, satellite imagery and other sources, information is derived on current state and trends in environmental issues such as climate change, soil degradation and urban pollution. The complex conversion, integration and moulding of 'raw' data into meaningful information shows considerable shortcomings and uncertainties, while there is still little feedback and validation during this process among collectors, collators, analysts, disseminators and end-users. With recent calls to focus not just on environment, but take a holistic approach in terms of sustainability or human security, the need for data becomes even more challenging.

The data-to-information process cannot and should not only support consistent reviews of the global environment throughout the years but also enable timely evaluations of different policy options for the future. For GEO, this process is being undertaken by a wide variety of organizations around the world, connected through the GEO-related networks of Collaborating Centres and Working Groups. Box 1 shows the overall GEO project organization and outputs. The development of the necessary alternative scenarios and underlying models is deliberated in separate GEO background reports. This report concentrates on the data issues involved in environmental assessment and reporting. As such, focus is on current and historic data needed to analyze and interpret environmental trends, derive causes and effects and to formulate policy advice. Such data can also be used to look into both the long-term future through systematic modelling and to feed Early Warning systems for short-term potential threats. For example, on the one hand, the impact in the next century of different pathways for economic and population growth on global climate, deforestation and water availability can be shown, while on the other hand, the analysis of current trends may point to anomalies and potential short-term threats.

Box 1. GEO project organization and outputs



The GEO assessments confirm that the empirical base is still fairly weak, and that it is already quite difficult to derive useful information on the current and past state-of-the-environment, let alone to make sound projections for the (near) future. At the same time, the participatory approach shows that huge amounts of local, regional and global data are available and can be to mobilized with an adequate infrastructure. As a first step, the demand and supply of core data for broad integrated assessments need to be further and fully clarified. The gaps identified then need to be addressed and demand and supply better cross-matched in cooperation with core data providers

and observation initiatives. Subsequently, the data sets need to be collated, tailored and made available to the partners for integrated environment assessment (IEA), most notably in the realm of UNEP's Global Environmental Outlook. Clearly, from the assessment point of view, this represents 'only' the first step in the information process.
The four critical questions on data for IEA/GEO assessment and reporting can thus be identified as follows:

1. What information do we need?
2. What data do we have and what is missing?
3. How can we derive the necessary information from existing 'raw' data sets?
4. How do we organize, operate and improve data and information management in the real world?

Basically, it comes down to making supply (of data) meet demand (for information). What we have is sometimes not what we need; what we need is often not available. Actually, we do not yet have a clear and complete picture of what data and information we need, or how to derive useful information from raw data. In fact, this document should answer this question, at least in part, while urging completion of the global picture for data requirements. Indeed the need for information is high and broad-ranged, not only because of the already broad topic of 'the environment' and a further broadening towards 'sustainability', but also because of the need to raise the policy relevance of assessments by addressing the causes and effects of environmental change and policy responses. Information is thus not only needed on the environmental state *per se* (quality of air, land and water) but also on underlying driving forces (population, economy), concomitant pressures (emissions), the state of the environment and impacts on humans and nature (e.g. biodiversity loss, human health), and on the effect of policy measures. Together with the need to consistently derive trends and enable projections for major regions of the world, this implies a very large capacity (both in width and depth) of a core database. To avoid getting lost in this expanse it will be necessary to limit the scope to the environmental issues of the highest priority and to be very specific about the methods and data needed to address these issues. This is elaborated in **Chapter 1** where the environmental agenda and assessment framework for environmental issues along the DPSIR loop are discussed.

The first years of the GEO assessment project showed great strides in identifying the core data sets for IEA/GEO and some of the most obvious gaps and shortcomings. The identification addressed basically questions 1 and 2 and produced an extensive list of existing core data sets for global environment assessment, based needs listed by various organizations. However, the ambition to actually mobilize these data for GEO or other assessments could not be fulfilled (see also http://www.grid.unep.ch/geodb.html and http://www.rivm.nl/env/int/coredata).

During the second GEO assessment, an attempt was made to address the third question by compiling a core data table for country statistics and use these for mapping selected environmental issues. Based on readily available global compilations such as the World Development Indicators, the GEO-2000 Data Table went through an exercise of validation and addition by Collaborating Centres using regional and national data sources. Even this limited data exercise proved inconsistencies, shortcomings and gaps to be profound, thus threatening the feasibility and reliability of assessment altogether. The IEA/GEO-related data initiatives and the lessons learned are reported in **Chapter 2**.

Postulated is that what is needed, in theory, is first to produce a full list of the major environmental or even sustainability issues to be addressed in assessments, and from there define what the information and underlying data needs are. Survey and observation programmes need to be set up, directed or re-focused to satisfy those needs, and subsequently, the actual data have to be made available in a form comprehensible to those performing the assessment. At the same time, the expertise to make use of the data and produce relevant information needs to be improved among participating 'assessors'.

In practice however, the list of global environmental issues is very dynamic, as old problems are addressed or new ones identified or given higher priority. Methods used to derive information from raw data develop with increasing knowledge and observations. The fact remains that assessments are often driven as much by scientific knowledge and data availability as by policy demand. Also, a considerable overlap exists among different environment-related reporting programmes. In reality, all this implies the need to compile a generic, flexible core database, which can also serve other assessments than 'just' GEO. The sheer magnitude actually makes it very difficult for any single organisation to compile such an empirical base. Thus, in fact, this could and should be an UN-wide effort, which would benefit the assessment activities of UNEP, UNDP, FAO, CSD, IPCC, Convention Secretariats, UN Economic Commissions and possibly others.

Chapter 3 lists and briefly describes the most important elements of such a generic database along the DPSIR analysis cycle, starting with the driving forces of population, economy and land use, and ending with societal responses.

Chapter 4 illustrates these elements by giving four examples of how information is actually extracted from the basic data, for the issues of ozone depletion, acidification, eutrophication and climate change.

Emerging, cross-cutting issues that need our special attention are described in **Chapter 5.** These are geographic scale (through a description of freshwater assessment), the need to include responses (through an evaluation of possible trade in emission permits) and the enlargement of the concept of ‘environment’ to ‘sustainable development’.

The examples of Chapters 4 and 5 also highlight the fact that gaps and uncertainties are profound and that standardization among presumably trivial matters such as coding systems, country delineation and regional groupings is urgently needed.

Not knowing in full detail what the data and information needs are and how methods might change over time, recent IEA/GEO assessments have made clear that it would be highly favourable to produce a generic and harmonized global ‘no-regrets’ core database, complemented with a data validation mechanism and tools for access, use and visualization of such data.

Finally**, Chapter 6** summarizes the lessons learned during the GEO assessment years, addresses practical organizational issues (question 4), and concludes with further recommendations for IEA/GEO data management.

Chapter 1. What should we focus on? The agenda & framework for global environment reporting

Environment agenda

Traditionally, environmental reporting focused on the quality of air, water and soil. Monitoring programmes were set up accordingly (e.g. GEMS), mainly to measure concentrations and conditions at measuring stations around the world or, more recently, remotely sensed from space satellites. This is a very logical and necessary part of the assessment process, answering questions on what is happening to the environment in the first place. Once problems have been identified, the challenge is to find out what the causes are, so that actions can be defined and taken. Assuming rational behaviour, the problems which harm the environment the most *and* which can be solved relatively easily and cheaply, usually get the highest priority. Actions and directives are formulated and instruments designed to remove the causes. These are not only applied by governments, but often also by individuals, non-governmental organizations (NGOs), private companies or other groups in society. Once measurements have been applied for a certain period of time, it is of interest to ascertain if the desired effect can be seen or what is needed additionally to reach the final goal.

The ultimate goal, described by concepts of ‘a sustainable world’ or ‘maximum well-being’ will need further operationalization before these concepts even can be used to set the agenda for future assessment and reporting programmes, let alone for policy making. Current assessments need to address specific issues and enable policy makers to answer questions on how to solve environmental problems and set priorities. Monitoring should enable adequate, reliable reporting, not on the environmental state per se but also on pressures, impacts and policy responses. Assessments must answer policy issues, and if the concept of environment is broadened to global sustainable development, we will need to take into account the pressures on the environmental state and the socio-economic forces behind those pressures, as well as impacts on human welfare and natural ecosystems and policy responses to the environmental problems at hand. The need for truly integrated assessment is being recognized more and more, as witnessed by the first GEO assessment, IPCC's climate assessments and current EU/EEA studies.
Table 1.1 further illustrates the different levels of assessment:

Level	*Main question*	*Assessment*	*Examples of data needed*
1. Describing	What is happening ?	Describe state of environmental media in physical parameter.	• Air quality data
2. Explaining	Why is it happening ?	Relate physical parameters to their causes	The above, plus: • Emissions from transport
3. Advising	Are these changes significant and what could be our responses ?	Relate changes in the environment to driving forces, impacts and solutions	The above, plus: • Economic output • Impacts on human health • Possible effect of a ban on leaded petrol
4. Sustainable development assessment	Are environmental, social and economic objectives being adequately met ?	Combine and evaluate environmental, economic and social objectives	The above, plus: • information regarding the implementation of economic and social objectives

Table 1.1: Levels of environmental assessment

Over the years, the pollution of air, water and soil and their causes, impacts and interlinkages, have been further specified as to single out policy-relevant environmental issues. These are now both widely recognized and can be addressed by policy makers and researchers in quantitative terms. Climate change, ozone depletion and urban air pollution are well-known examples, but the list usually includes a dozen or so other environmental problems. In addition to common sense, scientific research, past assessment experiences and policy making, regional consultations and specific surveys have been used to identify or confirm the most prominent global and regional environmental problems. From all this, the most prominent problems related to the environment and common to most world regions, can be singled out as being:

- Land use & agriculture (incl. nature, biodiversity)
- Energy & climate change
- Urban stress & health

Partly because of the aggregate nature of the above short-list, it has been rather stable over the years and could serve as an umbrella agenda for integrated environment assessments. From these three issues, problems such as climate change, acidification, eutrophication, water stress, soil degradation, biodiversity loss and ozone depletion have been singled out in several assessment studies. Chapter 2 reports on the actual use of such an agenda for IEA/GEO purposes so far. Obviously, disaggregating the environmental system implies that interlinkages and cycles need to be addressed because of dependencies and interactions among the '(sub)themes' e.g. acidification and climate change, biodiversity and land use / forests. In fact, these interlinkages are highly policy relevant since they could point to synergy among the measures taken. The integrative context of the prominent issues mentioned can be illustrated as in Figure 1.1.

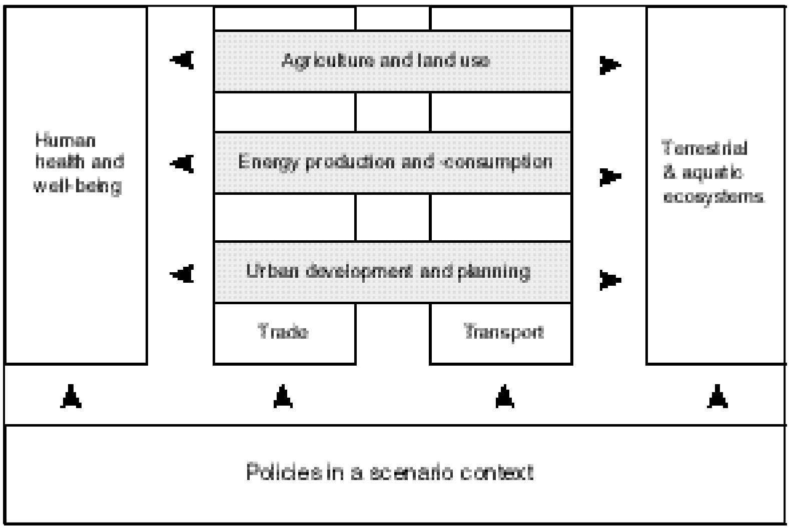


Figure 1.1 Priority-setting for environmental issues. Arrows represent relations that need to be quantified.

Agricultural development, increasing energy use and urbanization, linked by trade and transport, are the main processes and activities affecting natural ecosystems and human health. Society reacts through the formulation of policies, laws, agreements and conventions, and the application of accompanying instruments to reach the targets, usually by either reducing pressures (emission reductions), and/or limiting impacts (end-of-pipe measures). In practice, these are highly complicated processes. There are many actors at various levels (from individual to global) with diverse reactions (e.g. behaviour, legislation, conventions). This is addressed in the main GEO-2000 report, while this document focuses on the data and information needed to feed these policy actions.

The main challenge of assessment is to further disaggregate the priority issues and to define a framework to analyze these issues in more detail. Such a framework includes both the core data sets and the methods (models, tools) to derive the relevant information from the data; this part can be fairly stable and robust. The scenarios to be analyzed for the evaluation of policy options can be added to raise policy relevance; this part is obviously more dynamic in nature. Many data, models and tools have been generated and developed over the years by numerous organizations throughout the world. For IEA/GEO purposes, what is needed is to identify and mobilize these with help from Collaborating Centres, cooperate with other international agencies to improve on gaps and shortcomings and support the actual use of global and regional assessments. Because of the fairly broad range of issues, changing scientific insights and the dynamic policy-making process, the IEA/GEO core data should address 'only' the very most important and widely used basic data sets as well as the mechanisms to improve data management and availability.

Assessment framework

Integrated environment assessment can be structured around the DPSIR framework, where economic and demographic driving forces (D) exert pressures on the environment (P), altering the state of the environment (S), which in turn results in impacts on ecosystems and health (I), provoking responses (R) from the natural system (e.g. self-regulation) and human system (e.g. environmental policy actions, human behaviour) which give feedback on the various stages in this causality chain. This framework helps to explain the scope of data requirements, although other frameworks can serve the same purpose.

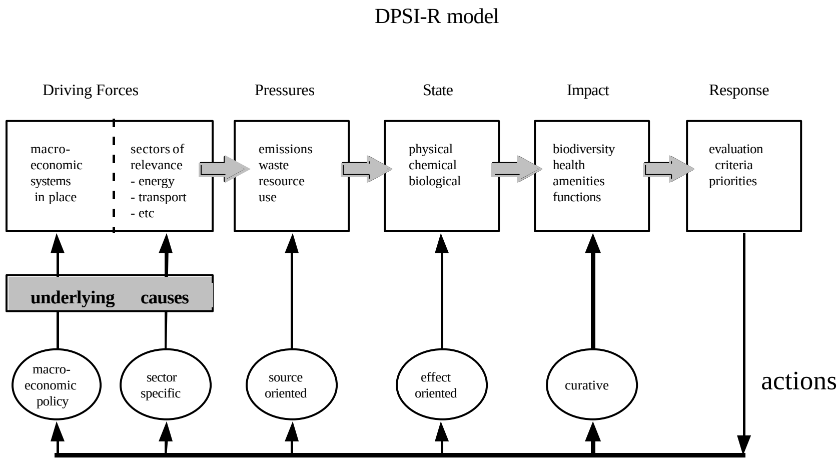


Figure 1.2. The Driving Forces-Pressure-State-Impact-Response (DPSIR) scheme.

Generally speaking, data integration ranges from administrative units and physical measurements for Driving Forces and Pressures (economy, population, land use / cover, emissions) to natural systems for State and Impacts (ecosystems, river basins, soil units). The challenge underlying assessment is to translate data on driving forces and pressures to natural systems entities and vice versa in a meaningful way, and with some indication of reliability. Although flawed by many practical problems and uncertainties (e.g. resulting from spatial interpolation, differences in classification, country delineation), such geographical integration is often achieved through a grid-cell-based approach. The examples below give an impression of some of the data integration issues involved.

Every step in DPSIR (Figure 1. 2) represents an information layer. In each layer, the information seldom covers the complete field. Statistical and geographical methods (models) are used in order to improve coverage (e.g. through spatial or temporal interpolation techniques). Besides this, it should be possible to trace one layer of information into the other (e.g. from emissions to concentrations), which is where computer models can play an important role as well. In this way, a coherent system of linked information layers can be established. The accuracy and information density of these layers is determined by the purposes for which it is needed (and often by availability). Environment assessments need to be driven by the question on how far social developments and policies could lead to negative environmental impacts and cause damage to human health and ecosystems. Theoretically, priority should be given to assessment of the impacts causing the most damage. Other perceived problems can receive less attention, at least for the time being. For example, if soil pollution were to have little or no impact on human health, it would be less important to gather very detailed information on soils.

Chapter 2. What has been done so far? Past IEA/GEO core data initiatives

In practice, it has simply not proven feasible to identify (let alone make available) each and every data set used for integrated environment assessment and underlying research around the world; one could easily drown in the sea of data. At the same time, several assessment activities have made it clear that major data gaps still exist. Over the years, several organizations and programmes have been set up to improve global data management and logistics, focusing on the state of the environment and natural resources. One could mention GEMS, GRID's (Meta)Database, NASA's MasterDirectory, and CIESIN's Global Information Infrastructure, and compilations such as the WRD (World Resources Database by the World Resources Institute), the WDI (World Development Indicators by the World Bank) and the Human Development Database (UNDP).
In an effort to try and bring such initiatives closer together, and to focus the data work, several attempts were made in the 1990s to further scrutinize and harmonize global core data sets and to focus attention on the most important data layers for priority environmental issues. For monitoring of biophysical issues, co-ordinating and steering bodies have been set up i.e. the G3OS Global Observation System (GTOS - Terrestrial, GCOS - Climate and GOOS - Oceans), among others guided by the Integrated Global Observing Strategy (IGOS) of Committee on Earth Observation Satellites (CEOS) and the International Group of Funding Agencies for Global Change Research (IGFA). Focusing on environmental assessment and sustainable development strategies, a broad-based symposium organized by UNEP and UNDP in Bangkok in 1994 (UNDP/UNEP 1994) singled out major data requirements for the key issues of:

- Land-use change and degradation,
- Freshwater and coastal zone management,
- Sustainable use of natural resources,
- Human health, pollution, waste management, and natural and environmental disasters,
- Food and energy for an increasing population,

and identified the following ten high-priority data themes:

- Land use, land cover,
- Demographics,
- Hydrology,
- Infrastructure,
- Climatology,
- Topography,
- Economy,
- Soils,
- Air quality,
- Water quality.

Building further on this initiative and using other earlier work by RIVM (Data management in support of international environmental assessment and modelling, 1995), a matrix of core data sets was drawn up by the IEA/GEO Data Working Group in cooperation with many associated UN and other organizations (UNEP 1996, 1997a, 1997). The needs in terms of content (theme, issue) corresponded to needs already identified by the Bangkok meeting and by RIVM; they can be grouped as follows:

- Climate change,
- Freshwater use and pollution,
- Air emissions and quality,
- Coastal zones,
- Biodiversity,
- Land degradation and deforestation.

The working group identified a wide variety of variables, not only for these environmental issues as such, but also for underlying pressures in society (population, economy, energy, land use/land cover) and supporting data layers and tools (topography, infrastructure, coding systems etc). This initiative went one step further in the sense that data needs were matched with data availability, while information on those data sets was made available to the public (UNEP 1996, 1997a). Thus for each of the 150 or so variables, one or more existing core data sets were identified (if at all possible), together with their spatial resolution and temporal coverage. These include well-known, broad compilations of the World Bank (WDI), World Resources Institute (WRD), ESRI (Digital Chart of the World, ArcWorld) and RIVM (HYDE), as well as thematic layers for agriculture and soils (FAO's

FAOSTAT, Soil Map of the World), for climate (WMO, IIASA/RIVM and CRU), for population (UN World Population Prospects, NCGIA gridded maps) and for emissions (RIVM-EDGAR). The list of core data sets is summarized in Annex 1.

While trying to match existing data sets with defined needs, this process also revealed the major data gaps and shortcomings. These related not only to natural resources (e.g. forests, water, and fish stocks) but also to health impacts on man and ecosystems, to effects of policies in quantitative terms as well as to supporting layers such as watersheds and roads. Not surprisingly, many shortcomings were noted in temporal and spatial coverage, as well as in quality, documentation and availability of the data.

On the other hand, several observation programmes have improved over the last couple of years, and so have major global data compilations. This not only in terms of coverage and quality (observation) but due to the strong growth of information and communication technologies, also in terms of availability throughout the world (distribution). Although far from perfect, positive examples are the World Development Indicators, FAOSTAT, and the global 1 x 1 km^2 land-cover maps.

Over the last few years, there have also been several attempts to define information needs for assessment of sustainable development and human security, including the World Bank's Genuine Savings Rate, UNCSD's Sustainable Development Framework, IHDP's Human Security Index and UNDP's Human Development Index and Human Poverty Index. But work on underlying core data sets as follow-up to the Bangkok Symposium and IEA/GEO data initiatives was very limited, probably because (i) the task goes beyond everybody's remit and not one organization has the mandate to take full responsibility and (ii) the ever returning financial constraints meant that even more modest proposals to improve the data situation were never put into practice. For example, the idea to make identified core data sets available to the GEO Collaborating Centres and other users in an appropriate form never materialized and the idea to set up a small project to define the steps needed to fill major data gaps never came off the ground. What ***was*** done within the framework of UNEP's GEO-process is summarized below.

Recognizing the time, staff and funding constraints it was decided to limit the GEO data work by:

- focussing only on country statistics from readily available sources, to be used for the GEO-2000 report chapter on recent trends in the state of the environment; and,
- preparing a separate data text for the introductory pages of the GEO-2000 report documenting data problems, hopefully highlighting that serious action is required to solve the many problems still existing around the data issue.

For the country statistics exercise some 90 variables and indicators were selected to enable analysis of the (natural) resources of:

- Land,
- Forests,
- Biodiversity,
- Fresh water,
- Marine and coastal areas,
- Atmosphere,
- Urban and industrial environment.

The 90 variables were selected after comparing several existing core data and indicator lists or programmes such as:

- The key issues and themes list prepared during the Bangkok 1994 symposium
- The UN DPCSD Indicators on Sustainable Development programme
- The World Bank's World Development Indicators report
- UNDP, Human Development Indicator report and the like.

The data compiled along these lines in the data table were to support the texts on the environmental issues and resources identified for the GEO-2000 report:

- Climate change,
- Stratospheric ozone depletion,
- Nitrogen loading,
- Toxic chemicals and hazardous waste,
- Natural disasters,

- El Niño,
- Forest fires and biomass burning,
- Human health and the environment,
- Land and food,
- Forests,
- Biodiversity,
- Freshwater,
- Marine and coastal areas,
- Atmosphere,
- Urban areas.

The statistics were intended to be used to illustrate the more qualitative global, and (sub-)regional overviews that would be prepared on the current trends in environmental issues and in the state of environmental resources, together with developments in society threatening these environmental resources. For each country the data values were compiled for each variable or indicator in the data table, limiting the exercise to the most important statistics, using both global and regional statistical data sets and trying to cover both a base year period (1989/90) and the latest available year (1996 or 1997). Emphasis was given to the rule of using the appropriate, recognized international source for each data theme, e.g. FAO for land and forests, WHO for health, World Bank/IMF for economy, or UN-DESD for population. In practice, mainly the following data sets were used to fill the global and regional tables:

- Asia-Pacific in figures for 1993 & 1995, UN/ESCAP, Thailand
- Bio-diversity Data Source Book, WCMC, 1994
- Energy Statistical Year Book 1994, UN New York, 1996
- Environmental Treaties and Resource Indicators (ENTRI) (http://sedac.ciesin.org/pidb/pidb-home.html)
- ESCAP Population Data Sheet 1997, UN/ESCAP, Thailand
- FAO AGROSTAT Data Base on Line (http://www.fao.org/.)
- Human Development Report 1997, UNDP
- Http://www.wcmc.org.uk:80/protected_areas/data/summstat.html
- Land Degradation in South Asia: Its Severity, Causes and Effects upon the People, FAO, UNDP, UNEP, 1994
- OECD Environmental Data Compendium 1997, OECD, France
- Significant Data on Major Disasters World-wide, 1990 – Present, Office of U.S. Foreign Disaster Assistance (OFDA)
- Statistical Year Book for Asia-Pacific 1996, UN/ESCAP, Thailand
- UN Basic Social Services for All 1997 Sheet, UN
- UNEP Environment Data Report 1993-94, UNEP
- World Urbanization Prospects: The 1994 Revision, UN, New York
- World Resources 1996-97, WRI
- World Development Indicators 1997 CD-ROM, World Bank, 1997
- World Resources 1996-97 Database Diskettes, WRI, 1997

After the data tables were filled for 202 countries and geographical areas some “quick and dirty” comparisons were made between these figures originating from various global data sources and available figures originating from national or regional data sources. Fourteen core variables and indicators were selected for this validation exercise by Collaborating Centres. This process revealed various problems, including:

- *Incompatibility* of global vs. national data sets:

Arable land in China	92×10^6 ha (FAO)
	95×10^6 ha (national source)
Total mangrove area in Thailand	196×10^3 ha (WRI)
	268×10^3 ha (WCMC)
	1686×10^3 ha (national sources)

- *Inconsistencies* among (mistakes in) international data sets:

  Totally protected marine & coastal areas in Bahrain

  1989 (base year) = 13,035,051 ha (WRI)
  1994 (recent year) = 0.05 ha (WCMC)
  (Note: total area of Bahrain = 68,000 ha)

  Totally protected marine & coastal areas in Colombia

1989 = 160,000,000 ha (WRI)
1994 = 650,000 ha (WCMC)
(Note: total area of Colombia = 113,891,000 ha)

Totally protected marine & coastal areas in Costa Rica

1989 = 10,049,838,000 ha (WRI)
1994 = 330,000 ha (WCMC)
(Total area of Costa Rica = 5,110,000 ha)

Totally protected marine & coastal areas in Côte d'Ivoire

1989 = 1,183,524,000 ha (WRI)
1994 = 33,000 ha (WCMC)
(Total area of Côte d'Ivoire = 32,246,000 ha)

Although harmonization of measurement is thought to have improved over the years, a review of data sources reveals several inconsistencies in definitions. For example, 'primary school' in one country is often different from another. Or 'agriculture' is defined as including forestry and fishery in some countries but not in others. 'Industry' might include manufacturing in some countries, in others it does not. Data of land-use classes such as 'forest' or 'wetlands' are among the most notorious. Even a supposedly straightforward variable as 'amount of land' proved fairly inconsistent, depending on the inclusion of inland water bodies, coastal waters, overseas territories, or conflict areas. A more in-depth analysis was undertaken for the land resources theme and is presented in Box 1. In general, and not surprisingly, somewhat 'established' indicators on driving forces such as GDP and total population experience the least problems, while those on state of the environment and certainly on impacts have substantial shortcomings. Confirming the notion of where the most notorious gaps are, data problems were found to be particularly significant in the areas of:

- Pesticide application,
- Areas affected by water and wind erosion,
- Fish stocks,
- Forest quality and biodiversity,
- Wastewater treatment coverage,
- Water-related diseases,
- (Air) emissions.

Inconsistencies in the data table structure itself also caused problems (it for instance being a mixture of simple variables and more complex indicators). Comparing global data sets with regional and national data sets is in fact a problem in itself since these data sets have been produced for different purposes, using different data processing techniques which may be valid for one scale but not for the other. Furthermore, for many variables and countries relevant data sources could just not be found or accessed, and, if available, data often corresponded to different years among the sources. Overall, about one-third of the GEO-2000 data table could not be filled from readily available data compilations.

Another practical problem was that due to time constraints the preparation and filling of the 90 variables in the data table had to take place at the same time as the writing of the qualitative texts for GEO-2000. The actual structure of the text changed over time while going from first draft to final text. As a result the variables included in the data table no longer matched completely with the issues described in the text. It turned out, for example, that variables and indicators on impacts were poorly represented (such as impacts of negative trends on health), as were for example early-response variables (such as those related to natural disasters or forest fires).

In some cases indirect indicators were selected, which could be used to obtain an impression of a problem. For instance, attempts were made to approximate desertification by local run-off and the ratio of pasture land to total land areas. Another example is acidification, which is often expressed in terms of the area where acid deposition exceeds the threshold value in particular ecosystems. For this, information has to be found to assess the sensitivity of ecosystems and to show underlying pressures such as emissions or agricultural expansion. Subsequently, information is required on the root causes in society such as energy, consumption patterns, and economic and population growth.
In summary, only one-third of the data table could be used to adequately evaluate and illustrate the environmental issues described in GEO-2000.

Additional work was done using computer mapping tools to apply some accuracy and consistency analyses. The data tables that were based on statistical data were linked to a simple Geographic Information System (GIS). Some comparative analyses were made to try and illustrate selected environmental problems among the regions and to try and identify underlying causes of some environmental problems. Clearly, great care is required here, since visualization can also be misleading. With the same data one can often produce different pictures, depending *inter alia* on underlying methods for regional aggregation, spatial interpolation or thematic classification. Most of this is also true for tabular presentations of data, but keeping the saying "a picture is a thousand words" in mind one should realize that pictures often grab the attention more easily. Using the same argument, pictures can also be very useful tools to realize that certain data manipulations are not sound. Examples are given below.

Comparative analysis:

Figure 2.1 shows the share of global CO_2 emissions at the country level. Substantial regional differences can be seen in the contribution to this aspect of the climate change problem. The USA, Russia and China are clearly the three biggest producers of CO_2 in the world. Figure 2.2 demonstrates, however, that from the point of view of per capita emissions the USA and Russia are comparable to many countries of Europe, West and Central Asia, while China is more comparable to the per capita emission levels in Africa, South and South East Asia (apart from Singapore) and Latin America. Both maps tell "a different truth", to be used for different purposes.

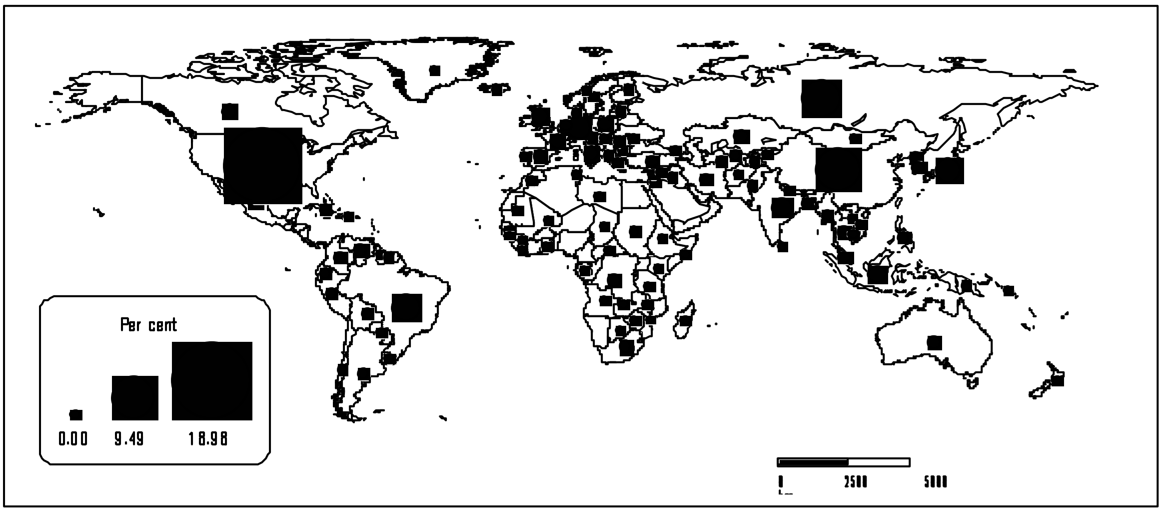


Figure 2.1. Share of global CO2 emissions per country.

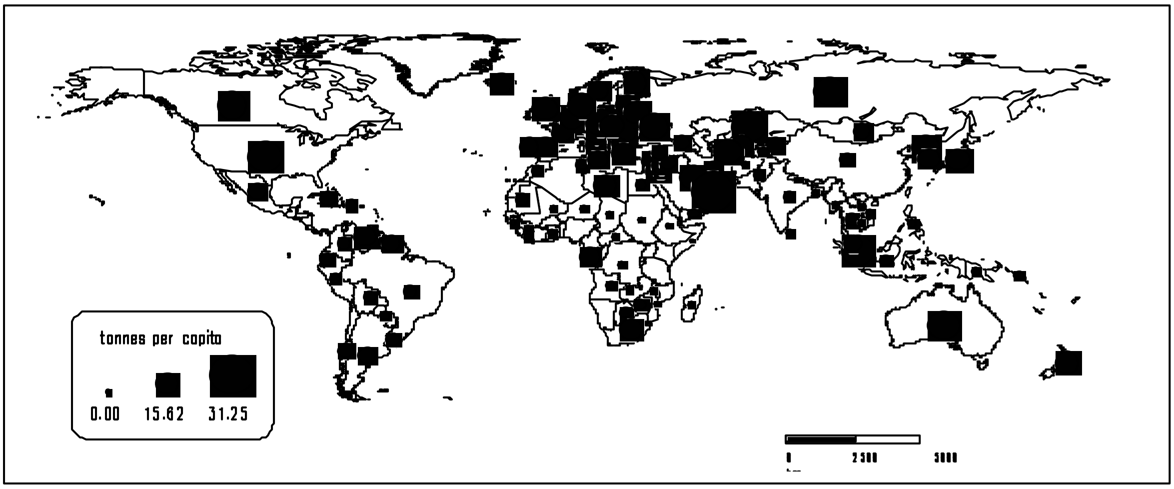


Figure 2.2. Per capita CO2 emissions per country.

Figure 2.3. shows water withdrawals per capita, differentiating for domestic, agricultural and industrial use. The map gives an idea of how much water is used per capita and how much of that is used for the three dominant uses. As some countries and (sub-) regions have more water than others, this can only tell half the story, but still. An overall conclusion can be that per capita water consumption is very high in Central Asia as compared to the rest of the world. And most of it is used in agriculture. This does seem to say something about agricultural water use efficiency in that sub-region and is one of the reasons for the Aral Sea catastrophe.

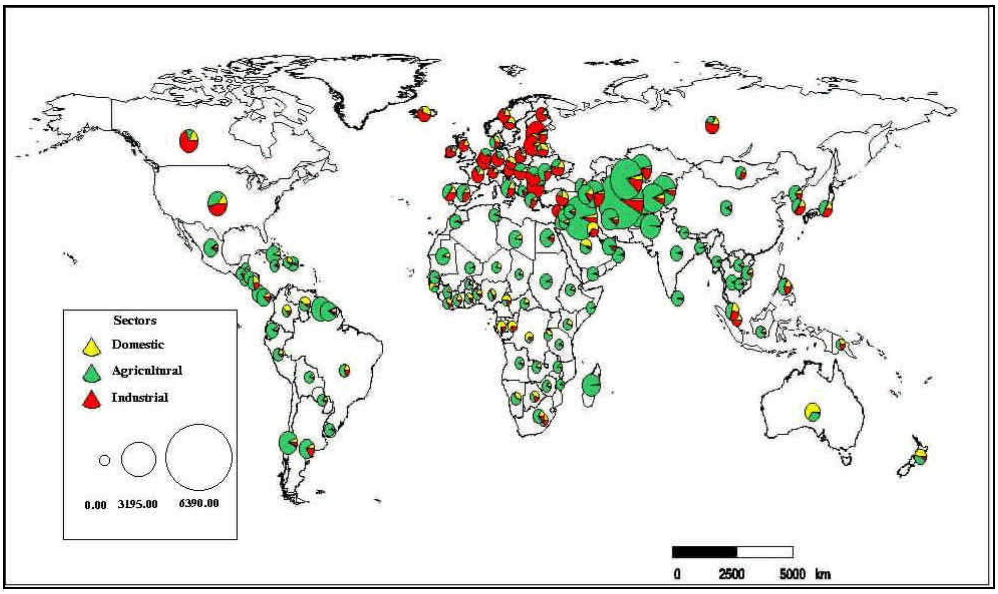


Figure 2.3. Freshwater withdrawals per capita for the three dominant water uses.

Underlying causes

While searching for policy-relevant causes of environmental degradation, an attempt was made to analyse the problem of deforestation. Figure 2.4 shows the most direct indicator of per cent annual change in forest area. The major deforestation took place in tropical forest areas of Africa, South America, western Asia and in some parts of the Asia-Pacific region.

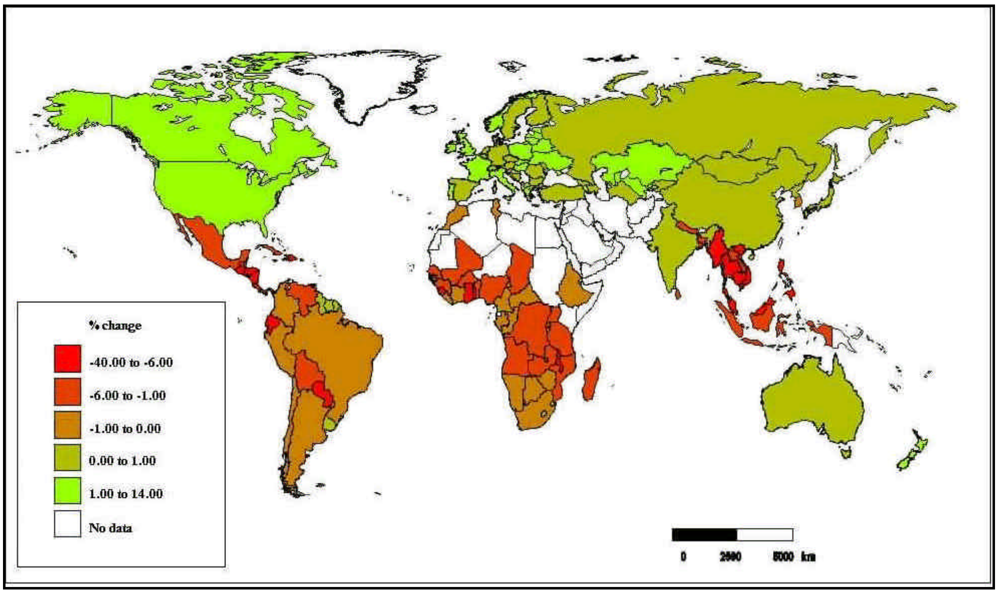


Figure 2.4. Annual change in forest area.

In order to explore socio-economic factors responsible for deforestation, the total roundwood production (million m^3 per year) was looked at. It turns out that several main producers of roundwood in the world (US, Brazil, India, China, Russia and Canada) are not characterized by high values of change in forest area (i.e. with the exception of China, Brazil) (see Figure 2.4). Statistics on the total area of forest plantations shows that many top producers actually have considerable areas of forest plantations, which supply them with major share of timber, thus avoiding real deforestation.

Besides roundwood production, another important factor for deforestation is given in Figure 2.5, which shows the use of 'traditional' fuel as a percentage of total fuel use. The consumption of traditional fuels such as firewood and charcoal occurs mainly in Africa (except northern Africa), South and South East Asia, the Mekong Basin and South America, notably in the Caribbean. Somewhat surprisingly, traditional fuel use was fairly high in certain parts of Central Europe, particularly in areas affected recently by conflicts i.e. Albania and the states of former Yugoslavia.

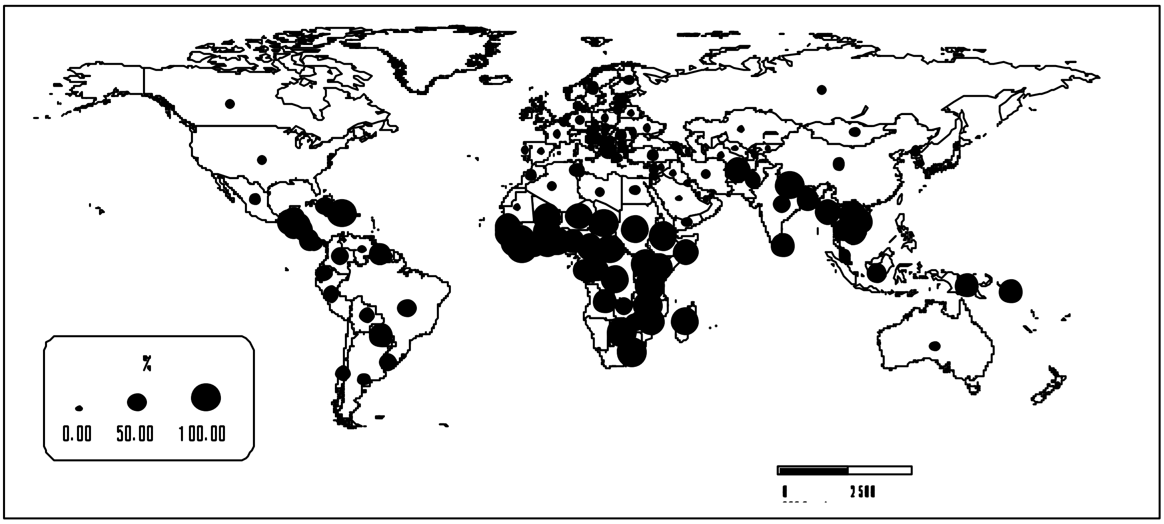


Figure 2.5. Traditional fuel as percentage of total fuel use.

From a casual examination of the above map, one could conclude that deforestation occurs mainly in Africa and South and Southeast Asia – the result of growing pressure of the population on forests for the use of traditional fuel. But such a conclusion may be too simple. Wood is a very profitable commodity and in many countries a large part of roundwood production is illegal and not captured in official statistics. In addition, the impact of traditional agriculture in African countries could be high, but it is not easy to reflect the expansion of agriculture into forest lands in national and global statistical reports. In other words, the basic statistics and therefore the map do not include all aspects, and therefore do not represent the full picture.

Thus, visual comparison of country-level maps can explore the links between different parameters but only superficially, as illusions are easily created. Combining several relevant maps can already shed more light on the issue at hand. However, the use of global statistical databases, whether in maps or in tabular format, are limited because:

- many phenomena cannot be depicted easily by statistical databases and, therefore, by cartographic analysis;
- the complex nature of many issues means that problems cannot be understood by analyzing a limited number of simple parameters;
- variation at lower levels are often neglected (the scale issue – see also chapter 5): one problem in a region, for example, may arise from different causes in different countries. Showing only this one problem may lead to the illusion of only one major cause, resulting in only one type of policy.

The above exercise illustrates that country level statistical data compilations like the GEO data table, do allow mapping and analysis of several issues relevant for regional and global state of the environment overviews, despite the shortage of data on environmental problems. The exercise also shows that country level statistics alone constitute only part of the input required for global environment assessment, while geographic presentation is only one of the methods for analysis. Therefore, GEO aims to use other inputs and assessment tools as well. Reference is made to the text on data issues in the main GEO2000 report, as well as to the GEO-2000 web-version, for instance to see the (sub-) regional groupings used for GEO-2000 (http://www.unep.org/geo2000).

All in all, it became clear that it had been too optimistic to assume that the data tables could be fully used for GEO-2000. It was, therefore, decided to limit the data table for GEO-2000 to the following short list of 15 variables:

- Total population,
- Arable land per capita,
- Calories per capita,
- Fertilizer use per hectare of arable land,
- Total Fish catch by country,
- Extent of total forest,
- Commercial energy consumption (per capita),
- Global carbon dioxide emissions per capita,
- Fresh water resources,
- Urban population,
- Urban population growth,
- Vehicles/1000 population,
- Gross domestic product per capita,
- Threatened animal species,
- Number and size of protected areas.

For each of these variables the most logical global data source was used, or a combination of several of such sources. The tables were filled in for all countries, at five-year time intervals, where possible starting in the 1960's, early 70's. Data were then packaged for the GEO-2000 sub-regions and regions and used to produce graphs comparing regions or sub-regions to illustrate the text in the global perspective and State of the Environment chapters of GEO-2000.

In addition, region and sub-region specific data sources were used to illustrate a certain aspect for one region only and occasionally national or even local level examples and figures were given in the text to highlight a point.

From all the above it is clear that, despite some progress, much data related work is required in future, starting early on in the preparation for GEO-3, and trying to make sure that all major players are involved, in particular the international (mainly UN) agencies that have specific data compilation mandates, like FAO, WHO, WMO, UN Social and Economic commissions, UNDP, the World Bank, the World Resources Institute and the like.

Chapter 3. What should a core database look like? Basic elements

As outlined in Chapter 1, the assessment methodology requires the clear definition of policy issues, and subsequently the availability of models and data, as well as interfaces to communicate answers to policy makers. Chapter 2 presented experiences from the GEO assessments and outlined practical data issues. Here, in Chapter 3, the most important and generic *elements* and characteristics of a core database for environmental assessment are presented. This could form the foundation for and further guide the development of the required data and knowledge base for use in GEO-3 and other assessments. It is no news that many data layers themselves need further improvement and that we need tools to integrate the layers and communicate results. Thus what needs to be done now is to become more specific about what is missing and to `provide detailed proposals to alleviate the data and information problems.

Chapters 4 and 5 will illustrate the data flows among the distinguished key elements, not only to show how this works in practice, but also to identify major critical gaps in integrated assessment and monitoring, i.e. gaps in scientific understanding and in availability and integration of data. In Chapter 4, four environmental issues are analyzed: acidification, eutrophication, climate change and ozone depletion. These were chosen because all major steps in the data-to-information processing could be easily illustrated. But for the development of a 'full-blown' information infrastructure, these examples should be complemented with several other environmental and sustainability issues.

To underline cross-cutting data issues such as geographic scale, and also the need to focus more in environmental impacts and responses, Chapter 5 follows with an assessment of water stress, a recent attempt to address policy responses to environmental problems (emission permit trade) and a case for broadening the concept of 'environment' to 'sustainability'. These examples illustrate important new directions for future observational and assessment activities.

What are the key elements of a generic environmental core database?

Having learned from the various past assessment experiences, we can outline the main constituents of what could be called a generic global core database in support of integrated environment assessment. Again the DPSIR framework can be used to broadly structure these key elements. An attempt is made here to link the thematic elements with existing data sources and to describe briefly their characteristics, as well as what the challenges are for further use in integrated assessment.

Core data sets on driving forces relate to the size, composition and health status of human ***population*** (the 'consumers') and to production and consumption patterns within the ***economy***. In addition, population size and density are widely used as a means to distribute environmental pressures from the country or district level to grid cells.

Population characteristics are usually reported at the national level (UN-DESD and various regional collectors e.g. Eurostat for Europe). Attempts to convert such data to smaller grid cells include those by NCGIA (homogeneous and 'pycnophylactic' distribution in some 20,000 districts over the world at 5 min.), CGEIC (country totals distributed according to rural-urban split at 1 dg.), and UNEP/NCGIA and RIVM, who derived gridded population for several continents by combining district numbers with city population, distance to roads, railways, coastlines and land use (10 min.). This approach needs further work to produce a global, consistent and high-quality coverage with additional attributes on yearly growth, urban/rural split and age distribution, and validated against reported population data surfaces. In order to learn more about impacts on human health, much more and better information is needed on death rates and causes of death (mortality and morbidity), behaviour patterns and illnesses. Observation and survey activities need a substantial boost in many countries, as basic statistics are glaringly absent in many regions of the world.

Data on the economy in terms of GDP, added value, private consumption and purchasing power are usually reported as well at the national level, while being collated by the World Bank, UNDP and regional institutions. Very few collections at the district level are available. Usually population size is used to distribute economic activities over grid cells. This holds both for financial measurements (GDP) and physical processes such as production and consumption of fossil fuels. This spatial distribution mechanism needs to be checked against available information on physical parameters within the economy.

Land use, a socio-economic variable, can be derived by combining country statistics collected by FAO at the global level with physical information on soils, climate and land cover. Such land use data sets are the result of processing and integration of 'raw' data collected through physical measurement, surveys and country collections, including Olson's World Ecosystems, FAO Soil Map, and FAOSTAT. From land use, indicators for terrestrial biodiversity can be derived as was done for GEO-1 i.e. domesticated vs. natural area. ***Land cover*** is usually obtained through remote sensing. At the global level, mainly NOAA satellite imagery is currently used; at regional levels Landsat, SPOT or radar imagery are also used. Land cover, together with land use, is used for initial distribution of land as a starting point for projections of global terrestrial changes in the future. Land cover is also used to estimate the degree of fragmentation of natural areas as one of the pressures on biodiversity. The recent 1x1 km data set needs further checking against available regional and country data such as EEA/CORINE Land Cover and RIVM/Staring Centre European Land Use data sets. Historic land use changes are to be improved to better enable trend analysis and model calibration. Global soil maps, produced by FAO, need constant checking and updating. Gridded climate data are derived by interpolation of station measurements, mainly undertaken by IIASA/RIVM and CRU on the basis of WMO inputs, for different periods in time and with somewhat different methodologies.

There is still little information on the composition and characteristics of ecosystems and biogeographical areas. The physical extent of natural areas can usually be derived from land-use classes and inventories of protected areas, but data on composition, quality and biodiversity in terms of flora and fauna are very scarce and erratic. WCMC, EU/Eurostat and a few others have collected some information to date. This urgent data issue will possibly be addressed by the Convention on Biodiversity.

Country ***emission*** levels can be derived by combining driving forces (i.e. consumers, industrial and agricultural activities and energy) with emission factors per activity. This will be a major effort, requiring the integration and validation of vast amount of statistics. Distribution to gridcells is done through population size in the absence of economic information for small, subnational units.

The results of this 'top-down' method need to be compared with the national reported 'bottom-up' emission levels, which are now starting to appear (National Communications to IPCC). In-depth analysis and detailed measurements of emissions and economic activities are required to improve on the quality of emission factors.

Global data on the state of the environment in terms of ***quantity and quality of water, soil and air*** are very poor, largely due to lack of capacity and resources for systematic monitoring in developing countries. Information on water quantity (availability, consumption, runoff etc.) and soils is available for many regions for recent years, but certainly measurements of environmental quality (depositions and concentrations) show many gaps and shortcomings. For air quality, for example, the GEMS-Air programme does not cover the global data needs. The currently available data are still mainly of a random nature. Relatively simple models can be used to derive such information from pressure data, 'only' needing real measurements for calibration and validation. The results of such an analysis can be used to determine to what extent additional data on the state of the environment is required.

Information on the state of the environment needs to be translated to exposure of humans and ecosystems to agents detrimental to their health and quality, respectively. For health impacts, this can be done by combining demographic data with dose-effect relationships for specific pollutants, resulting in impacts on the status of human health in terms of ***mortality, morbidity, and disabilities.*** At the global level, the main bottleneck is the poor demographic and health data at the national and subnational levels. National reporting to WHO shows many gaps and uncertainties. As a first step, mortality statistics need to be collated and standardized for smaller spatial units. This is a sizeable job, currently not within the reach of many developing country institutions. Recently, mortality rates for Europe at the district level have become available through a joint WHO/RIVM/UNECE/CBS-Nl) effort.

Degradation of ecosystems can be expressed by the vulnerability to environmental pollution. Highly vulnerable ecosystems will degrade easily with an increase in sulphur of nitrogen, while others can absorb heavy loads. The exceedance of critical loads can be used as an indicator of potential impacts of degradation and pollution. These impact indicators are becoming available for critical ***loads for acidification, climate change and soil erosion***, although much more analysis is needed to complete the global picture with enough detail.

Gridded data on climate, meteorology, soil characteristics and land use can be used to derive indicators for (sub)surface water flows and potential land productivity. For example, the degree of water stress can be extracted by combining potential water supply and actual water consumption by different sectors. In the analysis of the water issue, thus far only water quantity has been addressed at the global level in this way; the issue of water quality needs to be added. Here too, data integration is a complicated matter: input data range from country statistics on consumption, global maps showing aquifers, river run-off station data to drainage basin water tables. Furthermore, potential land productivity can be compared to actual yields as determined by prevailing agricultural practices. Decreasing potential productivity or yields are a sign of a shift to unsustainable use of natural resources.

In addition, new methodologies are required to express the dimensions of ***biodiversity*** (habitat area and ecological quality). The habitat area approach is currently under development through analyses of combined pressures on ecosystems. Such a conditional approach needs further work and integration with biodiversity quality, combined with new data collection activities.

To a large extent, core data sets are being used by many other organizations involved with assessment, such as UNEP, FAO and UNDP, UNCSD and OECD. Certainly the input data on the D-P side of the D-P-S-I-R chain (economy, population, land use, energy) are common to many assessment activities. Underlying observation (surveys, measurements, remote sensing) form the most basic data layer, with considerable overlap among several global assessments. Emissions and concentrations still overlap substantially, while going further to the other side (i.e. towards I-R), damages and losses are more specific to each individual assessment.

The overlap in observed and input data means that efficiencies and consistencies can be gained if basic surveying, reporting, and observations and first-level consolidation to assessment input data, are regarded as a generic UN-wide activity. Assessments by different bodies already use similar input data to a large extent, while specific core data generated by one body can be used in the context of several assessments. Such collaboration, illustrated in Figure 3.1 as a joint basis for observation and core data, also helps to ensure consistency and to build consensus.

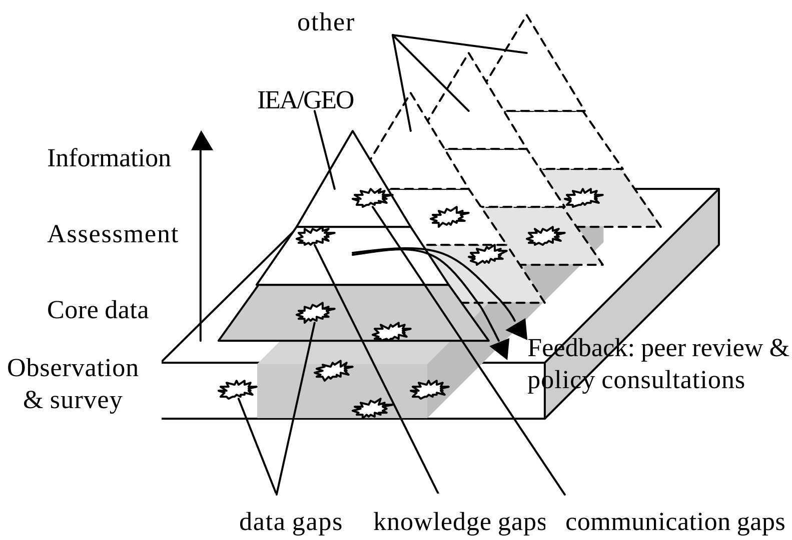


Figure 3.1: From data to information: data management for IEA/GEO assessments, with underlying observation layer, feedback mechanism and a joint basis with other assessments.

In this illustration, the solid gray shade represents the IEA/GEO part of a wide observation layer, which also serves other core databases i.e. for other assessments such as by UNDP, FAO, CSD, OECD. The patterned gray shade represents the core databases derived from the observation layer. Gaps are found in underlying data layers, in assessment expertise (knowledge) and communication to the users (presentation, visualization for policy-makers, general public and other target groups)

Finally, a key element in the assessment processes is authorization through validation and feedback. The quality and value of assessment results can be substantially improved when reviewed by the collaborating centres and regional offices. In the GEO processes the Regional Policy Consultations have been used to allow national governments to comment on assessment activities and the data used. In future, the Collaborating Centres could be used more systematically to channel comments on data back to the original compilers, as was attempted in the GEO-2000 Data Table exercise. Rather than at the input data level (too much) or at the final information level (too late), this is most efficiently done at the intermediate level i.e. after compilation of chosen indicators (see also Figure 3.1). Thus, collaborating centres can take into account any criticism on input data, but only at the assessment stage, and only if relevant for assessment conclusions. Inconsistencies and gaps need to be taken up with the original data compilers.

Chapter 4. How does the information flow in practice? Four examples of environmental issues

The data-to-information processes and elements outlined above can be further illustrated by various examples, which should give a better feel for assessment in practice. Here, four major environmental issues are presented, which collectively already take up a considerable part of the environmental agenda. Described is how the end-indicators have been derived from underlying data sets. Backtracking on DPSIR, we can unravel impacts on human health (ozone) and on ecosystems (acidification, eutrophication), while the issue of climate change illustrates the complexity of the assessment process and the need for integration and cooperation both horizontally and vertically. As previously stated, the next step will be to complete these examples so as to encompass all identified issues of environmentally sustainable development and, subsequently, to take 'real' action, improving observation and assessment programmes accordingly.

4.1 Ozone depletion: how do we assess excess skin cancer risk increase in Europe as a result of past ODS emissions?

One of the effects of ozone depletion is an increase in the incidence of skin cancer. The destruction of ozone results from increased emissions of CFCs and other halocarbons into the atmosphere over the last few decades. This, again, has resulted from the production and consumption of ozone-depleting substances (ODS) contained in air conditioners, sprays, refrigerators and other goods. Although production and consumption of ODS are successfully being reduced, impacts such as skin cancer incidence will increase in the coming decades due to the delay in recovery of the ozone layer. Climate change may hamper this through stratospheric cooling, which facilitates the destruction of ozone.

Figure 4.1.1 shows the excess skin cancer risks in Europe in the period 1980-97. The risks are derived from a dose-time response model (UV-Chain) for the relation between skin cancer induction and change in UV. Maximum values are estimated for around 500 extra cases over the normal 1100 per million people per year in North West Europe. Assuming a population of 160 million in North West Europe, this accounts for some 80,000 extra people every year. The risk is related to biological skin characteristics and age distribution and cannot be extrapolated to other regions without more information on human sensitivity to UV and demographic patterns.

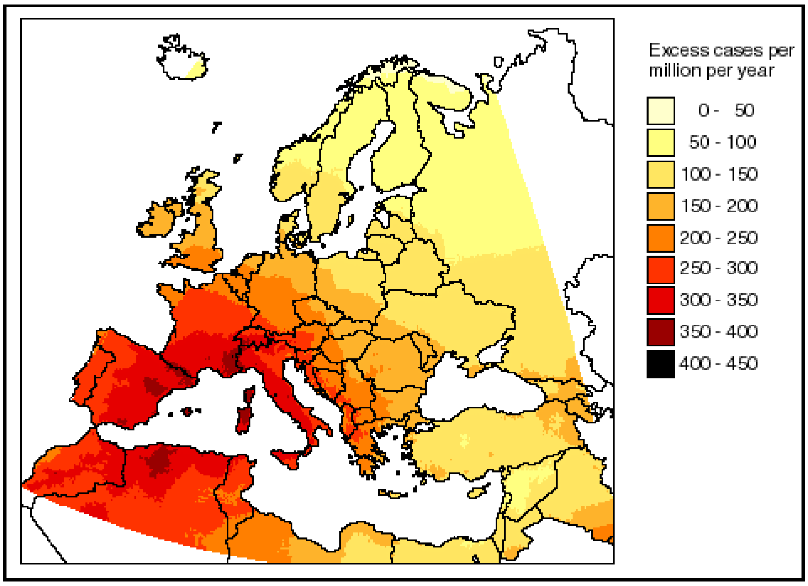


Figure 4.1.1. Excess skin cancer risk in Europe, based on 1980-1997 UV change.
Source: RIVM, Slaper *et al*., 1997

Higher skin cancer incidence results from increases in the UV dose at ground level. The carcinogenic UV dose is ascertained by weighting the ambient UV spectrum according to the carcinogenic effectiveness. Figure 4.1.2

shows the yearly UV increase over Europe. Increases have been most profound in Western Europe, although the highest risks are found more southwards.

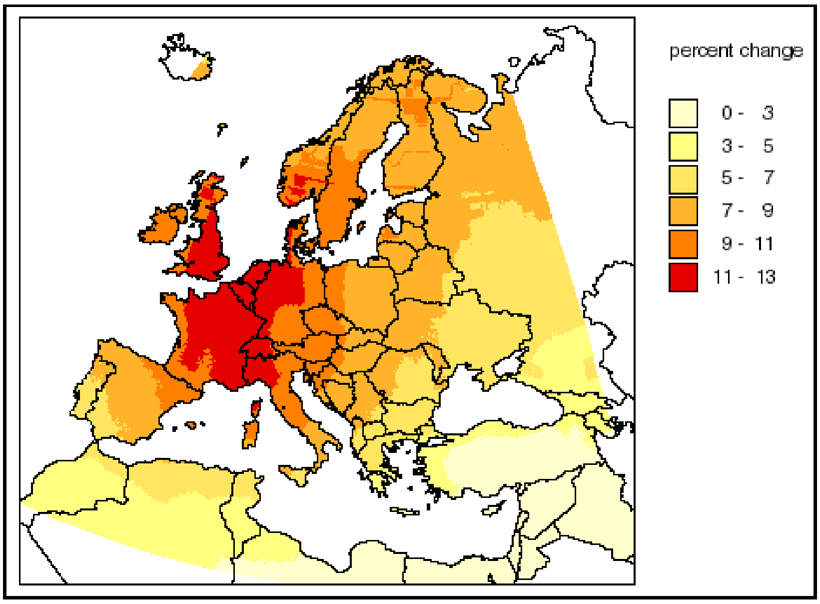


Figure 4.1.2. Increase in yearly UV dose over Europe, 1980-1997.
Source: RIVM , Velders *et al*., 1998

The increase in UV results from depletion of the ozone layer in the atmosphere. Photochemical breakdown releases active chlorine and bromine atoms, which catalyze ozone destruction. The decrease of ozone concentration can be derived from satellite imagery such as TOMS and Nimbus data. Figure 4.1.3 shows ozone depletion between 1980 and 1997 based on such images.

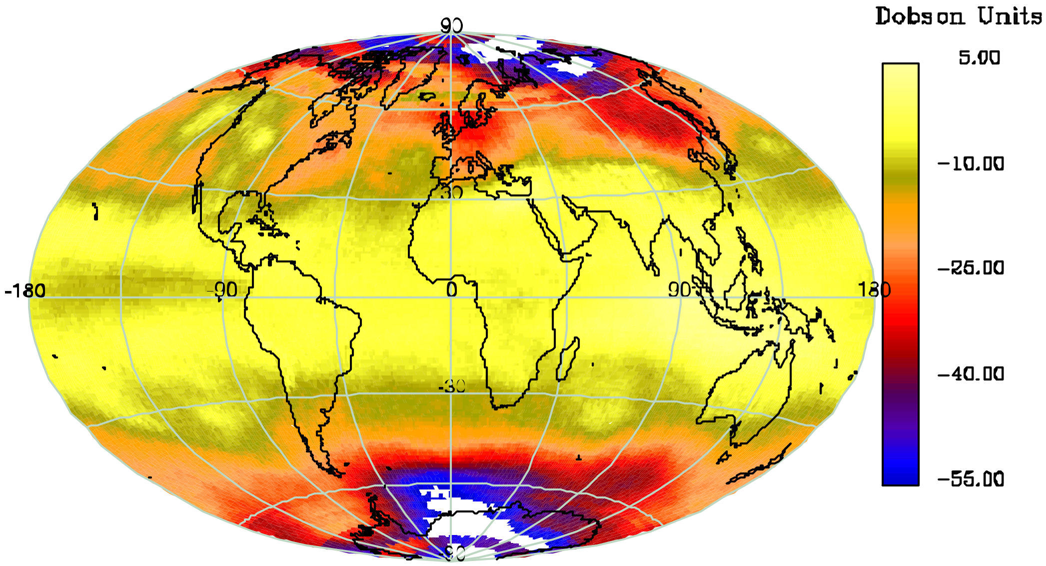


Figure 4.1.3. Ozone depletion, 1980-1997.
Source: NASA (TOMS data), mapping by RIVM, Longstreth *et al*., 1998

Emitted halocarbons are transported to the stratosphere and catalyze ozone destruction. Global emission levels of CFCs and other substances are estimated by multiplying volumes of source categories by emission factors or by adding up nationally reported emissions. National emissions usually result from combining locally measured emissions of point sources (e.g. industrial plants) with estimated emissions of diffuse sources (e.g. road traffic). Huge amounts of data on human activities and nature, together with emission factors and individual measurements, are needed in order to build a consistent and validated global emission database. Figure 4.1.4 shows 1990 CFC emissions from the EDGAR database.

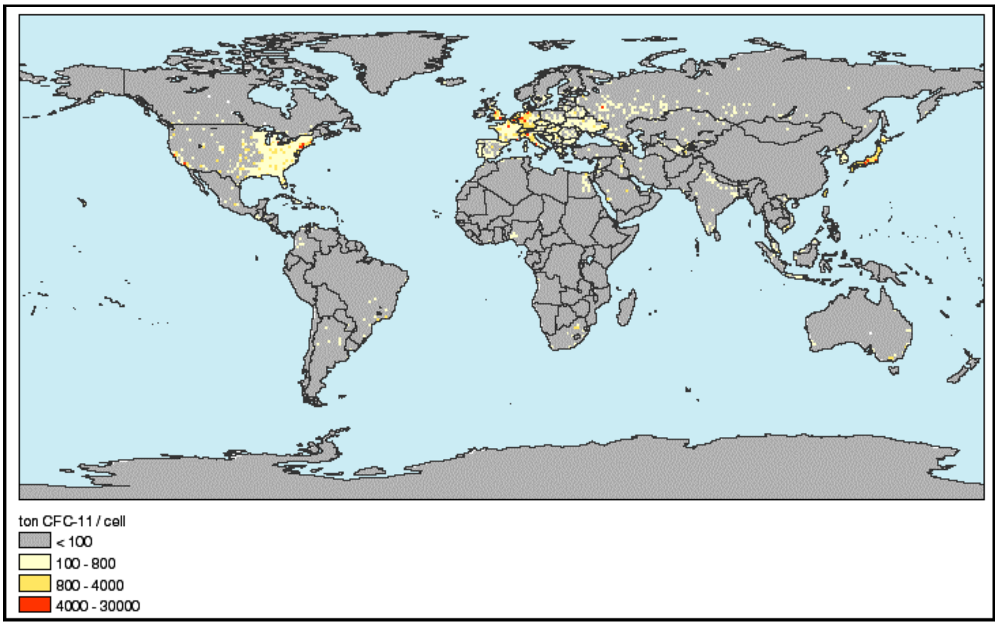


Figure 4.1.4. CFC emissions 1990 (CFC-11, 12,113,114,115).
Source: RIVM/TNO EDGAR Database, Olivier *et al*, 1996

The 'bottom line' of emissions causes is, of course, human activity through the production and consumption of these substances. In the case of CFCs, emissions occur by and large when these substances are consumed or applied ; the production itself is a minor source. Sales are often used as a proxy for consumption. For the indirect or 'top-down' method, as for the EDGAR global air emission database, very detailed data on economic activities and processes are needed, as well as population characteristics.
The main steps of this process can be summarized as follows:

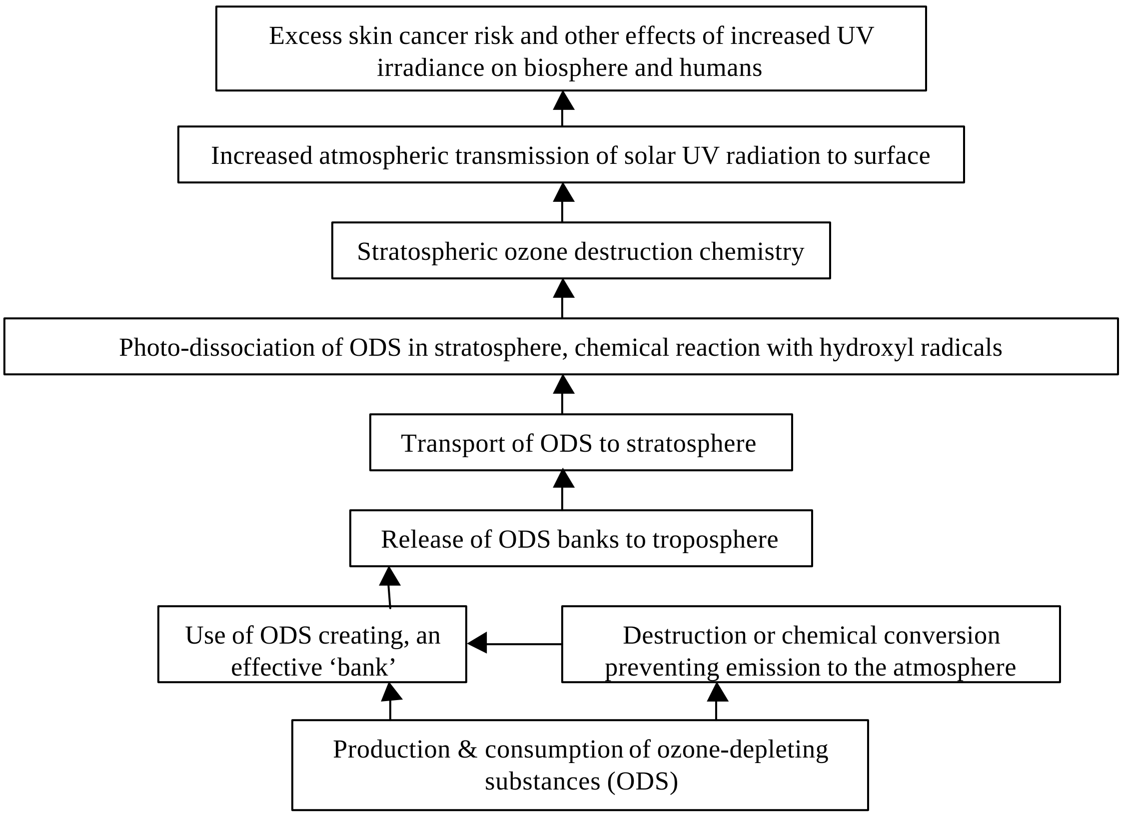


Figure 4.1.5. Data-to-information process for ozone assessment

4.2 Acidification: how do we assess exceedance of critical levels for sulphur?

Increasing industrial production, transport, agriculture and other economic activities result in higher emission levels of acidifying compounds, mainly sulphur and nitrogen. Acidification occurs when terrestrial ecosystems can no longer absorb the deposition of SO_2, NO_x and NH_3 without showing damage to soils and vegetation. When critical levels have been exceeded, the health of the ecosystem is at risk.

Acidification is being studied for Europe within the framework of the UN Convention on Long-Range Transboundary Air Pollution. Data on emissions and air transport by EMEP and on the sensitivity of ecosystems by CCE is integrated by IIASA in the RAINS model. RAINS-optimization scenarios directly support the negotiations under the convention on future emission reduction obligations by the countries in Eastern and Western Europe. Similar RAINS calculations are now also being made for Southeast Asia, within the RAINS-Asia project sponsored by the World Bank.

At the global level, SEI has recently analyzed sulphur-related acidification, using as core data sets the GEIA/EDGAR databases for emissions, the MOGUNTIA model for deposition, and the FAO Soil Map for ecosystems characterization (Kuylenstierna *et al.*, 1998). Figure 4.2.1 shows emissions of sulphur (SO_2) for 1990 from the EDGAR database with a spatial resolution of 1 degree (Olivier *et al*., 1996). To derive such a consistent global grid map is a major effort in itself, needing the integration of data on underlying driving forces.

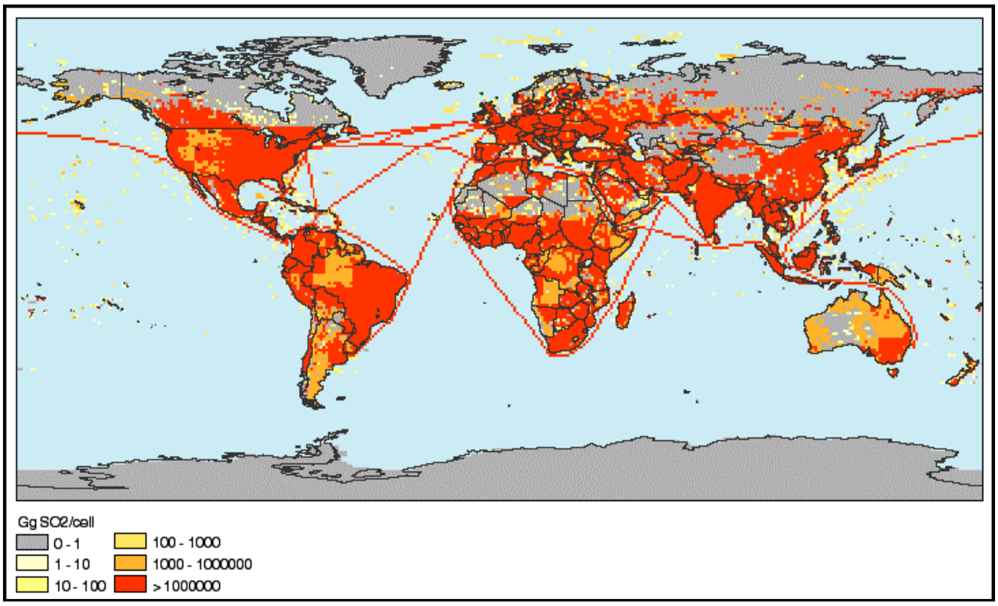


Figure 4.2.1. Emissions of SO_2 in 1990.
Source: RIVM/TNO EDGAR Database, Olivier *et al*., 1996

Vast amounts of statistical data at the country level need to be coupled with emission factors, distributed over small grid cells with the help of population density and validated against reported emission data (i.e. IPCC National Communications). In turn, the collection, maintenance, integration and verification of underlying country statistics and population density are all sizeable jobs in themselves.

Total emission of SO_2 in 1990 amounted to some 148 Tg (IPCC: 150 Tg), derived mainly from production of heavy metals, cement and H_2SO_4, as well as from biomass burning and local fires. To calculate sulphur deposition, the emission data are applied to information on the transport of substances (climate, weather) using atmospheric transport models like MOGUNTIA or STOCHEM. Figure 4.2.2 shows deposition for 1992 derived from the STOCHEM model with a spatial resolution of 5 degrees (5°x 5°).

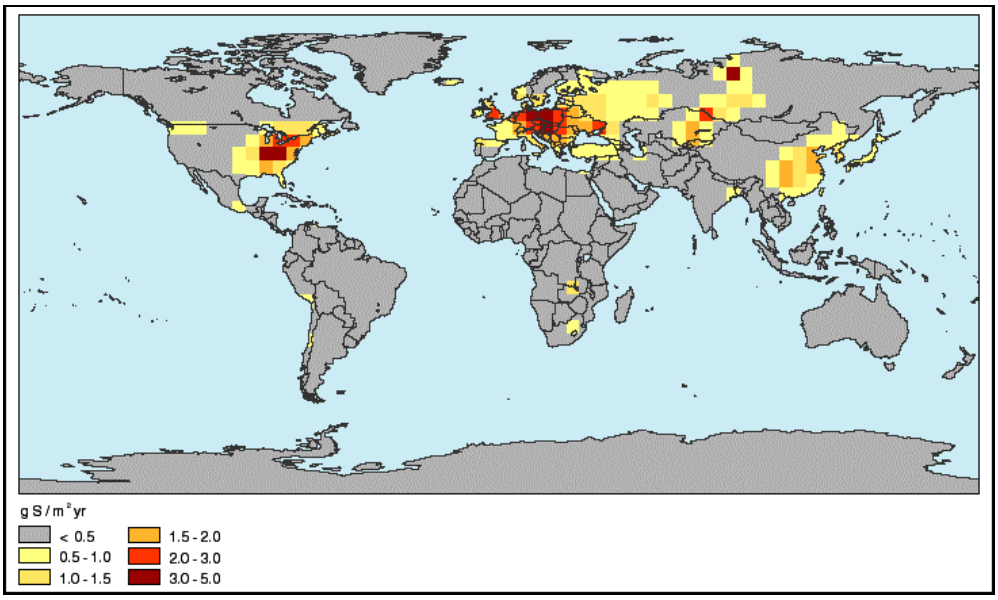


Figure 4.2.2. Annual deposition of sulphur in 1992.
Source: Stevenson *et al., 1998*, UK Meteorological Office (STOCHEM model)

The critical load or sensitivity of ecosystems has been derived from application of the buffer ability of different soil types (using base saturation and the soil's cation exchange capacity, CEC) to the FAO/UNESCO Soil Map of the World. Figure 4.2.3 shows the outcome, representing the results of a consultation process with developing countries, ecologists and experts around the world (Kuylenstierna *et al*., 1998).

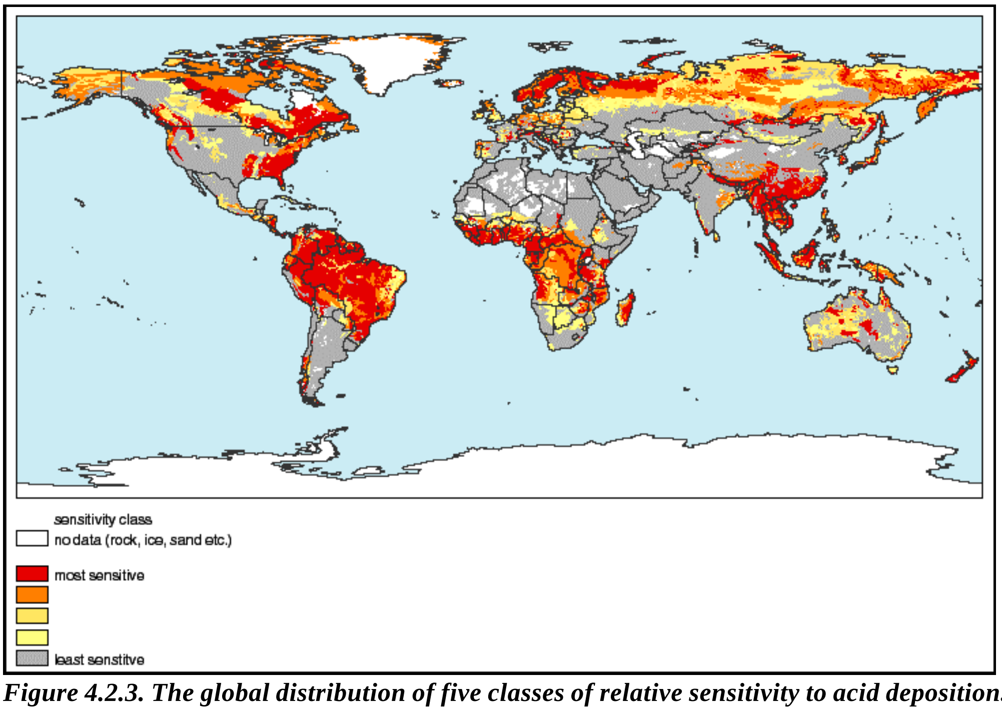


Figure 4.2.3. The global distribution of five classes of relative sensitivity to acid deposition.
Source: Stockholm Environment Institute (SEI), Kuylenstierna *et al*., 1998

Finally, the sensitivity and deposition maps are combined to produce the risk maps of where critical loads are actually (Figure 4.2.4). In addition to the already well-studied regions of Europe and South East Asia, the western part of North America exhibits acidification as a major problem. A scoping of future trends, together with projections for 2050 on the basis of the IPCC IS92a scenario, indicate that large areas in South America and southern Africa will exceed critical levels of sulphur deposition (Kuylenstierna *et al*., 1998).

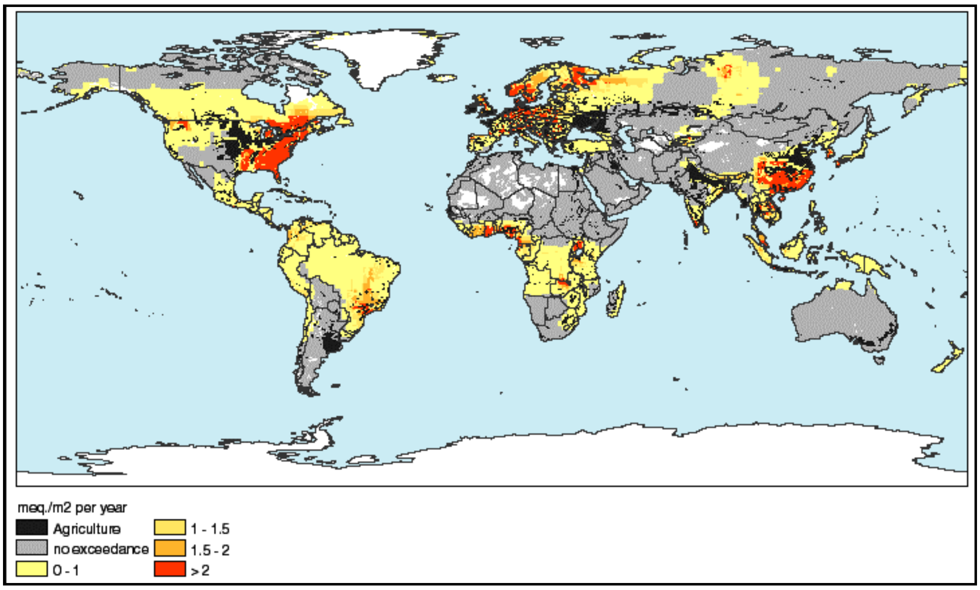


Figure 4.2.4. Global risk of acidification-related damage to terrestrial ecosystems from sulphur deposition in 1992.
Source: RIVM, Bouwman and Van Vuuren, 1999

The main steps of this data-to-information process for the assessment of acidification can be summarized as follows:

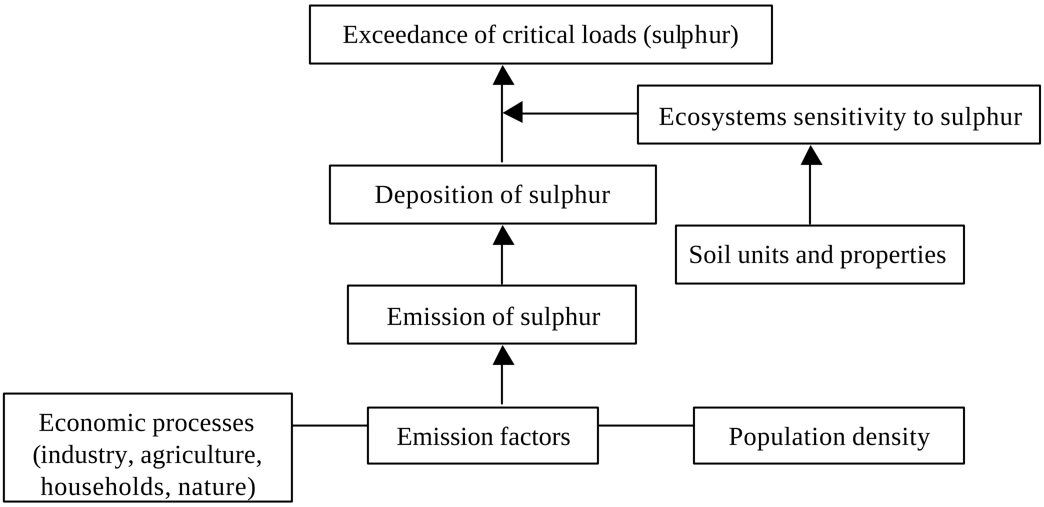


Figure 4.2.5. Data-to-information process for acidification assessment.

4.3 Eutrophication: how do we assess the effects of nitrogen on ecosystems?

Industrial, agricultural and other anthropogenetic activities have modified global bio-geochemical nitrogen (N) cycles by doubling the natural rate of nitrogen fixation. This is reflected in increasing emissions of nitrogen gases into the atmosphere, increasing riverine transport of nitrogen into the oceanic environment, accumulation in inland aquatic systems and deposition to natural ecosystems. Because nitrogen is the primary nutrient limiting biological production in many terrestrial and freshwater and marine environments, increases in nitrogen inputs (in any form) can alter those ecosystems through eutrophication.

This section presents a global analysis of the eutrophication hazard based on best available data on emissions, deposition and critical nitrogen loads for terrestrial ecosystems.

Emissions. The main nitrogen substances emitted by human activities are nitric oxide (NO) and nitrogen dioxide (NO_2) (together denoted as NO_x), and ammonia (NH_3) (Figure 4.3.1). Global emissions of NO_x and NH_3 amount to 56 and 54 million ton N per year, respectively. Livestock production is by far the dominant source for atmospheric NH_3, while industrial sources and fossil fuel combustion are the most important sources of NO_x. Regionally, this pattern varies, for example, in regions with extensive rural areas or where large-scale burning is in progress.

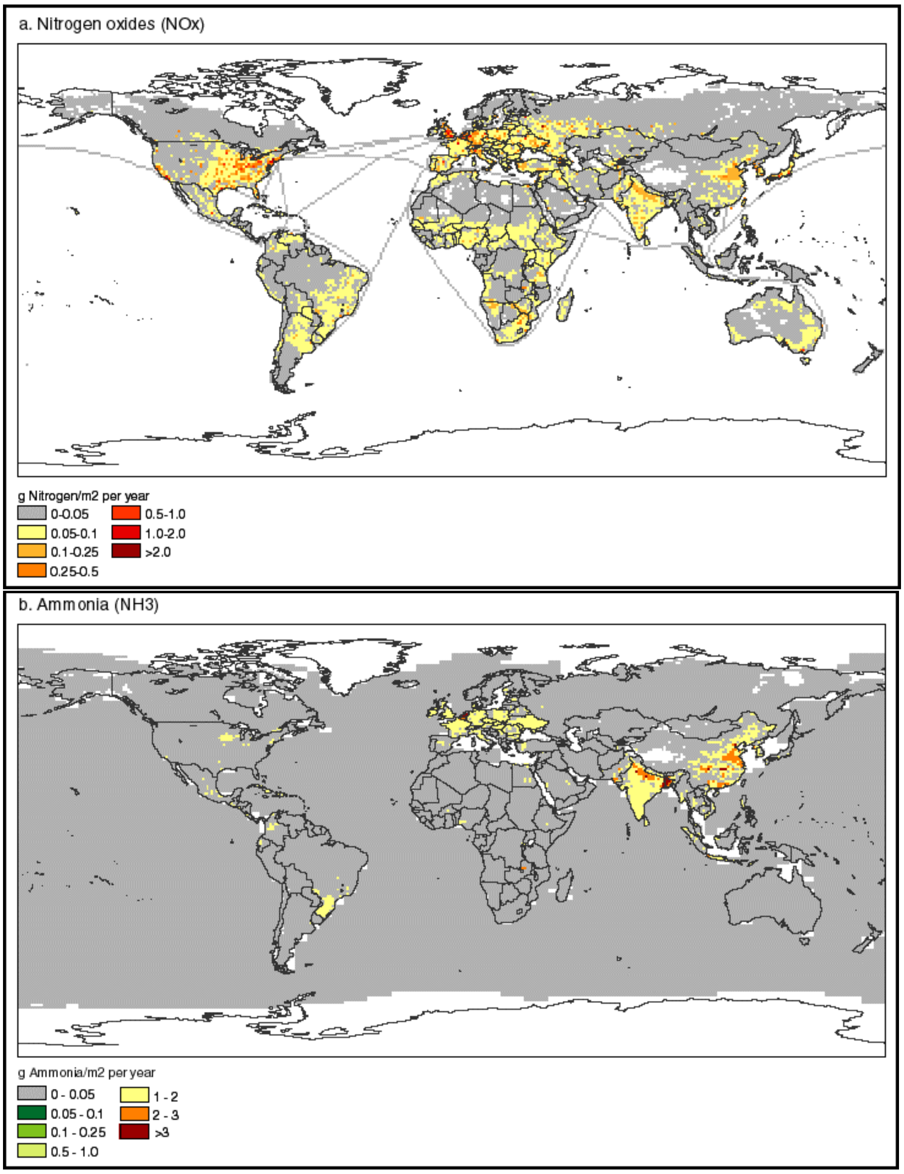


Figure 4.3.1. Global distribution of emissions of a) nitrogen oxides (NO_x) and b) ammonia (NH_3) from all anthropogenic and natural sources, including oceans, 1990, for 1 dg cells.

Sources: RIVM-EDGAR (Olivier *et al*.,1996) for NO_x, and Bouwman *et al*. (1997) for NH_3. For NO_x , the emissions from soils were derived from Davidson and Kingerlee (1997), which is an update on the basis of recent measurements and a detailed stratification scheme of the current inventory of Yienger and Levy (1995) for the Global Emissions Inventory Activity.

Deposition. The calculated 1992 deposition onto global land areas amounts to and $4.4x10^{12}$ eq N per year (Stevenson *et al.*, 1998). The highest mean regional nitrogen deposition rates of 1200 mg nitrogen per m^2 per year occur in Eastern Europe. South Asia and OECD Europe have mean deposition rates of 80-90 meq nitrogen per m^2 per year, respectively. Other regions with somewhat lower deposition rates are Japan and East Asia. The highest maximum deposition rates (~150 meq nitrogen per m^2 per year) occur in East and South Asia and somewhat lower deposition rates occur in Western and Eastern Europe, North America, South East Asia, Western and Eastern Africa and Japan.

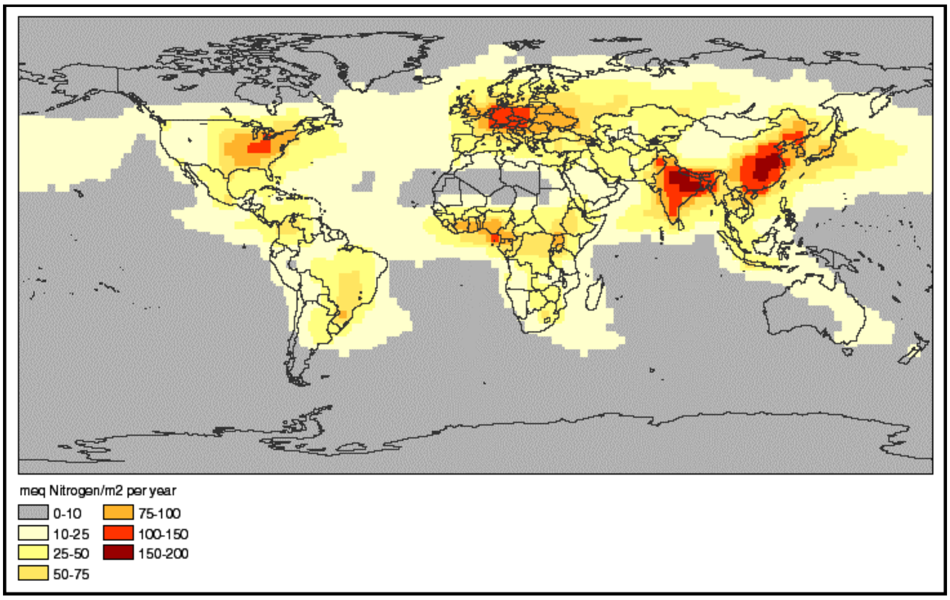


Figure 4.3.2. Annual total (wet plus dry) deposition of nitrogen.
Source: Deposition is simulated with the STOCHEM model (Stevenson *et al*., 1998). The original model output is presented as 5°x5° grid boxes. For this study the data were converted to a 1°x1° grid using a smoothing filter.

Critical loads. The regions with the highest potential susceptibility to nitrogen deposition (2.5-5 kg N per ha per year) are in northern Canada, Scandinavia and northern Russia, all host to tundra-taiga systems (Figure 4.3.3).

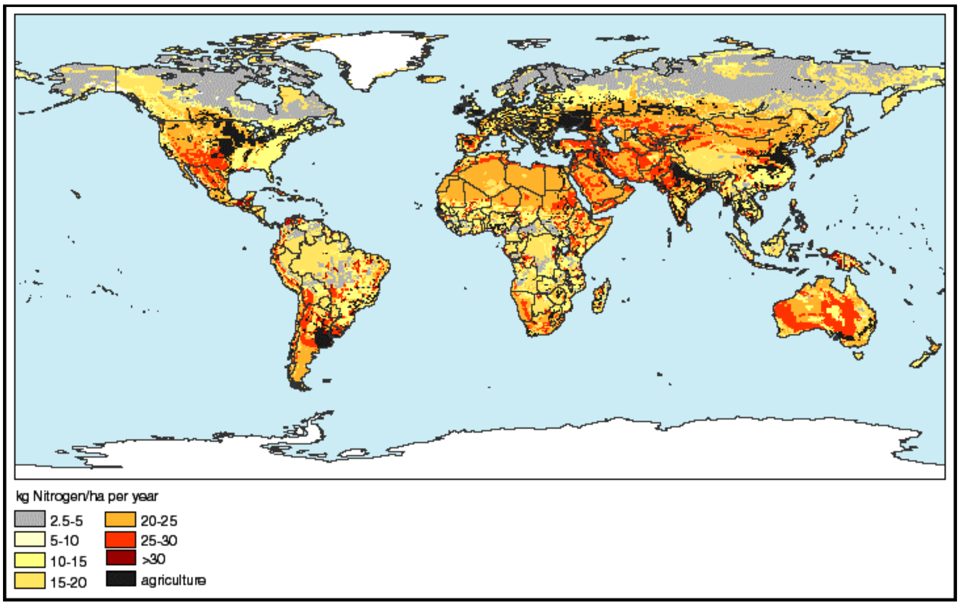


Figure 4.3.3. Medium ranges of critical loads for nitrogen used in this study.
Source: RIVM (Bouwman and Van Vuuren, 1999. In the original report, three sensitivity ranges were compared.

Scattered regions of high susceptibility occur in South America and Africa. In tropical forests the low soil pH is the major cause of low critical load values, while in other parts the ecosystem itself (savannah and other dry and semi-arid vegetation types) is highly susceptible, locally exacerbated by low soil pH. Intermediate susceptibility occurs in the western USA, Europe and Russia.

Table 4.1. Percentage of the area of (semi-) natural ecosystems with exceedance ratio > 1.0 for a number of major world regions.

Region	Exceedance ratio (%)	Ecosystem most affected
Canada	5 (2-17)	Temperate forest
USA	21 (18-25)	Temperate forest
South America	12 (7-21)	Tropical seasonal and dry forest, savannahs
Western Africa	16 (13-27)	Savannahs
Eastern Africa	8 (6-15)	Savannahs
Southern Africa	4 (2-11)	Savannahs
OECD Europe	32 (20-45)	Temperate forests
Eastern Europe	61 (44-77)	Temperate forests
Former USSR	9 (3-21)	Tundra and taiga ecosystems
South Asia	32 (24-38)	Tropical forests
East Asia	19 (15-25)	Tropical forests
South East Asia	12 (6-22)	Tropical rainforests
Japan	6 (3-9)	Temperate forests
World	*11 (7-18)*	

Eutrophication risk. Deposition exceeds critical loads for eutrophication in 7-18% of the global area of (semi-) natural ecosystems (Table 4.1). Large parts are affected by nitrogen deposition, particularly in Europe and North America. In the former USSR 9% of the (semi-)natural ecosystems is affected mainly in remote tundra and taiga ecosystems. Within the group of developing countries, Asian and African countries have extensive natural and semi-natural areas where critical loads are exceeded. The results suggest that, apart from the heavily industrialised regions, a number of regions with low population densities, such as South America and Africa, and remote regions in Canada and the former USSR, may become or already be affected by nitrogen eutrophication.

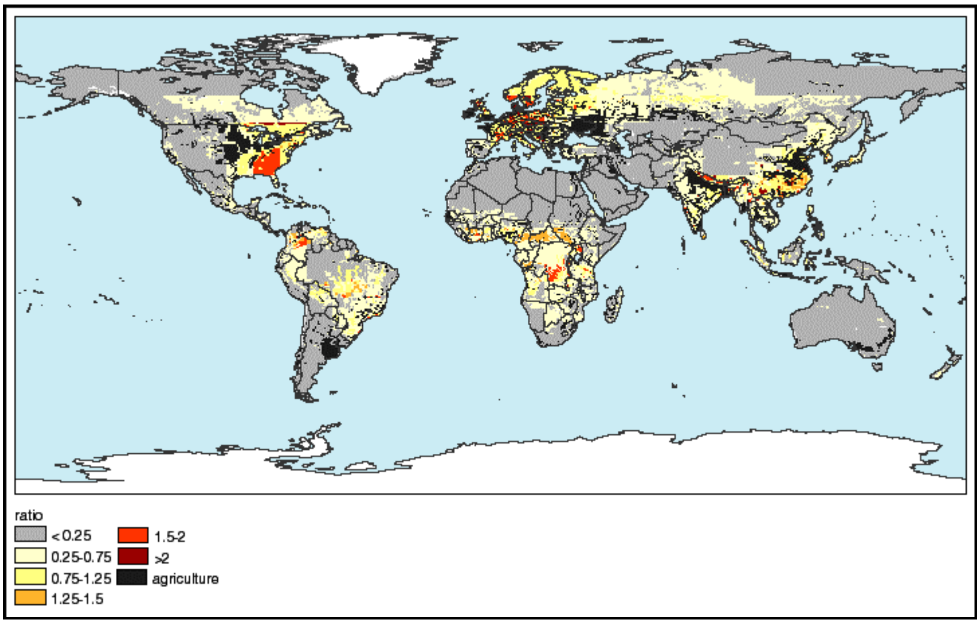


Figure 4.3.4. Exceedance of the critical load of nitrogen, for the medium estimate of critical loads (expressed as the ratio of nitrogen deposition and the critical loads)
Source: RIVM (Bouwman and Van Vuuren, 1999)

Future trends. Scenarios indicate that agricultural nitrogen (fertilizer and animal waste), the dominant source of NH_3, may double between 1995 and 2025 in tropical countries. Scenarios for anthropogenic NO_x emissions excluding agriculture indicate an increase of 50%, with no or only slight increase in North America and Europe. Major increases come from southern and eastern Asia, the Middle East, Africa and Latin America. This suggests that in many tropical regions nitrogen emissions and deposition may sharply increase in the near future, and that problems of nitrogen-related eutrophication may be aggravated and expand over larger areas in these regions.

The data-to-information process for this example of eutrophication is identical to that of acidification as depicted in Figure 4.2.5.

4.4 Climate change: how do we assess the greenhouse effect?

The increasing atmospheric concentrations of greenhouse gases (GHGs: CO_2, CH_4, N_2O, CFCs and others) will lead to a change in radiative forcing and, hence, to changes in global and regional climate. **Emissions** of GHGs stem from several natural processes and ecosystems, and human activities. Emissions are increasingly dominated by human activities, such as the burning of fossil fuels for energy and deforestation. Central to the DPSIR chain of climate change are the global bio-geochemical cycles of carbon and nitrogen. These cycles determine the final atmospheric **concentrations** through a broad range of processes and their interactions. For example, plants absorb CO_2 through photosynthesis, which ecosystems can either store or release (CO_2 photosynthesis is larger than respiration or smaller than decomposition). The rate of most processes is dependent on locally prevailing climatic **conditions**. The resulting change in climate has **impacts** on many natural and human systems. For example, the potential to produce food and other resources may change, sea levels may rise, distribution of plant and animal species may shift, and the frequency and magnitude of storms and other extreme weather events may change. All this, again, impacts on many economic and demographic activities and subsequently leads to changes in emissions, thus closing the DPSIR loop.

The data-to-information flow can be illustrated as follows:

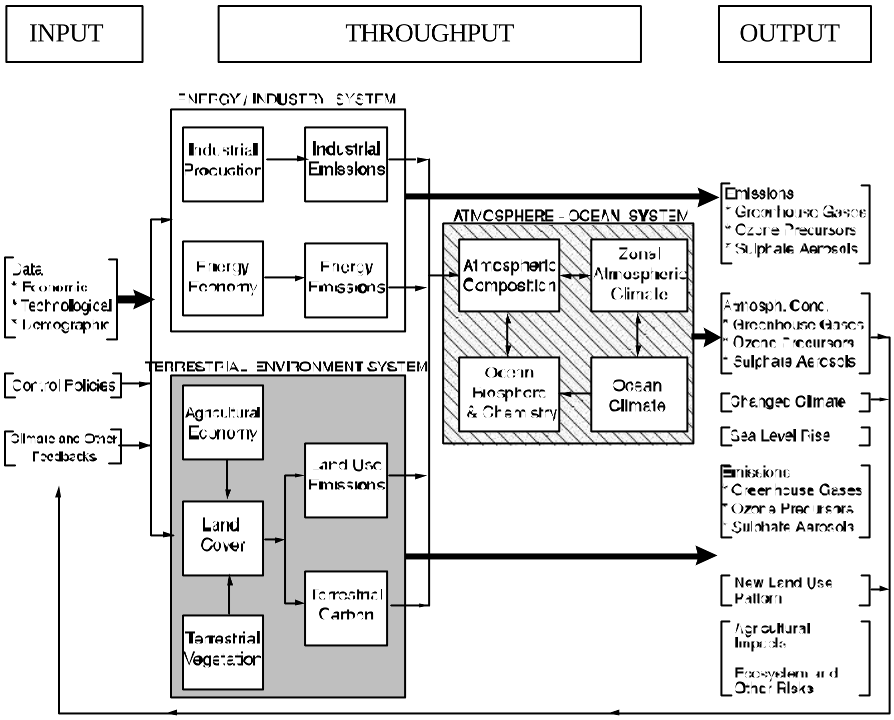


Figure 4.4.1. Input-throughput-output flow for climate change assessment.
Source: Alcamo *et al.* (1998)

The main conclusion of IPCC's second assessment report (SAR) was that the balance of evidence suggests a discernible human influence on climate (Houghton, 1996). This conclusion was based on the resemblance of simulated patterns by GCMs (theory) and observed climatic change over the last century. The SAR further concluded that there are large uncertainties with respect to the understanding of the processes and to the assessment capabilities for future emissions and concentrations, regional climate change and impacts and responses. Thus, these uncertainties increase toward the outward ends of the DPSIR chain.

A decade ago, the first Integrated Assessment Models (IAM) for the climate system emerged. Initially, these models were straightforward energy-balance models, which were coupled to emission-energy models. Fluxes from land-use change (i.e. deforestation) were generally prescribed. Environmental impact models were sometimes attached as well (e.g. IMAGE-1, Rotmans *et al*., 1990). These early IAMs were still strongly natural science-based, but showed that without climate policies, emissions would continue to increase, leading to a doubling of the concentration of greenhouse gases by the middle of next century (Pepper, 1992). Gradually, the IAMs were further developed. The first broad integration of the DPSIR chain in climate-change models has been achieved in IMAGE-2 (Alcamo *et al*., 1998) and TARGETS (Rotmans, 1997). These models include more advanced routines that determine changes in energy use and land use, and include technology improvements and changes in demand and resource availability. They further incorporate a wide range of impacts on sea level, ecosystems and agriculture, and also quantify and calculate many important feedback mechanisms within the climate system. The TARGETS model, moreover, emphasizes different responses by explicitly including several cultural perspectives. The models, currently being integrated to develop a single, broad and consistent integrative global environmental assessment tool, enable projections and analysis of environmental change over the next century.

The environmental and societal data sets needed to initialize these models are obtained from international organizations (e.g. World Bank, OECD and FAO) and research programmes (e.g. IGBP and IHDP). Scenarios with largely different assumptions on demographic, economic and technological developments, and with or without dedicated climate policies, have been developed and used to support negotiations with the Framework Convention on Climate Change (FCCC) and the scientific assessments of IPCC and IGBP. The scenario simulations illustrate the major negative consequences that will occur if no action is taken through climate policies. These include:

- A doubling of current atmospheric levels of CO_2 by 2050 and important negative impacts on crops, natural vegetation and sea levels in all regions;
- The rate of increase of impacts on world vegetation, which could be larger in the first half of the next century than ever before or thereafter.
- Impacts on vegetation (agricultural and natural) which will slow down in the second half of the next century, but sea levels that will continue to rise substantially.

Chapter 5. What are the emerging data issues? Three cross-cutting requirements

In addition to practical data problems encountered when applying core data to a specific assessment (GEO-2000), applying the DPSIR framework to environmental issues also reveals several broad data issues deserving special attention. These relate to the geographic scale and spatial resolution of assessment, to the need to encompass policy responses and to a broadening of the concept of environment to environmental sustainability. These cross-cutting issues are addressed here, again, by pragmatic and recent examples.

5.1 Geographical scales: Water assessment

Theoretically, there is no water problem at the global scale. Not even one tenth of the amount that falls on land is currently consumed by society. Even when looking at the continental scale, there are hardly shortages of water. The water table of Africa is positive in the sense that availability is higher than actual use, and this situation will continue for a long time. But going further down the scale to the natural unit for water resources, i.e. river basins, problem areas can be easily noted, not only in the daily lives of farmers and city dwellers, but also among societies and countries, as witnessed by numerous overt or latent conflicts. Many relevant issues actually occur on even smaller units in both rural areas (irrigation) and urban areas (shortage, pollution).

From the assessment point of view, there is growing awareness that discrepancies between the demand and the availability of fresh water pose a threat to sustainable development. In other words, development of society and economy is in competition with ecosystem integrity. Both water quantity and water quality are at stake here. The situation seems to be getting worse in many areas all over the world. Predicted global changes may aggravate water stress in the future, in particular, climate changes. The water issue requires research and assessment at these different scales in order to serve as instruments in solving the problem:

- Global: assessment of the nature and magnitude of water problems in order to prepare for proper policy actions at the international level (UNEP, CSD); some quality aspects are strongly connected with global issues; e.g. the nutrient impairment among regions stems from the uneven distribution of demand for and supply of food.
- Regional: assessment of the consequences of large-scale economic and social developments for the aquatic environment, and assessment of the impairment of demand and supply, both in time and place. Possible solutions must be obtained in regional agreements and conventions (e.g. EU); water-quality aspects sometimes have a regional component. Nevertheless, regionally differentiated approaches still need a common approach.
- Catchment: assessment of management options to support actual management in river basins; a comprehensive approach is especially challenging for international rivers; management at this level has to be agreed upon in treaties. At this level a comprehensive approach incorporating quality and quantity aspects will be necessary. Guidance and supportive methods provided by international bodies like UNEP can strengthen such assessments substantially.

In fact, it seems desirable to go even further down the scale i.e. to the local level of many relevant activities in society such as irrigation and urbanization. For instance, it would be somewhat misleading to conclude that there are hardly any water problems in the Niger River basin, while urban and rural dwellers experience frequent shortages in many parts of the tributary river basins. A cell-based approach, which allows the integration of complex activities and processes (urbanization, irrigation), seems more appropriate. In addition , the issue of time scale and horizon could be added here: an area might experience problems once every 10 years on average; but in practice it may happen four years in a row. Impacts, such as those from climate change, may only be apparent on long-term time scales. The implication is that we have to look back a reasonable time period e.g. 50 to 100 years and, for policy-relevant, integrated outlooks, also several decades into the future.

In support of global water assessments, various institutes (e.g. SEI, WRI, RIVM) have already developed databases, models and other tools. Applications have been made at various levels of detail and for various regions, but often in isolation. Further international cooperation and harmonization could benefit the assessment work substantially.

In any case, a critical challenge in freshwater assessments is how to deal with different geographical scales. Information on driving forces and socio-economic developments is usually available at the country level. Further refinement to areas of, for example, 50 by 50 km is needed for several variables, such as irrigation, population density and land use. Climate changes are relevant at the global and continental level. The actual freshwater assessments are only meaningful when based on calculations at the catchment level and below. Translations back and forth among these levels and processes require the use of dedicated geographic information systems (GIS). Tools have already been developed which use hydrological linkages between grid cells to perform these translations in a sophisticated way. Figure 5.1.1 illustrates the relation between different geographical scales.

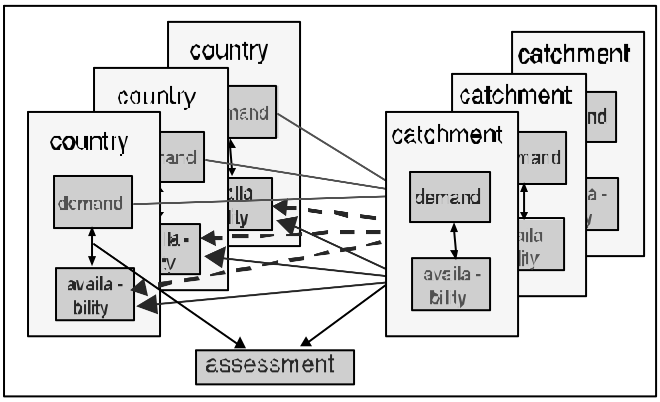


Figure 5.1.1 Relation between country and catchment scales.

I Assessing *global* water problems

The comprehensive assessment of the fresh water resources by the UN-DPCSD (with background documentation by SEI) compared present and future water withdrawal and availability on a country-by-country basis. This already provides insight into a number of the problems to be expected with water supply for personal consumption and irrigation. For various regions, however, the full extent of water problems is not recognized because of the scale of assessment.

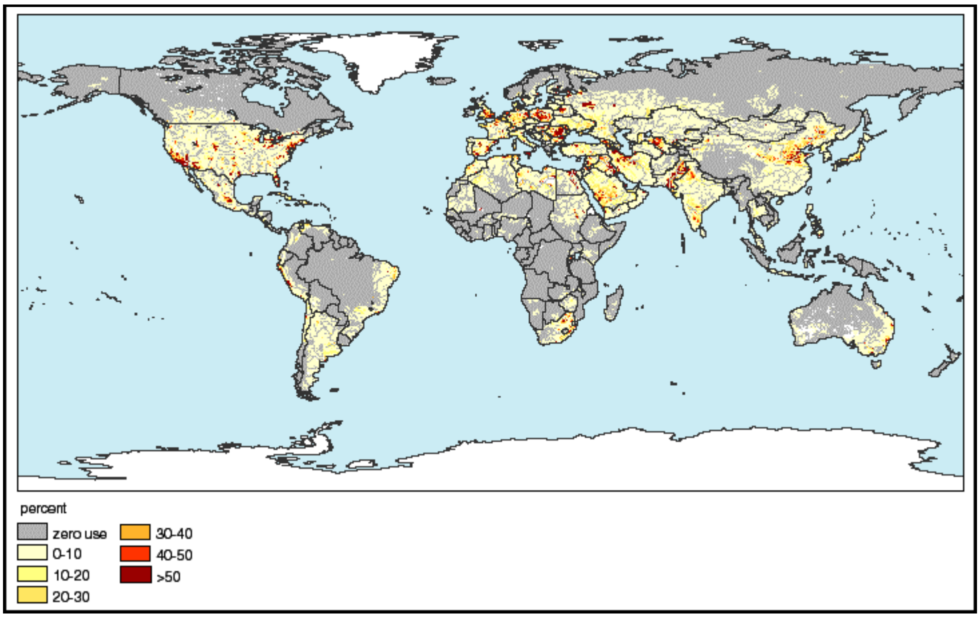


Figure 5.1.2 Water stress (total use / total resources).
Source: RIVM, Klepper and Van Drecht 1998

For the world as a whole, water stress was analyzed for GEO-1 using calculations at the catchment level. Presently, global water problems are more thoroughly assessed at the catchment and even subcatchment level, using clustering techniques to recognize similarities between problems in different regions and taking into

account the local scale of relevant processes. Figure 5.1.2 shows global water stress at a resolution of 0.5 degree to illustrate recent attempts to analyse this issue at the scale of the main processes that influence the consumption and availability of water. Similar approaches will probably help to clarify aspects of universal water problems and thus may contribute to solutions.
With global climate change as a distinct possibility, different regions of the world will have to cope with a different water situation than currently is the case. A first global scenario analysis has been made to broaden the scope of water assessments into the socio-economic domain (interactions with societal developments) using comprehensive assessment models such as TARGETS-AQUA and IMAGE/WaterGap.

However, at the moment available instruments at this level 'only' focus on water quantity. Future work will expand this to include major water quality issues, as exemplified by the case of nitrogen. Nitrogen (next to phosphorus) is the primary nutrient limiting plant, algae and microbial production in many freshwater and marine environments. Increases in nitrogen inputs (in any form) can alter those ecosystems. For example, shifts in plant and algal species composition, increased productivity, decreased species diversity, changes in foodweb structure, as well as development of hypoxic (low oxygen) and anoxic (no oxygen) conditions in aquatic systems (with consequences for fish and other higher organisms) can result from increased nitrogen inputs. World-wide, about 58% of the total export of Dissolved Inorganic Nitrogen (DIN) of 20.8 Mt nitrogen per year stems from fertilizers, while human sewage and deposition account for 24 and 18%, respectively. The contributions to nitrogen export from fertilizer use, deposition and human population show very similar patterns, with the highest nitrogen export in OECD Europe, Eastern Europe and southern and eastern Asia, largely reflecting the distribution of agricultural production intensity and human population.

Given human-induced acceleration of nitrogen fixation and other changes in the cycle, it is no surprise that nitrogen concentrations in surface waters have increased over time. Historical data indicate that nitrate fluxes and concentrations in the large rivers of the world are correlated with human population densities in watersheds (Cole *et al*., 1993). Using relatively undisturbed areas as references, Howarth *et al*. (1996) estimated that riverine total nitrogen fluxes from most of the temperate regions surrounding the north Atlantic Ocean have increased from pre-industrial times 2- to 20-fold. To illustrate the magnitude of global nitrogen inputs to rivers and aquifers, the results of a recent analysis by Seitzinger and Kroeze (1998) have been used in Figure 5.1.3. The results presented indicate that the largest riverine DIN transport and nitrogen inputs to estuaries are found in OECD Europe and Eastern Europe, north-eastern United States, South Asia, eastern Asia and South East Asia.

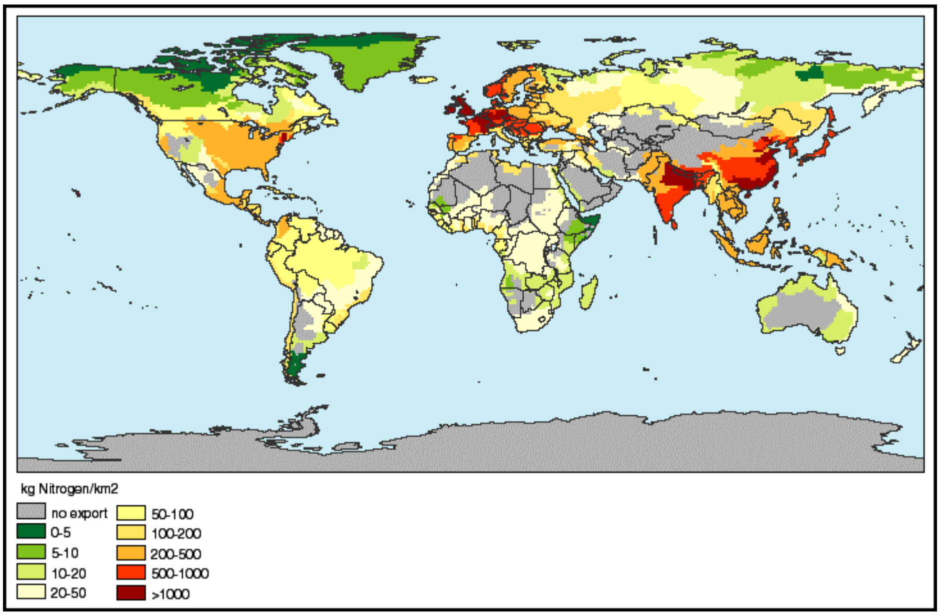


Figure 5.1.3 Export of Dissolved Inorganic Nitrogen by rivers from all discharges.
Source: Seitzinger and Kroeze 1998.

II Assessing *regional* water problems

In freshwater systems with sufficient phosphorus, addition of inorganic nitrogen can cause eutrophication. This can occur either independently or coupled to acidification (Schindler *et al*., 1985). Decreased diversity of both animal and plant species generally accompanies both eutrophication and acidification. Most often, eutrophication in estuaries and coastal seas is caused by anthropogenic nitrogen loading, in sharp contrast with freshwater systems in which phosphorus is the element limiting net primary production and controlling eutrophication (Schindler, 1977).

Eutrophication can cause anoxia and hypoxia, both of which appear to be becoming more prevalent in many estuaries and coastal seas. Conditions of low oxygen concentration have resulted in significant losses of fish and shellfish resources. Increasing anoxia has been observed in the Baltic Sea, Black Sea and Chesapeake Bay, while hypoxic events have increased in the North Sea, the Kattegat and Long Island Sound. Eutrophication is also associated with a loss of diversity, both in the benthic community and among planktonic organisms, as manifested by the incidence of nuisance algal blooms in many estuaries and coastal seas (Vitousek *et al*., 1997).

For aquatic ecosystems, it is difficult to establish a system of critical loads for nitrogen. This is caused by the complexity of the interactions between nitrogen and phosphorus in the eutrophication of freshwater systems, and the high seasonal and interannual variability of weather conditions causing runoff and associated nitrogen inputs and water discharge. Therefore, for aquatic ecosystems the anthropogenic nitrogen export (here assumed to be represented by DIN) is used as an indication of the potential for eutrophication.

The analysis of riverine DIN export to estuaries is a good illustration of the distribution of estuaries and coastal seas with potential eutrophication. However, the method can only be used to estimate total river export at the river mouth. To calculate concentrations of nitrogen in freshwater systems, in combination with phosphorus, a similar but more advanced approach could be used. For this, river discharge at any point can be calculated on the basis of precipitation surplus, runoff and flow to groundwater. Together with nitrogen and phosphorus in the runoff, the concentrations of these in the water can be calculated. The model used to calculate river discharge also calculates water percolation through the soils into aquifers. Hence, the same method could be used to calculate leaching of nitrogen and phosphorus to groundwater.

On a regional scale calculations have been carried out for Europe using the CARMEN model (Klepper *et al*., 1995) on a 10 x 10 min. resolution. The retention within watersheds and atmospheric deposition the export to European coastal seas has been calculated from the total nitrogen load of surface waters in watersheds (Figure 5.1.4). Results indicate that concentrations depend highly on the hydrologic conditions of coastal waters, with high concentrations in the Baltic and Black Seas (having less contact with oceanic waters), and lower concentrations in the North Sea, where water is constantly refreshed with oceanic water.

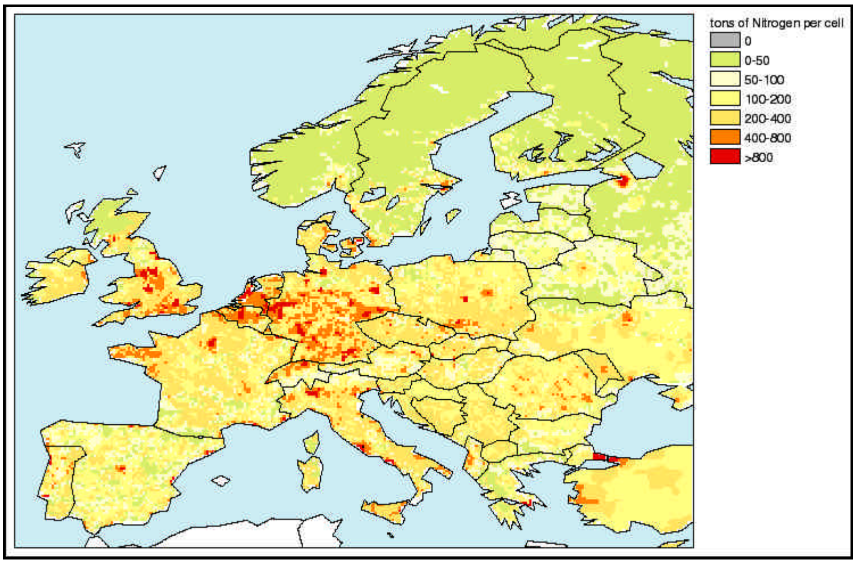


Figure 5.1.4 Total nitrogen load in surface waters in Europe, 2010.
Source: RIVM, Klepper *et al*, 1995

Using the CARMEN model, the nutrient fluxes in the European region have been recently analyzed, as well as other aspects of water stress (EU, EEA). Currently, European water assessment work is taking a step forward through the development of the Eutrophication Network.

III Freshwater assessments at *catchment* level

The third phase is a more thorough assessment of actual water problems in individual catchments. A Five Step Approach has been developed together with UNEP (Bannink *et al.*, 1997) as a tool to assist relevant parties in catchment analysis. Basically, the five steps are:

1. Setting the scene (characterization of the catchment)
2. Introducing the actors (characterization of socio-economic pressures)
3. Choosing the script (defining the system; quantifying the status and problems; 'Business as Usual')
4. Acting out possible futures (scenario analysis and assessment of possible measures)
5. Re-writing the script (implementation and management).

This approach has been used to study, for example, the Zambezi catchment and the subnational catchment of a tributary to the Pearl River, the Dong Jiang River (China). Results are presented in Table 5.1.

Table 5.1 Water Policy Score Card – 2025 for the Zambezi River system.
(Percentage change in index values by 2025 compared to 1995 levels, for eight scenarios; Bannink *et al.*, 1998 (in prep.))

Index	BaU	No measures	Supply max	Sanitation max	Waste water treat.	High irri-Gation	Saving water	Selling water
Pressure (demand+waste water)	44	92	64	44	-53	67	-21	43
State (availability+quality)	-4	4	-4	-4	-3	-7	-4	-5
Functions (power+food+ supply+sanitation)	-2	-20	7	8	-2	-2	-1	-3
Response	32	7	40	38	44	108	0	32

The Rhine River basin was studied earlier (Knoop *et al.*, 1996) by a consortium of European institutes in the comprehensive RHINE -DELTA analysis of nutrients, heavy metals and organic micro-pollutants. Figure 5.1.5 illustrates results from this study.

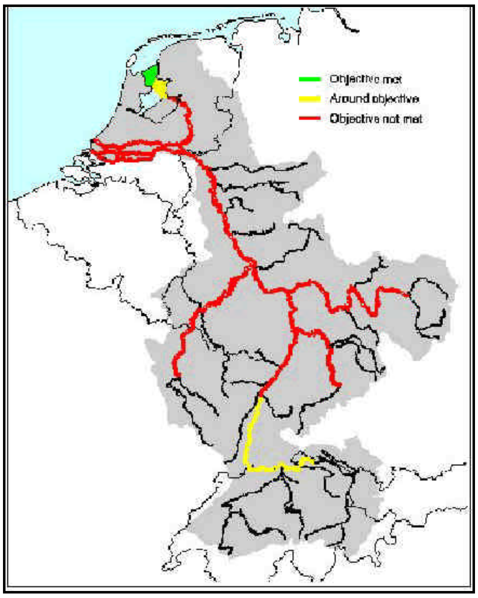


Figure 5.1.5 Lindane concentrations in surface waters in 2000 for the Rhine River basin.
Source: RIVM, Knoop *et al.*, 1996.

5.2 Policy responses: emission permit trade

Among the different steps in the DPSIR loop, I(mpacts) is now gaining more attention, and R(esponses) is probably still the weakest. Research on the effects of environmental policies and instruments is now taking off hesitantly. Growing focus on ways to address climate change after the Kyoto Protocol and Brazil Conference of Parties (CoP) presents an interesting challenge to evaluate the effectiveness of applying flexible policy instruments in order to curb the continuing increase of these emissions and to stabilize their levels in the atmosphere in the coming decades. These instruments relate to the trading of hypothetical emission permits among countries. Different possible cases have been analyzed:

- That no trade at all will take place in permits for emissions of greenhouse gases, and that each country adopts its own policy (unilateral policy);
- that permit trading will only occur among industrialized countries[1];
- that of full global trading of emission permits occurs.

Preliminary analyses with the WorldScan model (Geurts *et al.*, 1995) show that marginal cost reductions can be achieved through markets in which permits for emission of greenhouse gases are traded. Such trading effectively equalizes the marginal cost of emission reduction among countries.

Figure 5.2.1 shows the permit price (i.e. marginal cost of reduction) in 2015 and 2050. Prices are expressed per unit of avoided emission, in tonnes of carbon, assuming carbon dioxide as the greenhouse gas. All three cases are considered for 2015 (A), and only the last two for 2050 (B). For the medium term (Figure 5.2.1A) it is assumed that Annex-1 countries (A-1) will reduce emissions in accordance with the levels agreed in Kyoto plus an additional 3% of 1990 levels by 2015.

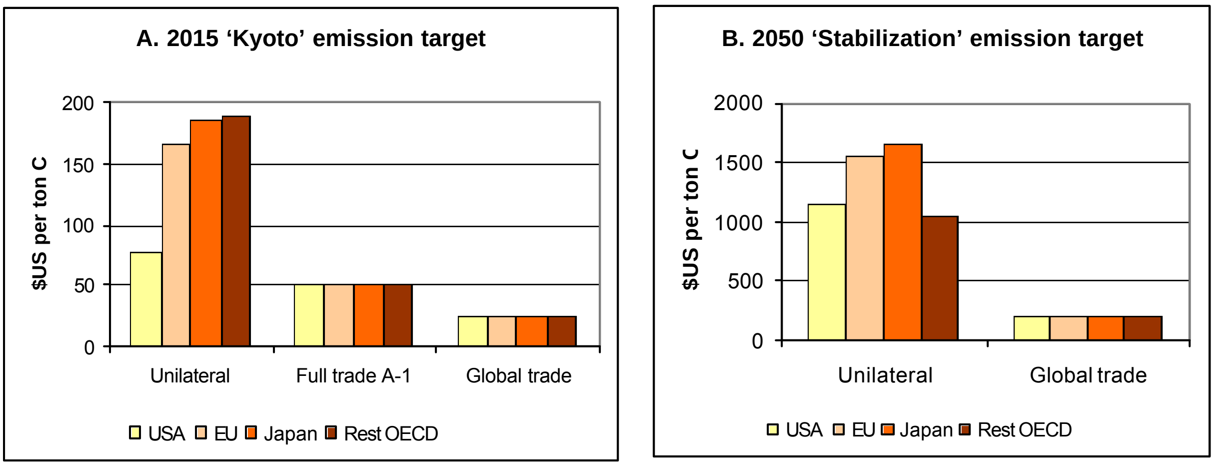


Figure 5.2.1 Carbon prices for stabilization: influence of flexible instruments (in $US 1992 per ton carbon), (A) 2015 'Kyoto' and (B) 2050 'Stabilization'.

In the case of unilateral policy (no permit trading), regional differences exist in the marginal cost to achieve the targeted emission level: up to $US 75 /t C and $US 160 /t C in USA and the EU, respectively, by 2015.

In the case of full permit trade in A-1 countries, the marginal costs of abating carbon dioxide emissions will be equalized through the competitive supply of and demand for permits on the market. The marginal costs of abatement in 2015 are lower in most regions when compared to the unilateral policy case where they would fall to $US 50 /t C. For this case, Eastern Europe and the former Soviet Union will become large exporters of emission permits on the A-1 permit market.

If, however, a global permit market is established, the marginal cost of abatement will fall even further, to $US 20 /t C. For the case of global trade, permits of Non-Annex-1 countries (NA-1) have been set equal to a Business-as-Usual scenario, while A-1 countries will receive permits up to the level agreed in Kyoto. Most of the NA-1 countries will then be exporters of permits on this global permit market.

[1] That is. the countries which appear on Annex-1 of the Framework Convention on Climate Change.

For the longer term (Figure 5.2.1B), binding targets for both A-1 and NA-1 countries are assumed. Global emission levels are supposed to result in stabilization of concentrations of greenhouse gases in the atmosphere at 550 ppmv by the year 2100 (IPCC, 1996, Wigley *et al*., 1995). In 20 years (up to 2045), regional permits will move from the 2025 regional emission levels (in NA-1), or the permitted levels (in A-1), to equal per capita emission levels.

Calculations show that a global permit market equalizes regional marginal costs of reducing emissions of carbon dioxide and will lead to a substantial reduction in the marginal costs. As can be seen from Figure 5.2.1B, in the unilateral policy case the A-1 countries would incur marginal costs for abatement greater than $US 1000 /t C, whereas this would be reduced to approximately $US 200 /t C in the case of global trade. In the latter case, the non-energy exporters among NA-1 countries are large permit exporters. Thus in the long-term, NA-1 countries gain by participating in a global permit market if they are granted appropriate amounts of permits.

This preliminary case study shows that flexible instruments can substantially reduce the costs of abatement for all countries, both in the short and longer term. Moreover, the countries with low-abatement costs are likely to be absolute winners, i.e. Eastern Europe and the former Soviet Union (in the A-1 permit case), and NA-1 countries that are not net-energy exporters (in the global permit case). Even in the case of global permit trade, Eastern Europe and the former Soviet Union will still incur lower costs than for the unilateral policy case.

5.3 From environment to sustainability?

Experiences over the last decades have shown that several important relationships exist between global and local environmental problems, and other issues such as human and economic development, population growth, poverty and changing political structures. In fact, many environmental problems arise largely from fundamental social or economic problems and cannot be solved by isolated measures in relation to environmental technology and legislation. The concept of ‘sustainable development’ has been put forward as a guiding concept for policy making to design development policies that appropriately address the economic and social needs and aspirations of a growing global population, while maintaining the quality of the environment and its resource base. It will become increasingly important to clearly place information on the environment within a sustainable development context.

The first Global Environment Outlook addressed mainly environmental issues as such. GEO-1 indicated the relative importance of these issues at the regional level and presented current trends. Environmental concerns appear to change over time, depending on the transitional stage of society. Human and ecosystems’ health and global environmental issues are usually not the highest priority in mainly agriculture-based economies. Environmental concerns related to urbanization and the use of natural resources often become more important in the transition towards industrialized and wealthy service-oriented economies. The environmental policy responses to these problems change accordingly from sectoral policies to market-based initiatives.

Assessment for sustainable development requires a broadening of both the assessment and policy horizon. It requires a comprehensive approach to all the economic, social and ecological issues involved. This is a difficult task, in part because sustainable development is a concept linked to values that depend on one’s cultural perspective. If one considers nature to be fragile, a precautionary type of environmental policy seems to be appropriate. However, if one considers nature to be robust, a virtually unlimited exchange of natural capital for economic and social capital is appropriate. In the end society, and therefore politicians, will have to decide what is sustainable and what is not. The uneven distribution of problems and opportunities in time and space will have to be taken into account when these decisions are made. Therefore, these decision-makers must be provided with the best scientific data and information in easily understandable form.

Many authors now agree that sustainable development simultaneously includes social, economic, environmental and institutional objectives. Consequently, assessment for sustainable development needs to address these four domains and their interaction. During the past few years several organizations and institutes have focused on assessment for sustainable development, in particular, through the use of indicators. An interesting step was made by the World Bank, which proposed to focus on different types of capital. Indicators of sustainable development will have to reflect the size of economic, ecological and social/human capital and the degree to which people actually have access to such capital. A system of indicators for meeting these requirements is not yet available. The Wuppertal Institute for Climate, Environment and Energy (Spangenberg and Bonniot, 1998) has proposed a set of indicators based on earlier work of the World Bank (Figure 5.3.1) and CSD.

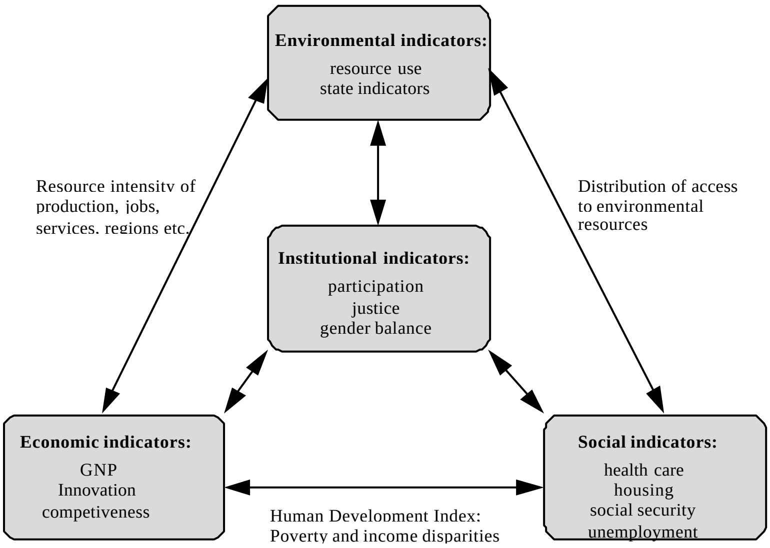


***Figure 5.3.1 Integrating indicators for new approaches to sustainable development*.**
Source: Spangenberg and Bonniot, 1998.

The potential use of indicators of sustainable development can be illustrated to a certain extent by some indicators currently being developed or already accepted among the international community. These include indicators for economic, social and natural capital (World Bank), human development (UNDP) and biodiversity pressures (Convention on Biodiversity, RIVM). The savings rate could indicate the vitality of an economy because it illustrates the capability to invest in new developments. Still under debate, the World Bank advocates the use of the 'genuine savings' rate, in which the investments and depreciation (or sales) of all forms of capital is accounted for. In summary, Sub-Saharan Africa, the Middle East and North Africa currently show a negative genuine savings rate of about 10 % of GDP per year. Latin America has also experienced a negative genuine savings rate, but there the trend has been reversed to a positive trend. With this method, the genuine savings rates in 'rich' regions are currently positive. The costs of solving environmental problems are - in comparison with national income - relatively low in these regions. Figure 5.3.2 shows the development of GDP in major world regions, as the main established and readily available economic indicator.

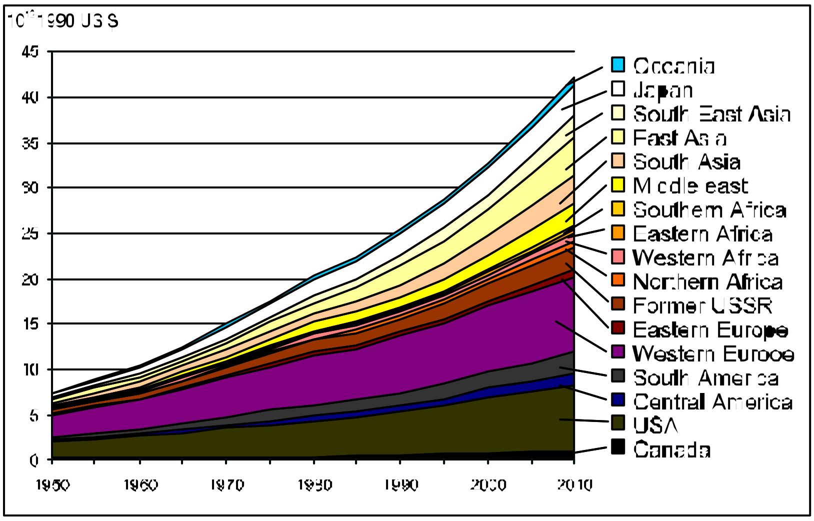


Figure 5.3.2 Regional GDP 1950–2010, expressed in Purchasing Power Parity. (Penn World Tables, Summers *et al*., 1994)

The social dimension of sustainability can be illustrated by the Human Poverty Index (HPI), as developed by UNDP (UNDP, 1997) (Figure 5.3.3). This index represents sets of variables expressing the percentage of people expected to die before the age of 40, access to social resources (education and health services) and access to natural resources (food and safe drinking water). Research reveals that the number of people living in poverty - following the definition of HPI – is likely to continue to decrease until 2010 (Hilderink, 1999). However, the numbers in Africa and India will still increase. Only a minority of the African population is not facing poverty at all. Access to natural resources will become a more important cause of poverty in developing countries. Access to adequate food and clean water is also an important factor in the improvement of public health.

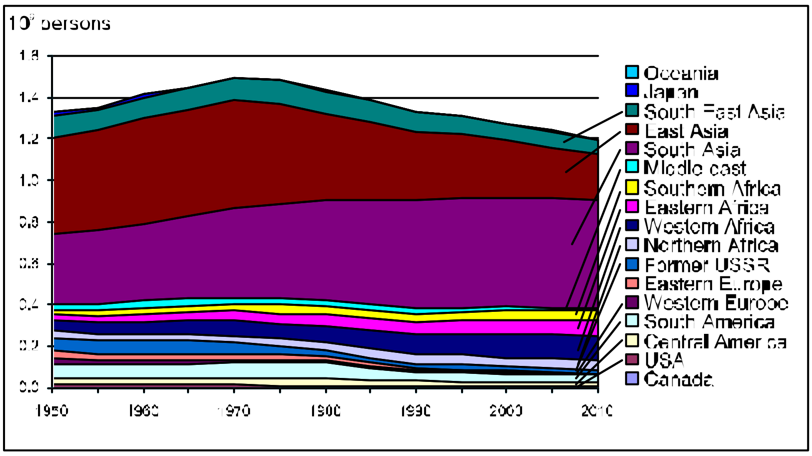


Figure 5.3.3 Population in poverty 1950–2010. (Hilderink, 1999)

Another major environmental health problem is air pollution, both in the developed and in developing countries. Air pollution by Suspended Particulate Matter (SPM) causes about 6% of the 50 million deaths that occur globally per year (WHO, 1997). Due to growing fossil fuel combustion, as well as increases in traffic and industrial emissions, air pollution is expected to become even more important, especially in countries in transition and in developing countries

The area of land used for human purposes in an extensive or intensive manner may increase by about 20 % in the period 1970–2050. Assuming a Business-as-Usual scenario, it is expected that in the next century some 40 % of the total land will have been domesticated, leaving around 35 % for forest, grassland or savannah (the remainder being ice or desert). The most rapid decrease in natural land takes place in Africa and Asia (Figure 5.3.4). The pace of conversion of land is already slowing down in North America and Europe; it might even be reversed. Agricultural reform is the main cause of these changes in land use patterns. World-wide, however, land conversion from nature to agriculture will be the most prominent cause of loss of natural capital. In addition, physical factors such as salinization, erosion and lowering of watertables, and pollution (acidification, eutrophication and smog) may have detrimental effects on the quality of ecosystems. Finally, climate change could also result in substantial changes in ecosystems. All these problems are highly connected in both their underlying causes and their effects.

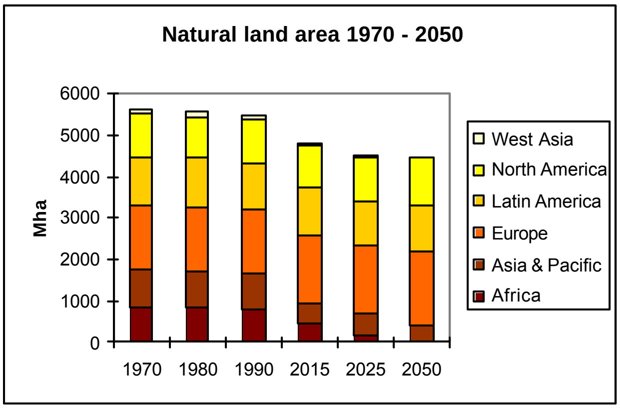


Figure 5.3.4 Natural land area 1970–2050 (forest, grassland, savannah). (Alcamo et al., 1998, Klein Goldewijk *et al.*, 1997). Note: total land area equals 13 000 Mha.

Chapter 6. Conclusions and recommendations: Towards better environmental information

The production of the first GEO and the underlying data management activities have made clear that it is necessary, but difficult, to focus attention on specific environmental issues in support of tangible assessment activities. Even modest proposals to mobilize the identified core data sets for GEO partners could not be realized. The Data Table exercise for the second GEO showed that it was even difficult to set up a limited, dedicated country statistics database for selected core data sets and to organize data validation at the regional/national level.

From these experiences and similar assessment work as presented in this report, one can conclude that the challenge is rather daunting. We do not even have a full and clear picture of what data are needed, nor do we know exactly what needs to be done to address the data issues and who should do what. However, our situation is not hopeless. We do have at least some idea of what the main environmental issues are (and might be in the future), and we do have a notion of the indicators and underlying data needed to assess these issues. What is clear is that we need to plan for flexibility and a generic approach: issues can change rather quickly over time, but indicators and certainly core data sets are already much more stable and generic in nature (i.e. at the bottom of the data-to-information triangle, see Figure 3.1).

In order not to get lost in the world of indicators and data, it would be desirable if any follow-up activity to the IEA/GEO core data work :

a. focused on priority environmental issues;
b. continued the efforts to clearly identify and address data gaps and shortcomings;
c. cooperated with other core data providers to avoid duplication and inconsistencies;
d. cooperated with collaborating centres to optimize the use of regional/national data.

a. Focus

In principle, the focus of assessment should be on issues that are most harmful to humans and the environment and thus jeopardize sustainability most. The policy-making process would further favour the analysis of those issues that are the easiest and cheapest to solve, taking into account any synergies among measures. A full-blown analysis of all potential environmental issues, their causes, effects, interlinkages and costs/benefits is beyond the scope of this report, and is actually addressed in the main GEO-2000 report and other global assessments. The list of issues is not fully fixed, as perspectives of what is important change over time. Some problems are solved while others, yet unknown, might need to be added in the future. But as stated in Chapter 1, a handful of global environmental issues stand out, as related land, water, and energy resources. These can be further disaggregated one level down into lists of some 15 to 25 environmental problems, as addressed in major global or regional assessment reports: climate change, water stress, urban pollution, ozone depletion, biodiversity etc. Such issues, depicted in Chapter 4 and elaborated in Chapter 5, are singled out or confirmed by past experience, current practice, common sense, global and/or regional consultations and survey, and may be generically itemized as encompassing:

- climate change,
- acidification & eutrophication
- ozone depletion,
- land degradation & deforestation
- biodiversity,
- fresh water,
- marine and coastal degradation,
- chemical risks,
- human health,
- urban stress

The point here is not so much that these may be the most prominent global or universal environmental issues, and thus need to be addressed first, but that analysis is necessary in terms of causes, effects and what the costs and benefits are of solving them. This implies the need for compilation of broad data sets, that is, beyond the state of the environmental state *per se*, including data on population, economy, energy and also on effects of policies on the environment and economy.

The geographical focus should be maintained at the global level, broken down systematically into (sub)regions on the basis of socioeconomic and political similarities. The compilation of data for global assessment should include data on spatial units other than 'just' countries or regions i.e. ecosystems, drainage basins as well as geo-referenced data with spatial resolution at the level of the processes to be studied (e.g. landuse change, water consumption patterns, urban pollution). Small-scale gridcells in the order of 5 min. could be instrumental here.

b. Specific data gaps & shortcomings

The core data needed for indicators on the above issues are already of a more generic nature, and have largely been addressed by IEA/GEO-related data initiatives, mainly through the Bangkok meeting, the IEA/GEO Core Data Matrix and the GEO-2000 Data Table exercise. From these we have learned that:

- Major gaps exist in information on impacts and responses (damages, costs, effectiveness, synergies)
- Important shortcomings and uncertainties exist in the monitoring of the state of the environment e.g. soil degradation, deforestation, climate change
- Even data on so-called straightforward, underlying subjects, such as population numbers, energy use, or country emissions, are immensely complicated and flawed by difficulties and uncertainties
- A wealth of data exists, but only a part is used, mainly due to ignorance, copyright issues, lack of documentation, incompatibilities and lack of regional/local expertise. Some data collection efforts have become obsolete, but still persist, while on the other hand several parameters are not monitored sufficiently (or not at all)
- Validation and recognition of data by governing bodies would greatly enhance policy-relevance. Derived policy information gains considerable status if the underlying data have been checked and recognized by regional bodies and/or national governments. Such reliable information is more likely to be used for formulating, implementing and monitoring of environmental policies
- Data quality and reliability continue to be major problems

From the exercises and examples discussed in this report, some specific data issues can be derived. Again, this picture needs to be completed with a 'full-blown' information analysis for the major issues related to environment and sustainability.

For the assessment of sulphur-related **acidification**, critical data issues include:

- knowledge on the sensitivity of ecosystems to acid deposition (local expertise)
- integration with nitrogen deposition to include all major causes
- long-term monitoring of concentrations and deposition for model validation and calibration
- coarse spatial resolution of global/regional deposition models and emission databases
- different geographical scales among D-P-S-I-R elements
- validation of top-down pressure data with bottom-up information
- availability and consistency of underlying data on economic and anthropogenetic driving forces, including derived data for gridded population density and urbanization

For the assessment of global **eutrophication**, major gaps in data and information stem from:

- uncertainties in the deposition fluxes and their spatial distribution, which are strongly dependent on the emission data and the atmospheric-chemistry transport model used
- scaling errors caused by differences in the spatial detail of the various data used
- poor regression models used for extrapolating riverine nitrogen loads
- lack of data on spatial distribution of agricultural nitrogen use within countries
- scant quantitative information on effects of enhanced nitrogen deposition on terrestrial and aquatic ecosystems

The analysis of eutrophication needs to be integrated with the assessment of other environmental stresses, including acidification and climate change. In future studies not only should nitrogen deposition be addressed, but also sulphur deposition, climate change and rising atmospheric CO_2 concentrations. Eutrophication studies could then also consider effects of increasing nitrogen inputs, changing climate and the CO_2 fertilization effect on ecosystem net primary production. Recommendations for future research on these topics are summarized in Table 6.1.

Table 6.1. Major uncertainties and recommendations for future global assessments in the field of emissions, deposition fluxes, critical loads and riverine nitrogen loads.

	Major uncertainties	Recommendation for future global studies
Emissions of NH_3 and NO_x	Lack of measurement data; scarcity of data on agricultural management; scarcity of information on spatial and temporal distribution of fluxes within countries	Since no data will be available in the near future to improve currently available emission inventories, one approach is to validate emission fields where possible, using forward and inverse atmospheric chemistry transport models.
Deposition fluxes	Low resolution of deposition fields which are used in combination with a high resolution vegetation database; errors in emission fields (see above) and chemistry transport models	Three alternatives approaches may be used: (i) use of source-receptor matrices on a 1^o grid for (sub)continental calculations; (ii) refining the chemistry transport model to $1^o x1^o$ resolution by accounting for sub-grid effects; (iii) Simple source-receptor matrix to be used in combination with country data on emissions.
Critical nitrogen loads	Eutrophication effects of enhanced nitrogen deposition in permafrost, arctic, tundra and taiga systems, high-altitude forests, calcareous soils, and tropical ecosystems, mainly tropical forests and savannahs	Stimulate field research, or consultation of experts world-wide.
General	Uncertainty resulting from omission of acidifying effects of nitrogen and sulphur, which may interact with eutrophication and climate change in certain regions	Consider eutrophication coupled with acidification, rising atmospheric CO_2 concentration and climate change.

For the assessment of **climate change**, the DPSIR chain is complex and dominated by feedbacks and other interactions. No individual discipline can claim to fully comprehend climate systems. Analysis of this issue could benefit substantially from integration among relevant disciplines. Many different models have already been developed to simulate (part of) climate systems (Harvey *et al*., 1997; Figure 6.1). The most frequently cited models are the General Circulation Models (GCM) for the Atmosphere. These climate models use (the change in) atmospheric concentrations of greenhouse gases to simulate the transient pattern of climate change. The models solve the complex process equations that describe 3-dimensional circulation in the atmosphere. The most recent models interact with ocean circulation and include a simple parameterization of the biosphere. Emissions, bio-geochemical cycles, atmospheric chemistry and impacts are not considered in these models. The GCMs are thus computationally complex but not very comprehensive with regard to the entire DPSIR chain. Other models that cover parts of the climate system are the biome models, the sea-ice models, and the carbon-cycle models (Figure 6.1).

Although our capabilities for carrying out climate-change science and assessment have developed rapidly over the last decade, the quality of climate-change assessments is still strongly dependent on the data used. Data and assumptions for socio-economic, energy, land-use and atmosphere variables need to be integrated at the level of countries, regions and interpolated cells ranging in size from 1 km2 to 10 dg2. These resolutions do not always allow for the necessary coverage of all the administrative, spatial and temporal heterogeneity and diversity that determines the driving forces and responses.

More serious data problems arise, however, when attempts are made to create historical data sets over longer time periods in order to validate the assessment models that describe relevant trends. The HYDE database, covering the period 1880-1990 was envisioned to be of use in a long-term validation experiment over a period with known outcomes i.e. the last century (Klein Goldewijk and Battjes, 1997). This experiment proved very difficult due to large gaps in available socio-economic and environmental data. Although some regional and global data collection systems have been improved, a globally comprehensive system for both socio-economic and environmental data is not yet available. Blueprints for such a global observation strategy have only recently been drawn up (i.e. IGOS, the Integrated Global Observation Strategy).

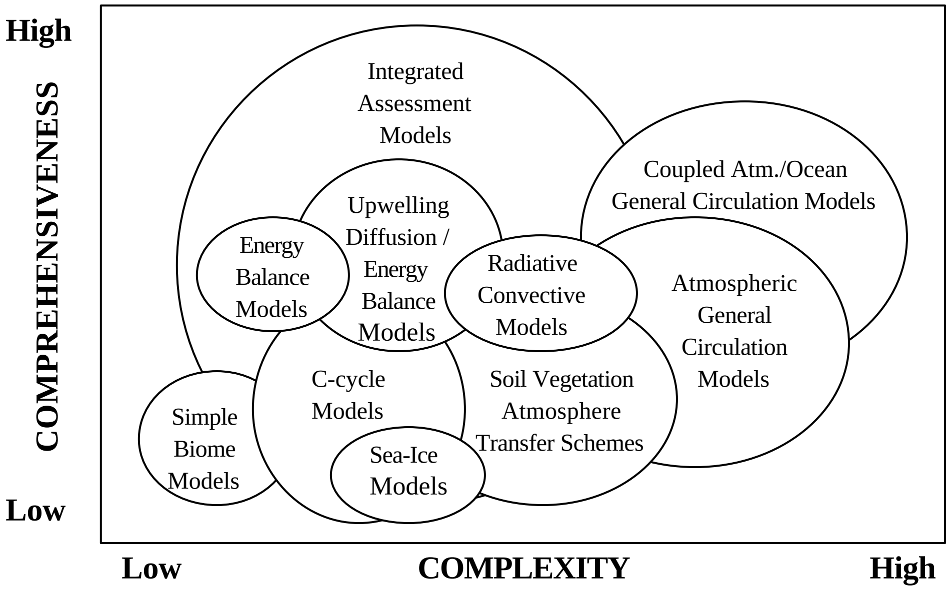


Figure 6.1 Different models to assess climate change and its components.

The following data issues can be mentioned in assessing global **water** resources:

- Water quantity: scarcity in some regions; in urban areas linked with quality problems; conflicts over water between regions/countries and users (environmental security); abundance and security problems elsewhere;
- Water quality: a variety of problems, such as health (microbiological); eutrophication and toxification
- Integration of water quantity (groundwater and surface water) with water quality is needed for a comprehensive assessment of water as a global resource, while also accounting for relationships with issues such as eutrophication, acidification, desertification and erosion.
- Analyses need to be performed for regions with common economic policy (e.g. EU), and in collaboration with the countries that have interests in a particular catchment; interactive scenario analysis has proven to be a powerful tool in reaching acceptable conclusions.

c. Generic empirical base, common to major global reporters

The examples in this report serve to illustrate *parts* of the information processes for *part* of the environmental issues. What needs to be done is to complete this picture i.e. to further define and prioritize global and regional environmental and sustainability issues, and to analyze the information needed for the assessment of these issues. After that we can explicitly state what can be done with existing data and what additional data needs to be collected. This will provide us with a clear notion of what is necessary to address the major issues and elements adequately, and what is not. The next step is to further guide the global programmes and organisations aimed at data collection and coordinate the availability of the relevant data to those who perform the environment assessments. It is recommended to set up a global mechanism that will bring together the compilers of global assessments on environmentally sustainable development (as data users) and key actors in the production and dissemination of the required data. Such a mechanism should elaborate on specific, realistic arrangements to address data gaps and accessibility, and take initiatives to better cooperate with global monitoring activities such as Earthwatch and IGOS. Furthermore, this mechanism should facilitate data sharing with secretariats created through multilateral environmental agreements.

There is not so much need for whole new data collection efforts; more attention is needed for better targeted compilation, validation, (regional) inspection and accessibility for GEO and related assessments. From a pragmatic point of view at least three actions could be undertaken:

1. Known core data sets like the World Development Indicators, FAOSTAT, IGBP DISCover, IEA Energy Balances can already be made more easily available as part of the common observation/survey layer (see Figure 3.1, observation/survey layer). In many countries and regions, a political decision is needed to what extent core environmental data can be made freely and publicly available.

2. Such 'raw' data sets can be validated, complemented and aggregated at the regional level identified under GEO for recent years, and taking into account standard coding systems, units of measurement and regional/national inputs with the help of Collaborating Centres (Figure 3.1, core data layer)
3. The overview of needs and issues can be completed so as to further guide data collection from the perspective of environment and sustainability in the coming years.

Thus, although still modest, it would be highly beneficial if global assessments could tap from a consolidated, well-documented and easily accessible common core data layer of 'no-regret' data sets, most notably times-series on driving forces and pressures (population, economy, energy, emissions, climate, land use) at aggregate geographical levels. This idea was already proposed at the IEA/GEO Core Data meeting in 1996, and partially tested at the country level through the GEO-2000 Data Table exercise. Global compilations such as WRI's World Resources Database and the World Bank's World Development Indicators have been very instrumental during this work. Together with additional regional data compilation work for GEO-2000 (GRID, RIVM), these exercises have again proven that much value can be added by building such a global IEA/GEO core data table. Such work can benefit from recent work by UNEP/GRID-Geneva for GEO-2000, and by RIVM for global change modelling. This has resulted in consistent basic data on population, economy, land use and energy, for major regions of the world for at least the 1970-95 period (GEAS under http://www.rivm/nl/env/int/coredata)

d. Feedback mechanism

An important lesson learned is that the actual use of even the best available and well-documented data sets can pose major problems in terms of inconsistencies and incompatibilities. Things are never what they seem, not even core data sets. Differences in data definitions, units of measurement, coding systems, reference years, as well as missing values and anomalies, are among the most notorious data problems for global change researchers. More precisely, typical data problems relate to differences in definition of *contents* (e.g. what area exactly is labelled as 'forest' or 'grassland' in the case of ecosystem delineation), differences in *spatial resolution* (country statistics, soil units, river catchments, gridded emissions and depositions) and differences in *reference years* or simply not having anything up-to-date. Validation of results with independent data is obvious (if possible at all), and so is documentation of sources and methods. Errors are often reported back to the data supplier, but usually on an ad-hoc, individual basis. In this field of complex data logistics for environmental policy-making, it would be very relevant, and still 'do-able', to have aggregate assessment results checked at the regional level, while reporting data problems back to the respective sources (e.g. discuss landuse data problems with FAO, population data with UN-DESA, economic data with theWorld Bank). A validated and authorized global core data table can thus develop iteratively; these data are needed to produce assessments that can be accepted by policy makers and really be used for taking action.

The development of a consistent, authorized and easy available core database requires a dedicated organization and network. Currently, bits and pieces are picked up by GRID centres, RIVM, World Bank, WRI, CIESIN and a few others, but no one is really sufficiently charged with the task of supporting IEA/GEO by developing such a core set, while cooperating with data-providing agencies, GEO collaborating centres and overlapping assessment programmes.

For immediate action to improve data availability for environment assessment, it is recommended that:

- The analysis of information needs be completed, focusing on priority environmental issues and including underlying causes as well as impacts on humans and nature;
- A start be made with developing a set of 'no-regrets' data sets on driving forces and pressures at the regional level, using existing work done by GRID, RIVM, WRI and others;
- Coordination with monitoring programmes be further strengthened, taking into account the needs from the perspective of integrated assessment of environment and sustainability issues;
- Access to indicators and underlying data for Collaborating Centres be improved through a dedicated GEO-2000 intranet platform, the public Internet and CD-ROM;
- The participatory approach and data status be strengthened through capacity-building at regional centres for integrated environment assessment, and data validation and feedback;
- More attention is paid to institutional and political aspects of observation and to translating data into information; a better understanding would lay the foundations for long term improvement of the data situation.

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List of abbreviations

Symbols:

C	: Carbon
CO2	: Carbon dioxide
H2SO4	: Sulphuric acid
N	: Nitrogen
NH3	: Ammonia
NOx	: Nitrogen oxides
SO2	: Sulphur dioxide

Units:

Dg.	: Degrees
Ha	: Hectares
Min.	: Minutes
t	: Ton
Tg	: Tera gram (trillion)

Abbreviations:

CARMEN	: Cause-effect Relation Model for Environmental policy Negotiations, RIVM
CBS-NL	: Statistics Netherlands
CCE	: Coordinating Centre for Effects, RIVM
CEC	: Commission of the European Communities
CEOS	: Committee on Earth Observation Satellites
CEU	: Central European University
CFC	: Chlorofluorocarbon
CGEIC	: Canadian Global Emissions Interpretation Centre
CIESIN	: Consortium for International Earth Science Information Network
CoP	: Conference of Parties (to the FCCC)
CORINE	: Coordination of Information on the Environment, EEA Task force
CRU	: Climatic Research Unit, University of East Anglia
DIN	: Dissolved Inorganic Nitrogen
DPSIR	: Driving forces-Pressures-State-Impact-Response framework
EDGAR	: Emission Database for Global Atmospheric Research, RIVM
EEA	: European Environment Agency
EMEP	: European Monitoring and Evaluation Programme
ENTRI	: Environmental Treaties and Resource Indicators, CIESIN
ESRI	: Environmental Systems Research Institute
EU	: European Union
FAO	: Food and Agriculture Organisation
FCCC	: Framework Convention on Climate Change
G3OS	: Global Observation System (GTOS/GCOS/GOOS)
GCM	: General Circulation Models
GCOS	: Global Climate Observation System
GDP	: Gross Domestic Product
GEIA	: Global Emissions Inventory Activity
GEMS	: Global Environmental Monitoring System
GEO	: Global Environmental Outlook
GHG	: GreenHouse Gases
GIS	: Geographic Information Systems
GOOS	: Global Oceans Observation System
GRID	: Global Resource Information Database, UNEP
GTOS	: Global Terrestrial Observation System
HPI	: Human Poverty Index
HYDE	: History Database of the Global Environment, RIVM
IAM	: Integrated Assessment Models
IEA	: Integrated Environment Assessment

IGBP	: International Geosphere-Biosphere Programme
IGFA	: International Group of Funding Agencies for Global Change Research
IGOS	: Integrated Global Observation Strategy
IHDP	: International Human Development Programme
IIASA	: International Institute of Applied Systems Analysis
IISD	: International Institute for Sustainable Development
IMAGE	: Integrated Model to Assess the Greenhouse Effects, RIVM
IMF	: International Monetary Fund
IPCC	: Intergovernmental Panel on Climate Change
MOGUNTIA	: Model of the Global Universal Tracer transport In the Atmosphere, RIVM
MSU	: Moscow State University
NASA	: National Aeronautics and Space Administration
NCGIA	: National Center for Geographic Information and Analysis
NGO	: Non-Governmental Organisation
NOAA	: National Oceanic and Atmospheric Administration
ODS	: Ozone-Depleting Substances
OECD	: Organisation for Economic Co-operation and Development
OFDA	: Office of U.S. Foreign Disaster Assistance
RAINS	: Regional Acidification Information and Simulation, IIASA
RIVM	: National Institute of Public Health and the Environment, Netherlands
SAR	: IPCC's Second Assessment Report
SEI	: Stockholm Environment Institute
SoE(R)	: State of the Environment (Report)
SPM	: Suspended Particulate Matter
SPOT	: Satellite Pour l'Observation de la Terre
STOCHEM	: UK Meteorological Office Global Three-Dimensional Lagrangian
TARGETS	: Tool to Assess Regional and Global Environmental and health Targets for Sustainability, RIVM
TOMS	: Total Ozone Mapping Spectrometer
UN	: United Nations
UN-CSD	: Commission on Sustainable Development
UN-DESD	: Department of Economic and Social Development
UNDP	: United Nations Development Programme
UN-DPCSD	: Department for Policy Coordination and Sustainable Development
UN-ECE	: Economic Commission for Europe
UNEP	: United Nations Environment Programme
UNEP-DEIA	: Division of Environment Information and Assessment
UNEP-EAP/AP	: Environment Assessment Programme for Asia and the Pacific
UN-ESCAP	: Economic and Social Commission for Asia and the Pacific
UNESCO	: United Nations Educational, Scientific and Cultural Organisation
USA	: United States of America
USSR	: Union of Soviet Socialist Republics
UV	: Ultraviolet
WCMC	: World Conservation Monitoring Centre
WDI	: World Development Indicators, World Bank
WHO	: World Health Organisation
WMO	: World Meteorological Organisation
WRD	: World Resources Database, WRI
WRI	: World Resources Institute

Annex 1. Summary of IEA/GEO Core Data Set Matrix

Data set name	Source	Time period	Geographical coverage	Spatial resolution
Agriculture, forestry, fishery				
AGROSTAT 1992	FAO	1961-1990	world	countries
Animal stocks European Union	Eurostat	1977-1995	Europe/EU	NUTS-0/1
Crop areas European Union	Eurostat	1975-1995	Europe/EU	NUTS-0/1
FAOSTAT 1995	FAO	1961-1993	world	countries
Growing season database Europe	RIVM	1992	Europe	thematic areas, 10“ x 10”
Historical agricultural indicators (HYDE)	RIVM	1890-1990	world	countries, regions
International fertilizer statistics	IFA	1971-1994	world	countries
Time series state of food and agriculture world (SOFA’94)	FAO	1961-1993	world	countries
World fishery production (FISHSTAT-PC)	FAO	1950-1994	world	countries
Climate				
Climate database Europe	CEC	1930-1987	Pan-Europe/EU	stations
CLIMATE global database (temp., precip., evapo., cloudiness)	RIVM	1931-1960	world	0.5^{o} x 0.5^{o}
IIASAClimate Database	IIASA	1991	world	0.5^{o} x 0.5^{o}
Monthly surface air temperature and precipitation world	NCAR	1920-1980	world	0.5^{o} x 0.5^{o}
Observational Data Sets (ODS) of weather stations	ECMWF	1980-1989	world	stations
Precipitation excess Europe	RIVM	1991	Europe/EU	0.5^{o} x 0.5^{o}
Wind Vector Grids in Europe	KNMI	1983-1996	Pan-Europe	stations
Demography, health				
Demographics of the republics former Soviet Union (FirstBookDIS) 1992	New World Demographics	1950-1990	CIS	sub-national
Global Mortality Database	WHO	1950-1995	world	countries
Global population density	NASA, Harvard University, UNEP	1984, 1985	world	1^{o} x 1^{o}
Global population density and totals	NCGIA	1994	world	5“ x 5”
Gridded population data world per country	CIR/CIESIN	1971-2005	world	20“ x 30”, 5“x 7.5”
Health for all, Europe	WHO	1970-1990	Europe	countries
Health for all, global indicators	WHO	1983-1994	world	countries
Historical population indicators (HYDE)	RIVM	1890-1990	world	various
International Data Base (global demographic and socioeconomic data)	CIR	1950-2050	world	countries, provinces
Mortality for sub-national administrative units of Europe	Eurostat	1980-1990	Europe/EU	NUTS-2
OECD-CREDES Health data programme	AEA	1960-1990	OECD	countries
Population density Africa	UNEP	1991	Africa	5“ x 5”
Population density China	NGS	1987	China	sub-national
Population density Europe	RIVM	1989-1992	Pan-Europe	10“ x 10”
Sub-national boundaries and population of Latin America, US, Europe, Africa, CIS	CIAT,ESRI, Eurostat,UNEP, NWD	1971-1990	Latin America	sub-national
World cities population database WCPD	UNEP	1990	world	places
World cities populations	Bartholomew	1991	world	places
World population prospects: the 1992 revision	UN-DESIPA	1950-2025	world	countries
World population prospects: the 1994 revision	UN-DESIPA	1950-2050	world	countries

Data set name	Source	Time period	Geographical coverage	Spatial resolution
Economy				
Africa Development Indicators	World Bank	1970-1994	Africa	countries
Historical economic indicators (HYDE)	RIVM	1890-1990	world	countries, regions
Time series European Union: Eurostat-CD, Panorama of EU-Industry	Eurostat	1983-1993	Europe/EU	NUTS-2
Trade Analysis System PC-TAS	UNCTAD/ITC/ GATT	1990-1994	OECD	countries
World Debt Tables 1993-94	World Bank	1970-1993	world	countries
Environment				
Acid deposition in Europe	RIVM	1989	Europe/EU	thematic areas
Agricultural waste burning	RIVM	1991	world	1^{o} x 1^{o}
Air Quality in Major European Cities	RIVM	1985-1992	Pan-Europe	places
AIRBASE Air Pollution Information System	CEC	1968-1995	EU, Pan-Europe	stations
Aluminium concentrations in groundwater in Europe	RIVM	1990	Pan-Europe	10“ x 10”
Areas with saline seepage in the European Union	RIVM	1996	Pan-Europe	thematic areas
Biomass burning	Max Planck Institute	1975-1980	world	1^{o} x 1^{o}, 5^{o} x 5^{o}
CORINAIR	CITEPA	1985, 1990	Europe/EU	NUTS-1/2/4
Critical loads/levels in Europe	RIVM	1996	Pan-Europe	150 x 150 km
EDACS: European Deposition Maps of Acidifying Components on a Small scale	RIVM	1989, 1993	Pan-Europe	10“ x 10”
EDGAR: Emission Database for Global	RIVM	1971-1992	world	1^{o} x 1^{o}
Endangered ecosystems Europe	RIVM	1992	Pan-Europe	thematic areas, 10“x 10”
Environmental statistical database (IEDS)	UN-ECE	1980-1992	OECD	countries
Erosion database Europe	ISRIC	1992	Pan-Europe	thematic areas, 10“ x 10”
European Air Quality Maps	RIVM	1989-1990	Pan-Europe	5 0 x 50 km
Forest soil ecosystems database	SC-DLO	1992	Pan-Europe	0.5^{o} x 1^{o}
Global assessment of human induced soil degradation (GLASOD)	UNEP/ISRIC	1991	world	thematic areas
Global distribution, characteristics, methane emission natural wetlands	NCAR	1986	world	1^{o} x 1^{o}
Global Ecosystems Database	USDOC/NGDC/ EPA	1992	world	10“ x 10”
Global ecosystems database 1992, 1994	NOAA-NGDC/ ERL/ EPA	1992-1994	world	l0“ x 10”
Global environmental research data (Global Grass CD II)	US-ACE	1993	world	5“ x 5”
Global ozone data (TOMS)	NASA	1978-1991	world	1^{o} x 1^{o}
Groundwater nitrate concentration Europe	RIVM	1992	Europe	thematic areas
Groundwater resources in the EC	RIVM	1992	Europe	thematic areas
Halons and methyl chloroform production and emission data	ICI	1960-1992	world	thematic areas
Holdridge Life Zone Classification	IIASA/RIVM	1931-1960	world	0.5^{o} x 0.5^{o}
Hydrogeology Africa (RIVM)	UNDP	1994	Africa	thematic areas
Landfills in Europe	Eurostat	1991	Europe/EU	NUTS-2
LOTOS emission database 1986	TNO	1986	Pan-Europe	1^{o} x 2^{o}
Methane emission from animals	NCAR	1984	world	1^{o} x 1^{o}
NASAglobal distribution of aircraft emissions	NASA	1990	world	1^{o} x 1^{o}
Nitrogen excretion by various categories of animals	RIVM	1985	world	1^{o} x 1^{o}
Nitrogen loads Europe	RIVM	1991	Europe/EU	various
Nitrogen pollution in Europe	RIVM	1991	Europe/EU	thematic areas
Pesticides loads Europe in soils and groundwater	Eurostat/FAO/ RIVM	1991	Pan-Europe	countries, 10“ x 10”

Data set name	Source	Time period	Geographical coverage	Spatial resolution
Production and Emission data on CFCs and HCFCs	AFEAS	1931-1991	world	places
Protected areas Africa	UNEP	1989	Africa	thematic areas
Risk map of European nuclear powerplants	RIVM	1992	Pan-Europe	0.5^o x 1^o
Road traffic: fuel consumption and emissions	TNO	1990	world	countries
SO_2 concentrations Europe	RIVM	1992	Europe/EU	5“ x 5”
Socioeconomic impacts study environmental problems (SEIS)	RIVM	1994	India	country
Soil Organic Matter Map of Europe	RIVM	1993	Europe/EU	10“ x 10”
Soil Water Holding Capacity	NASA	1990	world	1^o x 1^o
Total Ozone Mapping Spectrometer (TOMS)	NASA	1978-1991	world	1^o x 1.25^o
Tropospheric Ozone Research (TOR)	Eurotrac/EMEP	1988-1995	Pan-Europe	stations
Wetlands Africa	ESRI	1993	Africa	thematic areas
Wetlands in the European Communities	CEC	1991	Europe/EU	thematic areas
World ecosystems (Olson)	NOAA	1970-1989	world	0.5^o x 0.5^o
World wilderness areas	UNEP	1989	world	thematic areas
WSL global distribution of aircraft emissions at 5 x 5 degree	WSL	1989-1990	world	5^o x 5^o
Industry, energy				
BP Statistical Review of World Energy	BP	1965-1993	world	countries
Energy Statistics and Energy Balances	IEA	1960-1992	OECD	countries
Historical energy/emissions indicators (HYDE)	RIVM	1890-1990	world	countries, regions
Historical industrial indicators (HYDE)	RIVM	1890-1990	world	countries, regions
IISI Steel Production and ConsumptionI Statistics	ISI	1983-1992	OECD	countries
Industrial Areas in the EU	RIVM	1992	Europe/EU	thematic areas
UN Energy Statistics and Population Database	UNSTAT	1950-1991	world	countries
UN-ECE Buildings Statistics	UN-ECE	1980-1990	world	countries
UNSO Commodity Production Statistics	Aristotle University	1970-1990	world	countries
Land cover				
Experimental calibrated global vegetation index ECGVI 1994	NOAA	1985-1991	world	10“ x 10”
Global distribution of rice paddies	RIVM	1994	world	1^o x 1^o
Global distribution of wetlands	Max Planck Institute	1988	world	2.5^o x 2.5^o
Global soils for climate research (Zobler)	NGDC		world	1^o x 1^o
Global vegetation database (Matthews)	NASA/GISS	1992	world	1^o x 1^o
Historical land cover indicators (HYDE)	RIVM	1890-1990	world	various
Monthly generalized global vegetation index	NOAA	1985-1988	world	10“ x 10”
Natural Vegetation of the European Communities	CEC	1989	Europe/EU	areas
Normalized Difference Vegetation Index (NDVI)	NOAA	1983-1984	world	1^o x 1^o
Pan-European 10 minutes land use database	RIVM	1975-1990	Pan-Europe	10“ x 10”
Pan-European land use statistical database	RIVM	1985-1990	Pan-Europe	various
Pan-European land use vector database	RIVM	1975-1985	Pan-Europe	thematic areas
Soil database for Europe	RIVM	1993	Europe/EU	10“ x 10”
Soil Map of the European Communities	CEC	1985	Europe/EU	thematic areas
Soil map of the world	FAO/UNESCO	1974, 1994	world	thematic areas
Vegetation map of Brazil 1988	USGS/EDC	1988	Brazil	thematic areas
Vegetation, land use and seasonal albedo	NCAR	1950-79	world	1^o x 1^o
World Soils for Global Climate Modelling (Zobler)	NASA	1974-1981	world	1^o x 1^o

Data set name	Source	Time period	Geographical coverage	Spatial resolution
Broad data sets				
Global socioeconomic indicators (World Data) 1994, 1995	World Bank	1962-1992	world	countries
Global topographic database: digital chart of the world (DCW) 1992, 1993	ESRI	1993	world	various
Human Development Report database 1994-1995 (UNDP)	RIVM	1992	world	countries
Social Indicators of Development 1993-1994	World Bank	1965-1992	world	countries
World development indicators (WDI) 1994	World Bank	1970-1992	world	countries
World resources database 1992-1993	WRI	1970-1993	world	countries
World Tables 1993, 1994	World Bank	1970-1992	world	countries
Global topographic database: ArcWorld 1: 3M 1992	ESRI	1992	world	various
Support information				
Chemical Evaluation Search And Retrieval System (CESARS)	Mich.Dep. of Nat.Resources	1983-1995	world	---
CHEMINFO	Mich.Dep. of Nat.Resources	1983-1995	world	---
Delta Study	IIASA	1950-1988	Rhine basin	catchment
Development activity information world (DAI) 1994,1996	IDRC	1930-2013	world	world
ECOTOX aquatic ecotoxicological database	RIVM	1993-1994	world	---
European emission sources	RIVM	1980-1994	Pan-Europe	0.5^o x 1^o
Global elevation map ETOPO-5	NOAA/NGDC	1986	world	5“ x 5”
Global relief data	NOAA/NGDC	1980-1990	world	various
Global river basins database	RIVM	1996	world	catcments
Global topographic grids	RIVM	1996	world	various
Hydrogeology Europe (RIVM)	RIVM	1993	Pan-Europe	thematic areas
Major settlements Pan-Europe	CEC/EEA	1989	Pan-Europe	places
Maps ‘n’Facts (PC Globe). World Edition, Version 1.0	Broderbund Software	1989-1991	world	countries
Monthly river discharge of major rivers	GRDC	1996	world	stations
River basin Ganges, Bramaputra	RIVM	1994	India	catchments
River basin Rhine, Meuse	RIVM	1995	Pan-Europe	catcment
River basins Africa	UNEP	1984	Africa	catchments
River basins Europe	RIVM/Eurostat	1994	Pan-Europe	catchments
River basins world (GGHYDRO)	Trent University	1994	world	catchments, 1^ox 1^o
River basins world (Global Grass)	Rutgers University	1993	world	catchments, 5“ x 5”
RTECS - Registry of Toxic Effects of Chemical Substances	NIOSH	1983-1996	world	---
Topographic index of world places (Times World Index)	Bartholomew	1991	world	places
UNCED Earth Summit Rio de Janeiro 1992 / Agenda-21 / Treaties	IDRC	1972-1992	world	world
World boundary databank WBDII 1972	DMA/ESRI/ UNEP	1972	world	various
World boundary databank WBDII 1972 - PC version	UNEP	1993	world	various
Worldwide digital terrain data (TerrainBase)	NGDC	1994	world	various