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CONCEPTS AND METHODS OF ENVIRONMENT STATISTICS STATISTICS OF THE NATURAL ENVIRONMENT

A Technical Report

UNITED NATIONS

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DEPARTMENT OF INTERNATIONAL ECONOMIC AND SOCIAL AFFAIRS

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Preface

Under the guidance of the Statistical Commission and with the financial support of the United Nations Environment Programme (UNEP), the Statistical Office of the United Nations Secretariat launched a phased programme for the development of environment statistics. The first phase (1978-1982) consisted of surveys of data needs and statistical practices of countries and international organizations. The results of these surveys have been presented in two publications, *Survey of Environment Statistics: Frameworks, Approaches and Statistical Publications*[1/] and *Directory of Environment Statistics*.[2/] The surveys revealed the need for a flexible framework which would facilitate the organization and development of statistics on the complex subject of the environment.

The current second phase of the programme has been devoted to the development of *A Framework for the Development of Environment Statistics* (FDES)[3/] and to the provision of further methodological guidance for the establishment of environment statistics at the national level. The scope and contents of FDES and thus of environment statistics themselves have been based on the perception of environmental problems and statistical priorities of countries; their views were expressed in regional workshops and national pilot studies, organized by the Statistical Office of the United Nations Secretariat, in cooperation with the United Nations regional commissions, UNEP and other organizations.

At its twenty-third session, the Statistical Commission requested that a technical manual for the compilation of selected high-priority statistics in the areas of human settlements and natural resources be prepared by the Statistical Office of the United Nations Secretariat.[4/] However, since environment statistics are still at a relatively experimental stage of development, it was deemed more appropriate to present concepts and methods of such statistics as a series of technical reports rather than a manual.

The first draft of the present report was prepared by Anthony Friend (Institute of Research on Environment and Economy, University of Ottawa) with the support of Statistics Canada. The report complements another publication, *Concepts and Methods of Environment Statistics: Human Settlements Statistics*.[5/] Together, the reports cover the whole field of environment statistics as delimited by FDES. By applying the FDES structure and principles to those reports, the environmental aspects of natural resource and human settlements statistics were determined, including related social, demographic and economic statistics.

The major purpose of the technical report series is to propose concepts, definitions and classifications for statistical variables that describe high-priority environmental issues in most countries and that can be compiled by national statistical services in an environment statistics programme. Extensive use of national and international compendia of environment statistics has been made in order to identify those concepts, definitions, classifications and data sources which are most widely applied. The statistical variables identified in this manner are therefore likely to reflect typical data needs of planners, policy makers and administrators in environmental and related socio-economic fields.

Even then, the sets of variables presented in the report may still be too extensive for the initial phases of an environment statistics programme. The goal is, however, to provide national statistical offices with at least a starting point for a first selection of appropriate statistical series and to assist them in the determination of relevant definitions, classifications and data sources. From this point of view, the report can be considered as an extension of the original FDES - i.e., as a framework that facilitates the establishment of environment statistics programmes, rather than as an international recommendation of generally accepted concepts, definitions and classifications. Particular environmental conditions, data needs, statistical capabilities and national priorities may well require data sets that differ both in scope and in content from those presented in this report.

It is the intention of this report to promote the application of the methodologies proposed in it and its companion on the environmental aspects of human settlements statistics at the regional and national levels, in cooperation with the regional commissions of the United Nations and other interested international organizations. Experience gained from applying the reports in countries is expected to lead to further modification. In particular, the possibilities of combining the two reports for the selection of key baseline statistics required for establishing minimum or phased programmes of environment statistics could be further explored. The reports should thus become a useful tool in the development and harmonization of environmental data collection at national and international levels.

The draft report was circulated to United Nations bodies, other international organizations and experts in the field for the discussion of its format, technical contents and applications. The numerous comments and contributions received are gratefully acknowledged. Further comments on this first attempt to present a consistent picture of concepts and methods in a new and rapidly developing field of applied statistics are not only welcome but are deemed invaluable for refining and standardizing the existing methodologies.

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Units of measurement

Numbers	nos.	(numbers)
Area	km^2	(square kilometre)
	ha	(hectare)
Volume	m^3	(cubic metre)
	bbl	(barrel)
	l	(litre)
Weight/mass	t	(ton)
	kg	(kilogramme)
	mg	(milligramme)
	μg	(microgramme)
Length	km	(kilometre)
	m	(metre)
	mm	(millimetre)
Heat units	J	(joule)
	cal.	(calorie)
	kw	(kilowatt)
	kwh	(kilowatt hour)
	°C	(centigrade)
Expenditure/cost/value	$	(monetary value)
Time	hrs	(hours)
Other (level/proportion)	pH	(acidity)
	BOD	(biological oxygen demand)
	ppm	(parts per million)
	GBq	(gigabecquerel)
	pCi	(picocurie)
	%	(percentage)

INTRODUCTION

Environmental concerns have increasingly become the subject of mainstream policies. Sustainable development has been generally advocated as the best approach to integrating environmental concerns into national and international socio-economic development.[8] Such integration needs to be supported by similarly integrated databases. From the outset, the scope and contents of environment statistics have therefore included, apart from bio-physical data, related social, demographic and economic statistics - as reflected in the generic *A Framework for the Development of Environment Statistics*,[3] described below in some detail. Further relationships with economic statistics, notably those presented in national accounts are discussed in annex I.

Environment statistics are thus interdisciplinary in nature. Their sources are dispersed, however, over a variety of data-collecting institutions, and a similar variety of methods are applied in their compilation. Environment statistics aim to overcome this heterogeneity by providing a synthetic presentation of data from various subject areas and sources. This is to assist in the formulation and evaluation of coordinated - if not integrated - socio-economic and environmental programmes and policies. The scope of environment statistics includes the media of the natural environment (air/climate, water, land/soil), the biota found within these media, and human settlements. Within this broad range of subject areas, environment statistics describe the quality and availability of natural resources, human activities and natural events that affect the environment, the impacts of these activities and events, and social responses to these impacts.

Environment statistics are compiled, stored and disseminated by central statistical services, government departments, specialized research institutes, local authorities and international organizations. They are collected through censuses, surveys, the use of administrative records and monitoring networks. Many of the same institutions are also the major users of environment statistics. Further demand for environmental data arises from business and industry, scientists, the mass communication media and the general public.

1. A framework for the development of environment statistics

The interdisciplinary character of environment statistics and the variety of data producers and users call for a comparative analysis of data availability and the coordination of data collection, processing and dissemination. The systematic development and organization of a complex field of statistics is a familiar concern which has been addressed by means of statistical systems, frameworks or less rigorous methodological guidelines. Various national and international efforts have been made towards developing systems or frameworks for environment statistics, either for planning a programme of such statistics or for presenting available data in a coherent statistical publication. Some years ago these efforts were surveyed by the Statistical Office of the United Nations Secretariat in order to identify common characteristics which could be incorporated into a widely applicable international framework.

Based on the results of these surveys, *A Framework for the Development of Environment Statistics*[3] (FDES) was prepared. The major objective of FDES is to assist in the development, coordination and organization of environment statistics. More specifically, FDES is designed to:

(a) Review environmental problems and concerns and determine their quantifiable aspects;

(b) Identify variables for statistical descriptions of the quantifiable aspects of environmental concerns;

(c) Assess data requirements, sources and availability;

(d) Structure databases, information systems, statistical publications and methodological guidelines.

FDES relates components of the environment to information categories, as shown in table 1. The components of the environment define the scope of environment statistics. Statistics of the natural environment thus refer to the environmental media of air, water and land/soil, as well as the biota (flora and fauna) found in these media. Statistics of the "man-made" environment are the subject of a previously issued report on *Concepts and Methods of Environment Statistics: Human Settlements Statistics*[5/] (cited as "*Human Settlements Statistics*" below). That report addresses the environmental aspects of human settlements which consist of physical elements - namely, shelter and infrastructure - and services to which these elements provide the material support.

The information categories of FDES reflect the fact that environmental problems are the result of human activities and natural events. Human activities and natural events have an impact on the environment, which in turn provokes individual and social responses to avoid or mitigate these impacts. A priori, this sequence of action, impact and reaction would suggest further analysis of cause-effect relationships. However, such relations are not specified in FDES. Its purpose is primarily organizational rather than explanatory, focusing on the identification, description and presentation of data variables which should be useful in tracing and verifying the interrelationships. A distinction, should thus be made between a system of statistics like the System of National Accounts (SNA) and a framework like FDES. The latter is more in the nature of a logical structure to organize information, whereas the former can be likened to a model based on identities and double bookkeeping entries. The activity-impact-response structure of FDES begins to approach the modelling perspective, however, when, for instance, the databases are organized on a stock/flow basis, as in the case of natural resource accounting (see annex I).

The contents of FDES are termed "statistical topics". They describe those aspects of general environmental concerns which can, at least theoretically, be subjected to statistical assessment. The determination of statistical topics under each information category constitutes an important step towards the identification of relevant statistical variables for each topic. The statistical topics are reviewed in some detail throughout the present report. The following brief description of the information categories under which the statistical topics are presented shows the defining characteristics of both the information categories and their respective statistical topics.

Table 1. Format of the framework for the development of environment statistics

Components of the environment	Information categories			
	Social and economic activities, natural events	Environmental impacts of activities, events	Responses to environmental impacts	Stocks, inventories and background conditions
Flora				
Fauna				
Atmosphere				
Water (a) Freshwater (b) Marine water				
Land/soil (a) Surface (b) Sub-surface				
Human settlements				

<u>Social and economic activities, natural events</u>

Human activities and natural events included under this category are those that may have a direct impact on the different components of the environment. Human activities consist mostly of the production and consumption of goods and services but could also include activities in pursuit of non-economic goals. They produce environmental impacts through the direct use or misuse of natural resources or through the generation of waste and emissions in production and consumption processes. Natural events and disasters are also included in this information category because human activities frequently contribute to natural disasters and because natural events may have impacts on all environmental components.

<u>Environmental impacts of activities, events</u>

The statistical topics under this information category represent impacts of socio-economic activities and natural events. Responses to environmental impacts (see below) also affect the environment and, ultimately, human welfare. Environmental impacts, which may include the depletion or discovery of natural resources, changes in ambient concentrations of pollutants and deteriorating or improving living conditions in human settlements, can thus be either harmful or beneficial.

Responses to environmental impacts

Individuals, social groups, non-governmental organizations and public authorities respond to environmental impacts in different ways. Their responses are intended to prevent, control, counter, reverse or avoid negative impacts and to generate, promote or reinforce positive ones. Policies, programmes and projects designed to those ends include the monitoring and control of pollutants, the development and application of environmentally sound technologies, changes in production and consumption patterns, management and sustainable use of natural resources, the prevention and mitigation of the effects of natural disasters and the improvement of living conditions in human settlements.

Stocks, inventories and background conditions

Statistical topics in this category are intended to provide "benchmark" data and to illustrate links with other subject areas for possible further statistical analysis of these relationships. They include the stocks of natural resources and of capital assets of human settlements and refer to environmental inventories, as well as to economic, demographic, meteorological or geographical background conditions. However, in view of the increasing interest in assessing interactions between environment and socio-economic development, a slightly different approach was taken in the present report: selected economic "background" statistics are now presented under the different statistical topics of the "activities" information category.

2. Scope and characteristics of statistics of the natural environment

The present report follows the structure of FDES in terms of its environmental components and its four basic information categories. Table 2 presents the statistical topics for statistics of the natural environment in the framework format, grouped together according to common characteristics (underlined). The scope and contents of information categories are described in the introductions to sections A, B, C and D. The introductory paragraphs to the sub-sections describe their "statistical topics", providing further detail as to the scope and nature of pertinent statistics.

Bio-physical databases differ from socio-economic databases in their statistical properties and other characteristics, among which are:

(a) Data variables based on scientific readings from instruments or laboratory analysis;

(b) Analytic/synthetic data produced from ground surveys and remote-sensing imagery, frequently recorded in mapped form;

(c) Sampling frameworks based on spatial rather than population distributions;

Table 2. Framework for the development of environment statistics: statistics of the natural environment

Social and economic activities and natural events (A)	Environmental impacts of activities and events (B)	Responses to environmental impacts (C)	Stocks and inventories (D)
1. <u>Use of natural resources and related activities</u> 1.1 Agriculture 1.2 Forestry 1.3 Hunting and trapping 1.4 Fisheries 1.5 Minerals, mining and quarrying 1.6 Energy production and consumption 1.7 Water use for human activities 1.8 Land use and environmental restructuring	1. <u>Resource depletion and increase</u> 1.1 Biological resources 1.2 Cyclical and non-renewable resources	1. <u>Resource management and rehabilitation</u> 1.1 Protection and conservation of nature 1.2 Management and conservation of natural resources 1.3 Rehabilitation of degraded environments	1. <u>Biological resources</u> 1.1 Agricultural stocks 1.2 Forestry stocks 1.3 Fishery stocks 1.4 Fauna and flora inventories
2. <u>Emissions, waste loadings and application of biochemicals</u> 2.1 Emissions and waste loadings in environmental media 2.2 Application of biochemicals	2. <u>Environmental quality</u> 2.1 Atmospheric pollution 2.2 Water quality 2.3 Soil and land quality 2.4 Quality of biota and ecosystems	2. <u>Pollution monitoring and control</u> 2.1 Pollution research and surveillance 2.2 Standards, control and enforcement 2.3 Environmental clean-up and rehabilitation 2.4 Public pollution control facilities	2. <u>Cyclical and non-renewable resources</u> 2.1 Hydrological systems 2.2 Climate 2.3 Lithosphere 2.4 Mineral resources
3. <u>Natural events</u>	3. <u>Human health and environmental disasters</u> 3.1 Human health and contamination 3.2 Impacts of environmental disasters	3. <u>Prevention and hazard mitigation of natural disasters</u>	3. <u>Energy stocks</u> 3.1 Non-renewable energy sources 3.2 Renewable energy sources
		4. <u>Private sector responses</u> 4.1 Enterprises 4.2 Households	4. <u>Ecosystem inventory</u>

(d) Longer time intervals than is commonly the case in socio-economic systems in order to detect significant environmental changes;

(e) Natural spatial units which are rarely as well-defined as administrative boundaries;

(f) Data based on physical measuring units (e.g., weight, volume and area);

(g) Lack of well-developed methods and techniques for aggregation and of common denominators;

(h) Interest in unique and/or heterogeneous phenomena rather than stochastic and/or homogeneous properties (e.g., descriptions of species diversity) which calls for the "statistical" use of lists and maps rather than statistical tables and measures of central tendency.

Social, economic and demographic statistics are typically collected through questionnaire surveys of individuals, households, enterprises and institutions, or obtained from administrative databases of institutions and government agencies - e.g., tax records, school enrolment records, hospital files and so forth. Well-documented statistical methods and classifications are an important component of the data collection process. Socio-economic data collection has thus evolved over time into a mature statistical system. This is in contrast to environment statistics which are to some extent still at an "immature" stage of statistical development. Bio-physical data are largely obtained from monitoring programmes, natural resource inventories, mapping and survey activities, and interpretation of remote sensing imagery.

As pointed out above, environment statistics seek to link these bio-physical data with relevant socio-economic data. Such linkage can be considered the first step towards the incorporation of environmental data into national accounting systems. Annex I describes therefore the main links between the organizing framework for environment statistics, the FDES, natural resource accounts and the standard System of National Accounts (SNA).

3. Purpose and organization of the report

FDES is first and foremost an organizing frame. The present report elaborates further FDES by identifying "statistical variables" required for the development of environment statistics, not only on the state of the environment but also on the human (and natural) activities that are factors of environmental change. The major purpose of the report is thus to propose concepts, definitions and classifications for these variables which were selected primarily with the data needs of planners, policy makers and administrators in mind. In addition, these statistics should provide technical managers and administrators with supportive baseline data to complement specialized research information. To the extent possible, statistical variables were also selected on the basis of their potential use for calculating environmental indicators and indices. More specific criteria used in selecting the variables are relevance to environmental issues and to corresponding FDES topics, data availability and access, degree of sensitivity to change in environmental conditions and international comparability.

The lists of variables are neither exhaustive nor the only possible ones for the assessment of the statistical topics. Particular environmental conditions and statistical priorities in countries may well demand different selections and formulations of statistical topics and related variables. In most cases, the report will provide at least a starting point for a first identification of appropriate statistical series and will also help to determine relevant classifications and data sources. The textual material is not addressed to experts in the different environmental fields but rather to statisticians who have been given the responsibility for implementing an environment statistics programme. At this stage, environmental concepts and definitions are frequently unfamiliar to statisticians trained in the socio-economic field. Furthermore, there is still some uncertainty as to the nature and role of environment statistics in "official government statistics".[7] Compared to social, demographic and economic statistics, this domain is still in its infancy, and the methods, techniques and choices of variables will improve with the interaction of producers and users of these data.

The report does not provide detailed recommendations on how to carry out a statistical programme. Apart from indicating typical data sources and some examples of data presentation, actual data collection, processing, storage in and retrieval from databases, or procedures of data dissemination and publication are hardly discussed. Widely differing administrative arrangements and capabilities in both environmental policies and data collection are the reasons that these issues are intended to be dealt with in further in-depth reports on selected subjects of environment statistics. Furthermore, in the initial stages of developing a data collection network, the wide range and apparent complexity of statistics of the natural environment as presented in this report might appear overwhelming. The report should therefore be treated as a relatively comprehensive "menu" to assist in making decisions on priorities for statistical development. The choice of variables is clearly a function of the specific environmental problems of individual countries. The strategy for statistical development is also influenced by the availability of data, by the resources devoted to the production of environment statistics, and the capacity, skills and level of cooperation of departments and agencies, involved in monitoring the environment and the development of natural resource databases.

The comprehensive "menu" approach of this report has certain advantages for an early-stage development of environment statistics. In the first instance, it provides an overview of the field. It is also important to recall that statistical offices do not generally collect bio-physical data themselves. Therefore, a large part of their effort is devoted to identifying data sources and making the arrangements for regular data acquisition. This could be in the form of questionnaires to natural resource departments and agencies concerned with environmental management, in order to select parameters from large in-house data banks such as those maintained by a meteorological office or hydrological institute. The report can assist in the identification and selection of these data sources and relevant statistical variables.

Statistical offices collect and compile statistical data from surveys of households, farmers, manufacturers, service establishments, institutions and so forth. A good portion of environmental databases can be created by recasting these data into environmentally relevant categories. There is also an opportunity to obtain environment statistics by modifying questionnaires and by survey redesign. For example, questions on fuelwood uses and sources can be added to household surveys. Of course, there is also the possibility of introducing new surveys, devoted to the collection of environment statistics, such as surveys on industrial pollution abatement, recycling activities, and solid-waste generation and deposition. The report provides numerous examples of such environmental surveys.

The present report describes statistics on the natural environment, covering the FDES components of fauna, flora, atmosphere, water and land/soil. A technical report on the "man-made" environment - i.e., the environmental aspects of human settlements - has been issued.[5/] The general breakdown of both reports follows the FDES information categories described above. There are numerous interactions between human settlements and the natural environment. In the first instance, human settlements can be considered "modifiers" of the natural environment. Secondly, human settlements interact directly with ecosystems. Statistical measures of air and water quality, rural/urban land use conversions, and the impact of natural disasters are illustrative of data which refer to both worlds. Cross-referencing is extensively employed to link the variables found in the different "statistical topics" of the two reports. Also, the same data are sometimes reclassified to provide a more complete statistical picture. For example, atmospheric pollution databases to describe conditions and trends in (urban) air quality in the first report are reclassified in the present report to describe long-range transport of air pollutants.

The application of FDES to the organization and structuring of the present report allows the use of a coding system which assigns capital letters to information categories, numbers to statistical topics and small letters to statistical variables. For instance, B.2.2.1.b refers to the variable b (Concentrations of chemical contaminants) under the statistical topic 2.2.1 (Inland water quality) which is part of the section and information category B (Environmental impacts of activities and events). The flexible "building-block" structure of FDES permits the selection or rearrangement of topics and corresponding statistical variables for comprehensive assessments and selective studies of environmental conditions in countries.[8/]

For each statistical topic (at the three-digit level), the report provides:

(a) A description of the topic and related environmental concerns;

(b) A tabular listing of the statistical variables with an indication of possible classifications and further observations on the classification and interpretation of the statistical variables;

(c) Textual elaboration of the tabular information, indicating the reasons for selecting a particular variable and further explaining concepts, definitions and classifications.

Within this overall outline, there is considerable variation in the present report on the degree of detail with which each statistical topic is covered. This is because these is considerable variation in national experiences with the treatment of individual topics. Also, users of the report are reminded that not all of the topics are equally relevant for any one country. In terms of development of environment statistics in any given country, an early task will be to establish priorities among the various topics described in the report for initial attention. Existing classifications are not reproduced in the report in general but are referred to where appropriate. Two notable exceptions are classifications developed by the Economic Commission for Europe (ECE), of land use and fresh-water quality, presented in annexes II and III. The development of new or modification of existing classifications will be discussed in depth in planned technical reports on selected high-priority areas of environment statistics. An indication of likely data sources and methods of data collection is given in each subsection at the two-digit level. In some cases, particularly useful tabulations, other means of data display, such as mapping or graphic presentation, and possibilities of further processing the basic data into indicators or indices are also outlined.

A. SOCIAL AND ECONOMIC ACTIVITIES AND NATURAL EVENTS

The concept of activities employed in FDES is that of human activities and natural events that exert negative impacts on the environment.[9/] The notions of environmental impacts, or stress, are critical, since they define the criteria for the identification of the activity variables. The following categories of activities are distinguished:

(a) Human activities which extract non-renewable resources, harvest renewable resources, restructure the environment and use "in-place" environmental resources (sect. A.1);

(b) Loading of waste residuals and contaminants, generated by human production/consumption processes, on the environmental media of air, water and land (sect. A.2);

(c) Natural events and processes that stress the environment and social well-being, such as droughts, floods, earthquakes, volcanic eruptions and hurricanes (sect. A.3).

Interactions between economic activities of production, consumption and capital formation with the environment can be analysed in terms of the mass balance approach whereby production/consumption processes obey the physical laws of conservation of energy and matter.[10/] Materials and energy, in essence, become throughput of a process which transforms natural resources into desired economic goods and services. Waste residuals become the "unwanted matter" and "degraded energy" of this process. The statistical description of the emission of residuals is presented in section B.

Harvesting can be conceived as selected removal from a reproducible biological stock and extraction as the removal of selected minerals and hydrocarbons from a non-renewable (or exhaustible) stock (see sect. D). Environmental restructuring is a result of the human activities that build and "reconstruct" on one side and destroy on the other. The latter stems largely from the misuse and/or overuse of the "environmental carrying capacity", whereas the former is motivated by the desire to control the environment and improve productivity. "Restructuring" in this context means any permanent change in the composition of biomass, landscape and hydrological systems. The construction of large-scale hydrological projects, transport networks, urban land use conversions, clearing of lands for agriculture and drainage of swamps are examples of purposeful environmental restructuring activities. Desertification, deforestation and loss of habitat can also be caused by inadvertent environmental restructuring, such as over-harvesting, poor agricultural practices, population pressures on marginal lands and industrial pollution.

Activities that are characterized as "in-place" use of natural resources are generally referred to as "services" in the economic context - i.e., waste disposal, recreation, transportation (waterways, for instance) and tourism. The latter are not the activities associated with the development of tourist facilities, which is environmental restructuring, but are the enjoyment of the original resource of attractive climate, beaches, mountains, lakes and so forth. The in-place use of the natural resource implies neither the removal of the resources nor the permanent restructuring of the environment. Nonetheless, ecosystems can be seriously disturbed as a result of these activities.

Resource using activities include "primary production" such as agriculture, forestry, fishing, mining and energy production that are classified as economic activities of the International Standarded Industrial Classification (ISIC).[11] "Secondary" (manufacturing) and "tertiary" (services) activities affect the environment mainly through emissions of pollutants. Rather than presenting conventional production statistics for these activities, the "joint production" of loading the environment with pollutants is shown only in section A.2. Statistics on natural events or processes that affect human activities and welfare as well as natural systems are described in section A.3 as far as these events represent significant deviations from "normal" situations.

A.1 USE OF NATURAL RESOURCES AND RELATED ACTIVITIES

Statistical variables identified in section A.1 fall into four distinct types:

(a) Resource-based economic activities of agriculture, forestry, fishing, mining and energy, in the context of extraction and/or harvesting of natural resources - e.g., crop production, mineral output and water abstraction;

(b) In-place uses of the natural environment - e.g., recreation and water power;

(c) Actions that permanently restructure the environment - e.g., land conversion, drainage of marshlands and construction of dams;

(d) Selected economic indicators that provide background data on the contribution of the environment to the economy - e.g., capital formation and exports.

These four types of activity statistics are conveniently distinguished for organizing statistical databases. In the real world, they may be different dimensions of the same or related activities which calls for cross-classification of the variables for the purpose of integrated analysis. Activities described as "harvesting" can also be considered a factor in the "permanent restructuring of the environment". An example is land use. In the sections on agriculture and forestry (A.1.1 and A.1.2), land-use data describe the spatial dimension of the annual production, whereas in the section on land use and environmental restructuring (A.1.8) these data show the change in land use, in particular where land-use conversion has taken place by crossing "activity boundaries" - e.g., forest to agricultural uses. Selected economic indicators include the income generated from the production of the land and the capital value of land. In market economies, the relative price of land is a major factor in land-use conversion.

A.1.1 Agriculture

Agriculture is an ecology-dependent industry. The critical natural inputs are solar energy, water and nutrients. Human inputs are knowledge (technique, science, organization and past experience), labour (direct and indirect through the use of machinery or draught animal power), materials and energy (seeds, recycled nutrients, chemical fertilizers, pesticides and fossil fuels), and capital stock (land, machinery, equipment and infrastructure such as buildings, fences, wind breaks, drainage, water delivery systems and genetic material). What needs to be kept in mind is that the human inputs do not produce agricultural commodities themselves but rather control the output through a selective process - e.g., by eliminating pests and enhancing the rate of production.

A major environmental concern is to improve agricultural output and, at the same time, maintain the natural factor inputs of production at the level required for long-term sustainable yields. This objective, however, needs to be in harmony with other national goals of food security, public confidence in food quality, and income maintenance of farmers.[12/] Higher production levels are obtained by increasing yields per unit area or by expanding the area of cultivation. The environmental impact of the spatial extension of agriculture is manifested, inter alia, in deforestation, cultivation of steep slopes, livestock foraging in marginal lands and the transformation of dry lands by irrigation (see sect. B - in particular B.1.1.1 - where changes in the biological resources of agriculture are identified).

The environmental impact of increasing yields is manifest in the vulnerability of new cultivars to disease and drought (see sect. B.2.4.1), brought about by increased intensity of soil use accompanied by heavy doses of agricultural chemicals, restructuring of hydrological systems and narrowing of gene pools towards "specialized agriculture", often associated with monoculture. Modern agricultural technology leads to increasing chemical contamination of soils, water, and biota (see sect. B.2), creating secondary effects on the stability of ecosystems and the mechanisms for natural controls of disease and insect infestations. Irrigation has increased the land available for crop production, but this must be placed in context of increased risk of crop land losses due to salinization, alkalinity and waterlogging (see sect. B.2.3.1). Irrigation is also associated with the secondary effects of increasing the risk of waterborne disease vectors affecting human health (see sect. B.3.1).

Agriculture is one of the best surveyed and monitored of human activities. A wealth of statistical data is obtained from agricultural censuses and surveys, among which are income, area of farms, crop and livestock production, and material energy inputs. Most statistical offices routinely sample farm households on a seasonal and/or annual basis to monitor socio-economic conditions and agricultural outputs. These surveys can also be employed to obtain data on farming practices and other information relevant for environmental analysis. Village surveys play a similar role. Sampling of field crops to calculate annual yields for harvest forecasts, undertaken by departments of agriculture and/or statistical offices, is an important source for changes in productivity. Other sources include interpretation of remote sensing imagery, data from agricultural extension services, research studies of universities and agricultural departments, administrative records, farm records, farm management surveys and rural income/expenditure surveys.

A.1.1.1 Crop and livestock production

The variables identified in the text table below are the output, input and selected techniques of agricultural production. Time series of these data reflect both cyclical variations and structural changes. The cyclical variables are annual crop production, life cycles of livestock and replacement of perennial plants - e.g., fruit trees. These cycles can be further subdivided into activities of soil preparation, seeding and breeding, nurturing and harvesting. Spatial activity is especially important in the agricultural domain.[13] It can be described by area (km^2) and location (geographical coordinates). Structural changes can be inferred from the composition of outputs and inputs, or more directly by analysis of changes in agricultural practices - e.g., tilling practice. Water use in agriculture (irrigation) is included in a separate section on water abstraction (A.1.7).

The major focus of traditional agricultural statistics is the production of agricultural commodities. Environmental concerns suggest modifications of agricultural surveys to inquire into the relationship of agricultural activities and ecosystem health and to monitor key indicators of agricultural sustainability. In part, this requires identifying areas of high environmental risk, such as cultivation of steep slopes. Some of the questions of interest include:

(a) Cultivation practices - e.g., rotation, tilling and seeding;

(b) Level of fertilizer and pesticide use;

(c) Type of farming practice - i.e., shifting cultivation, large-scale monoculture, mixed farming, paddy etc.;

(d) Introduction of new cultivars.

Livestock can also be analysed along a similar vein by identifying the introduction of new hybrid stocks, the use of chemicals, and foraging and feeding practices - e.g., pasture, rangeland, feedlot.

Institutional factors and agricultural policies are of importance in the analysis of agriculture and the environment, such as size of holdings, ownership, accessibility of markets, price support, marketing boards and so forth. These factors need to be considered for a better understanding of the linkages of agricultural policies, institutions and the environment. In principle, they may be viewed as response or background variables, and the appropriate databases could be developed in sections C or D. Geographical specifications, such as ecozones, drainage basins and soil/climate mapping, are key parameters for the environmental dimension of agricultural statistics. The text table provides a limited list of generic variables. Nonetheless, the environment-agriculture interaction varies greatly between countries, and even within countries. Careful consideration should therefore be given to the choice of variables, describing crop and livestock production for purposes of environmental analysis.

Variables	Classifications	Observations
	<u>Output</u>	
a. Annual crop (t, km^2, kg/ha)	Type of crop Type of practice	Including mixed, monoculture, shifting cultivation, subsistence

b. Perennial crop (t, km^2, kg/ha)	Type of crop Type of plantation	Including large-scale plantation, communal, mixed farming
c. Livestock (nos., km^2, nos./km^2)	Type of livestock Type of practice	Including nomad herding, rangeland, pasturage, feedlot, hatcheries
d. Other products (t, kg, nos.)	Type of product	Including milk, eggs, honey, skins, manure, foraging
	Input	
e. Nutrient input (t, km^2, kg/ha)	Type of nutrient	Including chemical fertilizers, manure, crop residuals, rotation cropping
f. Pest control (crops) (t, km^2, kg/ha)	Type of control	Including pesticides, mechanical weeding, biological and integrated pest control
g. Feed input (t, km^2, kg/nos.)	Type of feed/foraging	Including rangeland, pasture, on-farm and off-farm feed grains
h. Disease and predator (nos., kg, km^2)	Type of control	Including drugs, inoculations, chemical spraying, insect habitat, shooting/poisoning of predators
i. Energy input (J)	Type of energy	Including fossil fuels, electricity, animal and human labour
	Soil preparation, seeding and breeding	
j. Tillage (ha)	Type of tillage	Including hoe, plough (tractor/draught)
k. Seeding (ha)	Type of seeding	Including wide-row, close-row, drill, broadcast, transplant
l. Breeding (nos.)	Type of breeding	Including artificial insemination, incubator hatching

A.1.1.2 Agricultural land uses and practices

Integrated databases on agricultural activity can be developed from land use data (see sect. A.1.8.1). Using criteria of crop production and agricultural technology, land use data can be further broken down to represent different kinds of agricultural practices. This requires assembling data on the physical characteristics of cultivation, such as rotation practices, monoculture and mixed farming with those of agricultural technology, such as the use of agricultural chemicals. The purpose of this approach is to portray the complex and dynamic processes associated with agricultural production.

An agricultural practice classification is a prerequisite for the development of these kind of databases. What is required are criteria for classifying land use and technology variables with known environmental effects, for example, distinguishing farming activities in well-watered valleys and plains from soil degrading practices such as marginal cultivation on hillsides and/or drylands. Other distinctions include stable "agro-ecosystems" of self-sufficient village communities in contrast to agricultural systems influenced by market prices. An important aspect is the overlay mapping of agricultural practices with ecozones and/or drainage basins (see sect. D.4, Ecosystem inventory). These approaches are useful for the analysis of food security, soil erosion and environmental risk. The variables listed in the text table should be adapted to the particular situation of individual countries.

Variables	Classifications	Observations
a. Crop practice (ha)	Type of practice	For example, crop rotation, monoculture, mixed farming, exposure to wind and water erosion
b. Livestock practice (ha)	Type of practice	For example, feedlot, pasturage, rangeland, exposure to wind and water erosion
c. Intensity of land use for agriculture (t/ha, nos./ha)	Type of practice	For example, high yields supported by agricultural chemicals

A.1.1.3 Selected economic indicators

As agriculture emerged from self-sufficiency to open market systems, agricultural commodity prices and other economic conditions dominated the choice of crops and livestock and greatly influenced the organization, cultivation practices and technology employed in farming. The variables selected here can be found in national accounts and production statistics, such as the value of outputs or the value of intermediate consumption (input). Physical quantities should be linked to the monetary values. Capital formation contributes to man-made capital stock in agriculture (see D.1.1.3). Further calculations are necessary to arrive at a net capital formation figure, allowing for depreciation of machinery and equipment and depletion of natural capital (see annex I).

Exports of agricultural commodities are, in many countries, a driving force behind agricultural land use. Although trade is considered mutually beneficial, there are certain aspects of resource commodity trade that have had detrimental effects on the environment and on human health. Adverse terms of trade have been considered to be responsible for much of the natural resource depletion in developing countries.[8] Other critical factors in environmental degradation are the pressures to employ the most fertile lands for plantation and cash crops, development of monoculture systems, land alienation and degradation of the nutritional status of the local population.

A recurring theme of environment statistics is that of spatial distribution of human activities. The economic indicators, particularly those from the census of agriculture, should be shown by natural geographical units, such as ecozone or drainage basin. Overlay mapping of economic statistics and physical parameters provide a powerful analytical tool for studying the relationship between agriculture and the environment. It is, therefore, recommended to organize the data records of economic indicators by geographical coordinates.

Variables	Classifications	Observations
a. Value and quantity of sales ($, t)	Type of commodity Type of farming	Distinguish modern from traditional farming
b. Cost and quantity of purchased inputs ($, t)	Type of input Type of farming	Indicator of industrialization in agriculture
c. Capital formation and land purchases (nos., $)	Type of expenditure Type of farming	Including machinery and equipment, buildings and land improvement
d. Value and quantity of exports (t, $)	Type of commodity Destination	Indicator of foreign market dependency
e. Imputed value of self-produced and consumed goods ($)	Type of commodity	Level of informal economy in agriculture

A.1.2 Forestry

Forests are bioproductive systems which provide raw material for the forest industries and are an important source of energy (fuelwood and charcoal for cooking and heating) in developing countries. They also provide habitats for a multitude of animal and plant life. Forest cover is an effective protector of soils and regulator of water flows and carbon cycles. Conversion of forestland to agricultural uses, large-scale commercial tree felling and increasing demand for fuelwood and charcoal have resulted, in many parts of the world, in deforestation (see sect. B.1.1.2). This not only depletes a potential resource for wood and habitat but also threatens the capacity of the biosphere to regulate atmospheric and hydrospheric cycles. Research on long-term climate change has included the effects of deforestation, along with burning of hydrocarbons, as contributors to the CO_2 build-up in the atmosphere. Further environmental impacts of deforestation include loss of wildlife habitat and species (B.1.1.4 and B.2.4), soil erosion (B.1.2.2), siltation (B.2.2), and flooding and landslides (A.3).

Data on forest cover, biomass content and changes are typically collected by departments of forestry for purposes of forest management. Statistics on the economic variables of wood production are part of the industrial statistics database. Other data are obtained from household and agricultural surveys (e.g., on fuelwood gathering, slash and burn, and foraging), and interpretation of remote sensing data (e.g., area of cutover, slash and burn, and forest road construction).

A.1.2.1 Harvesting, natural loss and regrowth

The following categories of activities and processes can be distinguished in forestry:

(a) Commercial harvesting;

(b) Informal harvesting, generally for fuelwood and village building material, but could also include forest charcoal production and "illegal harvesting";

(c) Natural tree mortality due to disease, fire, wind and pollution;

(d) Natural regeneration, which could be further distinguished by dominant successional forest type;

(e) Silviculture and/or afforestation.

Category (e) could also be considered as a response to deforestation, and as such could be included in C.1, Resource management and rehabilitation. In regions where tree planting is an integral activity with harvesting, as is the case with the temperate forests of Europe, it is recommended that the relevant physical parameters, such as number and area of trees planted, be treated as an activity associated with harvesting and the cost of forest management be included in C.1.2, Management and conservation of natural resources. The planting of forests in non-forestlands - e.g., abandoned farmlands, heathlands and semi-deserts - is shown in A.1.8.1, Land use change. In subsequent years these "new forests" will be part of the forest inventories - i.e., addition to stock (D.1.2.1).[14/]

Consideration should be given to linking the variables identified here with those of changes in forest stocks (B.1.1.2) and of forest inventories (D.1.2.1). The activity statistics provide the data which describe additions to, and subtractions from, stocks. To obtain a net balance, tree removal (variables a and b) and natural mortality (variable c) must be based on the same measures as those of regeneration (variables e and f). The common denominator for these kinds of net balances is a measure of biomass. The task is to develop a biomass model for specific types of forests whereby annual increments of new growth are estimated as well as the amount of annual biomass loss resulting from human removal and natural activity. Data on commercial harvesting are generally available as volume harvested (i.e., cubic metres). This provides relatively robust data for estimating biomass loss, taking into account that the loss of biomass can be up to 25 per cent greater than the wood removed, including limbs, roots and other biomass remaining on site. Similarly, various assumptions must be employed to estimate the informal removal of biomass.

Forestry statistics document the area/volume of forest harvest and forest replantation (i.e., silviculture) on an annual basis. However, to obtain a complete picture of the net gains and losses, additional variables are required. These are estimates of "natural" mortality, including losses due to forest fires and dieback due to acid rain, and annual new growth. Deforestation is characterized by additional variables, such as forestland cleared for agricultural uses, or depletion due to environmental stress caused by overuse for grazing, fuelwood and charcoal production. The variables specified here are the information base for estimating the "net change" in biological resources (see sect. B.1.1.2).

Variables	Classifications	Observations
a. Commercial harvesting (m^3, km^2)	Type of species Type of activity	Including volume of wood, area harvested and method of felling
b. Informal harvesting (m^3, km^2)	Type of species Type of activity	Including fuelwood, building material, illegal harvesting, charcoal production
c. Natural tree mortality (m^3, km^2)	Type of species Type of activity	Including forest fire, insect infestation, disease, drought, windfall, atmospheric pollution (acid precipitation)
d. Deforestation (m^3, km^2)	Type of species Type of activity	Including land clearing, flooding, drought, overgrazing and fuelwood gathering
e. Annual new growth (m^3, t, km^2)	Type of species	Including growth measured as biomass
f. Tree planting (nos., km^2)	Type of species Type of activity	Including both afforestation and reforestation

A.1.2.2 Other forest activities

Other forest activities can be cross-referenced to A.1.1, Agriculture (e.g., use of forestland for foraging: variable b), A.1.3.1, Hunting, trapping and gathering (variable d), A.1.8, Land use (e.g., recreation: variable f), A.1.2.1 (deforestation: variable c) and B.1.1.2 (change in commercial timberlands: variable c). The variables identified in the text table are selected in-place activities associated with forestlands.

Variables	Classifications	Observations
a. In-place harvesting (t, km^2)	Type of product	Including rubber tapping, fruit and nut collection
b. Foraging use (nos., km^2)	Type of livestock Type of forest	Including area of forest damaged by overuse
c. Slash and burn (km^2)	Type of forest	Including area under slash and burn cultivation
d. Trapping and hunting (km^2)	Type of forest	Including forest area used for hunting and trapping
e. Logging road construction (km)	Type of forest	Disturbance indicator of forest ecosystems
f. Recreational use (nos., km^2)	Type of activity Type of forest	Including population using forestland for recreation

A.1.2.3 Selected economic indicators

The linkage of forest resources with the economy can be traced along a processing sequence from raw material to finished goods used for domestic consumption or exportation. The major processes are logging (round wood); saw milling (planks or boards); veneer, plywood etc.; pulp and paper. The indicators in the text table depict primary wood production and exports. Secondary wood production statistics, as classified in the ISIC,[11] are part of conventional production statistics.

Variables	Classifications	Observations
	Primary wood production	
a. Logging ($, m^3)	Type of species Type of product - e.g., pulp wood, saw wood	Including value added of logging
	Exports of wood products	
b. Logs ($, m^3)	Type of product Country of destination	Value and quantity
c. Other wood products ($, t)	Type of product Country of destination	Value and quantity

A.1.3 Hunting and trapping

Hunting, at least for the larger mammals, was perhaps the first "organized" economic activity of humankind. Planning, assignments of specific tasks and co-operative actions were found to have a greater kill success - i.e., productivity - than individuals hunting alone. Except for a few isolated tribes dependent on hunting as a source of food and clothing, this activity has been drawn into the commercial market to provide highly valued furs, skins, ivory, and to capture various wildlife species for the growing market of zoo collections. Among affluent societies, hunting has become an important recreational activity, with a growing associated commerce of hunting equipment and tourist trade. The latter also includes the growth of tourism, involving passive observation and photography. In some countries, such as Kenya, wildlife observation has become a major source of foreign exchange earnings. Wildlife hunting and declining habitats have created concerns in over-harvesting and, in the worst cases, species extinction (see sect. B.1.1.4). The problem is exacerbated by the progressive loss of wildlife habitat (B.2.4), the deliberate destruction of "pest species", and the high prices paid in the illicit trade for such items as leopard skins, ivory and rhinoceros horns. The global alarm over this latter activity has resulted in international protocols, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), prohibiting the import of products from "listed wild species". Gathering or harvesting of plant life is also of environmental concern when it threatens rare and endangered plants.

The major data sources are government departments concerned with wildlife management, economic surveys in the fur market (i.e., number and value of pelts sold to commercial agents), international trade figures and household/village surveys. With the exception of the formal fur market, the data sources provide essentially indirect estimates of the number and species type slaughtered. Licensing data might provide information on the "allowable quota" but not necessarily the actual number killed. Wildlife managers often conduct sample surveys of hunters to obtain estimates of annual slaughter of wildlife. Estimates of poaching, informal hunting and culling activities can be obtained directly from game wardens. Analysis of import statistics (e.g., ivory) in other countries might also provide data on poaching. Village surveys could be useful sources of data on the informal economy generated by hunting, trapping and gathering.

A.1.3.1 Hunting, trapping and gathering

Developing statistics on hunting, trapping and gathering is made difficult by the unorganized character of these activities, in which a large number of individuals participate independently. In addition, hunters and poachers tend to evade the regulations of wildlife management, leading generally to underestimation of wildlife mortality. As pointed out above, estimates of the order of magnitude of hunting and trapping may, however, be ascertained by data collected from the commercial sector on the purchase of furs and skins, licenses issued for sport hunting and surveys of wildlife management.

Data collection is, of course, far easier in countries with well organized wildlife management systems. In many countries, however, hunting is neither formalized through markets nor effectively controlled through administrative instruments. In situations of this kind, the alternative approach is to design surveys at the village level to obtain data on hunting, trapping and gathering of wild fauna and flora. Populations living in, or on the edge of, large wilderness tracts are often economically dependent on hunting and trapping. Declining areas of natural habitat and growing human populations are key factors in threatening these traditional ways of life.

The suggested variables in the text table are divided into a formal and informal sector. The dual approach is recommended because of the social importance, among "hunting tribes" and rural communities, of wildlife populations. Hunting and trapping in their commercial and recreational guise are, in many respects, quite different, but should be assessed regarding their role in wildlife policies and management. The data in this section should be cross-referenced to statistics in D.1.4 and B.1.1.4, which record stocks and changes in stocks in fauna and flora.

Variables	Classifications	Observations
	Formal sector of hunting and trapping	
a. Large mammals (nos.)	Type of species Purpose[a/]	Commercial, recreational, culling, zoological
b. Small mammals (nos.)	Type of species Purpose[a/]	Commercial, recreational, pest destruction
c. Birds (nos.)	Type of species Purpose[a/]	Including game birds, waterfowl, pests, ornamental
d. Other animals (nos.)	Type of species Purpose[a/]	Including reptiles, amphibians
	Informal hunting, trapping and gathering	
e. Mammals (nos.)	Type of species Purpose[a/]	Including poaching, food provision, pest destruction
f. Birds (nos.)	Type of species Purpose[a/]	Including pest destruction, poaching, ornamental purposes
g. Other fauna (nos.)	Type of species Purpose[a/]	For example, snakes, crocodiles, frogs
h. Gathering of flora (nos.)	Type of species Purpose[a/]	Including food provision, medicinal, ornamental purposes

a/ Purpose classifications for fauna and flora include food, skins, furs, medicinal, collection for zoos, recreational sports and elimination of pests. The illegal aspect should also be noted, particularly as it affects endangered species.

A.1.3.2 Selected economic indicators

The contribution of these activities is relatively small in comparison to the economic value from other major resource sectors. Nonetheless, the impact on fauna and flora is high. Factors that contribute are high prices paid for endangered and rare species by commerce (a particularly attractive proposition to low-income people), and the destruction of wildlife by recreational hunting. It should be noted that the loss of wildlife habitat has also endangered the economic support base both for hunting tribes and the supplemental incomes of villagers in wilderness areas. The economic indicators fall into three kinds: market value of the products of hunting and trapping, income generated and international trade in wildlife.

	Variables	Classifications	Observations
a.	Market value of wildlife, furs/skins and meat ($)	Type of species	Indicator of the direct economic contribution of wildlife
b.	Income generated from sale of equipment, licensing and tourist infrastructure ($)	Type of product Type of service	Indicator of the indirect economic contribution of wildlife
c.	International trade in wildlife ($)	Type of species Country	Indicator of export earnings from wildlife
d.	Informal income generated from wildlife ($)	Type of activity	Estimate of the contribution from the informal economy
e.	Recreational hunters (nos.)	Type of hunting	Estimate of the participation rate

A.1.4 Fisheries

The products of marine and freshwater fisheries are of growing importance as a source of protein for humankind. Fish products are also used increasingly in animal feed, fertilizers and industrial chemicals. In countries with rich off-shore fishing grounds, fish catch is an important source of income and employment, producing food for both domestic consumption and exports. [15/] Aquaculture is growing in importance as a source of protein. Although the cultivation of freshwater fish in ponds is an ancient tradition in parts of Asia and Europe, the development of "marine aquaculture" is of more recent origin, specializing in such highly valued species as salmon and invertebrates - e.g., oysters, shrimps and lobsters. Recreational fishing has spawned a substantial economic infrastructure, ranging from neighbourhood "fee-entry" fish ponds to wilderness fishing camps and deep-sea fishing. Government support for the fishing industry is manifest in subsidies for fishing technology, fish hatcheries and management of "allowable catch".

A major environmental concern is over-harvesting and indiscriminate fishing practices (driftnet fishing). A priori, sustainable development of fisheries can be achieved through the management of stocks by regulating the total allowable catch. This is a complex process requiring monitoring data on stocks and scientific knowledge of the ecological influences on the growth cycles of specific fish stocks. Nutrient cycles, shifts in ocean currents and water temperatures are major factors in fish population cycles. Fish biologists are just beginning to understand how stocks are affected by polluted waters, in particular in freshwater ecosystems, by the natural cycles of micro-organisms, by disease vectors and by predator-prey relationships. There is already alarming evidence of declining stocks in many of the traditional ocean fishing grounds. Similarly, freshwater fish catches are declining due to over-fishing and loss of viable habitats.

Data on commercial catch are collected by fishing departments and through surveys of industrial establishments in fish processing. Data on informal fishing activity, aquaculture and recreational fishing are obtained from a variety of sources among which are household surveys, fish management and licensing administrative records, sample surveys of recreational fishermen, village surveys on food sources etc.

A.1.4.1 Fish catch

The most important variables to assess the stress on fish populations are the statistics on fish catch. The correlation of these data to fish stocks should be qualified by the following caveats. In the first instance, market prices (i.e., profitability of the catch) influence the catch intensity. Secondly, natural cycles of fish populations may account for the periodic rise or fall of annual catch. Steady decline in catch may be considered as *prima facie* evidence of a real decline in population. Thirdly, the catch data must be carefully analysed in terms of changes in government regulations with respect to quotas, licensing, allowable catch and other limits and restrictions. Fourthly, the weather conditions may influence catch - e.g., a particularly stormy season may reduce the fishing days available. Fifthly, bias in the reporting of catch statistics should be considered, for example the tendency to report catch within quota limits. A particularly difficult problem is that catch statistics are obtained from "landing data" of different fishing ports and might not always be consistent with "total catch" from fishing grounds shared by several nations. Finally, there is always the possibility of discoveries of new fishing grounds, such as the feeding area of Atlantic salmon, off the coast of Greenland.

The variables identified refer to freshwater and saltwater fisheries, for which different fishing practices should be distinguished. In addition, a distinction is made between commercial, informal and recreational fish catch. Recreational fishing is generally associated with high-income countries, whereas informal fishing is associated with low-income countries. The latter is usually undertaken as a supplement to local food needs. The data variables depicted here attempt to describe the level and change in levels of fishing activities. They complement the variables found in C.1.2, Management and conservation of natural resources - e.g., through "fish quotas"; D.1.3, Fishery stocks; and B.1.1.3, Fish.

Variables	Classifications	Observations
	Commercial fish catch	
a. Marine fish catch, off-shore (t)	Type of species Type of practice	Allocate to fishing zones[a]
b. Marine fish catch, near-shore (t)	Type of species Type of practice	Allocate to fishing zones[a]

c.	Invertebrate (t)	Type of species	Allocate to fishing zones[a]
d.	Freshwater fish catch (t)	Type of species	Commercial - e.g., large lake fisheries, salmon runs
e.	Aquaculture (t)	Type of species	Distinguish fresh- from salt-water, including invertebrate
		Non-commercial fish catch	
f.	Recreational catch (t)	Type of species	Including lake, river and ocean game fish
g.	Informal catch (t)	Type of species	For local food consumption

a/ As a means of obtaining consistency between "fish caught" and "fish landed" data.

A.1.4.2 Selected economic indicators

The economic indicators depict the market value of the fish landings and exports. Data on fishing fleets, equipment and public capital infrastructure, supporting the fishing industry are found in D.1.3, Fishery stocks.

	Variables	Classifications	Observations
a.	Market value of fish landings ($)	Type of species	Contribution to economy
b.	Export of fish and products ($)	Type of product	Export earnings by country of destination
c.	Imputed value of informal catch ($)	Type of species	Measure of the contribution of the informal economy

A.1.5 Minerals, mining and quarrying

The activities of extracting subsurface materials are dealt with in two sections. In this section, mining of metals, chemicals and stone is described, while the following section (A.1.6) presents energy production and consumption. This particular division of energy and non-energy mining is largely a matter of organizing all energy activity data under one heading. The environmental impact of mining energy sources such as coal, uranium, tar sands, shale, and so forth is much the same as other kinds of mining. Extractions of oil and gas, on the other hand, are characterized by quite a different technology and associated environmental impacts, such as oil spills and gas/oil well fires.

Mining, in general, follows a distinctive sequence of activities - namely, exploration, development of infrastructure, extraction and transport of materials, exhaustion of ore bodies and abandonment of mining sites, and rehabilitation of site. Mine sites are on occasion re-opened, prompted by changes in prices and/or technology. Although from a purely geological standpoint minerals are spread throughout the lithosphere, there are only a few areas of the earth's crust where the concentration of minerals is sufficient for viable mining operations. This explains why a relatively small number of mining areas accounts for the bulk of world mineral output.

The statistical variables identified in this section are organized in part on the basis of the mining cycle, presenting Mineral exploration (A.1.5.1) and Mineral production, including mine closing (A.1.5.2) here. Other activities of the mining cycle are shown, in line with the respective FDES categories, under sections A.1.8.2, Permanent environmental restructuring (for mining development); A.2.1.3, Waste loadings on land (for mineral waste generation); and C.1.3, Rehabilitation of degraded environments (for rehabilitation of mining areas). Some indicators of the secondary production of minerals - i.e., mineral processing - are included under A.1.5.3, Selected economic indicators. A comprehensive analysis of all mining activity - e.g., for purposes of mineral resource accounting - could usefully combine all these FDES components, including the stock (D.2.4.1) and changes in stock (B.1.2.3) of mineral reserves.

Time series data on production, exports and employment of the mining industry are obtained from the economic statistics databases maintained by national statistical offices. Departments of mines usually monitor mining activities, including exploration, development of new mines and assessment of reserves. Regional planning departments and mining associations are also useful sources of data, in particular for infrastructure development. Another valuable source of information is interpretation from remote sensing imagery, especially for mineral exploration.

A.1.5.1 Mineral exploration

The purpose here is to measure the area and intensity of exploration activity and to estimate new discoveries to be added onto reserve stocks in D.2.4.1, Mineral reserves. Measures of the exploration intensity are active prospectors, number of drilled cores, number and area of mineral claims registered, area surveyed for minerals by remote-sensing technology and annual expenditure by mining companies for exploration. Potential impacts of exploration and mining can be assessed by mapping indicators of mineral exploration. In some parts of the world, particularly where highly valued minerals such as gold and gemstones may be found, the exploration can generate "informal mining" operations - for example, the so-called "gold rush". The lone prospector is a disappearing breed, however, and mineral exploration is now associated with high technology, including that of remote- sensing and computer analysis of geological formations. Surveys of establishments engaged in exploration activities, formally registered assay records and documentation of registered mineral claims are sources of information obtained by Governments to update their databases on national reserves.

Variables	Classifications	Observations
a. New discoveries (proven reserves) (t)	Type of mineral	Addition to reserve estimate
b. Mapping of exploration activities (km^2)	Type of mineral	Identify area of intensive exploration activity
c. Selected indicators Number of registered claims Number of "field geologists" Number of bore holes drilled Area covered by geological surveys (km^2) Expenditure on exploration activity ($)	Type of mineral	Including seabed exploration for minerals

A.1.5.2 Mineral production

The topics depicted here are production or mine output and the end of production - i.e., mine closing. Mining output is highly sensitive to commodity prices and global trade cycles. "Unproductive" mines are shut down when prices are low and reopened during periods of high prices. Time series of mineral output for specific mining areas are useful background data for state of the environment analysis. Mining is also one of the primary generators of solid wastes, in the form of tailings and rock removal (sect. A.2.1.3, Waste loadings on land).

Derelict sites, ghost towns and economically depressed regions are manifestations of the environmental and socio-economic consequences of exhausted ore bodies or collapse of mineral prices. The concern for environmental quality has initiated programmes to rehabilitate derelict mining regions, in particular where the sites are in populated areas. Abandoned mines and towns in remote areas, on the other hand, are generally retaken by nature. The variables selected to depict this particular problem are the number and date of mines closed (their relative size measured by their peak output and/or peak employment) and area covered by abandoned or derelict sites, including the supporting infrastructure. Rehabilitation of abandoned sites is discussed in section C.1.3, Rehabilitation of degraded environments.

Variables	Classifications	Observations
a. Production of underground mines (t)	Type of mineral	Gross output = shipment + inventory change
b. Open pit mining (t)	Type of mineral	Gross output = shipment + inventory change

c. Production of quarries (t)	Type of mineral	Gross output = shipment + inventory change
d. Mine closures (nos., t, dates)	Type of mineral	Capacity by peak production or employment
e. Area of abandoned mining sites and supporting infrastructure (ha)	Type of mineral	Including mine site, town site, and transport corridors

A.1.5.3 Selected economic indicators

The economic indicators on production reflect the role of mineral resources in the economy. The activities associated with the secondary processing of mineral output - i.e., smelting, refining and separation/concentration - are a major source of air, water and soil pollution (see A.2.1, Emissions and waste loadings in environmental media). In part, this is due to the scale of the material throughput and in part due to the toxic nature of smelting processes.

Variables	Classifications	Observations
a. Mineral production (t, $)	Type of minerals	Output and value, trends in mining activities
b. Raw mineral exports (t, $)	Type of minerals	Foreign market dependency
c. Ore inputs in smelting and refining (t)	Type of process	For example, ferrous and non-ferrous
d. Non-metal minerals in chemical and fertilizer industries (t)	Type of process	For example, potash, phosphorous, sulphur, salts
e. Other mineral processing activity (t)	Type of process	For example, porcelain, glass, bricks

A.1.6 Energy production and consumption

Energy input is a necessary, although not sufficient, condition of all human controlled and natural processes. The laws of conservation of mass and energy imply that the total energy of the universe will remain constant - i.e., energy is neither created nor destroyed. Energy incorporates the concept of the transformation of "available energy" to "unavailable energy" (e.g., burning of hydrocarbons) and conversion from an "unusable" to a "usable" form (e.g., hydropower to electricity). The process whereby energy degrades into an unavailable form according to the second law of thermodynamics is referred to as "entropy". In essence, production, both man-made and natural, is a (temporary) reversal of entropy, which can be conceived of as higher levels of organization. However, to achieve entropy-reversal requires external energy sources; in the natural world, the source is solar energy, whereas in the man-made world it is largely that of stored energy from fossil fuels.

Energy, unlike all other natural resources, is not a material substance but an abstract concept, defined scientifically as the capacity to do work. The great achievement of humankind is to harness energy to do work; a measure of power of a typical motor-car engine, for example, is equivalent to 100 horses. In reflecting the functional properties of energy, there are a variety of energy measures in the form of power, heat and electromagnetic force. The most general physical measure for energy production/consumption processes is that of "heat units" applied to produce work. A commonly used energy measure is that of joule, defined as the energy expended by a force of one newton acting through a distance of one metre.

Energy activity databases are, in essence, subcomponents of other "statistical topics" of this report. The strategic importance of energy policies and the evident impact of energy production and consumption on the state of the environment are sufficient reasons for drawing together energy activities under one heading. The approach employed here is to organize energy activities in terms of an energy cycle - that is:

(a) Discovery, development and extraction of energy resources;

(b) Energy conversion;

(c) Energy end use.

Energy consumption contributes to environmental pollution as energy in its dissipated or "unavailable" form. Statistics on this aspect of energy production/consumption are described in databases of emission of residuals into environmental media (A.2.1), concentration of pollutants, in particular in the atmosphere (B.2.1), and in *Human Settlements Statistics* (A.2.1, Emission and waste discharge; and B.2.1, Ambient concentration of pollutants and wastes). Figure I illustrates the connections between the building blocks of FDES for the statistical assessment of the "cross-cutting" issue of energy and environment.

Statistics on energy production and consumption are usually available in both physical and monetary units, the latter being the sale of and expenditure for energy commodities - e.g., fuel and electricity. The physical measures are of prime interest from an environmental perspective. There are several approaches to calculating energy expended from production and expenditure statistics. In the first instance, it is a relatively simple matter to convert monetary to physical units when the price per unit is known. Other methods are based on energy models which calculate energy coefficients from engineering data and apply these to gross output, transport haulage and space heating. Energy coefficients introduced to input/output models provide comprehensive data on energy "end use" and energy intensity of commodities.

Production and consumption statistics of energy are routinely collected by national statistical offices. Surveys of industries usually also include questions on the quantity and value of the purchased energy and, if self-produced, the quantity and value of production. Household and agricultural surveys inquire into certain aspects of energy consumption - e.g., gasoline in agriculture, type of fuel for cooking in households and annual expenditure for home heating. Energy variables can also be assessed from technology/process analysis and can be obtained from international trade statistics and administrative data of departments of mines and energy.

Figure I. Energy statistics in FDES

Energy sources (stocks and changes in stocks)			
Non-renewable resources		**Renewable sources**	
D.3.1	Stocks of non-renewable energy sources	D.3.2	Stocks of renewable energy sources
B.1.2.3	Depletion of mineral (including energy) resources	B.1.1 and B.1.2	Changes in biological and cyclical resources

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Energy production and consumption					
A.1.6.1	Discovery, development and extraction of energy sources	A.1.6.2	Energy conversion	A.1.6.3	Energy end use
				A.1.6.4	Selected energy indicators
				A.2.2.a,b	Application of fertilizers
				B.1.2.a,b	Settlements and households supplied with electricity (in *Human Settlements Statistics*)

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Environmental effects[a]			
Pollution		**Land use change**	
A.2.1	Emissions and waste loadings in environmental media	A.1.8	Land use and environmental restructuring
A.2.1.a,d	Air pollution emissions and solid waste collected (in *Human Settlements Statistics*)		
B.2	Environmental quality		
B.2.1.a	Ambient concentration of air pollutants (in *Human Settlements Statistics*)		

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Human responses			
Pollution monitoring		**Resource management and conservation**	
C.2	Pollution monitoring and control	C.1	Resource management and rehabilitation
C.4	Private sector responses	C.4	Private sector responses (energy conservation)
C.2	Pollution monitoring and control (in *Human Settlements Statistics*, especially air pollution and solid waste management)		

a/ Including the pollution sequence of emission, loading and concentration, and other effects of environmental restructuring.

Organizations that are sources of energy statistics include the International Energy Agency of the Organization for Economic Cooperation and Development (OECD), the Statistical Office of the United Nations Secretariat, the statistics divisions of the regional commissions of the United Nations, and the International Atomic Energy Agency (IAEA).

A.1.6.1 Discovery, development and extraction of energy sources

The activities of exploration for hydrocarbons and the development of supporting infrastructure and extraction processes are essentially the same as those already specified in mining activities (A.1.5). However, oil and gas exploration are associated with large-scale and environmentally disruptive operations. These include seismic techniques which result in the removal of large areas of surface vegetation, deep-well drilling and the use of heavy equipment for exploratory wells on land and off-shore oil rigs for exploration of ocean geology. Moreover, these activities are often undertaken in environmentally sensitive areas such as the remote wilderness. The sheer quantity in the output of coal and the complex infrastructure required in oil and gas development have created large-scale environmental disturbances through the construction of pipelines, railways and large-scale terminal shipping facilities. This situation is further exacerbated by hazards of oil spills, well-head and pipeline explosion and fires, as well as the chemical pollution of the associated petrochemical industry and low-level radiation from uranium mining.

	Variables	Classifications	Observations
a.	Exploration of oil and gas resources (nos., km, km^2)	Type of activity	Including seismic lines, exploratory wells, area of exploration
b.	New discoveries of oil and gas (bbl, m^3)	Type of oil/gas	Proven reserves, revision of existing reserves
c.	Other fossil fuels and uranium discoveries (t)	Type of fuel	Including anthracite, bituminous lignite, shale, tar sands
d.	Construction of infrastructure (km, t, nos.)	Type of activity	Including transport - e.g., pipelines, housing, refining facilities
e.	Oil and gas extraction (bbl, m^3)	Type of activity	Land and off-shore
f.	Coal and uranium extraction (t)	Type of activity	Underground and open-pit

A.1.6.2 Energy conversion

Although this activity is sometimes referred to as energy production, technically it is the conversion of the bound energy found in hydrocarbons, uranium and natural cycling systems into available energy for the purpose of heat, light and work. Electricity generation transforms heat energy and gravitational energy potential (hydro-power) into electromagnetic energy, a useful "medium" to transport energy over long distances. The variables in the text table focus on renewable and non-renewable sources of energy, whether they be obtained from fossil fuels, nuclear, biological, solar/geo-thermo or hydro/wind power. The source of energy, the technology applied and the efficiency of conversion need to be considered in assessing environmental stress. Energy conservation and strategies to reduce environmental risk in energy production (C.1.2) are a response to this concern.

The sources of available energy are:

(a) Nuclear reactors (electricity only);

(b) Fossil fuels, including conversion into electrical energy (thermal power stations), direct burning for space and cooking heat, and conversion into kinetic energy by the internal combustion and jet engine;

(c) Biological material, largely for cooking and space heating, although there may be limited conversion to kinetic energy - e.g., from alcohol fuels;

(d) Natural cycling systems: conversion of hydropower and wind into electricity, including traditional kinetic energy conversion, such as windmills and water mills;

(e) Solar radiation and geo-thermal sources, including conversion into electricity and direct heat source of geo-thermal waters and passive solar heating;

(f) Recycled waste for community heating plants and small-scale electricity generation.

Variables	Classifications	Observations
	Non-renewable energy	
a. Fossil fuels for heat and kinetic energy (J, t, l)	Type of fuel Purpose	Cooking, space, heating and transportation
b. Electricity generated from fossil fuels (kw)	Type of fuel	Including efficiency rating of energy conversion
c. Electricity generated from nuclear fuels (kw)	Type of reactor	Including capacity and efficiency rating

	Renewable energy	
d. Biological sources for heat and work (J, t)	Type of source	Including fuelwood, draught animals, agricultural wastes
e. Electricity generated from cyclical resources (kw)	Type of source Type of technology	Including hydro-tidal and wind power
f. Electricity and heat from solar and geo-thermal sources (kw, J)	Type of technology	Including community heating systems, passive solar power for cooking and heating
g. Electricity and heat from waste recycling (kw)	Type of technology Type of waste	Including municipal, industrial waste

A.1.6.3 Energy end use

The objective of this statistical topic is to break down the total national energy budget into end uses. The classification of end use can be either by process, such as tillage, hauling, smelting, space heating, cooking and transport to work, or by economic sector, such as agriculture, manufacturing, transport, households and government. The process approach is more difficult to apply because traditional statistical enquiries and classifications are product- rather than process-oriented. The text table describes energy use by economic sector, although the process approach is recommended where the data and modelling capacities are available.

Variables	Classifications	Observations
	Energy use in production	
a. Resource extraction and harvesting (J, kw)	Source of energy Type of industrial process or industry	Including self-supplied energy
b. Heavy industry (J, kw)	Source of energy Type of industrial process or industry	High-energy-use industries - e.g., iron and steel, smelting, concrete, chemical, petroleum
c. Other manufacturing (J, kw)	Source of energy Type of industrial process - e.g., assembly, shaping, packaging	Light-energy-use industries
d. Services in support of production and trade (J, kw)	Source of energy Type of service	Financial, technical support, insurance
e. Construction activities (J, kw)	Source of energy Type of construction	Engineering projects, buildings, transport network

f. Transport of goods (J, kw)	Source of energy Type of transport	Road, rail, air, water
Energy use by final consumption category		
g. Household energy use (J, kw)	Source of energy Type of activity	Cooking, heating and home maintenance
h. Services to households (J, kw)	Source of energy Type of service	Retail trade, personal services, restaurants, hotels etc.
i. Transport of people (J, kw)	Source of energy Type of transport	Including private and public transport
j. Government energy use, including defence (J, kw)	Source of energy Type of activity	Including energy use by the military and other public service functions

A.1.6.4 Selected energy indicators

Energy conservation, depletion of energy sources, dependency on foreign sources and the (value added) contribution of energy to the economy are key variables in energy policy. Energy depletion rates are presented under B.1, Resource depletion and increase. Per-capita energy consumption provides a first indication (especially in the international context) of wasteful or conservationist energy use. Actual conservation efforts are described as social responses to depletion under sections C.1 and C.4. The indicators selected here are to provide a general picture of the energy situation and will undoubtedly require further refinements for specific country needs.

Variables	Classifications	Observations
a. Per-capita energy consumption (J, kw)	Type of energy	Energy conservation
b. Ratio of renewable/ non-renewable energy consumption	Type of use	Cooking, space heating, agriculture, manufacturing, transport
c. Imported energy sources (J, kw, t, $)	Type of energy	Energy security
d. Exported energy (J, kw, t, $)	Type of energy Country	Energy security
e. Ratio of domestic to foreign sources of energy (%)	Type of energy	Energy security
f. Value added in the energy industry ($)	Type of industry	Economic significance

A.1.7 Water use for human activities

Insufficiency of water supply is chronic in many parts of the world suffering from drought. The quality of potable water is a critical public health issue, not only in poor countries but increasingly among the most prosperous. In the latter case, the problem is water pollution from leakage of toxic chemicals into water systems and the heavy use of water purifying agents such as chlorine. Further, the age-old scourges of water-borne diseases - cholera and typhoid, for instance - are still known in many parts of the developing world. Floods have also plagued humankind since the earliest riverine settlements. The control and distribution of water is responsible for some of the greatest engineering achievements of man. Although many well-documented benefits have accrued from human efforts to restructure natural hydrological systems, these very same engineering feats have added new dimensions to environmental problems, among which are the spread of water-borne diseases, stress on ecosystems, loss of natural and human habitats, waterlogging and salination of soils, and conflicts between up- and downstream water users. Deforestation associated with population pressures in head-water areas is blamed for higher levels of siltation and more devastating and frequent floods.

The variables identified here are drawn from an earlier report, "Draft guidelines on freshwater statistics."[16/] The data variables specified here under the topic of activities are water withdrawal and use and in-stream water use for recreation and transportation. Other aspects of in-stream water use for hydro-energy generation are found in A.1.6.2, Energy conversion, and in A.1.4, Fisheries (use of water bodies as fish habitat). The use of water as a sink for human-produced wastes is also treated separately under A.2.1, Emissions and waste loadings in environmental media. Data on water-caused disasters, such as floods and landslides, are specified in A.3, Natural events. When the lack of precipitation becomes a natural disaster (i.e., drought), this also is found under A.3. Figure II shows the complementary databases in the context of FDES - i.e., the availability of water resources stocks and inventories (sect. D), the impacts of water use and other socio-economic activities on water resources and their quality (sect. B) and social responses to water-related disasters, pollution and depletion (sect. C). The definitions and classifications used in the present report are based on the *ECE Standard Statistical Classification of Water Use*.[17/]

Water authorities (including those managing irrigation systems) are a major source of data. In many regions, water withdrawal is an informal activity or is organized at the village and municipal levels. Obtaining estimates of water withdrawal may require surveys of municipalities, agriculture, households and industry. Data on in-stream use is obtained from a variety of sources, such as household and business (including the tourist industry), surveys on participation rates, and expenditure for and sales of recreational services. Statistical information can also be obtained from navigation authorities and enterprises engaged in inland water transport.

A.1.7.1 Water abstraction

Water abstraction can be viewed as a (temporary) withdrawal of water from its natural cycle. Several environmental concerns are engendered from this activity (see fig. II). Among these are water removal from stocks at rates greater than natural replenishment, in particular from aquifers, reservoirs and lakes. In dry areas, water withdrawal from rivers for irrigation purpose might also seriously affect the quantity and quality of water for downstream users (see sect. B.1.2.1, Water resources). Other concerns relate to the quality of the water when it eventually

Figure II. Water statistics in FDES

Stocks and inventories		
Baseline data	**Natural stocks**	**Man-made stocks**
D.4 Ecosystem inventory D.2.1 Drainage basin mapping D.2.2 Climate	D.2.1.1 Water stock and flow	D.2.1.2 Man-made infra-structure stock D.1.2 Non-residential buildings and other physical infrastructure (in *Human Settlements Statistics*)

Social and economic activities, natural events		
Natural events	**Use of water**	**Hydrological restructuring**
A.3 Register of natural disasters, severe climate conditions A.3 Natural events (in *Human Settlements Statistics*)	A.1.7.1 Water abstraction B.1.2.b Households supplied with water (in *Human Settlements Statistics*) B.1.2.c Households with access to sanitation system (in *Human Settlements Statistics*) A.1.7.2 In-stream activities A.1.4 Fisheries A.2.1.1,2 Emissions and loadings into water	A.1.8.1 Land use change A.1.8.2.b Hydrological emissions and restructuring

Environmental impacts of activities and events	
Changes in stocks	**Changes in quality**
B.1.2.1 Stocks of water resources	B.2.2 Water quality

Responses to environmental impacts		
Natural disasters	**Pollution control**	**Management of resources**
C.3 Prevention and hazard mitigation of natural disasters (flood control)	C.2 Pollution monitoring and control C.4 Private sector responses	C.1 Resource management and rehabilitation

returns to streams, lakes and marine environments. Water used for cleaning, cooling and irrigation carries with it soluble salts, chemicals, soil particles and biological wastes which, if in quantities beyond the assimilative capacity of the receiving waters, leads to their general degradation. These questions are covered in section A.2.1.1, Emissions and loadings into inland waters, section A.2.1.2, Emissions and loadings into marine waters, and section B.2.2, Water quality (changes) as a result of loadings. Table 3 shows the annual abstractions by purpose of both surface water and groundwater combined for England and Wales.

The concept of "net withdrawal" should be considered in the context of hydrological flows: first, losses due to evapo-transpiration; secondly, interdrainage basin transfers for the purpose of redistributing water from "surplus" to "deficit" areas and for augmenting the generating capacity of electricity. Diversion schemes have come increasingly under attack for causing damage to ecosystems and precipitating changes in local climates. The budgeting of water and agreements on allowable withdrawals between up-stream and down-stream users can be traced to early riverine civilizations. The expansion of irrigation, the high rates of water use in large affluent metropolitan regions and the large-scale water withdrawals for industrial processes and cooling purposes have resulted in water supply deficiencies in many countries. The reduced (safety) margin between available supply and demand is particularly notable during low water periods. Thus, shortfalls in supply could be exacerbated by changing lifestyles, industrial technology and agricultural practices, e.g., the replacement of low water demand of native crops with high-water-demand cultivars. In this way, growth in demand for water can create drought conditions even when precipitation is well within the range of natural fluctuations.

The text table classifies water withdrawal by source and purpose/use. Statistics on water supply to individual households and access of households to sanitation systems are covered in *Human Settlements Statistics* - B.1.2, Access to infrastructure and services.

Variables	Classifications	Observations
	Water abstraction	
a. Surface water (m^3)	Source	Including rivers, lakes, reservoirs
b. Underground water (m^3)	Source	Including wells, aquifers
c. Interdrainage basin transfers (m^3)	Source	Specify drainage basins
d. Water withdrawals from other sources (m^3)	Source	Including desalination and direct rainwater catchment
e. Water export (m^3)	Purpose	Agreements on water sharing
	Water use	
f. Agriculture (m^3, km^2)	Type of irrigation	Including flooding, spray and drip

Table 3. Surface water and groundwater combined: annual abstractions by purpose in England and Wales
(Megalitres a day)

	Water supply[a/]	Agriculture		Industry		Total quantity abstracted
		Spray irrigation[b/]	Other	Central Electricity Generating Board[c/]	Other[d/]	
1977	14 768	115	120	13 406	6 958	35 367
1978	15 830	79	151	12 539	6 627	35 226
1979	16 268	106	140	12 710	6 773	35 997
1980	16 039	92	133	13 088	4 634	34 062
1981	16 039	116	111	12 208	4 972	33 446
1982	16 331	139	117	11 587	4 729	32 903
1983	16 360	170	119	12 179	4 095	32 923
1984	16 394	199	122	11 757	3 893	32 365
1985	16 685	102	121	10 710	3 920	31 538
1986	16 617	169	123	12 744	4 099	33 752
1987	17 240	101	121	12 806	3 702	33 970

Source: Department of the Environment, *Digest of Environmental Protection and Water Statistics* (London: Her Majesty's Printing Office, 1989).

a/ Water supply (piped mains water) includes abstractions by water authorities, water companies and small private abstractions.

b/ Including small amounts for non-agricultural spray irrigation.

c/ Excluding tidal water but including water used for water power (about 5,600 megalitres a day in 1987).

d/ Excluding tidal water and water used for water power and fish farming.

g. Industry (m^3)	Type of process	Major water use industries (including mining and quarrying) and level of recycling
h. Energy production (m^3)	Type of process	For cooling purposes, in particular
i. Households (m^3)	Type of purification Ozone	Including none, filter, chemical

A.1.7.2 In-stream activities

In-stream water activities are associated with the physical characteristics of water bodies and the surrounding human activities. Potential hydropower, for example, is a function of flow volume, height of fall and seasonal variability. Human in-stream water activities are of a more complex character, based on such factors as attractiveness of the water body, the accessibility to population centres, climate and competition from alternative sites. A major environmental concern is intensity of use, particularly when this endangers the viability of aquatic ecosystems. Waste loadings, recreational uses, transport uses and energy generation have all contributed, either singly or in combination, to degradation of aquatic ecosystems.

In-stream activities can be classified as follows:

(a) Fishing, measured as quantity of fish catch, emphasizing the composition of fish caught and further distinguishing between commercial and recreational;

(b) Recreation and tourism, measured as numbers participating in various types of water-associated recreation. These include swimming, fishing, boating, sailing, water-skiing and so forth;

(c) Waste loadings, measured as physical loadings into water systems. The underlying assumption is that of "assimilative capacity", which is a function of the size, flow and physical state of the receiving waters. Measures are tons of effluents and biological oxygen demand, classified by composition and source of loadings;

(d) Transportation, measured in terms of the intensity of use in relationship to the characteristics of the water body. Accidental spills of toxic chemicals and oil are particularly critical episodic events;

(e) Energy generation, measured by the amount and capacity of electricity generated.

In-stream activities of type (a), (c) and (d) are covered elsewhere in this report (see fig. II). The table below specifies variables of recreation/tourism and transportation.

	Variables	Classifications	Observations
a.	Participation in water sports and recreation (nos.)	Type of activity Type of water body	Including indicators of use intensity
b.	Tourism (nos.)	Type of water body	For example, overnight stays in resort hotels
c.	Waterborne traffic (t, km, nos.)	Type of traffic Type of water body	Inland water systems, including canals, number of passengers, weight of freight

A.1.8 Land use and environmental restructuring

Land use statistics record the spatial dimension of human activities. Distinctions are sometimes made between land use activities and land use cover. The latter is based on observed conditions, whereas the former is based on a formal designation and/or institutionally prescribed land use - e.g., conservation, national parks, military uses. This section identifies the variables required to record the transformation of the landscape - i.e., statistics on changes in land use and projects directed towards large-scale environmental restructuring.

To the extent that these activities take place in human settlements, the relevant variables will be found under A.1.5, Land use in human settlements, and A.1.2, Construction of shelter and infrastructure in *Human Settlements Statistics*. The status quo of land use at a particular point in time is described by land use maps and inventories (see D.1.1.1, Crop, livestock and soil inventories; D.2.3, Lithosphere (land use); D.1.2.1, Forest inventories; D.4, Ecosystem inventory). Land use management and planning variables are included in C.1, Resource management and rehabilitation.

Land use change takes place through the interplay of economic and technological forces, demographic conditions, political decisions, cultural values and natural activities of climate and geological events. The factors that influence the way land is actually used, abused or protected can be broken down into five major functions - namely:

(a) Productive capacity of land - i.e., natural fertility to support biological growth processes;

(b) Site potential for carrying out human activities - e.g., central place for markets;

(c) Aesthetic, spiritual and cultural values associated with landscape and human history - e.g., historic sites;

(d) Ecological functions in maintaining the equilibrium of natural systems and habitats for fauna and flora;

(e) Land morphology or landscape as a factor in determining drainage basins, climate conditions and natural transportation corridors or barriers.

Economic factors play a dominant role in land use conversions. For instance, land prices might result in highly productive agricultural lands being covered over with concrete and asphalt. The legal/institutional infrastructure also influences and often modifies the choices made on how land is to be used. To a large measure, environmental management is concerned with the problem of conflicts and resolutions arising out of the different social choices in land use - i.e., economic versus ecological uses. In section C, the variables are identified which monitor the actions taken to manage, protect and conserve land based on societal priorities and cultural values - e.g., the establishment of national parks, green belts to contain urban development, protection of heritage sites and so forth.

Land use statistics are generally scattered and fragmented. Major sources are local planning agencies, agricultural censuses, mapping agencies and remote sensing. In some statistical offices, land use data are considered part of the national statistical database and are collected on a systematic and periodic basis. Data on permanent environmental restructuring are obtainable from development planning agencies, and economic, resource and transportation departments.

A.1.8.1 Land use change

The variables identified here show land conversion from one use to another. National databases on land use and land use change require a standardized land use classification and systematic surveys on land use. The *ECE Standard Statistical Classification of Land Use* (see annex II) is designed essentially for industrial countries in temperate climate zones and could possibly be adapted for developing countries' needs and conditions. Databases which keep track of land use change need to make the distinction between fundamental structural changes in ecosystems from those which merely reflect activity changes, such as roadway construction in already highly urbanized land. Land use changes that cut across major activity classes, like forestland to farmland, are generally more environmentally significant than changes within sectors, like cropland to pastureland.

Land use statistics are collected and periodically updated by land use surveys of land management agencies such as municipalities, compiled from the land use component of the censuses of agriculture and abstracted from survey maps and remote sensing data. The complexity and high cost of developing detailed statistical land use databases and the need for updating at regular intervals has discouraged in the past the engagement of statistical offices in this domain. However, the amount of work has been considerably reduced by the introduction of computerized mapping systems - i.e., geographical information systems (see sect. D, introductory paragraphs). Land use data are of central interest in assessments of the state of the environment and should thus be accorded high priority in environment statistics programmes.

Variables	Classifications	Observations
a. Major land conversions between activity sectors (km²)	Land use[a/]	For example, forest to agricultural uses
b. Land use change within activity sectors (km²)	Land use[a/]	For example, natural forest to plantation forest
c. Special purpose land use change (km²)	Land use[a/]	For example, tourism, deforestation, desertification

a/ See annex II.

A.1.8.2 Permanent environmental restructuring

The variables suggested here are essentially an extension of the land use change database (A.1.8.1), recording in more detail the permanent structural changes taking place in the environment. These are developed along two distinctive lines. First is a formal inventory or register of major "environmentally restructuring" projects. These include transport and energy infrastructures, development of new settlements, irrigation projects and environmental rehabilitation programmes. Secondly, statistics are required on environmental restructuring which, in individual cases, may be small-scale but, combined, may be quite substantive. This would include housing subdivisions on the urban periphery, industrial estates and small-scale drainage projects. Although these data are largely associated with public and private capital investment, attempts should be made to estimate the level of informal restructuring of the environment, in particular as it concerns the clearing of forests for subsistence agriculture or newly populated lands (through migration).

Major projects are characteristically heavy construction activity spread over several years. Small-scale environmental restructuring is manifested in certain kinds of economic data, such as new housing construction, investment in urban and transport infrastructures, and land improvement. Economic data are in the form of expenditure over specified fiscal periods. More pertinent, from an environmental standpoint, are the physical parameters which depict not only the area of land use change, but other factors of environmental stress, such as cubic meters of earth removed, area loss of natural habitat, and material and energy use, such as the quantity of concrete in dam construction. A valuable source of information is the environmental impact statement (EIS) of major projects.

A major project register is proposed as a first step toward statistical data collection on permanent environmental restructuring. The register could be compiled from data on engineering specifications, economic costs and EIS. For projects that extend over several years, updates can be obtained from annual progress reports. The information required to produce the register is:

(a) Name of project (e.g., official designation in national plans);

(b) Purpose of project (e.g., irrigation, flood control, electricity generation, transportation, new settlement);

(c) Start and completion date (if a multiphased project, the start/completion date of components);

(d) Project components and phasing (e.g., transport access, building site preparation, project construction, ancillary construction etc.);

(e) Cost of project by component;

(f) Employment by component and phasing;

(g) Material and energy inputs (include quantities of building material, fuel and electricity);

(h) Equipment used (numbers and capacity of transport, earth moving, cranes, explosives etc.);

(i) Area disturbed by construction (distinguish, e.g., between severe disturbance from building site, workers accommodation or land cleared from medium and light disturbances from access roads, area of irrigation or transmission lines);

(j) Environmental impact statement (includes a summary of the findings of the EIS and suggested actions to protect the environment).

Permanent environmental restructuring may include the following activities:

(a) Multipurpose hydrological projects (e.g., irrigation/electricity flood control);

(b) Single purpose hydrological projects (e.g., electricity generation);

(c) Mega-energy projects (e.g., thermal, nuclear, hydro);

(d) Mining development;

(e) Extension of transportation networks;

(f) New agricultural settlement projects;

(g) Construction of new towns;

(h) Development of tourist areas;

(i) Development of industrial sites, particularly in heavy industry and chemical production;

(j) Infrastructures required for access to natural resources (e.g., roads);

(k) Environmental rehabilitation (e.g., sewage treatment plants, major reforestation, large-scale soil conservation and resettlement of populations from degraded environments).

It should be noted that environmental rehabilitation projects are both "environmental restructuring" and "response" to environmental impacts and are therefore presented under section C.1.3, Rehabilitation of degraded environments, and C.2.3, Environmental clean-up and rehabilitation. The construction of and access to infrastructure is described in *Human Settlements Statistics* (sects. A.1.2 and B.1.2).

The opening up of new mining areas is of particular importance in the above list. It forms part of a sequence of activities described above in section A.1.5, Minerals, mining and quarrying. The scale of mining development ranges from multimillion tons of annual extraction for supply of world markets to opening of quarries for local construction and building materials. These latter operations have only localized impacts, such as removal of topsoil, noise and dust. Since this kind of activity is often close to settlements, the public response may be highly vocal, particularly if it results in the loss of valued agricultural and recreational lands. Large-scale mining is sometimes of broader environmental concern, particularly when it disturbs unique ecosystems or tribal cultures.

Variables	**Classifications**	**Observations**
a. Transport network (km, $)	Type and purpose	Including energy network - e.g., transmission lines, oil pipelines
b. Hydrological restructuring (m^3, km^2, km, $)	Type and purpose	Including dams, reservoirs, canals
c. Construction of energy generating facilities (kw, $)	Type and purpose	Fossil fuel, nuclear, solar, water, wind etc.
d. New agricultural settlements (km^2, nos., $)	Type and purpose	Forest clearance, irrigation, number of households settled
e. New residential and industrial site development (km^2, $)	Type and purpose	Preparation of sites for new towns and industry
f. Development of infrastructure for mines, commercial forestry etc. (km^2, $)	Type and purpose	Construction of infrastructure for resource exploitation
g. Development of major tourist sites (nos., km^2, $)	Type	Public and private expenditure and overnight capacity
h. Environmental rehabilitation projects (km^2, $)	Type and purpose	Ecosystem rehabilitation, soil conservation, afforestation, waste water treatment

i. Informal sector environmental restructuring (km², nos.)	Type and purpose	Including land clearing, migration into new lands

A.1.8.3 <u>Selected land use indicators</u>

The variables identified here are general economic indicators and land pressures. The latter can be further considered in terms of carrying capacity of people, livestock and human activity. Population density, overlaid by land use, is a pertinent indicator of potential environmental stress. A more sophisticated variation may include, for example, variables weighted by energy consumption per head. Other indicators include intensity of agricultural production, livestock densities, and concentration of industrial activity. The database on population growth and population movement is described in A.1.1, Population growth and change in *Human Settlements Statistics.*

Variables	Classifications	Observations
a. Average price of land per hectare ($)	Land use a/	Economic incentive for land use changes
b. Total value of land transactions ($)	Land use a/	Economic analysis of land use changes
c. Population density (nos./km²)	Type of population b/	Carrying capacity
d. Activity intensity (production/km²)	Type of activity	Carrying capacity

a/ See annex II.

b/ This should include not only human population but also livestock and, in certain habitats, wildlife.

A.2 EMISSIONS, WASTE LOADINGS AND APPLICATION OF BIOCHEMICALS

Statistical topics A.1.1 to A.1.6 describe human activities in terms of the harvesting and extraction of natural resources, and topics A.1.7 and A.1.8 describe in-place use and restructuring of the environment. Section A.2 identifies variables describing environmental stress activities associated with human production and consumption. The statistical description of production and consumption is part of the well established body of economic statistics and is, therefore, not further dealt with here. The linkage to economic sector statistics should be established by classifying the sources of pollution in terms of economic activities - e.g., the ISIC and other classifications of private and public household activities of national accounts. The generation of waste residuals as a by-product of production/consumption processes (sect. A.2.1) and the deliberate application of biochemicals (sect. A.2.2) produce similar environmental effects. The separate statistical treatment of biochemicals from waste loading is, in part, due to the fact that the former are largely associated with "non-point" sources of pollutants, such as "agricultural run-off".

Emissions and loadings of environmental media with residuals are the initial stages of the pollution process, followed by ambient concentrations affecting the "environmental quality" of the media, exposure to and contamination with pollutants of biota, (including humans), pollution-related diseases, and pollution control and treatment of its effects. These different stages of pollution are described under the present section A.2 (for emissions and loadings), B.2, Environmental quality (including B.2.4, Quality of biota and ecosystems); B.3.1, Human health and contamination; and C.2, Pollution monitoring and control, respectively. The statistical topics covered in this section are A.2.1, Emissions and waste loadings in environmental media; and A.2.2, Application of biochemicals. Emissions of air pollutants and solid waste generation (collection) are covered in *Human Settlements Statistics* under A.2.1, Emission and waste discharge, due to their concentration especially in urban areas.

A.2.1 Emissions and waste loadings in environmental media

Emissions (discharges at the source) of residuals are more meaningfully measured in the context of the "receiving" environmental media or ecosystems which serve as temporary or ultimate "sinks" for these residuals - i.e., in terms of "loadings" of these receptors. The concept of the environment as a "sink" for wastes assumes that these wastes are assimilated and biodegraded by dilution (water), diffusion (atmosphere) and decomposition (ecosystems). The identification of waste loadings with specific media is based on the physical characteristics of wastes, gases, liquids and solids, rather than on their chemical composition or toxic potential. These distinctions are less meaningful in terms of ecosystem processes but are useful for the management of the different receptor media. However, air pollutants precipitate on land and water, solid wastes leak into water systems and liquid wastes solidify onto river and lake bottoms. Waste loadings are thus as much a problem of "pathways" as of the amount of emissions and loadings.

There are correlations between the quantity of waste residual loadings, concentration of population and production and consumption activity, and type of technology applied. Estimates of waste residuals can be obtained directly by measurement of "end-of-pipe" discharges/emissions or indirectly by data on locations, production and consumption, and the density of households. Direct emission statistics can be obtained by surveys of enterprises and municipal authorities. Indirect estimates require the estimation of pollution coefficients which link per unit waste with commodity production and household consumption. Non-point pollution loadings are best estimated by modelling methodology. For example, "run-off" of chemicals in agriculture would be a function of their level of application, the hydrological characteristics of the landform, seasonal rates of precipitation and so forth. Other non-point sources of water pollutants include atmospheric deposition, leaching of solid waste dumps and soluble natural chemicals in geological formation - e.g., mercury oxides. The estimates of gross discharges need to be adjusted to account for wastewater treatment, recycling and "low waste technology" to obtain net figures. Conversion to a common denominator for example a measure of biological oxygen demand (BOD),[18/] is useful for assessing relative contributions from various sources of pollution.

A.2.1.1 Emissions and loadings into inland waters

Since the earliest human settlements, streams and rivers have been employed as a convenient means to flush away human and animal wastes. With the exception of localized pollution, the vast "hydrological filters" of the biosphere were considered sufficient to clean up human waste residuals. Today, the sheer growth in waste loadings and the toxic nature of a good part of their content have led to questioning the capacity of the environment to assimilate wastes in the traditional form. The data variables identified here provide the analytical connection between human activity and water quality, and the secondary effects of degraded water on aquatic ecosystems and human health. These data should be cross-classified to, and be compatible with, the data sets shown for other statistical topics in figure II for the area of water.

Variables	Classifications	Observations
	Direct estimates of loadings from	
a. Households (t, BOD, m^3)	Drainage basin Type of discharge	Measure of effluent discharge
b. Industry (t, BOD, m^3)	Drainage basin Type of discharge Industrial sector	Measure of effluent discharge
	Indirect estimates of loadings from	
c. Households (t, m^3, BOD)	Drainage basin Pollutant	Based on household consumption patterns
d. Production (t, m^3, BOD)	Drainage basin Pollutant Production sector	Based on pollution coefficients
	Non-point source loadings from	
e. Agriculture (t, BOD)	Drainage basin Pollutant	Based on pollution coefficients and agricultural practices
f. Air to water (t)	Drainage basin Pollutant	Including acid rain deposition
g. Land to water (t)	Drainage basin Pollutant	Including leaching from solid waste dumps
h. Water to water (t, m^3)	Drainage basin Pollutant	Estimates of discharge at confluence and river mouths

A.2.1.2 Emissions and loadings into marine waters

Marine waters are distinguished from inland waters because of the obviously different uses of the water bodies, including the concept of the "oceans" as the ultimate sink of all soluble materials. Although marine waters are part of the global commons, the national perspective employed in environment statistics could refer either to the "territorial sea" (12-mile limit) or the "exclusive economic zone" (200-mile limit). Emphasis is on pollution discharged directly from coastal urban settlements and industrial activity and indirectly from the outflow from drainage basins and natural sedimentation in deltaic areas. Waterborne transport and off-shore oil/gas extraction activity in coastal waters have created additional threats to coastal ecologies, due to the risk of oil and chemical spills. Ocean dumping has been considered a convenient means for disposing of noxious substances, dredging waste, bilge oils and municipal wastes. Deep-ocean dumping has also been used to dispose of radioactive materials. Open-ocean pollution is generally outside national jurisdictional boundaries, but has been the subject of anti-pollution/ anti-dumping agreements and protocols. Pollution loadings of inland and regional seas are increasingly being "regulated" through international agencies for countries sharing the same body of water - e.g., the Mediterranean or Caribbean seas.[19/]

Variables	Classifications	Observations
a. Loadings from coastal settlements (m^3, BOD)	Coastal system Pollutant	Including estuaries, tidal flats, mangroves, tourist beaches
b. Loadings from coastal industries (m^3, BOD)	Coastal system Pollutant Industry	Tidal flats, mangroves, tourist beaches
c. Ocean dumping (t)	Type of waste	Distinguish deep-ocean dumping from coastal seas dumping
d. Oil and chemical spills (t)	Marine system	Including oil tanker, off-shore drilling, pipeline
e. Total loadings from drainage basins (t)	Marine ecosystem	Distinguish sediment loads from chemical loads

A.2.1.3 Waste loadings on land

Statistics on the generation of solid wastes, collected by municipalities, are covered in *Human Settlements Statistics*, A.2.1.d, Solid waste collected. The present statistical topic is concerned with the use of land as dump sites for solid wastes. The emphasis is, therefore, on the location, size and waste content of municipal and industrial waste disposal sites, the handling of hazardous waste sites (e.g., nuclear wastes and toxic chemicals) and the informal disposal of "unusable commodities". The latter includes litter such as plastics, styrofoam and rubber tires, found in stream beds and on river banks, village refuse sites, car dumps and leftover of construction material in remote areas.[20/]

Of particular importance are mining wastes, also associated with landslide hazards and siltation of streams. Rock and surface material wastes are generally inert and can be used later to refill mines after the ore has been removed. Topsoil is sometimes kept aside for eventual land rehabilitation. The environmental problems associated with solid waste dumps stem not only from their impact on their immediate surroundings but extend further through contamination pathways, due to leakages, poisoning of wildlife as a result of feeding off rotting garbage and disease caused by unsanitary conditions. Hazardous sites are of particular concern because of risk to human settlements and vulnerable ecosystems. There is also a risk of pollution being set off at such sites by unforeseen and uncontrollable natural catastrophes (e.g., earthquakes, floods and landslides). Recycling as a means of reducing the problem of waste disposal in an ecologically safe manner is described in *Human Settlements Statistics* (C.2.3.6, Reuse and recycling of solid waste) and is also included as a public and non-governmental response to pollution under sections C.2.4 and C.4, respectively.

Data on informal waste disposal, including the quantity, content and method of disposal and recycling, could be obtained from surveys of households, agriculture and small-scale industry. Data on organized or formal disposal are typically collected through surveys of municipalities and private enterprises concerned with the management of waste sites. Litter, which is often more of a nuisance than a hazard, is of interest to the extent that non-biodegradable waste tends to accumulate in the environment and that it can create special problems in remote areas. Measures taken from remote sensing imagery are one source of data, others might include sample surveys of litter characteristics over a given area. Other data estimation techniques include waste generation models based on spatial production and consumption patterns.

	Variables	Classifications	Observations
a.	Waste dumps (t)	Type of site Waste content	Open, landfill, incinerator municipal, industrial
b.	Hazardous waste (t)	Disposal technique Waste content	Burial, incineration
c.	Informal waste disposal (t)	Disposal technique Waste content	Household, village and litter surveys
d.	Mineral waste generation (t)	Type of waste Type of mine	Annual and accumulated waste under and above ground

A.2.1.4 Emissions and long-range transport of air pollutants

Emissions and long-range transport of air pollutants (LRTAP) are responsible for the acidification of lakes, rivers, soils, and diebacks in forests. Contrary to urban air pollution, which occurs largely in or around human settlements (see B.2.1, Ambient concentration of pollutants and waste in *Human Settlements Statistics*), the long range transport and deposition takes place predominantly outside human settlements and is therefore discussed here. The international dimension of the problem has stimulated programmes and protocols in an effort to reduce this serious source of stress on the environment. The United Nations Environment Programme and the Economic Commission for Europe have established a system of LRTAP monitoring. Statistics on major sources of acidic air emissions need to be linked to those on wet and dry deposition on water and land (see B.2.2.1, Inland water quality and B.2.3, Soil and land quality). These data can then be related to the rate of change in levels of acidity in water and soils. Acid rain models combine these data with information on soil/water buffering capacity (alkalinity), meteorological records (airsheds) and observation on flora and fauna to provide estimation of damage and to predict future trends. The effects of acid deposition should be correlated to the quality of and possible changes in the quantity of fauna and flora and their ecosystems (see B.1.1, Biological resources, and B.2.4, Quality of biota and ecosystems).

LRTAP is closely associated with weather patterns, linking the "source areas" with the "receiving areas". These general patterns are typically trans-boundary, continental and global in nature. The major man-made sources of sulphuric acid are centres of heavy-industry activity such as large-scale non-ferrous smelting operations, thermo-power generating plants and burning of coals for domestic heating. The emissions of the latter are closer to the ground and therefore have a more localized impact than the high smoke stacks of industrial sources. A major source of nitrogen oxides (NO_x) is the burning of hydrocarbons in internal combustion engines. Volcanic eruptions, major forest fires and burning of grasslands are natural sources of the acidification of precipitation.

The emission and deposition data of LRTAP are compiled from various sources, among which are statistical series on production, fuel consumption, transportation and natural events. These data need to be further supplemented by technological parameters - e.g., efficiency of fuel consumption or pollution abatement equipment and data on weather patterns. The trans-boundary dimension requires access to these data from other countries.

Variables	Classifications	Observations
a. Domestic sources of LRTAP (t)	Type of source	Including industrial, household, transport, natural (fires, volcanic)
b. Trans-boundary sources of LRTAP (t)	Type of source	Specify country

A.2.2 Application of biochemicals

Biochemical use statistics deal with artificial fertilizer use to enrich soils, and pesticide use to protect plants and animals from disease. Other chemicals accelerate growth of biota and preserve and enhance the quality and appearance of biological products. Environmental effects are generated by the diffusion of biochemicals through cycling systems and build-up of contaminants in water, land and species (through the "food chain") (B.2; B.3). Nitrogen and phosphorous from chemical fertilizers are increasingly found in streams and drinking water (B.2.2). Residues from pesticides are detected in food for human consumption, and in animal tissues (B.3.1; B.2.4.1). The environmental policy responses are in part to monitor food contamination (C.2.1), control the use of biochemicals (C.2.2), assess their costs and benefits, develop less toxic and/or more rapidly biodegradable chemicals (C.4.1) and in part to return to more natural means of maintaining soil qualities and pest control (e.g., use of natural predators) (C.1.2).

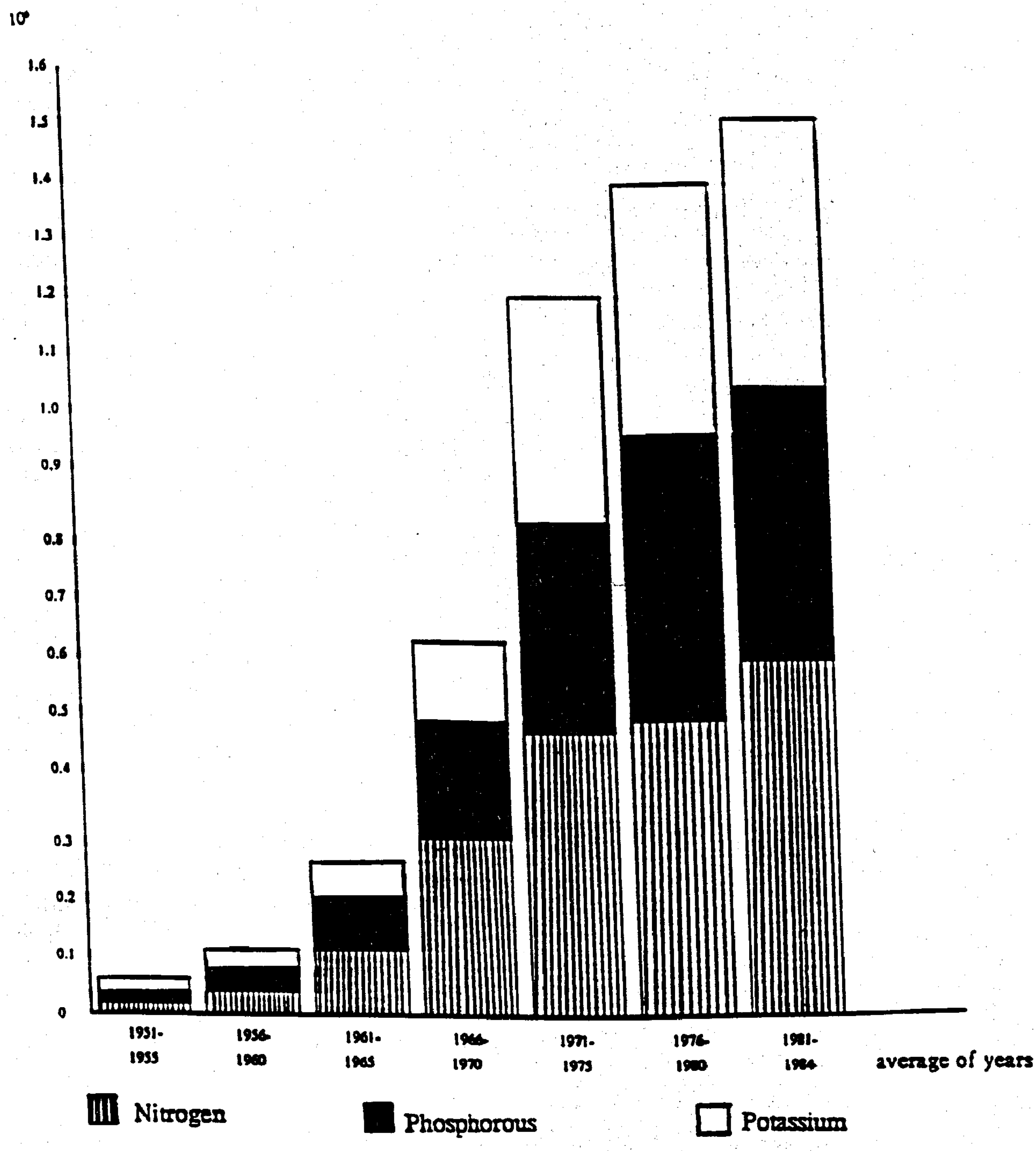
The variables identified for this topic are for the spatial analysis of the application and diffusion of biochemicals. This suggests the need to identify, where possible, the geographical co-ordinates of their application, for aggregation in drainage basins and ecozones. The measure of biochemical use should, if feasible, be in quantities of "active ingredients". Nutrient contents of fertilizers are generally recorded in fixed proportions of potassium (K), phosphorus (P) and nitrogen (N). Pesticides, on the other hand, are chemically more complex and sold as brand names rather than by their chemical formula. Thus, there is a requirement to match chemical properties with commercial "brand names". Pesticides can be classified by purpose - i.e., insecticides, herbicides and fungicides - or by chemical structure such as organochlorines, organophosphates, carbonates, etc.

At the international level, various efforts are under way aimed at disseminating information on products harmful to health and the environment. The Consolidated List of Products whose Consumption and/or Sale have been Banned, Withdrawn, Severely Restricted or Not Approved by Governments is part of the continuing effort of the United Nations to provide such information. The list which is jointly prepared by the United Nations Secretariat and other United Nations specialized agencies constitutes a tool which helps Governments to keep up-to-date with regulatory decisions taken by other governments and assists them in considering the scope for eventual regulatory action. It complements and consolidates information produced within the United Nations system, including the International Register of Potentially Toxic Chemicals of the United Nations Environment Programme.

The data on production of and trade in manufactured biochemicals are available from surveys of industrial establishments and international trade statistics. Data on the application of biochemicals on land can be obtained by surveys of the users (farmers, foresters, public health authorities) and more indirectly from wholesale and government suppliers. Surveys on the use of biochemicals should attempt to identify the active ingredient, the area and quantity applied, the method of application, and data on natural fertilizer use and biological methods to control disease and pests. Although quantities of the active ingredient are the preferred variable measure, data may be available only in monetary terms.

The variables specified in the text table are quantities of biochemicals applied by area and intensity - e.g., kilogrammes per hectare, domestic supply and method of application. The latter is largely concerned about the spatial diffusion and human exposure in the application of biochemicals, such as aerial spraying. Domestic supply is based on readily available national aggregates on production and international trade. Figure III provides an example of time series of such supply for three types of fertilizers, alerting to possible adverse trends in soil and water quality.

Figure III. Supply of fertilizers in active agent in hungary, 1951 - 1984



Source: Központi Statisztikai Hiwatal *A Kõrnvezet allapota és vedelne* (Budapest, 1986).

Variables	Classifications	Observations
	Application	
a. Natural fertilizers (t, km^2, kg/ha)	Type of fertilizer	Including manure, crop residues
b. Chemical fertilizers (t, km^2, kg/ha)	Type of fertilizer	Including ratio of active ingredient in fertilizer compound
c. Pesticides (l, t, km^2)	Type of pesticide	Including use to protect human and livestock health - e.g., malaria
d. Method of application (kg, km^2)	Type of method	Including aerial, hand, machine
	Supply/deposition	
e. Production of biochemicals (t, $)	Type of biochemical	Classify by active ingredient
f. Import/export of biochemicals (t, $)	Type of biochemical	Domestic supply[a]
g. Use (input) of biochemicals (t, $)	Type of biochemical Economic sector	Including agriculture, forestry, public health etc.

a/ Supply = production + imports - exports.

A.3 NATURAL EVENTS

The statistical topic of natural events in FDES identifies the activity variables associated with non-human ("natural") stresses on human production, consumption and well-being, and also on the environment. The synergistic dimension of natural events in relationship to environmental impacts of human activities is of particular interest. For example, malpractices in land use, especially agriculture, during drought may lead to desertification; the establishment of human settlements in vulnerable and earthquake-prone areas has brought about loss of life and property destruction. The current concern about climate change (i.e., the greenhouse effect) is a significant reminder of how human activity can influence natural processes. Historians have often noted the relationship between natural events and mass migration of people, abandonment of cities and the disappearances of once flourishing civilizations. Prolonged droughts, disastrous floods, catastrophic earthquakes and volcanic eruptions are recorded in human history in the same vein as wars and pestilence.

Unique or rare events associated with natural disasters can be distinguished from (abnormal) climate fluctuations - i.e., extreme variations from the mean. The concept of "normal" begs the question of the boundary of normal ranges. For instance, analysis of a long-time series might reveal variations from the mean which from a meteorological standpoint are "normal" but from a socio-economic standpoint "abnormal" events. The Sahel drought in the mid 1970s is a good example.[21/] Registers of natural disasters have been suggested for recording the frequency, location, severity, and environmental and human impacts of severe geological, atmospheric, hydrological and biological events. The latter refers to serious outbreaks of disease and infestations in biological species. The impact of natural disasters and man-made accidents on human settlements and welfare are described in *Human Settlements Statistics* (B.3.2, Settlement-related damage and accidents). Further impacts of man-made and natural disasters are described under B.3.2, Impacts of environmental disasters.[22/]

Registers of natural disasters record episodic events of:

(a) Physical and geological dynamics - i.e., earthquakes, volcanic eruptions, tidal waves (tsunamis), landslides, avalanches;

(b) Atmospheric dynamics - i.e., wind (hurricanes, tornadoes) and snowstorms and fires;

(c) Hydrological dynamics - i.e., floods;

(d) Biological population dynamics - i.e., population explosions (such as insect infestation) and severe disease outbreaks.

Data for a register of natural disasters can be obtained from government agencies, established to deal with episodic natural disasters. Other sources might include newspaper reports, meteorological offices and damage reports from insurance companies and local governments. Information on severe climate conditions is obtainable from the analysis of meteorological records. Other sources, such as satellite imagery, may supplement these records, for example by showing the extent of a drought area.

The variables identified in the text table describe the extent and intensity of natural events in the above-described breakdown of meteorological (including hydrological), geological and biological dynamics. Wild fauna and flora have usually adapted to normal ranges of natural events, but extreme conditions may present a risk to their survival. In the most severe cases, whole ecosystems could collapse and it may take many years for them, if ever, to recover. Human activity may have inadvertently weakened the resilience of natural systems to natural events. This could arise, for example, when human activities have reduced the size and diversity of natural habitats or otherwise degraded the ecosystem (see sects. B.1.1 and B.2.4). These data are critical explanatory variables in spatial analysis of biological production and conditions of the state of the environment. This suggests construction of geo-coded databases, for example, digitization of mapped data. Various techniques can be applied to delineate levels of the severity of events - e.g., areas severely affected, those moderately affected, and those lightly, or not at all affected. These maps, overlaid with other factors, such as crop production, provide the basis for spatial correlation of natural activities on economic and biological production.

	Variables	Classifications	Observations
		Weather and climate hazards	
a.	Precipitation, deviation from the seasonal mean (mm, km^2)	Geographical	Including areas of floods and drought occurrence
b.	Temperature, deviation from the seasonal mean (^0C, km^2)	Geographical	Including areas of unseasonably high or low temperatures, affecting crops and living conditions
c.	Cloud cover, deviation from the seasonal mean (hrs, km^2)	Geographical	Including areas of lack of sunshine, affecting crops, tourism etc.
d.	Wind (km/hrs, hrs, km^2)	Geographical	Hurricanes, tornadoes, snow storms, including speed, duration and impact area
e.	Fires (days, km^2)	Geographical Cause	Man-made, lighting, other, including impact area and duration
		Geological hazards	
f.	Earthquakes and volcanic eruptions (Richter scale, km^2, hrs)	Geographical	Including intensity, impact area, duration
g.	Tidal waves (m, hrs, km^2)	Geographical	Including height, duration, impact area
h.	Land slides, avalanches (km^2)	Geographical	Including impact area
		Biological hazards	
i.	Insect infestations (km^2, days)	Geographical Type of infestation	Including impact area, duration
j.	Disease outbreaks (nos., km^2, days)	Geographical	Including numbers of affected biota, impact area and duration

B. ENVIRONMENTAL IMPACTS OF ACTIVITIES AND EVENTS

Section B identifies the variables required to describe the impact of human and natural activities on the environment. Three categories of variables can be distinguished, referring to quantity changes in natural resources (B.1), changes in environmental quality (B.2) and consequential health and welfare effects (B.3). Changes in the availability of natural resources include biological resources (B.1.1), and cyclical and non-renewable resources (B.1.2). Quality indicators refer, on the one side, to air, water and land (B.2.1, B.2.2 and B.2.3) and, on the other, to biota and ecosystems (B.2.4). Finally, the health and welfare effects resulting from environmental contamination and natural events are assessed in section B.3. Statistical topics related to air pollution and the quality of living conditions in human settlements and the impacts of natural disasters on settlements and human welfare are covered in *Human Settlements Statistics*, B.2, Conditions of life-supporting resources, and B.3, Health and welfare conditions in human settlements.

Time series of environmental impacts in pertinent geographical areas form the core database for state-of-the-environment reporting. Time-series analysis in the field of socio-economic statistics is a well developed field, and so is to a lesser degree the regionalization of such statistics. However, there is no comparable experience in the nascent field of environment statistics. The central problem is an insufficiency of data to make valid interpretations of trends over geographical areas. The emergence of the technology of computerized mapping, referred to as "geographical information systems" (GIS), has greatly improved the capacity for spatial analysis, but these techniques are, in the final analysis, only as good as the reliability of the data input.

Environmental quality data are often characterized as "soft" because of the necessity to represent large areas by selected point (location) data or to reflect complex states of the environment by more or less "representative" variables or indicators. Of particular interest are the indicators which can be viewed as symptoms of ecosystem ill-health - i.e., of reduced capacity to support life. These are sometimes described as early warning indicators, e.g. rates of soil loss (as an indicator of reduced future agricultural outputs), or the presence of change in key species in ecological systems (for inference on trends in overall system health). Interpretation of observed data is often uncertain because environmental behavioural models tend to describe non-linear relationships (i.e., erratic fluctuations and sudden collapse) for which causes and effects are difficult to trace. Environmental monitoring is the major instrument in tracking the state of the environment. Considerable efforts have been devoted to the design of environmental monitoring systems. Nonetheless, there is a trade-off between a desirable environmental sampling frame and cost minimization of data collection. Points to be considered in designing the information content of a monitoring system are discussed in section C.2.1.

B.1 RESOURCE DEPLETION AND INCREASE

The World Commission on Environment and Development highlighted the urgency for nations to manage their own resource bases on a sustainable basis and to cooperate among themselves to maintain the "global commons".[6] The mute testimony of the failure to maintain resources at a sustainable level is found in abandoned agricultural lands, the replacement of superior by inferior biota, the collapse of fishing stocks and increasing rates of desertification and deforestation. Sustainability includes the concept of long-term equilibrium in renewable resources and replacement or substitution of non-renewable resources. Section B.1 thus identifies key variables required to support an information system for sustainable resource management and, ultimately, development policies. The approach employed is to focus on additions to, and subtractions from, the stock of biological resources, and gains and losses in water, soils and mineral resources. These data should be compatible as far as possible with the stock databases in section D. Such compatibility permits in particular the consistent presentation of changes in stock between two points in time together with the "total" amount of stocks or reserves of natural resources in physical resource accounting systems (see annex I).

B.1.1 Biological resources

Biological depletion is in part a result of harvesting and in part a result of natural mortality. The latter is understood as biological depletions that do not represent deliberate "removals" for human needs - i.e., for food, fibre, fuel and other material products for human uses. The "gross removal" of biological matter is, from an environmental standpoint, the appropriate measure. Thus, natural harvesting (e.g., from foraging) and mortality (from disease, climate effects and predation) must also be accounted for. Such natural decrease could also be aggravated by acid precipitation.

The concept of "over-harvesting" is generally applied to conditions where the rate of removal is greater than the natural rate of recovery. Over-harvesting is normally associated with natural resources in the "public domain" such as tropical forests, fish stocks and wildlife. However, "controlled" bio-productive systems, such as agriculture or plantation forestry, could also be considered overharvested when production and harvest activities are so intensive as to reduce the capacity of the support base for future harvests. This is, in part, a problem of the complex dynamics of artificial and natural nutrient cycling and qualitative degradations in water, soils and micro-organisms. Human experience in maintaining modern high-yield harvest systems are, at most, about 40 - 50 years. What is uncertain is whether these high-yielding methods can be maintained indefinitely by means of continuous "subsidies" of fertilizers, pest control and technology. Another, and perhaps increasingly serious, cause of biological resource depletion is that of competition between fauna/flora and human habitat and related land use. These depletions can be considered permanent when, for example, forestland is converted to agriculture. The loss of biological resources due to pollution or chemical contamination is a further factor, considered below in section B.2.4.1, Quality of biota.

In the natural regeneration of flora and fauna, particular successional patterns of growth can be observed. Such patterns depend on specific regenerative capacities of species, predator-prey relationships, environmental carrying capacity and the presence of threshold populations (i.e., populations that may not be recoverable if they fall below a certain number). Another factor is the adaptability of fauna and flora to changing environments. The increasing adaptation of wildlife to urban environments (e.g., learning to live off human refuse) is a case in point.

There are two possible approaches in developing databases on the depletion/accumulation of biological resources. Where separate records are kept of additions to, and subtractions from, inventory stocks (e.g., livestock in agriculture), net production can be distinguished from gross production. The second approach is to estimate inventory change based on differences in stock between two points in time. The latter approach uses gross stock estimates (see sect. D.1, Biological resources), the former monitors changes in stocks, e.g., by means of statistical surveys in agriculture, forestry and fishery (see sects. A.1.1 to A.1.4). Wildlife populations can be estimated from models based on lifecycle and survival rates, or from aerial and ground surveys. Other sources include interpretation of remote sensing data, particularly in estimating area spread or contraction of plant life. It should be noted that annual changes in biological inventories, with the possible exception of agriculture, are hardly relevant considering the slow process of change and the evident potential for a wide range of errors in these data. Five- to ten-year periods should be considered the norm for measuring changes in the inventory of biological resources.

B.1.1.1 Agricultural resources

Biological resources in agriculture are crops and livestock. Unlike wildlife resources, which are accumulated over epochs of evolutionary development, agricultural biological resources are selected, controlled and genetically manipulated for human purposes (see sect. A.1.1, Agriculture). Modern agriculture is increasingly characterized by rapid change in the composition of biological stocks. The stimuli for these changes are commodity prices, government policy and the scientific revolution in agriculture. Science has introduced new cultivars in crops and hybrids in animals; economics has changed the "output mix", usually towards increased specialization.

The variables in the text table complement the stock data in section D.1.1. Changes in the amount and composition of stocks are presented as changes in biomass and in area planted.[23/] The focus is on long-term change (trend analysis) in order to abstract from annual fluctuations of production due to weather conditions and statistical anomalies.

Variables	Classifications	Observations
a. Change (net) in area (km^2)	Type of crop	Relates to stock data in D.1.1.1
b. Change in annual crop biomass (t)	Geographical	Gross indicator of crop inventory change
c. Change (net) of livestock population (nos.)	Type of livestock	Recruitment less mortality
d. Change (net) in area of perennial plants (km^2)	Type of plant	New plantations less removal of old plants

B.1.1.2 Forests

Changes in forest inventories can be measured from the perspective of species composition, natural productivity and commercial productivity. The harvesting of particular species and "in-place" uses of forest have been described above under A.1.2, Forestry. The currently shown inventory change of forestland provides a database for the analysis of forest type, age and productivity and for the expansion and contraction of the area devoted to forest growth. The variables identified in the text table are complementary to the inventory stock variables in D.1.2.1. Net changes in area and biomass of forest lands may be considered indicators of the rate of deforestation.

Net inventory changes are estimated directly from a balance between the rate of depletion (tree removal + natural losses) and rate of regeneration (plantation + natural regeneration). Forest site productivity determines regeneration rates. Thus, a site with rich soils, long growing season and sufficient moisture would show a faster growth rate than a site with harsher conditions. Unfortunately, good data on site conditions, with the exception of cultivated forests, are not generally available, and crude averages on climate and soil conditions must be relied upon. Forest departments generally employ regeneration models to determine "allowable annual cut". If the inventory change data are not readily available, estimates can be obtained from comparison of "remote sensing data" over different time periods. The measures of net change can, in principle, be calculated from the databases described in section A.1.2.1, Harvesting, natural loss and regrowth.

Variables	Classifications	Observations
a. Net change in age/species mix (nos., km^2)	Forest type	Emphasis on ecological forest type
b. Net change in forest biomass (t)	Geographical	Indicator of the change in the density of forest cover
c. Net change in commercial timber stands (m^3, km^2)	Type of wood	Indicator of forest harvest sustainability
d. Net change in area of forestland (km^2)	Type of forest	Indicator of deforestation/ afforestation
e. Net change in area of forest (km^2)	Type of forest	Indicator of the plantation replacement of natural with plantation forest

B.1.1.3 Fish

Indicators of the net change in fish stocks are calculated from fish catch statistics (see sect. A.1.4.1) and models of fish stock population dynamics (see D.1.3, Fishery stocks). The data in the text table are essentially estimates made by marine and freshwater biologists for calculating allowable catch quotas. These calculations require information about natural conditions, such as ocean currents, water temperature, levels of nutrients available, predator/prey relationships (e.g., fish consumption of seals and birds) and disease vectors. Considering the data problems associated with these calculations, their results should be viewed as rough estimates only of overall changes in fish populations.

Variables	Classifications	Observations
a. Net change in marine fish populations (t)	Type of fish species[a]	Indicator of sustainability
b. Net change in freshwater fish populations (t)	Type of fish species[a]	Indicator of sustainability
c. Net change in invertebrate fish populations (t)	Type of fish species[a]	Indicator of sustainability
d. Net change in cultivated fish populations (t)	Type of fish species[a]	Indicator of the development of aquaculture

a/ See FAO International Standard Statistical Classification of Aquatic Animals and Plants in *FAO Yearbook of Fishery Statistics 1989: Catches and Landings*, vol. 68 (Rome: FAO).

B.1.1.4 Fauna and flora

Inventory changes in "wild" fauna and flora are measured by estimates of population and/or habitat range. Major difficulties arise in estimating fauna population because they remain largely hidden from human observation, the few exceptions being herds in open land and species "managed" for the purpose of hunting - e.g., ducks. However, the concern for the protection of endangered species has accelerated efforts to assess populations at risk. Changes in habitat range are generally easier to obtain, since they can be estimated from information on the location and frequency of sightings. The introduction and expansion of exotic (non-indigenous) species is particularly significant for the stability of ecosystems, as is the controlled population growth due to the absence of natural controls - e.g., from predator/prey relationships. The data in the text table are to alert to risks of serious depletion or extinction of species. They can also be considered as part of a species accounting approach when linked to the stock data shown in section D.1.4. Hunting and trapping, which can be major causes of species depletion, have been described above in section A.1.3.

Variables	Classifications	Observations
a. Net change in selected flora habitats and populations (nos., km^2)	Type of species[a]	Indicator of species at risk
b. Net change in large mammal habitats and populations (nos., km^2)	Type of species[a]	Indicator of species at risk, including aquatic mammals
c. Net change in selected small mammal habitats and populations (nos., km^2)	Type of species[a]	Indicator of species at risk
d. Net change in bird habitats and populations (nos., km^2)	Type of species[a]	Indicator of species at risk
e. Net change in fish habitats and populations (nos., km^2)	Type of species[a]	Indicator of species at risk

a/ See International Union for Conservation of Nature and Natural Resources, *Red Data Book*; and Draft ECE Standard International Framework for the Development of Fauna, Flora and Habitat Statistics (CES/548/Add.4/Rev.1).

B.1.2 Cyclical and non-renewable resources

Natural resource stocks can be conceived of as either material inventories or capital stocks (assets). The distinction between exhaustible (non-renewable), biological ("conditionally" renewable) and cyclical (renewable) resources in this report refers to this differentiation. Cyclical resources are linked to the biospheric cycles of air, water and land, though the latter refers to geological cycles and time periods rather than diurnal and seasonal ones. Despite their seeming physical indestructibility they can be degraded to a point where they fail to function well as a "means of production". The present statistical topic is thus concerned with the gains or losses of the productive capacity of the stocks of water, land, soils and sub-soil assets of mineral resources. The other major cycling system, the atmosphere, does not lend itself readily to this kind of quantitative accounting, except perhaps in a global sense.[24]

The major source of data for changes in stocks of water resources are hydrological surveys and water-basin planning authorities. Irrigation authorities and departments of agriculture keep data on the water balance for agriculture. Water availability for urban populations may be obtained from surveys of water treatment plants. Data on the changes in soil stocks can be compiled from several sources, among which are departments of agriculture (e.g., special programmes for soil conservation), survey and mapping agencies, regional planning departments, centres of remote sensing, and departments of environment (e.g., for estimates of soil sustainability). Departments of mines and energy generally keep detailed records of mineral and fossil fuel reserves and may calculate depletion indices for certain kinds of minerals and fossil fuels for the purpose of long-term planning. Other sources of data include international energy agencies, mining associations and surveys of enterprises. Production data are readily available from many sources, including statistical offices.

B.1.2.1 Water resources

Quantitative changes in freshwater resources can be monitored by changes in water levels of surface waters, stream flow and levels of the water table. Water storage systems can be assessed regarding their rate of turnover. At one extreme is the raging torrent and at the other is water accumulated over many centuries in aquifers and glaciers. Lakes and reservoirs fall somewhere in between, with turnover rates of several years. Therefore, water renewability is conditional on the specifics of the hydrological cycle and human withdrawal rates. Water from certain aquifers, for example, may be likened to mining. Changing levels of water table indicate the net result of withdrawal and replenishment, affected by irrigation, drainage and by changing patterns of precipitation (see D.2.2, Climate). Water security is of critical concern in areas of water shortfalls. In areas of high precipitation or erratic rainfall, surplus water may lead to water-logged soils and flooded land. The human response to too much water is drainage and pumping and water redistribution from surplus to deficit areas. An overview of the interactions between the various topics of water statistics is given in figure II above.

In addition to variables of changing levels of surface waters, water tables, stream flow rates and depletion rates of aquifers, gains and losses of water storage capacities are also considered in the text table. A distinction should be made between changes in overall and local capacities. The latter refers to small-scale storage systems such as village tanks or urban water reservoirs; the former focuses on the water balance for the whole drainage basin which, in some cases, may be multi-national in character. The capacity measures of newly constructed reservoirs, as well as losses of capacity in old reservoirs through leakage, siltation and discontinuity, should also be included. The development of these capacities can be seen as part of response strategies of water resource management and conservation (see C.1.2). In water surplus areas, the reverse question may be of interest (i.e., the capacity to drain water-logged lands). Another area that has received increasing interest among hydrologists is the seasonal and long-term variation of snowfalls and of the storage capacity of water in snow-fields and glaciers. Levels and flows are measured as deviation from the mean. Storage capacity changes are measured as changes in volume, and drainage by area drained and/or by volume of water removed.

Variables	Classifications	Observations
a. Changes in the average level of surface and ground water (m)	Type of storage Drainage basin	Depletion indicator
b. Changes of the average flow of streams (m^3/sec.)	Type of stream Drainage basin	Relevant for water quality assessment

c. Net change in water storage capacity (m^3)	Type of storage Drainage basin	Including aquifers, and man-made (at local and drainage-basin levels) and natural reservoirs
d. New construction and loss of old water storage capacity (m^3)	Type of storage Drainage basin	Including loss of capacity due to siltation
e. Net change in drained areas (km^2, m^3)	Purpose Drainage basin	Including pumping of water below sea level and drainage of land for agricultural purposes

B.1.2.2 Soil and land

Soil losses and gains result from the impacts of natural cycling systems of air and water, and human activities. Two kinds of processes are highlighted here in this context - soil loss due to erosion, and soil loss or gain due to changes in land use. Changes in land assets available for particular uses can be tracked by land use statistics as proposed in section A.1.8.1. Here, a more focused approach is suggested by distinguishing between land-use changes from productive to non-productive uses, and vice versa. "Productive" is used here in the sense of "natural" or biological production. By contrast, from an economic or market value perspective, changes from agricultural to industrial or residential uses may be viewed as an increase in the "economically productive" use of a given piece of land. The data in this section are related to A.1.1.1, Crop and livestock production (tillage practice), A.1.8.1, Land use change, and C.1.3, Rehabilitation of degraded environments.

Data on the rate of soil erosion are obtainable from sample plots calibrated by soil type, slope, precipitation levels and so forth; sample measures of soil depth taken at different times; and levels of siltation in rivers and streams. A rough indicator on the rate of soil erosion (by drainage basin) can be produced from sediment-load readings in rivers. This is particularly valuable in estimating erosion losses in the head-waters due to deforestation and crop cultivation of steep slopes. In addition to the actual estimates of soil erosion, there is also an interest in the development of soil erosion risk maps (see D.2.3, Lithosphere).

Data on bioproductivity gains and losses of land are obtained from monitoring the following area gain/losses:

(a) Loss of agricultural lands to urbanization, industrialization and transportation;

(b) Loss of agricultural lands to desertification processes;

(c) Gain of agricultural lands from irrigation, drainage of wetlands and conservation and rehabilitation;

(d) Loss of forestlands to agriculture and vice versa;

(e) Loss of farmland (abandoned) to wildlands;

(f) Loss of agricultural and forest lands through deforestation, pollution incidents, and other man-made and natural events;

(g) Loss of agricultural and forest lands through natural events such as lava flows, rising sea levels, changes in river courses.

Obviously, it is difficult to produce precise figures of soil and land losses and gains. However, the objective is to provide rough indicators of major trends in changes of land bioproductivity. Loss/gain balance sheets can, in part, be constructed from databases presented in A.1.1, Agriculture; A.1.8, Land use and environmental restructuring; A.3, Natural events; D.1.1, Agricultural stocks; and D.2.3, Lithosphere.

Variables	Classifications	Observations
a. Productive soil loss due to land use conversion (km^2)	Soil type	Including losses due to urbanization and environmental restructuring - e.g., dams
b. Productive soil loss due to erosion (km^2, t)	Soil type	Estimated by erosion models or sediment loadings
c. Productive land gain and losses (km^2)	Soil type Land use	Balance-sheet categories

B.1.2.3 Mineral (including energy) resources

Three factors have to be taken into account for estimating the availability (depletion) of non-renewable resources: exhaustibility, uncertainty regarding the quantities of (reserve) stocks, and economic supply as a function of price and technology. The human response to the non-renewability of resources is conservation of energy, parsimony in the exploration of exhaustible resources and full use of the recycling potential of materials (see sects. C.1.2 and C.4). The concept of a given reserve, subject to an annual rate of depletion, leading to the inevitable exhaustion of reserves in a certain number of years is too simplistic. A more realistic picture takes into account uncertainty in reserve stocks, increasing costs of extraction due to the need to exploit poorer reserves and/or increasing difficulty of access, modified by technological advances, the availability of substitutes and discovery of new resources. Nonetheless, as a crude indicator of depletion, a reserve depletion index is suggested in the text table below. The index measures the proportion of initial reserves depleted by annual production data as the ratio of cumulative production over initial reserves, the latter being updated by new discoveries and revised estimates based on price and technology. Thus, the possibility remains that the "depletion index" might show a decrease if new discoveries and revisions of reserve stocks are greater than the rate of depletion. Alternatively, a life index can be produced by dividing the remaining reserves by annual production.

The data for estimating rates of depletion are obtained from:

(a) Data on reserves (see sect. D.2.4.1, Mineral reserves and sect. D.3.1.1, Hydrocarbon and uranium reserves);

(b) Data on new discoveries (see sect. A.1.5.1, Mineral exploration and sect. A.1.6.1, Discovery, development and extraction of energy sources);

(c) Data on revisions to reserve estimates (see text table);

(d) Data on annual production (see sect. A.1.5.2, Mineral production and sect. A.1.6.1, Discovery, development and extraction of energy sources).

Natural resource accounts draw on these data bases, providing for an aggregative description of the stocks and changes in stocks from the beginning to the end of the accounting period (see annex I).

Variables	Classifications	Observations
a. Initial reserves (t, bbl, m^3)	Type of reserve	Accumulated reserves, adjusted annually for revisions
b. Accumulated production (t, bbl, m^3)	Type of reserve	Σ (e) (over all years of extraction)
c. Remaining reserves (t, bbl, m^3)	Type of reserve	(c) = (a) - (b)
d. Revisions to reserves (t, bbl, m^3)	Type of reserve	New discoveries and adjustments to estimates of recoverable reserves
e. Annual production (t, bbl, m^3)	Type of reserve	Annual extraction
f. Depletion index (%)	Type of reserve	(f) = (b/a) (100)
g. Life index (years)	Type of reserve	(g) = (c)/(e)

B.2 ENVIRONMENTAL QUALITY

Section B.2 identifies the variables that measure the qualitative changes in the environment, which include the quality of the environmental media, of biota and their interactions with the media in ecosystems. Measurements of the qualitative properties of air, water and land usually refer to accepted norms and standards. Statistical measures can then be depicted in terms of the range and/or frequency of deviations from these standards. Degradation of environmental media can also be analysed in terms of "loss of environmental functions" such as human and non-human life support and cultural or aesthetic values attached to human uses of the environment. Some welfare aspects, in particular health effects, of environmental quality degradation are addressed in section B.3. Environmental quality criteria and standards are thus as much cultural as scientific and may change with public perceptions and political objectives.

Environmental quality statistics face major problems, including:

(a) Lack of scientific experience and knowledge in the dynamics of ecosystems and the long-term impact of environmental degradation on human health;

(b) Inexperience in data collection methodology and techniques, interpretation of observed parameters and methods of ascertaining their statistical validity;

(c) Lack of benchmark data and long-term time series to assess the significance of cyclical (recoverable) deviations from permanent (structural) change.

Methods and techniques of data collection and the limitations of data use need therefore to be fully elaborated in presenting environmental quality statistics.

The measurement of environmental quality emerged in the mid-1960s out of concern over the industrial pollution of land, water and air, and the chemical contamination of biota. In developing countries, these concerns are of a more recent origin, and systematic monitoring is only beginning to take place. The choice of parameters has been, by and large, a product of regulatory needs, technological limitations and costs of data collection. These parameters change with new knowledge, shifts in priorities and improvements in measurement techniques, resulting in inconsistency in time series and incompatibility of readings taken at different locations. Therefore, the statistician's perspective for consistency, comparability, and statistical validity needs to be integrated into the design and planning of environmental monitoring systems.

The cost of environmental monitoring has inhibited the development of statistically valid space/time sampling frames. This has led to the search for integrative parameters where a few observations would suffice for a general picture of environmental quality. Ecological indicators, such as the average size of species, seem to be one of the more promising approaches to this problem. Another possibility is to develop a system of "environmental quality detectors" from remote sensing imagery, such as signals of the satellite spectrum to detect diseased plant life. This kind of monitoring can rapidly be produced by computer analysis of the remote sensing spectrum, a particularly attractive proposition for developing countries.

B.2.1 Atmospheric pollution

As indicated above in section A.2.1.4, urban air quality is described in *Human Settlements Statistics* (B.2.1, Ambient concentrations of pollutants and waste) because of its local impact. By contrast, atmospheric concentration of pollutants is presented here as "background" pollution. A distinction can thus be made between atmospheric pollution at global or transnational levels, urban air quality at local levels and indoor air quality at the micro-level.[25/]

Atmospheric pollution can be displayed in the form of contour mapping, reflecting the relationship of the source with characteristic dispersion patterns. Air movement, precipitation, temperature, general topography and land cover are factors that influence the pattern of dispersion. The quality and accuracy of these data are related to the location and density of the monitoring stations and the quality of the dispersion models. Quite clearly, there is a trade-off between cost and accuracy. Background air pollution variables should, where feasible, be correlated with the atmospheric parameters recorded by the meteorological office's network of weather stations - e.g., visibility, precipitation and radiation. These parameters are presented in section D.2.2, Climate.

One major concern arising from atmospheric pollution is the impact of acid deposition on biota and their habitat from acidification of lakes, soils, dieback of forests and reduced resistance of some fauna/flora to diseases. These effects are described below in sections B.2.2.1, Inland water quality; B.2.3.1, Soil quality and B.2.4, Quality of biota and ecosystems. The linkage of atmospheric pollution with local impacts permits the assessment of the effects of global phenomena at national and local levels. Such phenomena include emission of climate change, fluorocarbons and their effect on the ozone layer, consequential effects for human and non-human biota, and, in the case of nuclear accidents and weapon testing, the dispersion of man-made radiation.

Climate change and the reduction of the ozone layer are global issues and are therefore best treated in the context of world models. The alarming increase in radiation levels of strontium 90 and caesium in the 1960s led to their world-wide monitoring. The banning of atmospheric nuclear tests has considerably reduced this source of health hazard, although it could once again reach high levels through episodic events - i.e., reactor meltdowns. The recent development of international protocols to reduce fluorocarbons in the atmosphere is based on growing scientific evidence that industrial pollutants are responsible for the thinning of the ozone layer (a natural filter for solar radiation) in the high atmosphere.

The text table below presents two main variables: concentrations of selected background pollutants, including acidity of precipitation, and radiation. Spatial variation in the level of radiation reaching the ground is significant for the assessment of the exposure of human and other biological species to potentially harmful radiation levels. Although man-made radiation is of particular concern because its sources are readily identifiable, natural background radiation is of increasing interest because of its association with skin cancer and other health problems.

There are several international programmes designed to measure background pollution in the atmosphere, such as the Global Atmosphere Watch (GAW) of the World Meteorological Organization (WMO), which includes the Global Ozone Observing System (GO_3OS) and the Background Air Pollution Monitoring Network (BAPMoN). The data from WMO BAPMoN form a major information source for the Global Environmental Monitoring System (GEMS) of UNEP. Another pertinent programme is the ECE programme for the monitoring and evaluation of the long-range transmission of air pollution in Europe (EMEP). At the national level, sources of data are meteorological offices and departments or agencies of environment and health.

Variables	Classifications	Observations
a. Concentration of selected pollutants (ppm, $\mu g/m^3$, pH)	Type of pollutant	Including SO_2, NO_x, pH level in acid precipitation, Pb, O_3, CFCs, particulate matter, at background measuring stations
b. Atmospheric radiation (GBq/km^2)	Type of radiation Geographical coordinates	Man-made and natural

B.2.2 Water quality

This report distinguishes water quality of coastal/marine environments from those of inland waters - i.e., lakes, rivers and groundwater. The concept of water quality appears to be more complex than that of air quality, since water quality parameters depend on a variety of purposes and uses of water. For example, nutrient rich water may be beneficial for certain kinds of biotic life but unacceptable for recreational and drinking purposes.

A major cause of water degradation is the use of water as a cleansing agent and "sink" for industrial and household wastes. Sea-coasts, estuaries and shorelines of large lakes are particularly favoured for the location of highly polluting industries because they appear to be an easy solution for waste disposal. However, these uses have endangered the survival of the sensitive ecosystems described by the interface between land and water. The attributes of a desirable climate and the aesthetic qualities of shorelines have added to the competition for land use by the growing demands of recreation and tourism. Oil spills, oil slicks and contaminants transported by ocean currents have led to major concerns at local, regional and global levels. Acid precipitation has generated high acidity levels in lakes and rivers and has endangered or destroyed biota in these aquatic systems. The interactions between water use and management with the availability and quality of water are outlined in figure II above.

The major sources of freshwater quality statistics are the data bases of agencies concerned with water quality. In some countries, these are the environmental protection agencies, in others, they may include water authorities or local governments. Water quality parameters are being increasingly introduced in hydrological surveys. Other data are obtained from the analysis of remote-sensing imagery, such as chlorophyll a. There are a number of regional programmes collecting data on marine water quality, coordinated by the UNEP Regional Seas Programme Activity Centre, the Helsinki Commission, and the Paris and Oslo Commissions. Other sources of data are the international monitoring and research activities, coordinated by the Inter-governmental Oceanographic Commission. At the national level, data sources are agencies or departments dealing with marine pollution, meteorological monitoring and environment protection, fisheries and remote sensing.

B.2.2.1 Inland water

Water quality criteria are based on assumptions about the desirable physical, bio-physical and chemical properties of water which may vary greatly even in their natural state. The development of water quality statistics stems from concern about human contamination of water systems through loadings of pollutants from industry, agriculture and human settlements (A.2.1.1). The contaminants of major concern are toxins such as heavy metals and pesticides, organic matter, nutrient loadings such as fertilizer run-off, deposits from acid precipitation and pathogens such as coliform. The list continues to grow with each new discovery of contaminants and their associated stress effect on human health and aquatic ecosystems. Only a fraction of known contaminants are monitored on a regular basis.[26/]

Statistical data collection should aim at providing databases that permit the linkage of contaminant concentrations, depicting changes in "average conditions", with emission statistics and thus with human activities as sources of pollution. As described in figure II above, water quality statistics are related to the databases on Water use for human activities (A.1.7), Emissions and loadings into inland waters (A.2.1.1), Pollution monitoring and control (C.2) and Hydrological systems (D.2.1) by means of common geographical identifiers, obtained from ecological mapping (see sect. D.4). Water quality indexes attempt to generalize monitoring data for purposes of assessing water quality for particular water uses, such as aquatic habitat, potability and recreation. More general indices assess the overall state of water quality for different water bodies (see sect. B.2.2.3 below).

Water quality monitoring programmes are generally designed for the purpose of regulatory control and compliance. In other words, the choice of pollutants, the monitoring sites and the frequency of sampling are based on the minimum required to exert the necessary control of - e.g., chlor-alkali plants regarding mercury contamination. Environment statistics are expected to accurately represent the extent of water pollution (i.e., its distribution) and its rate of change (in terms of time series). However, water quality monitoring for regulatory purposes does not necessarily reflect statistical averages. What would be required are random sampling points or, if that were too costly, selected sites upstream and downstream from major sources of pollution and consistency in time series and sufficient observations to provide statistically significant frequency distributions and averages.

In addition to issues of sampling design, there is the question of the choice of parameters and the methods of data collection. The following factors need to be considered in developing water quality indicators:

(a) Selection of monitoring sites to represent different levels of water quality - e.g., high, medium and low levels of pollution;

(b) Choice of parameters which can be linked to specific human activities such as pesticide residues or phosphorus and nitrogen from agricultural upstream drainage basins;

(c) Choice of contaminants that can be associated with specific environmental objectives, such as human health or preservation of aquatic ecosystems - for example, pathogenic organisms, BOD_5, pH levels and heavy metals;

(d) Choice of statistical measures in addition to the mean value, such as frequency of observations above certain standards, contaminant detected as a percent of total samples, deviations from the mean.

Variables	Classifications	Observations
a. Physical/chemical properties (µg/l, %, pH)	Water body	Including turbidity, salinity, acidity and conductivity
b. Concentrations of chemical contaminants (ppm, µg/l)	Water body Chemical compounds[a/]	Stress on aquatic ecosystems and human health
c. Nutrient indicators - e.g., chlorophyll a (µg/l)	Water body	Indicators of eutrophication
d. Concentration of organic matter - e.g., BOD_5 (mg/l)	Water body	Level of dissolved oxygen
e. Concentration of pathogens (µg/l, nos./l)	Water body Type of pathogen	Indicators of potability of of water - e.g., fecal coliform count
f. Areas where water may carry waterborne disease vectors (km^2)	Water body	For example, bilharzia onchocerciasis
g. Water quality index (index value)	Purpose Water body	Including aquatic habitat, drinking water index, recreation (see B.2.2.3)

a/ There are several international lists of water pollutants, including GEMS/WATER Operational Guide, ECE Water Quality Statistics (see annex III) and WHO International Standards for Drinking Water.

B.2.2.2 Marine water

International agreements for the protection of marine environments and protocols on ocean dumping have been developed in response to marine pollution.[27/] Similarly, cooperative programmes are being undertaken by countries to clean up and rehabilitate shared inland seas, rivers and lakes, and to develop harmonized pollution control standards. There is a need to monitor the whole spectrum of shoreline activity and its impact on shoreline and near-shore aquatic ecosystems for rational planning and control of these systems (see sect. C.2).

Some of the factors that affect the degradation of seas are:

(a) Navigation accidents, especially of super-tankers and vessels transporting highly toxic chemicals;

(b) Dumping of hazardous wastes;

(c) Land/soil run-off, particularly from highly industrialized drainage basins;

(d) Off-shore mineral and hydrocarbon extraction;

(e) Atmospheric deposition of organic compounds, metals and nutrients.

The intensification of human activities along the coasts is also a major threat to the quality of marine environments. This intensification stems from processes of urbanization, industrialization and tourism in coastal zones, and from agricultural and aquacultural development, bringing about conversion of tidal swamps and flatlands into bioproductive systems (e.g., mangrove swamps to fish ponds).

The transportation of contaminants over wide areas by ocean currents and through the atmosphere threatens even remote aquatic habitats such as those of the Arctic seas and tropical coral reefs. Resource exploitation of the oceans, which in the past has been largely restricted to fisheries, is now being explored for the extraction of minerals from the seabed. In other words, the issues raised on marine water quality have grown from an essentially local or regional problem to that of the entire oceanographic system.

The monitoring of marine water quality is not as well established as that of freshwater. Typically, this activity is treated as a component of more general marine and oceanographic surveys. The parameters sampled include chemical contaminants, biological resources and surface and ocean-floor micro-biota. These data are useful in assessing conditions at a particular point in time as well as for time series analysis. Marine water quality trends may also be obtainable from interpretation of sequences of remote sensing imagery (e.g., growth/density of algae) or monitoring of pathogens found in fish catch.

	Variables	Classifications	Observations
a.	Physical/chemical parameters and concentrations (ppm, µg/l)	Marine organisms, Chemical compounds[a]	Including sedimentation, levels of contamination
b.	Biological indicators (nos., %)	Type of species	Biological indicators of pollution, e.g., phytoplankton, mussels, fish
c.	Pathogenic indicators (nos., %)	Type of disease	Including closure of shell fish sites and disease in fish
d.	Ecological indicators (nos., %)	Type of indicator	Species diversity, size of biota, bioproductivity
e.	Oil slicks (km^2)	Type of source	Including bilge oil, wreckage, blow-outs etc.

a/ The contaminants of major concern are listed in many regional conventions on the protection of the marine environment - e.g., the Barcelona and Helsinki Conventions.

B.2.2.3 Indices of water quality

Water quality is defined by a large variety of biological, chemical, physical and bacteriological characteristics of water and is measured by the values of a correspondingly large number of variables. The multitude of water quality variables makes it desirable to compound the data for a better grasp of the state and change of the quality of water bodies. One possibility of reducing the number of variables is the selection of key indicators which are representative of major quality characteristics. For example, selected biological data have been used for judging the suitability of stream waters for specific uses. In a case study of the Lower Laurentian Great Lakes, it was thus found possible to measure ecosystem health by a relatively small group of symptomatic indicators.[28]

The indicator approach is, however, still in an experimental stage. To obtain a summary picture of water quality, the first step is usually to define a limited number of water quality classes for each water quality variable or at least to determine a standard for a particular water use (i.e., two open-ended "above" and "below" standard classes). Water quality standards (called guideline values) are suggested by WHO for assessing the suitability of water for human consumption and for all usual domestic purposes. General water quality classes of the overall state of pollution or cleanliness of waters typically range from "unpolluted" to "grossly polluted", or "excellent " to "bad", as in the case of the draft quality classes proposed by the ECE. A (qualititative) description of classes and their definition in terms of ranges of pertinent variables is shown in annex III, part B.

A further step in the compounding of variables is their combination into an index which is usually (but not necessarily) linked to the above-described water quality classes. Methods of index calculation include:

(a) The determination of the lowest quality class number for any of the variables monitored as the index value;

(b) The calculation of a weighted average of the class number for the different variables where the relative weights (i.e., importance attached to the variables concerning their impact on overall pollution or a particular water use) are usually subjectively determined; or

(c) The application of multivariate methods such as component analysis to reduce the multidimensional space of the set of variables to a one- or two- (for graphic presentation) dimensional index.

Figure IV is a mapping of an overall quality index of the main watercourses in France, based on measurements obtained from permanent stations and back-up networks operated by river basin authorities. While providing a quick overview of the state and change of water quality, these aggregative methods obscure much of the information originally gathered, and the underlying data will still have to be consulted for environmental and water-related planning and decision making.

B.2.3 Soil and land quality

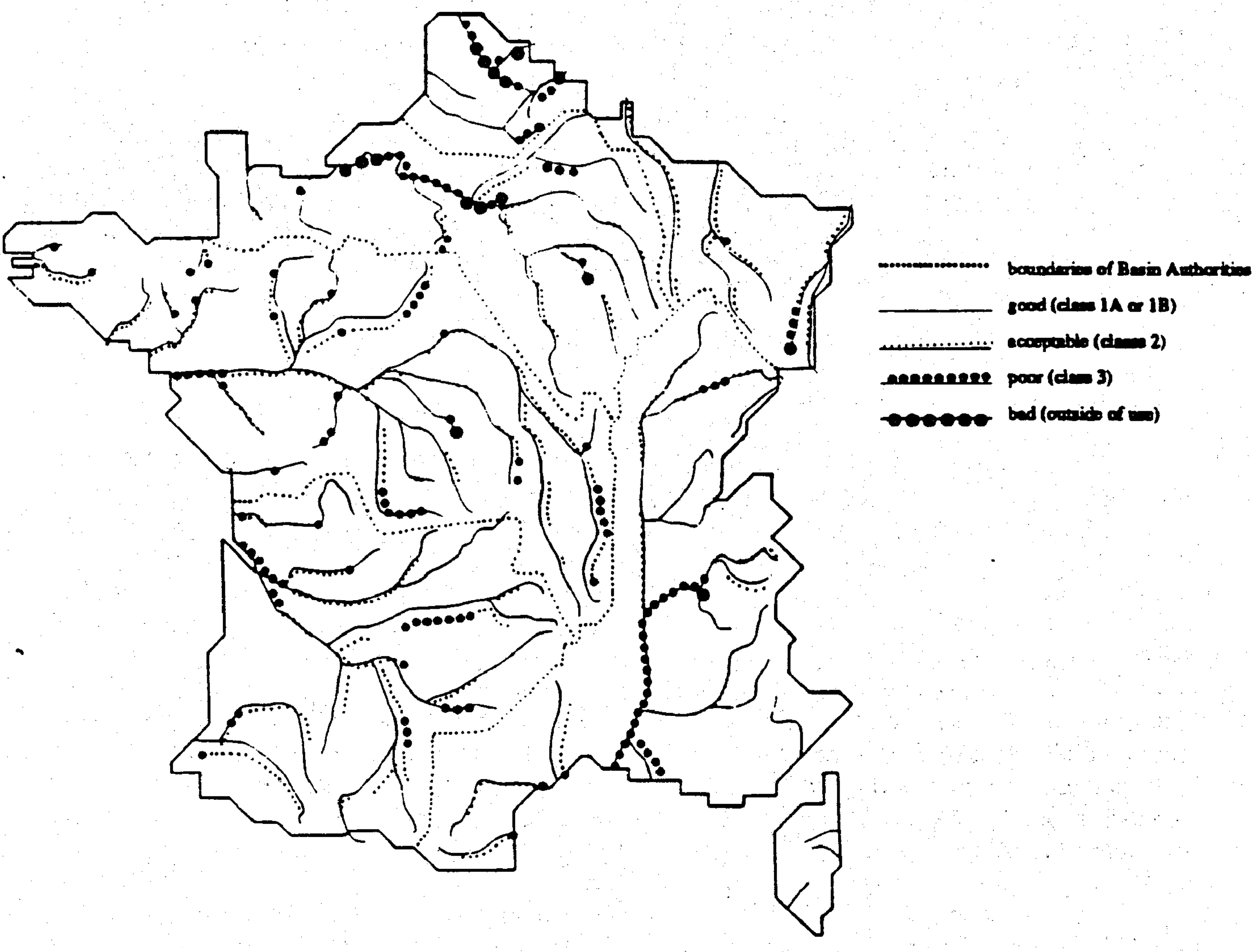
Soil quality (B.2.3.1) affects directly the productivity of bioproductive systems, since the degradation of soils reduces yields in plantlife. In the case of agriculture, reduced output would have to be compensated by the introduction of nutrients in the form of fertilizers. The concept of "land quality" (B.2.3.2), on the other hand, is associated here with cultural and aesthetic values of human land use. Degradation in land quality is reflected not only in reduced "carrying capacity" of biota but also in growing land use conflicts which tend to rise with increased human density. This report has retained the distinction between soil and land quality because it provides the opportunity to view land as a capital asset providing economic and cultural services and to consider soil as a means of (agricultural) production. Qualitative changes affect both the productivity and service capacity of these assets. The distinction between soil quantity and quality changes is controversial, however (see below). Land rehabilitation (C.1.3), soil conservation programmes (C.1.2) and land use planning (C.1.1) are the human responses to qualitative changes in soil and land.

Land use planning and soil conservation agencies and special programmes on land rehabilitation are potential sources for soil and land quality data. Certain aspects, such as desertification and soil salinization, can be assessed by remote sensing imagery. Data on land use connected with aesthetic qualities (e.g., attractive scenery) may be obtained from agencies concerned with tourism and conservation of landscape and nature. National ecosystem maps are also a pertinent source for developing land quality databases.

B.2.3.1 Soil quality

The problem of soil quality changes is complex. Changes in climate and geological events contribute to the widespread degradation or improvement (e.g., volcanic ash) of soils

Figure IV. Quality of the main rivers in France, 1985



Source: Ministry of the Environment, *State of the Environment, France, 1987 Report* Neuilly, 1988).

on which to grow crops or support livestock. Agricultural practices and land use patterns combine, often synergistically, to accelerate or decelerate processes of soil quality changes. Improved soil cultivation in terms of tilling and soil enrichment practices have halted or slowed down soil degradation. On the other hand, soil degradation in connection with the desertification syndrome and through soil erosion and nutrient leaching seems to be on the increase in much of the developing world. In industrial countries, other problems are of concern, among which are the effects of contamination from air pollution (acid depositions) and pesticide residues, the loss of humus material due to application of artificial fertilizers, and soil compaction due to the use of heavy agricultural equipment. Soil degradation can thus be connected with poor tilling practices and inappropriate use of land for crop and livestock production (e.g., of steep slopes causing soil erosion) (A.1.1.2, A.1.8), irrigation (salinization, alkalinization, waterlogging), overuse of agricultural chemicals (e.g., pesticide residuals) (A.2.2), air pollution (acidification) (A.2.1), forest harvest practices (e.g., clear-cutting, logging roads, use of heavy equipment) (A.1.2), urbanization and industrialization (e.g., removal of top soil, land taken out of agricultural uses), and population growth and migration (A.1.8, see also A.1.1 Population growth and change, and B.1.3, Human settlement sprawl and dispersion in *Human Settlements Statistics*).

Soil erosion can be seen as both a quantitative loss of productive soil and, depending on the extent of erosion, as a reduction in soil quality. The former is recorded under B.1.2.2, (depletion of) Soil and land. The latter is shown in the present section, broken down by "erosion intensity" categories. Of course, such distinction is arbitrary to some extent and will have to be decided upon in the context of the analytical use of data - i.e., environmental quality assessment vs. accounting of resource depletion. The improvement of soils can be attributed to good farming practices (e.g., application of fertilizers, tillage practices and soil protection activities) and activities directed towards slowing down desertification and erosion (e.g., tree planting, terracing and soil rehabilitation programmes) (C.1.2.3).

Variables	Classifications	Observations
a. Desertification (km^2)	Type of land use	Overlay desertified areas with land use categories
b. Areas of soil erosion (km^2)	Type of land use	Distinguish areas of high-medium-and low-erosion intensity; overlay with land use categories
c. Areas affected by soil toxicity (km^2)	Type of contaminant	Including pesticides, industrial chemicals
d. Soils affected by acid deposition (km^2)	Type of soil	Measure of pH from "non-natural" sources
e. Soils affected by irrigation (km^2)	Type of soil	Areas of salinization, alkalization and waterlogging

B.2.3.2 Land quality

The measurement of landscape quality is closely connected with the measurement of the "quality of life", regarding the value of nature's services, such as the worth of the hedgerow countryside of England or the rice terraces of the Philippines. Generalized aesthetic qualities of land use are often found in tourist maps (e.g., scenic routes). Ecologists are concerned with measuring the "carrying capacity" of the environment and land use planners with assessing the (often conflicting) demands for land use. A variety of "rating techniques" have been employed to designate areas for environmental protection and conservation (C.1.1). Japan has produced a national mapping system of land quality, referred to as the "green census". The system includes a method of rating areas in terms of human interference with nature. At one extreme, a built-over site would thus be rated at 0, and at the other, a site hardly touched by man (e.g., a remote mountain landscape) would be rated at 10. All other areas would fall in between, distinguishing between intense agriculture, mixed farm-woodland, protected natural parkland etc.

It is difficult to identify variables for land quality independently of the context of land use. Thus, designations of relative qualities would have to be assigned to agricultural use, forest use, wildlife habitat and the various designations (or zoning) for urban, industrial and touristic use. Another approach is to rate land quality directly from a cultural/aesthetic viewpoint. Yet a third approach is to rate land by its biophysical land quality or by its carrying capacity of maximum non-human and human (according to particular standards of living) populations on a sustainable basis.

Variables	Classifications	Observations
a. Land use quality indicators (km^2)	Type of land use	Separate criteria for each land use category
b. Landscape quality[a/] (km^2)	Type of land use	Rating based on aesthetic criteria
c. Bio-physical land quality (km^2)	Type of land use	Rating based on bio-physical criteria of carrying capacity

a/ Landscape quality ratings are based on a combination of criteria of human, environmental, restructuring and natural attributes. Examples of low-rated areas are derelict industrial/abandoned mining sites, and high-rated areas are pristine forests, lakes and mountains, or aesthetically rewarding farming landscapes.

B.2.4 Quality of biota and ecosystems

A distinction is made between indicators of biota quality and the more generic indicators of ecosystem health. Naturally, the two topics are interrelated and are distinguished only for the purpose of statistical development: ecosystem health indicators are essentially variables derived from ecosystem models whereas indicators of the quality of biota are quantitative measures obtained from various kinds of surveys. Both categories of data are linked to the flow and stock of biological resources. These include "wild" species populations and habitat range presented in section B.1.1.4 on the depletion/increase of fauna and flora, and changes of inventory stocks of "managed" resources, shown in section B.1.1.1, Agricultural resources; section B.1.1.2, Forests; and section B.1.1.3, Fish. Quantitative and qualitative aspects are not always easy to distinguish, however. Their identification and description is an important task of corresponding inventories of biological resources (D.1) and of ecosystems (D.4).

The indicators for assessing changes in the qualitative state of biota (B.2.4.1) are measures of average size of biota, longevity, frequency and incidence of disease, and various efficiency measures relating to productivity, growth rates and natural balances of species distribution. Qualitative assessments of the state of ecosystems (B.2.4.2) include data on the environmental conditions for "species survival", identifying symptoms of poor health, measures of capacity to return to healthy conditions after environmental stress, sufficiency of population for reproductive success and indicators of species diversity. Frequently, qualitative assessments are not solely based on "scientific criteria", but may include a strong cultural element reflected in preferences and priorities of wildlife management administrations and the general public for natural systems. For example, lakes with clear water are preferred to those green with algae, habitats that can maintain large mammals are preferred to those where only small mammals can survive, and natural old forests are preferred to young planted forests.

Data on the qualitative parameters of biota and ecosystems are largely products of specialized research activities, and their inclusion in statistical systems is debatable. General overviews, on the other hand, have been carried out in state of environment reports, ecological mapping and specialized surveys aimed at rating the relative qualities of land and biological resources, such as the "green census" in Japan. Other sources of data are resource management agencies - e.g., for areas of forest affected by disease, remote sensing analysis and agricultural production surveys.

B.2.4.1 Quality of biota

Statistics on the qualitative dimension of biota are still in the formative stage. The demand for assessments on the state of the environment has focused attention of the biological sciences on techniques and methods to monitor, at a macro-scale, the "health" of biota and the "productivity" of ecosystems. Distinctions should be made between biota that are essentially cultivated for human exploitation, biota that are not cultivated but have "economic value", and wildlife, which are neither cultivated nor have predominantly "economic" value. The increasing rate of extinction of individual species (see sect. B.1.1), declining habitats (B.2.4.2) and the subsequent reduction in wildlife populations (B.1.1.4) are well publicized facts of the late twentieth century, reflecting increasingly high social values attached to the existence of wild biota.

Qualitative changes of cultivated biota raise a somewhat problematical question regarding the nature of human manipulation to accentuate the desirable attributes for economic exploitation. Genetic manipulation can, in fact, reduce other qualities of biota, such as disease or drought resistance. The variables on loss of cultivated crops and livestock due to environmental conditions attempt to capture this elusive quality aspect of modern agriculture. Data on toxic residues in biota and average size of biota are less controversial indicators of quality. The latter have been considered as general indicators of ecosystem degradation. Table 4 presents data on contaminated marine species in national waters, compiled by an international agency, the Baltic Marine Environmental Protection Commission. Such data have also been used as general indicators of the quality of environmental media in which the contaminated species were found (see e.g., sect. B.2.2 for the quality of marine waters).

Variables	Classifications	Observations
a. Loss of cultivated biota due to disease, insects, natural disasters (% affected, km^2)	Type of biota	Specify crop cultivar and hybrid livestock
b. Toxic residues in biota (mg/l, % detected)	Type of species[a/]	Indicators of biological contamination
c. Change in average size of biota (kg, m)	Type of species[a/]	Indicators of biota degradation

a/ See B.1.1.4 and D.1.4.

B.2.4.2 State of ecosystems

Qualitative indicators of ecosystems are holistic and synthetic in nature, concerned with the productivity/efficiency of the system and its capacity to withstand external shocks. The indicators listed in the text table are shown as examples of measuring ecosystem integrity, a problem of increasing concern in environmental management. However, there is still lack of experience in measuring the state of ecosystems at the scale necessary to provide an overall assessment of the state of the environment. The following indicators are thus only illustrative in nature and their inclusion in systems of environment statistics needs still further discussion:

(a) Primary productivity: a measure of the efficiency of conversion of solar energy and nutrients into plant material. The concept is measured either as "stored energy" (e.g., calories per m^2) or as biomass (e.g., tons of living matter per km^2). A distinction should be made between "new production" (e.g., annual growth) and accumulated production (e.g., in-place inventory of biomass). Mature biological systems generally have low primary productivity but high biomass, while for immature systems the reverse is true (e.g., in recurrently harvested forests);

(b) Listing of rare and endangered species: the increase of the list of rare and endangered species is a good example of an early warning indicator of the general decline in wildlife habitat and species diversity;

Table 4. Concentrations of heavy metals in animal species in Finish sea areas, 1979-1984

Coastal area	Animal species		Cadmium mg/kg	Mercury Mean	Lead	Copper	Zinc
Bothnian Bay	Mesidotea entomon	1981	0.144	-	0.060	8.80	5.00
	Mytilus edulis	1983	0.183	0.057	0.173	22.20	21.00
	Baltic herring	1979	0.007	0.019	0.050	0.67	5.40
		1981	0.004	0.015	0.065	0.51	2.85
		1982	0.001	0.040	0.010	0.43	5.05
		1983	0.006	0.013	0.010	0.41	7.20
		1984	0.010	0.016	0.010	0.36	4.85
Bothnian Sea	Mesidotea entomon	1979	0.163	0.022	0.343	30.03	41.63
		1981	0.107	0.016	0.073	28.07	10.53
		1983	0.038	0.010	0.072	28.30	18.00
	Baltic herring	1980	0.004	0.015	0.015	0.39	2.60
		1981	0.003	0.029	0.060	0.59	3.60
		1982	0.001	0.018	0.010	0.42	5.45
		1983	0.009	0.016	0.015	0.44	5.75
	Cod	1979	0.015	0.025	0.033	4.45	7.79
		1980	0.029	0.028	0.157	8.02	12.05
		1982	0.017	0.025	0.026	6.09	10.38
		1983	0.022	0.029	0.018	5.88	11.30
Gulf of Finland	Mesidotea entomon	1983	0.026	0.017	0.123	9.47	11.67
	Macoma baltica	1979	0.132	0.017	0.660	8.50	85.80
		1980	0.127	0.014	0.793	13.33	-
		1983	0.121	0.015	0.126	8.00	57.20
	Baltic herring	1979	0.006	0.025	0.062	0.50	4.28
		1980	0.006	0.016	0.025	0.45	2.62
		1981	0.007	0.026	0.050	0.67	2.93
		1982	0.001	0.027	0.010	0.29	3.48
		1983	0.005	0.015	0.010	0.35	4.68
		1984	0.007	0.026	0.010	0.25	4.33
	Cod	1979	0.060	0.045	0.070	8.77	13.71
		1980	0.036	0.048	0.240	7.35	10.95
		1981	0.019	0.027	0.063	4.28	15.64
		1982	0.027	0.029	0.025	8.61	13.04
		1983	0.050	0.037	0.022	11.76	20.56
		1984	0.054	0.034	0.030	9.52	17.14

Source: Tilastokeskus, *Ympäristötilasto* (Helsinki, 1987).

(c) Species diversity: a measure of the variety of species in an ecosystem. The underlying assumption is that the greater the diversity of species the greater the probability of any one species to survive adverse conditions. A simple count of the different types of species is far easier to obtain than actual population levels and is therefore often used as an indicator of species diversity. Species diversity is also a measure of the level of "maturity" of the system, like the Amazon forest with its large variety of highly specialized niches. Another factor of interest is the ratio of endemic to exotic species. Areas with high levels of endemic species are particularly valued from a genetic perspective;

(d) Loss of wildlife biota by cause: loss of wildlife resulting from natural and man-made stresses, such as disease outbreaks, insect infestations and natural disasters (e.g., droughts), can be interpreted as signs of "ill-health" of ecosystems or lack of resistance of biota to stress. However, a clear distinction from "quantitative" losses, resulting from over-harvesting or land use changes, might not always be possible, and caution should be exercised in the use of these indicators;

(e) Resilience: a measure of the capacity of ecosystems to recover from shock. The underlying notion is that of the return to equilibrium after absorbing an external disturbance, such as an oil spill. Hardy systems are clearly more resistant than fragile systems, simple systems tend to recover more rapidly than complex systems, and large systems can absorb greater levels of shock than small systems. Complex ecosystems that have evolved over millenia in a relatively untouched state (e.g., tropical rain forests) might never recover.

A prerequisite for the development of ecological indicators is the mapping of ecosystems (see D.4). An understanding of the dynamics of the individual ecosystems is also of critical importance in the specification of these indicators. One objective is to provide answers to such questions as to whether the system is fragile or robust, or whether the spatial configuration is sufficient to maintain viable habitats. While selected indicators on these issues might well be presented in statistical compendia, the actual compilation of such data is probably still more of a research activity - e.g., of "statistical ecology" - than part of a routine programme of "ecological statistics".

Variables	Classifications	Observations
a. Primary productivity (t/km^2, $cal./m^2$)	Type of ecosystem[a/]	Indicator of natural productivity
b. List of rare and endangered species (nos.)	Type of ecosystem[a/] Type of species[b/]	Early-warning indicator of general decline
c. Number of different species (nos.)	Type of ecosystem[a/]	Indicator of diversity

d. Loss of (wildlife) biota due to natural and man-made causes[c] (% affected, km^2)	Type of ecosystem[a] Type of species[d]	Indicators of resilience to environmental stress
e. Time period of recovery (years)	Type of disturbance[c] Type of ecosystem[a]	Indicator of resilience

a/ See section D.4, Ecosystem inventory.

b/ See e.g., International Union for Conservation of Nature and Natural Resources (IUCN), *Red Data Book*, which distinguishes between endangered, vulnerable, rare, indeterminate, out-of-danger and insufficiently known species.

c/ Including area of dieback of forests due to acid rain, reproductive failures due to contamination - e.g., peregrine falcon - reproductive failure due to loss of habitat - e.g., panda bear.

d/ See D.1.4, Fauna and flora inventories, for a description of species classification.

B.3 HUMAN HEALTH AND ENVIRONMENTAL DISASTERS

Section B.3 deals with the impact of environmental conditions and man-made and natural disasters on human health and welfare. With respect to the ambient urban environment (e.g., air quality, noise and diseases, associated with housing conditions) and the impact of natural disasters on human settlements (e.g., damage to buildings, and injury and loss of life), health and welfare effects are covered in *Human Settlements Statistics* (B.3.1, Exposure and health effects and B.3.2, Settlement-related damage and accidents). The present topic covers therefore only more generic effects of food contamination and vector-borne diseases, as well as the impact of disasters on the natural environment that are not linked directly to environmental conditions in human settlements.

Data on human health are obtained from health statistics, typically maintained by health authorities. In countries where there are specific programmes to assess the environmental impact on health, more direct information can be compiled from sample surveys. Historical data on the impacts of natural events are available from meteorological and geological offices. The records of agencies concerned with emergencies (including the military forces) are a prime source for impact information. Insurance records, including crop insurance, are also a good source of data on the cost to production and of property losses. Other sources are investigative agencies in the case of impacts of man-made environmental disasters. Statistics on the area affected can be obtained by remote sensing imagery, especially for large-area events such as forest fires, floods, disease infestations and so on.

B.3.1 Human health and contamination

Health is a holistic concept, and it is almost impossible to trace separately the interrelationships of human health with cultural lifestyles, genetic heritage and the condition of the environment. Cause and effect relationships between exposure to environmental hazards and subsequent decline in health and general well-being can therefore only be established in the most obvious cases. Limitations in coverage of health statistics usually do not permit a comprehensive assessment of the incidence of environment related morbidity and fatality. In addition, the cause-effect relationship may become apparent only after some time lag. Furthermore, many symptoms from exposure to unhealthy environments are of a "non-specific" nature, such as stress, fatigue and allergies. Despite these ambiguities, there is, nevertheless, considerable interest in correlating human health with environmental conditions.

In principle, all causes of illness are environmental, particularly when one considers that even genetic susceptibilities and immunities are products of long-term changes of past environmental conditions. Also, improvements in longevity, for the most part, can be attributed to reducing exposure to environmental hazards through public health programmes, e.g., water purification and wastewater treatment (C.2.4), disease vector control programmes and health education. These major strides in public health are now being threatened by what might be referred to as technology associated with health hazards, such as risk from nuclear radiation, exposure to carcinogenic chemicals, risks associated with traffic and transport (see sect. B.3.2 Settlement-related damage and accidents, in *Human Settlements Statistics*). In addition, environmental restructuring, clearing of forests and the development of dams and irrigation ditches (A.1.8.2) have accentuated, in some parts of the world, traditional environmental diseases associated with water and malnutrition. The environmental health and welfare effects of urbanization, especially in marginal settlements, have been described in *Human Settlements Statistics* (B.3).

The statistical indicators selected to depict the effects of changes in the quality of the natural environment on human health fall into two categories: those obtained from food and drug administrations, and those selected from mortality and morbidity statistics.

Variables	Classifications	Observations
a. Chemical residues in food and water (ppm)	Type of contaminant	Average level of samples and/or number of samples above "safe limits"
b. Food condemned due to health risk (kg)	Cause of ban	
c. Radiation levels in food (pCi/l)	Type of radiation	Largely in milk - e.g., strontium 90, caesium 137
d. Contaminants in human tissue (ppm)	Type of contaminant	Based on autopsy samples
e. Mortality and morbidity from environmental vector diseases (nos., rate per 10^5)	Type of disease	Indicators of environmental health impacts, including typhoid, cholera, bilharzia
f. Mortality and morbidity from malnutrition (nos., rate per 10^5)	Cause of malnutrition	Indicators of poverty and food shortages (contributing factors to environment-related diseases)

B.3.2 Impacts of environmental disasters

This section draws together statistics on the impact of environmental disasters, typically viewed as "episodic events". The distinction is made between natural events and those which can be identified as human-caused accidents. Several difficulties arise in distinguishing an "event" from a normal or chronic condition. The major distinctive marks are severity and duration and, in some cases, location/area - i.e., accidents in high-density vs. low-density areas of population. Meteorologists have developed a classification system for wind velocity to alert shipping and other activities of potential dangers and have used duration criteria to define drought conditions. Seismologists have devised the Richter scale to describe the severity of earthquakes. As pointed out in section A.3, Natural events, the characteristic "uniqueness" of events precludes statistical sampling methods and other statistical techniques of large numbers. However, infrequent observations still permit calculating risk probabilities.

The text table presents the effects of natural and man-made disasters on the natural environment. Injury and loss of life and property from such disasters (including traffic and industrial accidents) are described as part of the hazardous conditions in human settlements (see *Human Settlements Statistics*, B.3.2, Settlements-related damage and accidents).

Variables	Classifications	Observations
a. Loss of cultivated biological resources (nos., km², $)	Type of event Type of resource	Crop, livestock and plantation forest loss - e.g., from drought, flood, locust plague
b. Loss of fauna and flora (nos., km², $)	Type of species Type of event	Including forest and aquatic resources loss
c. Impacts on land, soil, air and water (km², ppm, $)	Type of impact	Including pollution from volcanic eruptions and man-made disasters (war)

C. RESPONSES TO ENVIRONMENTAL IMPACTS

Section C constitutes the "human response" to situations which are considered undesirable in the context of the overall activity-impact-response framework of FDES. Human response attempts in principle to reverse adverse trends by achieving a new equilibrium in the relationship of human activities, the maintenance of healthy ecological systems and the sustainability of natural resource use. As pointed out in the introduction, the concepts of sustainability and environmental soundness of development express world-wide concern over natural resource depletion and the loss of environmental services of waste assimilation. National policies as well as international cooperation will have to address these questions according to their geographical impact at subnational, national and international levels.[29/]

Human response can be both collective and individual. Individual actions are those associated with microeconomic agents of households and enterprises, whereas collective actions are usually the domain of governmental organizations. Government policy reflects the "collective will" to protect, conserve and rehabilitate the environment and natural resources, in other words, to counteract environmental degradation and depletion as depicted in section B. Reactive policies that aim at curing environmental impacts can be distinguished from anticipatory ones that attempt to prevent the occurrence of any impacts at the outset. The latter have been considered to be more effective (less costly) than environmental clean-up. In the final analysis, such anticipatory policies will require the cooperation of all individual agents in the environmental field, reflecting a significant change in individual attitudes and behaviour towards the environment. This implies modifications in production and consumption processes, the technology applied in the activities depicted in section A, as well as changes in cultural values.

Responses can thus be roughly classified as defensive/curative (i.e., clean-up or escape) or preventive (i.e., modifying or regulating human behaviour). Another important distinction is between private and public sector responses. The latter reflect environmental legislation, regulations and public expenditure on the environment. The former represent compliance by households and enterprises with the regulations and responses to economic (dis)incentives - e.g., installation of pollution abatement equipment or recycling of household wastes by individuals or households. Avoidance of (escape from) deteriorating environments is another individual response conditioned by the capability of bearing the avoidance costs.

Three major categories of environmental policy can be distinguished:

(a) Environmental protection addresses the problem of improving and maintaining the quality of natural cycling systems (i.e., air and water), ecosystems, and human health and the quality of life as far as they are related to the environmental quality of human habitat and natural systems;

(b) Environmental conservation addresses the exploitation of highly valued natural and cultural assets (i.e., by developing a system of national parks and historical monuments), renewable and non-renewable resources (through conservation of energy, soils, water, fauna and flora), and genetic stock, through conservation of rare and endangered species;

(c) Sustainable and environmentally sound development approaches the problem of environmental goals in a more holistic manner focusing on the integration of environmental and economic goals. Sustainable development advocates the internalization of environmental externalities in production and consumption functions, the promotion of environmentally sound technology, intergenerational transfer of resource assets (i.e., management of resources on a sustainable basis, and international cooperation in the sustainable use and management of shared natural resources and global commons.

Collective and individual responses involve Governments, enterprises, institutions, households and individuals. From a statistical standpoint, responses must be defined in a quantifiable manner - i.e., in terms of measurable variables such as expenditure, area protected, quantities of recycled material and so forth. Individual responses reflect, however, personal and cultural values that can only be assessed in attitudinal and opinion surveys. The question of how to interpret "subjective data" is controversial (see sect. C.4.2). A major "collective" response measure is the development of laws, regulations and enforcement capacity. These data are obtainable from administrative files and might include the number of compliance inspections, fines levied on infractions and follow-up on public complaints of environmental nuisances.

The costs of environmental protection are sometimes referred to as "defensive expenditure". They are the costs associated with the maintenance of environmental quality and sustainable resource use incurred by enterprises, households and government. Defensive expenditure and other environmental costs of actual depletion and degradation of "natural capital" assets have been incorporated in an integrated system of economic-environmental accounting, currently being developed by the Statistical Office of the United Nations Secretariat.[30/] The measurement of environmental expenditure depends on where the line is drawn between environmental and other expenditures. In the traditional expenditure accounts, environmental expenditures are defined as operating and capital costs in waste water treatment, pollution abatement equipment and costs incurred in disposal of wastes and hazardous materials. The administration and enforcement costs are sometimes included if the government departments responsible for environmental protection and conservation are clearly identified. Environmental expenditures in other departments, such as soil conservation programmes in the department of agriculture, or reforestation in the department of forestry, are usually more difficult to identify in the overall departmental accounts.

Measures of the physical infrastructure for maintaining the quality of the environment and of the management of natural resources can be classified into:

(a) Land area protected by legislation, such as national parks, nature reserves and other environmental restrictions in the use of land - e.g., green belts around cities;

(b) "Fixed" capital infrastructure, such as installed capacity of pollution abatement equipment, wastewater treatment plants, clean-up (emergency) equipment and waste disposal and recycling facilities;

(c) Network of monitoring stations;

(d) Facilities for environmental and natural resource management and research, such as fish hatcheries, tree nurseries and laboratories.

The response variables identified in section C fall into four thematic domains:

(a) C.1, Resource management and rehabilitation (stewardship of natural resources)

(b) C.2, Pollution monitoring and control (maintenance of environmental quality);

(c) C.3, Prevention and hazard mitigation of natural disasters;

(d) C.4, Private sector responses (individuals, households and enterprises).

The first three categories are collective responses and normally the concern of public policy and expenditure. The fourth category is the response of the private sector. Response variables in C.4 may, from a thematic point of view, be difficult to distinguish from those in C.1 - e.g., in the case of private and public afforestation.

C.1 RESOURCE MANAGEMENT AND REHABILITATION

Resource management, in the traditional sense, aims at optimizing the (economic) output of natural resources for the purpose of raising incomes of resource-based industries - i.e., agriculture, forestry, fishing, mining etc. Resource management, in the sense of "response to environmental impacts", both reorients and broadens the question toward the stewardship of natural assets for current and future generations - i.e., to the goals of sustainable development and improvement of the quality of the environment. These objectives are met by long-term planning of energy/material flows, conservation of land and water, and protection of the environment. Expanded (multi-objective) resource management includes the following:

(a) Protection and conservation of ecosystems, including genetic stock;

(b) Rehabilitation of degraded ecosystems;

(c) Sustainable economic output from the natural resource base;

(d) Conservation and efficiency in the use of biological resources, soils, water and energy;

(e) Land use in harmony with ecology and cultural values, i.e., minimizing land use conflicts;

(f) Promotion of a conservation ethic through education, public information, research and economic (dis)incentives.

Natural resource statistics have been developed for the relatively narrow needs of economic exploitation. Conventional statistics will have to be modified and expanded to serve the assessment of multi-objective strategies. Such statistics should cover, besides trends in expenditure, employment and area of resource management, rehabilitation programmes, material-energy resource conservation, research and education. Background information on the legal and regulatory system, environmental attitudes (see sect. C.4.2) and international technical cooperation, directed at resource management, could supplement the above.

The data are, for the most part, obtained from the administrative records of ministries and agencies concerned with resource management. These include the ministries of agriculture, forestry and fisheries, as well as the agencies responsible for the protection and conservation of nature. In countries, where national planning agencies exist, annual reports and special sector plans are a rich data source for budgetary resource allocation to programmes of resource management, rehabilitation and conservation. It should be noted that resource management is often the responsibility of regional and local governments: the administrative records of the agencies at the subnational level should therefore also be consulted to obtain the full picture.

C.1.1 Protection and conservation of nature

The variables identified here describe the effort and level of protection of highly valued natural/cultural assets, unique habitats and wildlife. The different levels of protection depend on several factors, such as pre-existing activity in protected areas (e.g., tribal hunting and grazing), multipurpose uses (e.g., tree harvesting and wildlife habitat) and accessibility for recreation and tourism. Recently, the need to protect aquatic ecosystems has become particularly urgent with increasing seabed exploitation for minerals and hydrocarbons, recreational activity and increasing pressure on inter-tidal zones from harvesting of biological resources, restructuring of shorelines, pollution of estuaries and the use of tides for electric power generation (see sect. B.2.2.2). In particular, these variables should assess progress being made on the World Conservation Strategy's goals and recommendations on ecosystem conservation.[31/] Table 5 shows changes in different categories of protected land over a 10-year period in Indonesia.

Variables	Classifications	Observations
a. National park system (km^2)	Ecological[a/]	Indicator: percentage of ecosystems
b. Other protected areas (km^2)	Level of protection Ecological[a/]	Including wildlife reserves, protected migration routes, aquatic ecosystems
c. Wildlife protected (nos.)	Type of species[b/]	Based on the list of rare and endangered species[c/]
d. Public expenditure and employment for protection and conservation of nature ($, nos.)	Purpose	Indicators: percentage of all expenditures, wardens per hectare protected

Table 5. Trends in terrestrial conservation and marine conservation areas in Indonesia, 1976/1977 - 1987/1988

Year	Terrestrial conservation areas								Marine conservation areas		Total		National parks	
	Natural preserves		Wildlife preserves		Recreation parks		Hunting parks		Marine parks					
	Unit	Area[a]	Unit	Area[a]	Unit	Area[a]	Unit	Area[a]	Unit	Area[a]	Unit	Area[a]	Unit	Area[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1976/1977	121	212 006	28	1 543 097	11	869	3	126 470	1	1 000	164	1 883 442	-	-
1977/1978	124	220 829	29	1 546 097	11	869	3	126 470	2	3 500	169	1 897 765	-	-
1978/1979	138	3 553 536	38	2 444 434	20	35 036	7	227 470	3	4 600	206	6 265 076	-	-
1979/1980	154	3 792 566	48	4 284 058	28	132 502	8	231 221	3	4 600	241	8 444 947	-	-
1980/1981	162	6 204 041	56	4 489 258	35	133 954	10	325 921	3	4 600	266	11 157 774	5	986 294
1981/1982	166	6 279 451	64	4 645 137	49	142 534	10	325 921	3	4 600	292	11 397 643	5	986 294
1982/1983	174	6 781 173	66	4 905 358	52	171 574	10	325 921	5	7 480	307	12 191 506	16	4 406 671
1983/1984	174	6 784 150	67	4 913 223	54	173 592	10	326 291	5	8 600	310	12 205 856	16	4 406 671
1984/1985	177	6 827 780	67	4 913 223	55	175 592	10	326 291	5	8 600	311	12 251 486	19	4 665 326
1985/1986	180	6 908 480	69	5 009 977	55	178 730	10	326 291	5	8 600	319	12 432 078	19	4 665 326
1986/1987	184	6 778 604	72	5 045 833	63	195 705	12	364 541	6	14 600	337	12 399 283	19	4 665 326
1987/1988	177	5 913 357	70	5 698 519	60	260 018	13	327 507	7	72 930	327	12 272 331	19	4 776 951

Source: Central Bureau of Statistics, *Environmental Statistics of Indonesia 1988* (Jakarta, 1988).

a/ Hectares.

e. Area of country covered by land use planning (km^2)	Type of planning	Including watershed and regional resource planning

a/ See section D.4, Ecosystem inventory.

b/ See section D.1.4, Fauna and flora inventories.

c/ See, e.g., International Union for Conservation of Nature and Natural Resources (IUCN), *Red Data Book.*

C.1.2 Management and conservation of natural resources

The economic aspects of natural resource use and management are described as activity data in section A.1, Use of natural resources and related activities. The major focus here is on the conservation of renewable and the efficient (long-term) use of non-renewable resources. The statistics proposed are essentially indicators of resource management on a sustainable basis. The variables identified here are largely measures of conservation programmes in terms of area covered, public expenditure, percent of population involved and so forth. Programmes include soil, water, energy conservation, eco-development (integrated rural development),[32/] administrative control of resource use, renewable energy use, and associated education research and international support. Some of these activities are carried out in the private sector - in particular, recycling of materials - and may be treated as investment in or operational contribution to resource productivity (see sect. C.4).

Variables	Classifications	Observations
a. Conservation of soil, water, energy, fish and forests ($, km^2, %)	Type of programme	Range from village to national conservation programmes
b. Eco-development ($, km^2, %)	Type of project	Including biological pest control, organic farming and tree crop culture, village eco-development
c. Control of resource exploitation ($, km^2)	Type of control	Resource use/harvesting Quotas and restrictions
d. Renewable energy ($, km^2, %)	Type of project	Including village woodlot, solar heating, methane gas, conversion of organic wastes
e. Research, surveillance and education ($, km^2, %, nos.)	Type of programme	For example, inventories, remote sensing and educational programmes
f. Technical cooperation ($)	Type of programme	International support to conservation activities

C.1.3 Rehabilitation of degraded environments

The variables related to rehabilitation are large-scale investments (i.e., environmental restructuring, see sect. A.1.8) to restore environmental degradation from the over-exploitation of renewable and non-renewable resources and from other human activity. However, where possible, pertinent village level activities should be included as well - e.g., by means of a further breakdown of the data in the text table. Of particular interest are programmes and projects directed at the rehabilitation of wildlife habitats, seriously degraded agricultural lands, abandoned mining sites (see sect. A.1.5.2) and the reversal of trends, or at least the "containment" of desertification and deforestation processes. These programmes are sometimes integrated into large-scale economic development projects. One approach is to link area data on the spread of desertification (B.2.3.1), deforestation (B.1.1.2) and population and the decrease of threatened flora and fauna (B.1.1.4) with the level and rate of rehabilitation. This would produce a "balance sheet" of gains and losses for the assessment of net impacts.

Variables	Classifications	Observations
a. Agricultural lands ($, km^2)	Type of programme	Directed at exhausted and abandoned farmlands (soil rehabilitation)
b. Deforested lands ($, km^2)	Type of programme	For example, large-scale afforestation of former forestlands
c. Desertified lands ($, km^2)	Type of programme	For example, large-scale efforts to slow down desertification, including relocation of populations
d. Aquatic systems, shorelines and wetlands ($, km^2)	Type of programme	Restoration of systems
e. Fauna and flora ($, km^2, nos.)	Type of programme	Rehabilitation of habitats of threatened and endangered species
f. Other areas ($, km^2)	Type of programme	Including mining, industrial, and war-damaged sites etc.

C.2 POLLUTION MONITORING AND CONTROL

This section identifies sets of statistical indicators of collective responses to environmental pollution. Individual responses of "defensive action" by households and enterprises are described under C.4, Private sector responses. Response statistics on urban air pollution standards, air monitoring activities, and municipal and industrial solid waste collection and disposition, including recycling, are covered in *Human Settlements Statistics*, (see C.2.1, Environmental standards; C.2.2, Monitoring; C.2.3, Treatment, disposal and reuse of discharges; C.2.4, Expenditure for pollution control). The variables shown here are those related to water pollution, monitoring and control, food contamination and government support of these activities, such as research and development.

The major source of data are the administrative records of environmental protection agencies and government expenditure accounts, including local governments. Water authorities and special statistical surveys on waste treatment facilities might provide physical variables on capacities, number of households served and so forth.

C.2.1 Pollution research and surveillance

Governments are increasing their efforts in environmental research, surveillance and other information requirements to protect the environment. Research is the first step in understanding the linkages between human activity and environmental pollution and provides the basis for the development of surveillance systems, environmental standards and environmental protection programmes. The difference between research and surveillance is not always clearcut. Systematic monitoring for the purpose of regulatory enforcement can, however, be distinguished from surveillance associated with assessments of trends and conditions of the state of the environment.

Surveillance includes the establishment and maintenance of a pollution monitoring network, the collection and organization of data, and the analysis of data records. Interpretation of remote sensing imagery, and special area and/or population sampling programmes, designed to detect levels and trends in environmental pollution and its effects, should also be included here. Points to be considered in designing a monitoring system are:[33/]

(a) Environmental variability: environmental signals are noisy in both space and time;

(b) Non-convergence: in contrast to well-balanced models of classical statistical theory, time series sometimes do not converge but reflect the behaviour of chaotic systems where the amplitude rather than trends can become the important variable;

(c) Space and time correlations: environmental elements are correlated in space and time. The information content of an environmental monitoring system is not as great as might appear because of the tendency of any specific measure to be unique to place and in time (i.e., unreliable for generalization). In view of considerable costs in establishing and operating monitoring systems, this is not a trivial issue;

(d) Cause-effect relations: as is well known, the existence of a significant correlation coefficient implies an association but not necessarily a cause-effect relation. If one of the objectives of monitoring is to understand phenomena or to make predictions, it is not sufficient to monitor only the element of interest or even to extend the monitoring to include other elements showing high correlations. Rather, it is necessary to monitor the behaviour of the underlying processes at work. However, as understanding expands, an ever-widening monitoring system may be required;

(e) Biased perspectives: the design of monitoring systems may be based on an incomplete or even an erroneous perception of environmental behaviour, or may be constrained by technology and cost. The data may not, therefore, be entirely relevant, and may perpetuate existing myths.

The variables listed below are those that record activities in research and surveillance in the areas of pollution and food. These data should include public expenditure on environmental research, the level of water quality monitoring, including laboratory analysis of sampled water, and the public expenditure, inspection staff and facilities for monitoring food contamination. Other surveillance activities relate largely to the expenditure and facilities directed toward detection of contamination in fauna, flora and soils.

Variables	Classifications	Observations
a. Pollution research ($, nos.)	Type of research	Including expenditure and number of scientists in government research stations and universities
b. Water quality monitoring stations ($, nos.)	Type of pollutant[a]	Including the level of national coverage by river basin
c. Food contamination monitoring ($, nos.)	Type of facility Type of contaminant	
d. Other surveillance activity ($, nos.)	Purpose	Including ecosystem acidification monitoring

a/ See section B.2.2.1, Inland water quality.

C.2.2 Standards, control and enforcement

The variables identified in this section are associated with actions and expenditures in the administration and enforcement of environmental regulations. The major areas of regulatory control are content and quantity of emissions, production, transport, use and deposition of hazardous substances, and allowable levels of preservatives, additives, pesticide residues and sanitary conditions of food production and distribution. Emission directories should be consulted for lists of controlled substances and effluent standards.

Variables	Classifications	Observations
a. List of controlled substances and standards (nos., ppm)	Purpose	Human health, ambient quality and protection of biota; excluding indoor environments; including maximum, tolerable, desirable standards
b. Inspection activity and number of violations (nos.)	Purpose Industry	Including number of visits, number of officers and proportion of non-compliance
c. Licences issued and quantities used of restricted chemicals (nos., t, kg)	Type of chemical[a]	Largely pesticides but could include food and wood preservatives

a/ See section A.2.2, Application of biochemicals.

C.2.3 Environmental clean-up and rehabilitation

Clean-up operations can be a response to sudden events, such as oil spills or industrial accidents, or to a gradual accumulation of pollutants in the environment, for example, a waste dump site. Rehabilitation can be viewed as a response to restoring environmental functions of heavily polluted environments. Variables relate to cost (including compensation payments), area affected and other measurable factors of clean-up and rehabilitation. It should be noted that clean-up operations also have an emergency component and, in this respect, are similar to the mitigation of effects of natural disasters, particularly when the operations require rapid actions to save human lives and fauna. Environmental rehabilitation, on the other hand, is generally viewed as a long-term operation, requiring, in some cases, several decades of sustained effort, such as the rehabilitation of the Lower Great Lakes in North America.

Variables	Classifications	Observations
a. Emergency operations (nos., km^2, $)	Type of pollutant Type of ecosystem	Based on operations reports
b. Clean-up activity (nos., km^2, $)	Type of pollutant Type of ecosystem	Based on clean-up activity reports
c. Rehabilitation (nos., km^2, $)	Type of pollutant Type of ecosystem	Based on rehabilitation progress reports

C.2.4 Public pollution control facilities

A major response to polluted environments is the construction and operation of public pollution control facilities. The distinction between collective and individual responses is not always clear-cut. For instance, public funds may be directly spent on developing pollution control facilities for enterprises, or indirectly through tax benefits. Small-scale industries generally share the municipal pollution control facilities, although special charges may be levied by municipalities to cover the additional waste treatment costs. The bulk of public investment is in the construction of waste water treatment plants. Increasingly specialized facilities for the treatment of hazardous wastes and "safe" disposal facilities are being developed now. The question of urban solid wastes - i.e., garbage disposal - is covered in *Human Settlements Statistics* (C.2.3, Treatment, disposal and reuse of discharges). Two types of expenditure figures are suggested, annual capital investment and operating costs. In addition, other measures could be included, such as the capacity of the facilities, the type of treatment, number of people served and employment.

Variables	Classifications	Observations
a. Water treatment ($, nos., t, m^3)	Type of treatment Drainage basin	Mechanical, chemical and biological (including m^3 capacity, population served and level of treatment)
b. Sludge disposal (t)	Drainage basin	Including recycling (e.g., as fertilizer)
c. Hazardous waste treatment and disposal sites ($, nos., t, m^3)	Type of treatment	Including reprocessing, incineration and deep/safe burial
d. Public expenditure transferred to enterprise for pollution control ($)	Type of industry	Subsidies, tax incentives

C.3 PREVENTION AND HAZARD MITIGATION OF NATURAL DISASTERS

Human responses to severe natural forces can be:

(a) Scientific, including the study of the origins and pathways of natural events for the purpose of predicting their timing, frequency and location;

(b) Engineering, directed towards the prevention of natural disasters by such means as flood control systems, earthquake- and wind-resistant construction;

(c) Biological, similar to engineering in being essentially preventive but using nature as the "mitigative agent". Among the methods used are afforestation in basin head-waters, permanent vegetative ground cover to prevent erosion and biological pest control (see C.1.2.b);

(d) Administrative, relating to setting up systems of surveillance, developing regulations and land use planning, developing contingency plans and emergency storage of food and materials (the latter might also include a food security policy of harvest surplus accumulation and redistribution during deficit years);

(e) Humanitarian, now familiar in the context of international responses to major natural disasters. The capacity to respond depends, to some extent, on the in-place emergency services available.

The variables identified in this section provide selected indicators of "response activities", in terms of expenditure, physical infrastructure and area affected. The response variables describe actions to prevent floods, the surveillance operations in place to predict and track (in the case of moving disasters) violent natural events, the emergency actions to reduce their impact, including evacuation, and to deal with the "after-effect", such as medical aid, emergency shelter and food, clean-up and rehabilitation. Other preventive/mitigating activities are essentially administrative, such as building codes (e.g., for earthquake proofing), land use planning, restricted uses of flood plains, fire controls. It should be noted that the actions in C.1, Resource management and rehabilitation may contribute to the mitigation of natural disasters, particularly as they concern floods, droughts and landslides. Table 6 shows budgetary, physical (earth movement in cubic feet) and monetary data on the national flood control programme as a response to recurrent flooding in Pakistan.

Data sources include water authorities, planning departments and government departments responsible for emergency operations. In some countries, this might be the military. Local authorities, regional governments and non-governmental organizations are also potential sources of data. Remote sensing interpretation can be employed in assessing the area covered by preventive actions - e.g., flood control facilities.

	Variables	Classifications	Observations
a.	Research and surveillance ($, nos.)	Type of activity	Including seismic, meteorological and hydrological
b.	Physical infrastructure to control natural disasters ($, nos., km^2)	Type of infrastructure	Including dams, dikes, drainage systems, sea walls, shelters
c.	Biological activities ($, km^2)	Type of activity	Including tree planting to control water flow

Table 6. Flood control programme in Pakistan during the sixth plan

Agency	Earthwork		Stonework		Cost of remodelling of dams, etc. and of feasibility studies, consultancies etc.[b/]
	Quantity MCF[a/]	Amount Mill.Rs.[b/]	Quantity MCF[a/]	Amount Mill.Rs.[b/]	
Federal area	200	120	5	38	--
Punjab	600	360	15	112	--
Sind	500	300	15	112	--
Baluchistan	50	30	5	38	515
North-west frontier province	150	90	15	112	--
Federal Administrative Tribal Area & Azad Jammun & Kashmir	100	60	5	38	--
Total	1 600	960	60	450	515

Source: Federal Bureau of Statistics, *Environment Statistics of Pakistan* (Karachi, 1984).

a/ Million cubic feet.

b/ Millions of rupees.

d. Emergency facilities in place ($, nos.)	Type of facility	Including medical supplies, transport and food stocks
e. Administrative regulations	Type of regulations	List of regulations, including building codes, land use restrictions etc.

C.4 PRIVATE SECTOR RESPONSES

The present topic deals with the non-governmental responses of enterprises and households. Their responses include the internalization of environmental costs in production accounts, changes in attitudes and behaviour, and in production and consumption patterns. The recycling of residuals is seen not only in terms of sustainable development and material/energy efficiencies but also as reducing, in the case of solid wastes, the problem of waste disposal. The scarcity of suitable sites in highly urbanized regions has made it imperative to reduce the flow of wastes. A distinction is made between household, municipal and industrial recycling.

The sources of data are social and economic surveys, administrative records, fiscal records of subsidy/tax incentives for industrial pollution abatement and databases developed for control of hazardous substances. Attitudinal and opinion surveys are frequently carried out by the public media and non-governmental institutions.

C.4.1 Enterprises

The rationale for making enterprises bear the cost of pollution abatement and natural resource depletion is based on the "polluter-pays" and "user-pays" principles. The variables that describe the cost of urban air pollution and solid waste disposal are found under section C.2.4 (expenditure for pollution control), and C.2.3, Treatment, disposal and re-use of discharges, in *Human Settlements Statistics*. Possibilities of internalizing these and further (imputed) environmental costs in modified national accounts are explored in environmental accounting approaches (see annex I).

This section identifies the variables that describe the costs to enterprises of water treatment - e.g., in waste water treatment plants, lagoons and settling tanks, and (additional) costs stemming from regulations for the safe use, transport and disposal of environmentally hazardous substances, including nuclear wastes. To obtain a comprehensive picture of the cost to enterprises of pollution abatement, one should also include outlays for research and development in environmentally sound technology, investment in such technologies - e.g., low-polluting and low-waste processes, recycling of waste products, and costs of replacing environmentally harmful substances. These costs could also include expenses for the development and marketing of consumer products designed to adapt better to the environment, such as the organic approach to food production and processing, recyclable cans and bottles, biodegradable plastics and substitutes for fluorocarbons. Waste products sold as inputs to other producers may be treated as both a "by-product" and a "recycled product".

It is usually difficult to separate costs, incurred by enterprises to protect the environment, from the general production costs. Three problems stand out in this regard. Firstly, enterprises may assign costs to process changes which, in effect, reduce the total cost of production; secondly, normal operational costs may be presented as environmental, and thirdly, costs incurred by merely changing "pollution pathways" rather than treating or reducing pollution effects should be assessed according to their effective contribution to environmental protection. For example, the cost of construction of high smoke stacks to defuse emissions over a wider area might not be the most effective solution of dealing with environmental wastes and pollutants. These aspects need to be considered in the design of pollution abatement surveys.

	Variables	Classifications	Observations
a.	Wastewater treatment ($, m^3)	Type of industry Type of treatment	Enterprise-owned treatment facilities
b.	Additional costs in handling hazardous wastes ($, t)	Type of industry Type of substance[a/]	Production, distribution and disposal
c.	Material recycling ($, t, %)	Type of industry Type of material	Reuse and recycling[b/]
d.	Investment in, and additional costs of, environmentally sound and resource-saving technology ($)	Type of process Type of industry	Including energy efficiencies, reduction of materials and wastes
e.	Additional costs of environmentally benign consumer products ($)	Type of product	Including research and development, and costs of materials substitution

a/ Based on inventories of environmentally hazardous substances.

b/ See C.2.3.b in *Human Settlements Statistics.*

C.4.2 Households

The environmental response of households is reflected in changing patterns of consumer behaviour. The increasing levels of awareness of, and concern over, environmental quality are reflected in changed patterns of consumer expenditure. A more ecological approach to recreation and leisure and the increasing emphasis on natural materials are all significant symptoms of a more environmentally conscious life style. Some of these behavioural patterns are "defensive", in the sense of protection of health and/or escape from environmental degradation, others are more positive as reflected in the phrase "think globally, act locally".

Variables that depict this kind of behaviour are changes in the structure of consumer expenditures, household waste recycling, purchases of environmentally benign products and energy conservation measures. It should be noted that government policy on environmental education and awareness aims at encouraging such household responses (see sect. C.1.2). Attitude and opinion surveys provide an indication of public perceptions of environmental questions. Table 7 provides an indication of the perceptions of the seriousness of environmental problems as a result of such an opinion survey in Canada.

Variables	Classifications	Observations
a. Consumption patterns ($)	Type of consumption[a]	Use of consumer expenditure survey
b. Material recycled (t)	Type of material	Ecologically safe waste disposal
c. Behaviour patterns (%)	Type of action	Use of behavioural survey - e.g., percentage of population participating in recycling programmes
d. Attitudes/opinions (%)	Type of survey	Time series

a/ Obtain details of product distinctions - e.g., leaded versus non-leaded gasoline, plastic versus paper packages, size of automobiles.

Table 7. Public perception[a/] of the most important environmental problems in Canada at the national and provincial levels, 1981
(percentage)

Problems	Canada	Atlantic Canada	Quebec	Ontario	Western Canada
National					
Water pollution	22	13	26	23	22
Acid rain	18	24	14	18	18
Air pollution	9	9	10	12	5
Industrial pollution	8	6	9	6	12
Pollution (unspecified)	7	7	8	8	4
Air and water pollution	6	7	5	5	6
Dump sites/chemical dumps	3	3	1	4	3
Destruction of forests	2	4	4	1	2
Destruction of animals	1	0	2	1	1
Urbanization/no green spaces	1	1	1	1	1
Land/soil pollution	1	1	2	1	2
Don't know, and other	22	25	18	20	24
Provincial					
Water pollution	27	11	43	21	26
Acid rain	15	12	10	27	6
Air pollution	8	6	6	11	8
Industrial pollution	9	5	8	9	10
Pollution (unspecified)	6	6	8	7	4
Air and water pollution	6	3	5	5	7
Dump sites/chemical dump	4	2	2	5	4
Destruction of forests	6	36	2	1	5
Destruction of animals	2	2	2	1	2
Urbanization/no green spaces	1	0	1	1	3
Land/soil pollution	1	1	1	1	2
Don't know, and other	15	16	12	11	23

Source: Statistics Canada, *Human Activity and the Environment, A Statistical Compendium* (Ottawa, 1986).

a/ The total sample size was 1,960.

D. STOCKS AND INVENTORIES

Stocks describe the state of the economy and of the environment, whereas flows describe the changes therein. The statistical variables that measure change are identified in sections A, B and C. The present section describes the statistical variables for the assessment of stocks and inventories of environmental resources. Section B presented the qualitative and quantitative changes in these resources.

An important aspect in developing this stocks/inventory category of FDES is its relationship to natural resource accounting (NRA). The databases on natural resource stocks and inventories provide the foundation for the construction of NRA. In turn, NRA can provide the physical counterpart of monetary environmental accounts, representing the links between environment statistics as presented in FDES and national accounts systems such as the System of National Accounts (SNA). These links are further elaborated in annex I.

It is useful to make the distinction between capital stocks and inventory stocks for the purpose of analysis of natural productivity. Economic theory defines capital as "means of production" and inventories as goods produced but not yet "used up", in other words, goods available for intermediate or final consumption. In analogy, one can define natural capital stocks as environmental goods which are not consumed in the processes of production and consumption but provide services required for the production of other goods and services or for final consumption (e.g., recreation). Ecosystems, natural cycling systems (water, air), land and genetic stocks possess the characteristics of natural capital stock. Natural inventory stocks may consist of biological resources and subsoil reserves of minerals and fossil fuels. These inventories are available for inputs into economic production or for direct consumption, e.g., as food.

Classification of natural resources into capital and inventory stocks is ambiguous because of the multipurpose nature of natural resources. For example, cattle which are reared for breeding purposes should be considered as capital assets while their slaughter would make them a material input (into food processing industries). Changes in functional use are also factors that should be taken into account. For example, water can be treated as a component of the "life-support-system" or as a recreational asset. A pluralistic approach is therefore required to deal with the development of databases of stocks and inventories. Ideally, databases on natural resources should have capabilities to reclassify assets in terms of their environmental and economic functions. For instance, the objective of reclassifying forest inventories in terms of ecosystems is to estimate the "carrying capacity" of forests as wildlife habitats.

Statistics on natural resource stocks portray the current "in-place" inventory of natural resources. These databases, however, need to be supplemented with historical and benchmark data to enable assessments of the current state of resource stocks. These could include historical records of habitat range of fauna and flora, land use data from historical records such as forest cover 50 and 100 years ago, archival records of climatological variables and inventories of wilderness "untouched" by human activity - i.e., in pristine condition.

Statistics on the current state of natural resource stocks are of critical importance in the analysis of sustainable development. It is suggested that these databases be further supplemented with selected indicators to describe and monitor the changes in infrastructure capacity to exploit natural resources and the technology employed. Such information would usefully supplement data on actual resource exploitation (see sect. A) and its impacts (sect. B) with data on potential resource use/depletion.

Natural resource stocks can be broadly classified into three major types:

(a) Biological resources - i.e., reproductive and natural growth cycle systems (D.1; part of D.3.2.1);

(b) Non-renewable resources - i.e., minerals and fossil fuels (D.2.4, D.3.1);

(c) Cyclical systems - i.e., atmosphere, hydrosphere and, with some qualification, lithosphere (D.2.1, D.2.2, D.2.3, part of D.3.2.1).

The breakdown of section D does not fully apply this classification (as indicated in the parentheses above), because of the separate identification of energy resources, which can be of a renewable, non-renewable or cyclical nature. The common distinction between renewable and non-renewable resources is ambiguous. Biological resources may fail to reproduce on a sustainable level, exhibiting the characteristics of diminishing populations and, in the most drastic cases, extinction. Sustainability of biological resources is dependent, among other things, on the existence of sufficient and healthy habitats to maintain a viable population and on a level of harvesting which does not impair the natural recuperative capacity. Biological resources have therefore been referred to as "conditionally renewable". Similarly, certain cyclical resources can be considered renewable or non-renewable. In the case of withdrawal of groundwater supplies, their use might or might not be in excess of their natural replenishment. The term "mining" of groundwater is a metaphor used for the depletion of aquifers.

Natural resource stocks in FDES are measured in physical terms - i.e., by weight/volume/area. These data are, in principle, location-specific, although in practice they are often generalized (or averaged) over a defined spatial unit (e.g., density of cattle by district). Moreover, environmental stocks are frequently based on specific "area surveys" which may be geographically limited and may be taken at different time periods. This results in partial coverage and inconsistency. However, computer technology has greatly enhanced the measurement and analytical capabilities of spatial data. The (software) systems, referred to as geographical information systems (GIS), are now available for personal computer hardware and are becoming increasingly user-friendly. The development of spatial databases requires the digitization of mapped data or geographic co-ordinates in statistical records. This is generally time consuming work. However, once these databases are in the form required for computer mapping, the production of mapped data is relatively rapid. Thus, spatial statistics, which were previously a specialized area for geographers, have now become accessible to statistical analysis. Of course, synthesized (overlayed) maps and indices (based on several variables) are only as good as the reliability of the databases from which the original variables were obtained.

D.1 BIOLOGICAL RESOURCES

The stock of biological resources is characterized by population numbers, growth cycles, spatial distribution, density of populations or biomass, and species mix (a measure of ecosystem diversity). It is interesting to note the analogy between economic and biological productivity. The essential elements are product design (genetic stock), means of production (soil, water and climate), process of production (photosynthesis, metabolism) and material and energy inputs (nutrients, solar energy). The classification of biological resources should correspond, where appropriate, with the activities of agriculture, forestry, hunting and trapping, and fishing as described in sections A.1.1 to A.1.4.

D.1.1 Agricultural stocks

The variables identified in D.1.1 focus on the resource base of agricultural activities. Their components are crop and livestock inventories, genetic stock, and man-made capital stock. These data, combined with the variables of D.2 relating to water, climate and soils, are the main database for policy planning of sustainable agricultural development.

Although agriculture is one of the most intensely surveyed human activity, the kind of data specified in section D.1.1 are sometimes difficult to obtain. Agricultural surveys focus on production of food and other agricultural commodities. The orientation here is, however, on asset structure and in-place inventories. Some of these data can be inferred from production statistics. Agricultural censuses also inquire into the area of land under different cultivation regimes and the type and numbers of livestock. Farm equipment and implement surveys are also part of the inquiry system in agriculture. Other potential sources of data are remote sensing data, in particular for land use, and records of agricultural research stations, such as the diffusion of cultivars and hybrids. Direct surveys of "genetic stocks" inquire about the replacement of traditional plants and livestock, and adaptation factors such as pest control, nutrient needs and cropping patterns.

D.1.1.1 Crop and livestock inventories

The major objective of this database is to provide the background data to analyse annual agricultural production (A.1.1.1) and changes in agricultural resources (B.1.1.1). The concepts employed are those of field crop inventories, measured as growing crops in the field, and livestock populations. Although, for most purposes, it is desirable to keep records of agricultural inventories in terms of individual plant and animal species, more generalized measures of total biomass may provide sensitive indicators of the efficiency of material/energy conversion to biological matter (i.e., photosynthesis and metabolism). Biomass of "standing crops" is thus an appropriate measure of agricultural resources and the stress on the environment.

Biomass indicators differ from economic output, which measures crop production as the (annual) quantity harvested of a marketable product - i.e., the final product of the process of production. Coefficients can be applied to units of harvest output to obtain approximations of the biomass of a standing crop, although more direct methods include interpretation of remote sensing data and field surveys. Caution should be exercised in applying mechanically fixed biomass coefficients per unit of output. In the first instance, the calculation must be based on gross, rather than net, output - i.e., sales plus the amount retained on the farm (e.g., feed, seed, unsold inventories). Secondly, crop failures would clearly throw off crop output/ biomass ratios. Thirdly, adjustments of biomass coefficients need to be made when new cultivars are introduced, which might change the ratio of biomass to output - e.g., when short-stem wheat is newly introduced.

Field crops are harvested annually. The "growing crop" at a point in time, can therefore be treated as an inventory of goods-in-progress. The "standing stock" of perennial plants, on the other hand, functions as capital assets. The marketable products are the annual harvests of fruits, nuts and sap. Asset accounting should therefore measure not only annual output capacity but also the remaining "productive life" of the asset. Thus, the age structure of perennial plants needs also to be considered in such accounts.

Agricultural livestock inventories, describing species type, population and, in some cases, age, are generally included as part of agricultural censuses. In principle, the distinction should be made between livestock employed as capital (for working, breeding, milk producing, egg laying purposes) and those being fattened for meat production (i.e., goods-in-progress). Distinctions are not easily made where livestock may perform both functions.

Variables	Classifications	Observations
a. Standing field crops (t, km^2, t/km^2)	Type of crop	Measure of biomass and productivity
b. Perennial plants (nos., t, years, km^2, t/km^2)	Type of plant Age	Measure of production capacity
c. Livestock (nos., years, km^2, $nos./km^2$)	Type of species Age	Distinguish capital from inventory stocks

D.1.1.2 Genetic stock

Environmental concerns have increasingly focused on the problem of diminishing genetic stocks at the global level. In agriculture, research and science have added new cultivars and hybrid breeds to the genetic pool while, at the same time, traditional crop and animal species have disappeared. For example, the so-called "green revolution" has replaced traditional, often highly localized crops with generic cultivars. However, in traditional agricultural systems, there are social and economic barriers to the introduction of new species. In the first instance, there is the inherent conservatism of traditional societies. Secondly, many new cultivars require an advanced level of farming technology and knowledge of such successful adaptation. Preconditions to such adaptation include, therefore, education programmes, access to fertilizers and pesticides, irrigation infrastructure development and restructuring of agricultural systems by changing ownership patterns and marketing systems.

The purpose of developing a genetic stock database is to track the dependency on an (ever-narrowing) gene pool, to measure the rate of diffusion of new cultivars and breeds in the agricultural community and to record the loss of genetic material, largely by the disappearance of traditional plants and breeds. This new domain of statistics requires innovative concepts, techniques and classification systems to delimit the scope and coverage of genetic material, as well as methods of data collection.

Variables	Classifications	Observations
a. Variety of plant strains (traditional) (nos., km^2)	Type of species	Indicator of crop diversity
b. Variety of plant strains (new cultivars) (nos., km^2)	Type of species	Indicator of diffusion: b/a
c. Variety of livestock (traditional breeds) (nos., km^2)	Type of species	Indicator of livestock diversity
d. Variety of hybrid livestock (nos., km^2)	Type of species	Indicator of diffusion: d/c

D.1.1.3 Man-made capital stock

The man-made capital stock is a key variable in the measurement of the technological transformation of agriculture - one of the most important factors in changing the state of the environment. On-farm capital stock measures are obtained through agricultural surveys. Information on off-farm infrastructures, such as the distribution of electric power, rural roads or irrigation facilities (see *Human Settlements Statistics*, sect. D.1.2, Non-residential buildings and other physical infrastructure) might complement the data presented in the text table. The table lists selected variables that could measure the state of technology in agricultural systems. The choice of variables should focus on particular technologies which distinguish modern from traditional agriculture.

Variables	Classifications	Observations
a. Traditional implements (nos.)	Type of implement	For example, hoes per hectare of arable land
b. Mechanical equipment (nos.)	Type of equipment	For example, tractors per hectare of arable land
c. Water delivery (m^3, km)	Water source	Canals, artesian wells, hand-drawn facilities

D.1.2 Forestry stocks

D.1.2.1 Forest inventories

Forest inventories describe tree cover by variables of species type and mix, level of maturity (average age) and productivity (e.g., wood volume per hectare). A distinction can be made between actual conditions of forests and their potential capability for maintenance and growth, based on soil quality, climate variables and topographic characteristics. For the most part, forest inventories are designed for the needs of commercial forestry. However, forest management, particularly as a multipurpose public good, requires the consideration of additional variables in the forest inventory databases. These can be characterized as measures of the service function of forests in terms of wildlife habitat, water catchment, recreational uses and local fuelwood source. The recognition of the important role of forestland in global ecosystems has drawn attention to the need to develop national inventories of forest ecosystems (see sect. D.4 for the identification and classification of ecosystem inventories).

In many regions, the distinction between forestland and farmland is not always precise. An example are areas of tribal settlements where shifting cultivation is a common practice. Even in predominantly agricultural lands, woodlots are interspersed with fields. These woods may be treated as an extension of agricultural activity such as maple sugar production in eastern America, or as small-scale forest operations. Indeed, from a bio-physical standpoint, agricultural activities based on tree plantations and orchards are hardly distinguishable from forest cover. Other grey areas are the transition zones between forests and grassland or tundra. This calls for a careful definition of the boundary of forestlands.

Forest departments, particularly in countries engaged in large-scale commercial exploitation of forests, usually compile formal forest inventories. These can be considered as forest management databases which monitor the characteristics of forestland within managerial jurisdiction. The basic geographical unit is the "forest site" where species type, age structure and level of desirability for harvesting purposes - i.e., productivity - are recorded. These data are generally in the form of forest site maps. It is a major task to aggregate site data to produce a national forest inventory. These data are single-purpose and therefore fail to capture many of the characteristics required for environmental analysis. Nonetheless, with the potential for the computerization of these databases and the capacity of overlay mapping, there is an opportunity to employ commercially oriented "forest inventories" as base maps for environmental statistics on forest stock.

Data on the biophysical characteristics of forestlands, forest harvesting, silviculture, forest protection and conservation, as well as complementary data on roads and equipment, used for lumber operations, and forest industry output, are obtained from forest management agencies or the departments of forestry. The characteristics of woodlands and "non-commercial" forestlands are generally not well documented. For the most part, they are private or communal woodlots associated with farming and village activities. Village and agricultural surveys are a useful method of obtaining the relevant characteristics of these kind of woodlands. An alternative and in some respects a more accurate and reliable source is remote sensing.

Although forest inventories are a potentially rich source of data for environment statistics, careful analysis of their nature and scope is required. Some of the questions that need to be raised are:

(a) Spatial coverage: does the inventory include all forest cover or only those forests in the public domain? In some countries, the area of forests under "management regime" might be a small proportion of the total forest area;

(b) Temporal coverage: inventories are built up over several years. Up-dating is usually sporadic, however, replacing old data when new data become available. Thus, forest stock data are generally a mixture of different periods. Forest on the books may, in fact, no longer exist;

(c) Classification: one of the major problems is economic bias in the classification systems. Thus, the concept of "productive forests" is based on harvest potential rather than a more holistic view of natural productivity which includes further environmental functions or services of forests. For example, forests age data are indicators of the desirable size of trees for harvesting (rotation age). Consideration must also be given to alternative classifications based on ecological characteristics and human settlement needs - e.g., cultural or recreational values;

(d) Aggregation: forest inventories are generally compiled by site class and forest management area. Adding together numerous sites leads to aggregation problems where different classification criteria and techniques are employed.

The identification of variables to describe forestlands should be considered in the context of the environmental, economic and social roles of forests in specific regions and countries. The choice of variables would, for example, be different in a country with vast, productive forests from one where forests are scarce and largely for local use - e.g., fuelwood gathering. The general parameters are the area of forest cover and the type and age of forests. They are closely related to statistics of the use/exploitation of forests (see sect. A.1.2, Forestry; B.1.1.2, Depletion of forests) and on their protection and conservation (see sects. C.1.1 and C.1.2 on the protection, conservation and management of nature and natural resources).

Variables	Classifications	Observations
a. Productive forestland (km^2)	Type of forest	Economic perspective, including plantation
b. Forest ecosystem (km^2)	Ecological classification Forest functions	Ecosystem perspective, wildlife habitat and social/cultural functions
c. Forest maturity (km^2)	Average age	Age/size of trees

The conversion of forest inventory data to digitized maps provides powerful analytical tools in support of forest management with sustainable, ecological and economic yield objectives. The objective is the production of base maps of forest ecosystems, economic productivity, natural productivity, forest land use, forestland gains and losses, and forest administration (e.g., ownership, level of habitat protection). These data, combined with other mapped data, provide relevant parameters for the assessment of the impact of acid rain, deforestation and conversion of natural to cultivated forest systems.

D.1.2.2 Genetic stock

The distribution of genetic material is a function of evolutionary processes, natural selection and habitat conditions. Human manipulation has resulted in the promotion of desirable and suppression of undesirable species. Large-scale commercial harvesting of trees has accelerated these processes by replacing natural with cultivated forests, often with fast growing species. The introduction of "exotic species" has further endangered the survival of endemic species (see sect. A.1.2, Forestry). Natural and human-caused calamities (e.g., acid rain) are also factors in the survival of diverse and healthy forests. Mortality of trees, due to deforestation and disease (see sect. B.1.1.2, Forest depletion; and B.2.4, Quality of biota and ecosystems) is a major cause of loss of genetic stock. "Selective" cutting has also been blamed for the degradation of genetic stock by the removal of the finest trees. The variables which depict genetic stock are essentially species diversity in natural forests, and numbers and distribution of rare and endangered tree species or forest communities.

Variables	Classifications	Observations
a. Number of tree species per forest ecosystem (nos.)	Type of forest	Index of genetic diversity
b. Rare species and forest communities (nos., ha)	Type of species Type of forest	Specify level of protection

D.1.2.3 Man-made capital stock

Data on man-made capital stock for forestry provide the background information on the capacity of harvesting and silviculture. This includes machinery and equipment for tree felling, the infrastructure for hauling logs (e.g., forest roads, trucks, docks, barges etc.) and the capacity to produce seedlings for reforestation.

	Variables	Classifications	Observations
a.	Felling and hauling equipment (nos.)	Type of equipment	Measure of harvest capacity
b.	Silviculture capacity (nos., ha)	Type of operation	Including annual capacity of tree nurseries
c.	Forest transport network (km^2)	Type of transport	Road, rail and water

D.1.3 Fishery stocks

Estimates of fish populations and their rates of replacement (i.e., recruitment) are of fundamental concern to fisheries management. In terms of population, fish stocks in rivers and lakes pale into insignificance in comparison to those of ocean fisheries. Nonetheless, inland fisheries can be an important source of livelihood and protein for rural populations. Fishing is not the only cause for population fluctuations. Naturally occurring events, such as shifts in ocean currents, water temperature changes and predator prey imbalances have been cited as causes for fish population collapse - e.g., the anchovy population off the coast of Peru.

Fish stock in the marine environment can be distinguished from those in inland waters, although anadromous species inhabit both worlds. Further major distinctions are:

(a) Benthic (groundfish which feed near the ocean floor or lake bottom);

(b) Pelagic (which feed near the water surface);

(c) Anadromous (which spawn in fresh water but live their adult life in salt water);

(d) Invertebrate (e.g., shellfish).

Fish farming, or aquaculture, suggests yet another dimension in classifying fish populations. In many parts of East and South East Asia, aquaculture is an integral part of village agriculture and, to the extent these are integrated into agricultural practices, fish stocks of this kind are perhaps best treated as "agricultural livestock". A good example are the fish ponds and "paddy fish" in Java and Bali.

Fish biologists estimate stocks of mobile (and difficult to see) populations largely by the effort required to catch them - i.e., the ratio of quantity of catch (output) to labour, energy, and equipment (inputs). This is based on the assumption that declining stocks are reflected in compensating effort and, of course, vice versa for growing stock. Catch data (see sect. A.1.4.1, Fish catch) is the most readily available information, generally supplemented with models of fish population behaviour, the carrying capacity of fish management zones, space/time sampling and average size of fish caught. An increasing proportion of young fish in the catch is considered an indicator of over-harvesting. Statistics of capital stock (on boats and equipment) are indicators of fishing practices which, combined with information on fish stocks and harvest, provide the key parameters for the assessment of the sustainability of the fishing industry.

Data on fish populations and capital stocks are obtainable from three basic sources: surveys of fishermen, fish processing plants and fish farms; administrative sources from fish management agencies which provide data on fish stocks, fishing licensing, port and research facilities etc.; and scientific sources from marine and freshwater research stations. The latter provide data on population estimates, based on the carrying capacity of aquatic ecosystems, and data on fish breeding and conservation activities. In addition to national sources, it may be useful to obtain statistics on fishing activities, in particular on fishing grounds shared by several nations, from international fishing commissions and the Food and Agriculture Organization of the United Nations (FAO).

Variables	Classifications	Observations
	<u>Fish stocks</u>	
a. Marine fish stocks (nos., t)	Type of species	Classify by marine aquatic ecozone[a]
b. Freshwater fish stocks (nos., t)	Type of species	Classify by inland water ecozone[a]
c. Invertebrate stocks (nos., t)	Type of species	Classify by intertidal and estuarine ecozone[a]
d. Aquaculture stocks (nos., t)	Type of species	Including saltwater and freshwater
	<u>Capital stocks</u>	
e. Fishing fleet (nos., $, km^2)	Type/size of vessels Area of operation	Indicator of the level of fishing effort
f. Equipment (nos., $)	Type of gear	Including net size and fish detection equipment

a/ See section D.4, Ecosystem inventory.

D.1.4 <u>Fauna and flora inventories</u>

Fauna and flora inventories refer here to the popular notion of "wildlife". Biological resources of agriculture, forestry and fishery (sects. D.1.1,2,3) are excluded. Advanced technological societies have rediscovered the economic value of wildlife, not only for hunting and fishing but also as a tourist attraction of the "unspoilt wilderness" and as a source of genetic stock. Wildlife management aims at the conservation and protection of fauna and flora. Population growth and economic development have created major conflicts with respect to these objectives, raising moral questions about the "right to life" of wildlife.

The establishment of inventories of fauna and flora for well-defined areas, such as national parks, is an established practice among wildlife biologists. Growing concern over species extinction has intensified the effort to produce lists of rare and endangered species, along with regular updates of this information. Fauna and flora inventories are affected by the impacts of forestry (A.1.2), hunting and trapping (A.1.3), and fishing (A.1.4), resulting in the depletion (B.1.1) and degradation (B.2.4) of biota. Inventories usually refer to ecosystems and ecozones described in section D.4.

Inventories of fauna and flora and habitats are produced in university departments of biology and zoology, wildlife research institutes and government agencies concerned with nature protection. Remote sensing interpretation is a useful source for identifying the habitat of dominant plant species; these can sometimes be picked up by sensitive electromagnetic band "signatures". Environmental impact assessment studies may include detailed inventories of fauna and flora in the "impact region". At the global level, the International Union for Conservation of Nature and Natural Resources (IUCN) provides data on endangered species.

D.1.4.1 Fauna inventory

The first question to be addressed in the development of fauna inventories is the selection of species. Generally, large mammals and selected birds are included in population counts. Other fauna are typically registered or mapped by habitat range only. Population counts of fauna, other than the highly visible grassland herds, are prone to large error factors. Typically, the method of estimation is by frequency of sighting, combined with other parameters such as habitat carrying capacity, breeding success and threats to specific species due to hunting, poaching and pest elimination by farmers.

The variables listed below suggest a conventional taxonomy of species type and habitat - i.e., mammals (large and small), birds, reptiles, amphibians and fish. The Economic Commission for Europe (ECE) has provided guidelines for the development of fauna, flora and habitat statistics, including three basic variables: species type, species population, and species habitat.[34/] The two measures suggested here are population numbers and habitat range. Fauna population counts are difficult to obtain and update whereas the establishment of habitat range requires only occasional sightings to verify habitat boundaries. Overlay mapping of habitats for different species provides a crude species diversity index. The list of rare and endangered species (see sect. D.1.4.3) is a special case of population and range inventories.

Variables	Classifications	Observations
a. Large mammals (nos., km^2)	Type of species[a/] Type of ecozone[b/]	General indicator of ecosystem health
b. Small mammals (nos., km^2)	Type of species[a/] Type of ecozone[b/]	Distinguish by capacity to adapt to changing environments
c. Land birds (nos., km^2)	Type of species[a/] Type of ecozone[b/]	Distinguish breeding from migration range
d. Water birds (nos., km^2)	Type of species[a/] Type of ecozone[b/]	Distinguish breeding from migration range
e. Reptiles (nos., km^2)	Type of species[a/] Type of ecozone[b/]	Distinguish by frequency of sighting - e.g., common, rare
f. Amphibians (nos., km^2)	Type of species[a/] Type of ecozone[b/]	Distinguish by frequency of sighting - e.g., common, rare
g. Fish (nos., km^2)	Type of species[a/] Aquatic ecozone[b/]	Excluding commercial catch species found in D.1.3.1

a/ See section B.1.1.4.

b/ See section D.4, Ecosystem inventory.

D.1.4.2 Flora inventory

Flora inventories record the status of the non-cultivated plant life. The characteristics of flora species and habitat that should be considered in developing these databases are:

(a) Classification of plant communities by ecological niche, characterized by temperature gradients, soil moisture and other growing conditions;

(b) Factors that influence propagation, contraction and threats to survival of plant species - i.e., disease, foraging, contamination, land use change etc.;

(c) Introduction of non-native species;

(d) Elimination of weeds.

Most natural habitats can be described by the species composition of the dominant (and hardy) vegetation cover and their rarer and more fragile niche plants. These latter are generally more vulnerable to environmental stress and more difficult to detect by generalized observations - e.g., remote sensing.

A major policy objective is to maintain the diversity of plant species which have evolved over millions of years. Of particular global concern is the protection and conservation of the ancient rain forests of Amazonia, central Africa and the southeast Asian archipelago (see sect. D.1.2.1, Forest inventories). Countries, however, need also to develop policies directed toward the conservation of other flora in their natural ecosystems - i.e., in woodlands, wetlands, grasslands and deserts. The development of a national flora inventory is one of the first steps in the implementation of such policies.

Variables	Classifications	Observations
a. Tree species (km^2)	Type of species[a/] Type of ecosystem[b/]	Distinguish by density - e.g., biomass indicators, and by diversity indices
b. Other vascular plants (km^2)	Type of species[a/] Type of ecosystem[b/]	Distinguish by density - e.g., biomass indicators, and by diversity indices
c. Mosses, fungi, and lichens (km^2)	Type of species[a/] Type of ecosystem[b/]	Distinguish by density - e.g., biomass indicators, and by diversity indices
d. Aquatic plants (km^2)	Type of species[a/] Type of ecosystem[b/]	Distinguish by density - e.g., biomass indicators, and by diversity indices

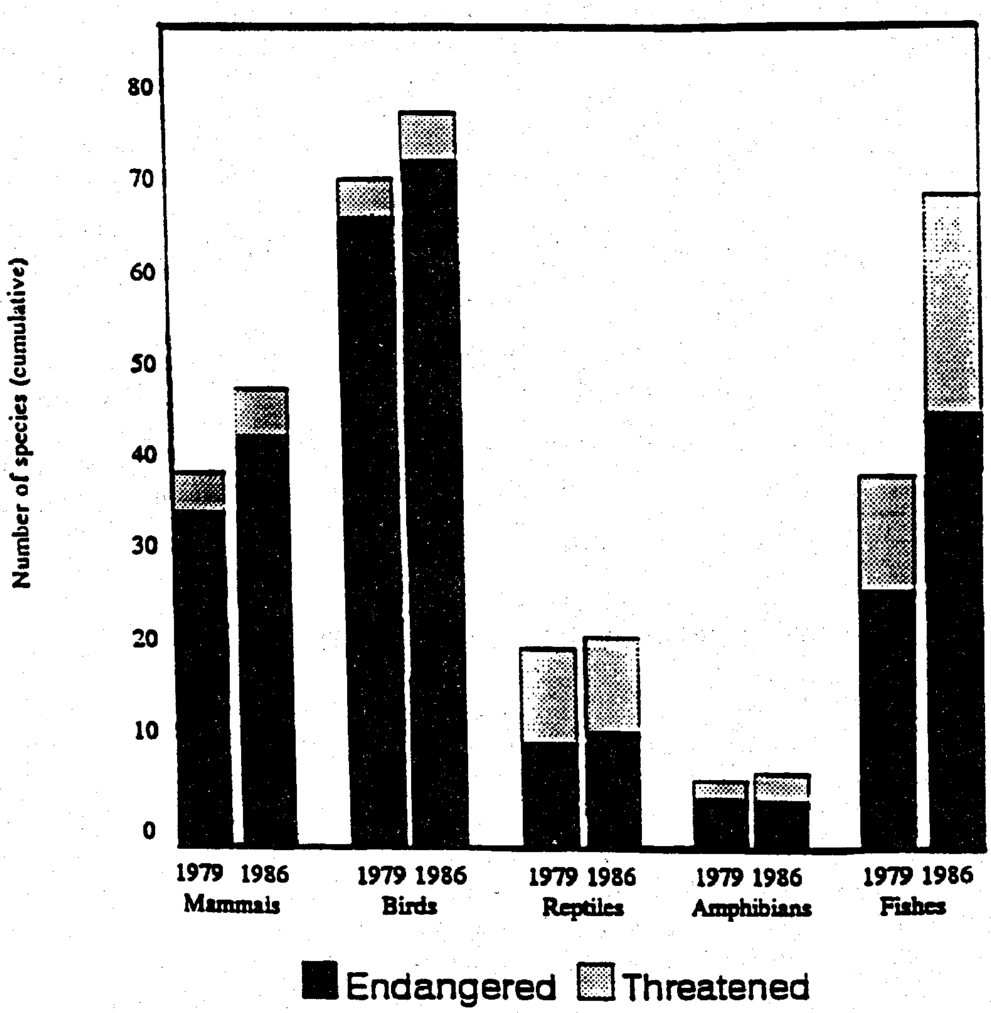
a/ See section B.1.1.4.

b/ See section D.4, Ecosystem inventory.

D.1.4.3 Rare, endangered, extinct and exotic species

The global alarm over the accelerating rate of species extinction has resulted in increased monitoring of species that are endangered. Biologists are concerned with identifying rare, endangered and (recently) extinct species and with the introduction and spread of exotic species. The identification and listing of these species not only alerts to the need for conservation and protection but functions also as an early-warning indicator of the state (instability) of ecosystems. The particular concern over the spread of exotic species is that they compete for food and habitat with native species. The extinction of species represents a depletion of genetic stock. Over-hunting or over-harvesting of species can lead to severe degradation of genetic stocks. An example is the selective felling of high-value trees, thus removing high-quality genetic stock and leaving inferior species to regenerate. Figure V is a cumulative time series assessment of endangered and threatened species in the main categories of the fauna taxonomy.

Figure V. Endangered and threatened species in the United States, 1979 - 1986



Source: Council on Environmental Quality, *Environmental Trends* (Washington, D.C., 1989)

Variables	Classifications	Observations
a. List of rare, endangered and extinct species (nos., km^2)[a/]	Type of species Type of ecosystem	Indicator of the loss of genetic material
b. Exotic species (nos., km^2)	Type of species (date of introduction) Type of ecosystem	Indicator of ecosystem instability

a/ See, e.g., International Union for Conservation of Nature and Natural Resources (IUCN), *Red Data Book*, which distinguishes between endangered, vulnerable, rare, indeterminate, out of danger and insufficiently known species.

D.2 CYCLICAL AND NON-RENEWABLE RESOURCES

Natural cycling systems do not provide a "product" in the sense of biological and geological stocks but are better viewed in terms of "services". Water extraction (see sect. A.1.7) should thus be considered as a "service" since its primary purposes are cleaning, cooling, dissolving and transport. Only a relatively small fraction of water use is material input into production. Hydrological stocks are measured by the volume of water in lakes (both natural and man-made), glaciers, underground reservoirs and stream flows. The concept of atmospheric stocks (i.e., volume), although of interest in long-term studies of the relative mix of the atmospheric gases (e.g., ozone, CO_2) as a factor in global climate change, is, however, less meaningful with respect to national statistics. National statistics could be used in measuring the nation's contribution to the changing condition of the atmosphere in terms of CO_2 or chlorofluorocarbons (CFC) emissions (see sect. A.2.1.4). These data, linked with global environmental monitoring data - e.g., from UNEP's Global Environment Monitoring System (GEMS) - could provide a global perspective to national emissions. Climate data presented in section D.2.2 are thus more in the nature of "background" information. Non-renewable resource stocks are, in essence, measures of (known) subsurface reserves of minerals, non-minerals and hydrocarbons. They are further classified in accordance with the degree of certainty of their existence.

D.2.1 Hydrological systems

Figure II above describes the stock/inventory aspect of water statistics in terms of data bases on water resources (stocks and flows), water-related infrastructure and of drainage basin mapping. Drainage basins are the key spatial unit for the development of environmental water statistics. Integrated watershed planning is increasingly employed in economic and social development. The factors that should be taken into account in creating drainage basin databases are as follows:

(a) Geo-coded socio-economic data, generally classified by administrative units, are difficult to allocate to basin boundaries;

(b) The level of aggregation should be correlated to the intensity of human activity and water use; thus, densely populated areas would be divided into subbasin levels, whereas lightly populated areas could include several subbasins;

(c) Drainage basins need to be harmonized across national boundaries;

(d) The basins of "critical rivers" should be singled out - i.e., those prone to high pollution, flooding, or low levels in the dry season.

National hydrological surveys provide data on water resources and flows. Water management authorities are a source of data on specific drainage basins, including hydrological structures. Data on water navigation infrastructure can be obtained from authorities concerned with maintenance and management of canals and navigation channels. Departments of agriculture are probably the best source for irrigation canals and their delivery capacity. Precipitation/transpiration data are obtainable from meteorological offices. Remote sensing data can also be employed to large areas for the assessment of drainage canals, irrigated area, permanent snowfields etc.

D.2.1.1 Water stock and flow

The total reserve stock of freshwater is measured by the volume of water in lakes, reservoirs, glaciers, permanent snowfields, aquifers and other underground waters, as well as the average volume of water contained in rivers and streams. The amount of water that can be withdrawn without reducing stock is based on the net balances between precipitation, transpiration, replenishment of underground stocks and recycling capacity. Stocks can be run down by natural processes, particularly where rates of transpiration are greater than precipitation and where annual snow melt is greater than winter accumulation in the case of glaciers and permanent snowfields. Another natural process of stock reduction that is frequently aggravated by man-made activities (e.g., through erosion from agricultural activities; see sects. A.1.1.2 and B.1.2.2) is the sedimentation of lakes and reservoirs. In a similar vein, natural and human processes can accumulate water stocks - e.g., through construction of dams and reservoirs (see *Human Settlements Statistics*, A.1.2.e).

Measures of the volume of stream flow and precipitation/transpiration provide a rough indicator of potential water supply. Water reserve stocks act as regulators to balance the (seasonal) differences between supply and demand. Overall changes in the availability of water resources are shown as an environmental impact category (B.1.2.1). Table 8 shows the area of the drainable basin and the sustainable ("divertible") use of water while maintaining the available water stocks.

Table 8. Surface water: estimates of runoff, total potential divertible resource and current use by drainage division in Australia
(million megalitres per annum)

Drainage division	Area (km²)	Runoff	Divertible resource[a]	Use[b]	Percentage[c]
North-east coast	450 945	84	22.9	0.9	3.9
South-east coast	274 413	43	14.7	1.7	11.6
Tasmania	68 200	53	5.4	0.2	3.7
Murray-Darling	1 033 530	24	16.9	9.2	54.4
South Australian Gulf	82 300	1	0.2	0.3[d]	150.0
South-west coast	314 500	7	1.4	0.4	28.6
Indian Ocean	518 600	4	0.2	-	-
Timor Sea	547 060	81	22.0	-	-
Gulf of Carpentaria	638 430	86	13.0	-	-
Lake Eyre	1 169 905	6	0.2	-	-
Bulloo-Bancannia	100 570	1	-	-	-
Western Plateau	2 012 080	2	0.1	-	-
Australia	7 210 533	390	97.0	12.7	13.1

Source: Department of Arts, Heritage and Environment, *State of the Environment in Australia 1986* (Canberra, 1987).

a/ Divertible resource is the average annual volume of fresh and marginal water which, using current practice, could be removed from developed or potential surface water or groundwater sources on a sustained basis at rates capable of serving urban, irrigation, industrial or extensive stock uses.

b/ Gross water consumed (i.e., water supplied that is not returned to a stream or body of freshwater or diverted for use a second time) for off-stream uses including irrigation, urban, industrial and rural uses.

c/ Use as a percentage of divertible resource.

d/ Including imported water.

Variables	Classifications	Observations
a. Water reserve (m^3, km^2)	Type of reserve	Including lakes, reservoirs underground water, glaciers and snowfields
b. Flow volume of streams (m^3/unit of time)	Monitoring station	Measure per unit of time (second, day, month, year)
c. Annual/seasonal precipitation (mm)	Drainage basin	Map monthly rainfall monsoon, heavy winter rains/snow, unreliable rainfall etc.
d. Annual/seasonal transpiration[a] (mm)	Drainage basin	Map monthly rates of transpiration

a/ Transpiration rates are based on temperature, sunlight, vegetation cover and properties of surface materials such as rocks, soils and water.

D.2.1.2 Man-made infrastructure stock

Man has restructured natural hydrology since the earliest riverine civilizations. Today, a substantial infrastructure is in place to deliver water, drain waterlogged land and swamps, control flooding, harness energy and support water transport systems. Some of the undesired side-effects of hydrological restructuring (A.1.8.2) are modifications of ecosystems (B.2.4), climate (D.2.2), and increased incidences of waterborne diseases (B.3.1). Some of the economic benefits are electricity supply (A.1.6), increased agricultural yields (A.1.1), security in water supply (A.1.7.1), improvements in navigation (A.1.7.2), flood control and provision of new recreational facilities (A.1.8.2). The dominant theme of hydrological restructuring has been engineering and economic benefits. In recent years, concerns of environmental damage and social upheavals have become increasingly prominent, resulting in more comprehensive cost-benefit analyses to evaluate any alteration of hydrological regimes. Statistical descriptions of civil engineering projects are given in A.1.2.e and D.1.2.b in *Human Settlements Statistics*.

The database focuses on five types of infrastructure systems: dams and reservoirs; water delivery systems (e.g., aqueducts, irrigation canals, pumping stations and water storage); water drainage and flood protection systems (e.g., drainage channels, urban sewers, dikes and pumps); water navigation systems (e.g., transport canals and deepening of waterways); and shoreline restructuring for habitation and commerce (e.g., landfill, retaining walls, docks and harbours, aquaculture ponds) and recreational shoreline use.

	Variables	Classifications	Observations
a.	Dams and reservoirs (m^3, km^2)	Purpose	Specify single- and multi-purpose use and stress
b.	Delivery systems (km, km^2, m^3)	Purpose	Distinguish agricultural from urban/industrial
c.	Drainage and flood protection systems (km, km^2, m^3)	Purpose	Distinguish urban/industrial from agricultural
d.	Navigation systems (km, m)	Capacity	Length, depth, including dredging operations
e.	Shoreline restructuring (km, ha)	Purpose	Including use of shoreline for aquaculture

D.2.2 Climate

Atmospheric cycling systems can be described by the physical properties of air-mass movements and the qualitative (chemical) composition of air samples. The latter assess air pollution (see sect. B.2.1), whereas the former are described here as climate variables in a narrow sense. These data are obtained from stationary points on the earth's surface or from probes into the high atmosphere (e.g., from weather balloons). Earth-orbiting satellites have enabled meteorologists to obtain images of complex weather patterns. The major problem of data availability is not paucity but overabundance. The development of databases needs careful analysis of selection criteria and of methods for synthesizing climate data. Archival records are the source material for benchmark data.

Data on climate variables and air quality form the basis of atmospheric databases. From an environment statistics standpoint, they are key background data to assess the rate of natural productivity and the ambient quality of the environment. Extreme deviations of normal temperature and precipitation ranges are treated as environmental stress factors, resulting in harvest failures and social and economic impacts. A particularly disturbing element is the possibility of human-caused, long-term climate change. The development of databases to monitor global warming as a result of the "greenhouse effect" is of high international priority.

Meteorological analysis and studies, both by Governments and non-governmental institutions, have produced base maps for planning purposes and risk analysis. These maps provide background databases for assessments of the state of the environment, sustainable development and risk analysis. The latter requires documentation of the frequency and location of meteorological events to produce climate risk and/or critical areas maps - e.g., tornado corridors, susceptibility to drought conditions and frequency of floods. Linking points by the same average value (i.e., isopleths) provides a mapping of climate gradations. Climate zones can be delineated by synthesizing several variables to produce climate types - e.g., temperate maritime, humid tropical, dry continental and so forth. The measurement of long-term trends in climate requires that normal annual deviations be described. One method is to describe climate variables in terms of a running average of 5 - 10 years. A major environmental concern, of course, is climate change and its implication for natural and human activity. The objective here is to produce benchmark data from archival records, showing climate conditions in widely separated time periods.

The choice of climate indicators is determined by the prevailing climate type in a country and the corresponding human activities and natural processes. Thus, in agricultural regions, the critical variables are those that affect harvest output, such as rainfall, temperature range and, in areas with short growing seasons, the first/last date of frosts. In dry areas, the sequence of days without rain during the critical growing period has to be determined. Similarly, in cold climates, the number of days with snow on the ground or, in hot climates, the number of days above a certain temperature are the relevant parameters.

	Variables	Classifications	Observations
a.	Mean daily maximum temperature (°C)	Selected sites	Site should be representative of different temperature gradients
b.	Mean daily minimum temperature (°C)	Selected sites	Site should be representative of different gradients
c.	Monthly precipitation (mm)	Selected sites	Distinguish snow, rainfall
d.	Sunshine (hrs)	Selected sites	Alternative: percentage of cloud cover
e.	First/last date of frost (date)	Selected sites	
f.	Mean humidity range (%)	Selected sites	

D.2.3 Lithosphere

The lithosphere is a convenient generic description of the solid part of the earth's surface. This includes the thin outer crust, containing the geological surface materials of soils and rocks, the sub-soil minerals and the largely basalt rocks under the oceans, as well as the topographical features of the lithosphere, such as mountains, valleys and plains. An unstable dimension of the lithosphere is manifested in violent events such as earthquakes, landslides, and volcanic activity. The surface of the lithosphere is also transformed by the actions of the hydrosphere and atmosphere in the context of water and wind erosion. Subsurface stocks of mineral resources and energy are treated in sections D.2.4 and D.3.1 below. An important aspect of environment statistics is data that describe human activity on the land. This is generally depicted by land use statistics and mapping. The area of land devoted to different activities can be conceived of as land surface stocks and are described here. By contrast, land use changes are shown as a human activity under A.1.8, Land use and environmental restructuring.

Lithosphere databases have largely been developed for regional planning and analysis, emphasizing, in particular, potential for economic development. An important element in FDES is the capacity to adapt and modify existing databases for the analysis of environmental stress and risk. The variables of interest in this context are essentially mapped data of lithospheric features - e.g., geology, soils, topography and generalized land use. Land use maps are based on a classification system of human use and natural features. The development of separate land use maps for "cover" and for "activity" is thus recommended. "Activity" corresponds to socio-economic activity; "cover", to the bio-physical environment. Cover statistics can be derived from interpretation of remote sensing imagery, whereas activity data require information on formally designated land use - e.g., military or informal uses like recreation. Critical background data for planning and environmental management are "risk potential maps". This requires information on the frequency, severity and location of such events as earthquakes, landslides and volcanic activities. A more generalized map of erosion potential can be produced by overlay mapping of slope, climate, soil type and human activities. Actual erosion is described as an environmental impact under section B.2.3.1, Soil quality.

Land use mapping is an important environmental management and planning tool. There are several different approaches to land use classification:

(a) Human activity: human uses of land in terms of such categories as agriculture, forestry, urban areas, military use, national parks, recreation, etc;

(b) Ecosystem mapping: natural and agro-ecosystem features of land such as desert, grassland, rain forest and alpine among natural features, and paddy, hedgerow, monoculture and plantation crops among agro-ecosystems characteristics;

(c) Economic productivity: in terms of sitting of economic activities such as industries, electricity generating plants and tourism;

(d) Natural productivity: distribution of levels of biomass production;

(e) Potential land use: land capability for agriculture, forestry, wildlife habitat, recreation and tourism;

(f) Natural resource mapping: inventories of biological resources - e.g., forest inventory or location of sub-surface resources;

(g) Jurisdictional and ownership mapping: legal, institutional or administrative land use.

The ECE land use classification (see sect. A.1.8 and annex II) is a combination of activity and vegetation cover classification, requiring further adaptation for use by countries outside the ECE region.

The national geological survey, the national mapping agency and the department/ministry of agriculture are the major sources for lithosphere data. Land use mapping, on the other hand, is complex, built up from several sources of data. These include agricultural and population censuses, remote sensing imagery and regional and local planning authorities.

Variables	Classifications	Observations
a. Topography (m, km^2)	Type of feature	For instance, alpine, low hills, plateau, valley, plains
b. Geology (km^2)	Type of mineral	Including geological indicators of resource potential - e.g., agriculture, hydrocarbons, minerals
c. Soils (km^2)	Type of soil Productivity	Including indicators of soil suitability for vegetation and agriculture
d. Land use[a/] (km^2)	Type of cover Type of activity	Including indicators of environmental stress based on "stress rating" of different uses
e. Geological risk mapping (km^2, nos., scale)	Type of event	Risk based on indicators of frequency and severity
f. Soil erosion potential (t/ha)	Type of erosion	Distinguish water from wind erosion

a/ See section A.1.8.1 and annex II.

D.2.4 Mineral resources

Statistics on mineral/hydrocarbon reserves and production are the basis for estimating rates of depletion (B.1.2.3). These data are critical inputs in policy decisions with respect to resource conservation, alternative sources of supply or substitutes and pricing policy. Mapping of mining activity and location of mineral deposits are useful supplements to these databases. Although the impacts in remote wilderness regions such as northern Canada, Siberia and Amazonia are of major environmental concern, one should also consider the environmental impact in populated regions. Mine tailings, subsidence and removal of surface materials in populated areas are major factors in environmental degradation (sects. B.2.2, 3). Abandoned mining sites have created major problems and costs in environmental rehabilitation (see sect. C.1.3).

The major source of data on mineral reserves is from departments concerned with mineral development and exploitation. Other sources of data include industry surveys of mining establishments. From these surveys, it is also possible to obtain additional data on capital stock and technology. Data on mining settlements are obtainable from the analysis of population censuses as well as other socio-economic surveys. The spatial configuration of mining activity, particularly surface mines and quarries and transport networks, can be extracted from survey maps and from interpretation of remote sensing imagery.

D.2.4.1 Mineral reserves

Economic reserves are distinguished from non-economic ones. The latter constitute reserves that would not be exploited under current costs of extraction, processing and transportation and the price obtainable on the world market. The term "proven reserves" refers to levels of concentration and reserve quantities which are known with a relatively high level of certainty. Economic reserves are "proven reserves" which are exploitable in the context of current prices and technology. Speculative reserves are not proven, but likely with knowledge of geologic formations and evidence of exploration activity. Proven reserve figures are published in both national and international reports on mining activities. Mineral reserves estimates, particularly in terms of the years remaining at current rates of extraction, can be crucial for the assessment of sustainable development. An example of balance sheets for selected mineral resources are given in table 9.

Variables	Classifications	Observations
a. Economic reserves (t)	Type of mineral Location	Under current exploitation
b. Proven reserves (t)	Type of mineral Location	Used for indicators of depletion rates (reserves/annual output)[a]
c. Speculative reserves (t)	Type of mineral Location	Potential exploitation

a/ See section B.1.2.3.

D.2.4.2 Mining infrastructure

The database on the infrastructure for extraction of mineral resources provides measures of the potential impact of mining activity on the environment and the capacity to exhaust the reserves. Three kinds of capital stock are of interest, namely in-place capacity (annual output capacity of individual mines); infrastructure capacity (transport capacity to ports or processing plants), and mining settlements (population). The latter is particularly important from an environmental perspective when new mining areas are being developed in remote regions.

Table 9. Reserve accounts for iron, copper and zinc in Norway, 1980 - 1986 (thousands of tons)

Year	Reserves 1 Jan.	Extraction	Reevaluation 31 Dec.	Reserves 31 Dec.
		Iron		
1980	157 300	-2 500	-3 200	51 600
1981	151 600	-2 667	-70 933	78 000
1982	78 000	-2 125	-873	75 000
1983	75 000	-2 299	-1	72 700
1984	72 700	-2 497	35 577	34 700
1985	34 700	-2 246	-4 494	27 960
1986	27 960	-2 385	-325	25 250
		Copper		
1980	502	-29	-83	390
1981	390	-28	-82	280
1982	280	-28	-2	250
1983	250	-23	-2	225
1984	225	-25	-22	178
1985	178	-24	-20	134
1986	134	-22	10	122
		Zinc		
1980	535	-27	-63	445
1981	445	-30	-85	330
1982	330	-32	2	300
1983	300	-32	2	270
1984	270	-29	-91	150
1985	150	-27	21	144
1986	144	-27	71	188

Source: Statistisk Sentralbyrå, *Miljøstatistikk 1988. Naturressurserog miljø* (Oslo, 1988).

Variables	Classifications	Observations
a. Mines (nos., t)	Type of mineral Location	Indicator of capacity, distinguish by technology - e.g., underground, open pit
b. Transport (km^2)	Type of transport	Transport corridors - e.g., through forests
c. Mining settlements (nos.)	Type of mineral Location	Population as indicator of environmental stress

D.3 ENERGY STOCKS

Energy stocks are treated as potential sources of available energy, embodied in the natural forces of wind, water, solar radiation and heat trapped under the earth's crust, and as combustible biological materials and reserves of hydrocarbons and uranium. In a modern industrial state, a precondition for economic development is access to abundant (cheap) energy sources and capacity for efficient energy conversion. The environmental stress from high-energy consumption and production has led to a re-evaluation of the process of industrial development and to the search for measures to reduce this stress. From an environmental perspective, a distinction can be made between renewable and non-renewable energy sources. The latter, in common with mineral resources, are ultimately exhaustible. Renewable sources of energy, on the other hand, are intimately linked to the state of the natural, biological or cycling (hydrosphere and atmosphere) systems.

Environmental impacts vary considerably depending on the energy source and energy conversion process. Hydrocarbons are heavily implicated in atmospheric pollution. Hydro-power affects the hydrosphere and may cause losses of fertile bottom lands. Nuclear power entails risk of accidents and radiation. Energy stock data are essential background information for the analysis of environmental impact (sect. B), management of energy supply-demand (A.1.6), energy conservation/security policies (sect. C.1.2). A synoptic description of the ramifications of energy resources in environment statistics is given in figure I, above.

D.3.1 Non-renewable energy sources

A key indicator of a nation's energy security are the estimates of reserves in oil, gas and coal. These statistics measure reserve estimates obtained from geological exploration. Further adjustment for economic and technical feasibility of extraction provides estimates of economic "reserves". The location of reserves is another aspect that needs to be considered in environmental analysis. Areas of hydrocarbon extraction and associated transport corridors are generally associated with high environmental risk. Reserves discovered offshore, in remote regions and in ecologically fragile areas, are of particular concern in terms of their potential social and environmental impacts.

Data on reserves are generally found in departments of energy and/or mines and in the coal and petroleum industry associations. The data on man-made infrastructures are obtained from the above sources and from statistical surveys of enterprises. Other sources of data are maps and remote sensing imagery. The latter can be particularly useful in assessing the area of disturbance around mining operations. The mapping of the spatial distribution of reserves, mines and wells, transport infrastructure (e.g., pipelines), exploration activity (e.g., seismic lines) and supporting settlements provides the basis for spatial analysis of environmental impacts.

D.3.1.1 Hydrocarbon and uranium reserves

Hydrocarbon reserves can be classified by their physical properties (i.e., solid, liquid and gaseous) and by their chemical properties (e.g., sulphur content, carbon concentration). Other attributes describe the depth of reserves, distance from markets and technological processes of abstracting and refining (e.g., tar sands). Distinctions should be made between reserves which are known but considered unfeasible to exploit under current conditions, and those that are either being exploited now or likely to be in the near future.

Variables	Classifications	Observations
a. Proven hydrocarbon reserves (t, bbl, m^3)	Type of hydrocarbon Location	Distinguish currently exploited from those held in reserve
b. Speculative hydrocarbon reserves (t, bbl, m^3)	Type of hydrocarbon Location	Including shale, tar sands
c. Uranium reserves (t)	Type of uranium Location	Distinguish currently exploited from those held in reserve

D.3.1.2 Capital stock of energy infrastructure

Some important variables for assessing the potential environmental impact of energy extraction are statistical indicators of mining and oil pumping capacity; transportation capacity, including pipelines; refining capacity; and other infrastructure support - e.g., for exploration of new sources of energy. This database should also be linked to the energy production and consumption statistics identified in section A.1.6.

	Variables	Classifications	Observations
a.	Extractive capacity (t, bbl, m^3)	Type of extraction Energy source Location	Hydrocarbon, uranium; annual production capacity
b.	Transport infrastructure and capacity (km, t)	Type of transport Location	Annual transport capacity and length of network
c.	Process infrastructure (bbl, m^3, t)	Type of product Location	Including oil refineries, coal washing and uranium processing
d.	Exploration infrastructure (nos., m, $)	Type of exploration Location	Including number of drill rigs and metres of exploration
e.	Mining towns (nos.)	Location	Population as indicator of environmental stress

D.3.2 Renewable energy sources

Sources of data for estimating renewable energy potentials are forest inventories, agricultural surveys (e.g., fuelwood access) and remote sensing data on vegetation cover. Energy potentials of "cycling systems" are obtained from geological and hydrographical surveys, meteorological records and institutions concerned with alternative energy development. Technological and engineering data provide statistics on feasibility - e.g., surveys and studies of hydropower potential of watersheds. Infrastructure data are obtained from various sources, including hydropower companies and agencies concerned with the development of alternative energy sources and energy conservation.

D.3.2.1 Energy potential

Data on renewable energy sources document the energy conversion potential of solar, biological and geothermal sources, and the tapping of the dynamics of the earth's cycling systems of the atmosphere and hydrosphere. Major factors in the choice of these sources are economic costs, technical feasibility, attractiveness of alternative use (e.g., wood for fuel or building material), cultural and social values, and the level of development. Some renewable energy sources are the traditional methods of tapping energy sources for heat and work, in particular in self-sufficient communities. Section A.1.6.2, Energy conversion describes the production variables of renewable energy. Here, the objective is to develop a database on the potential of renewable energy sources for which the following categories and variables can be distinguished:

(a) Solar: radiation levels on earth's surface, average annual hours of sunlight;

(b) Biological: forestland (biomass density), fuelwood (village woodlots), crop residues (crop production), cow dung (number of cattle), peat moss[35/] (area and depth);

(c) Cycling systems:

(i) Hydrological systems: rivers (flow/gradient), seas (height of tides, wave action)

(ii) Atmosphere: wind (velocity and consistency)

(iii) Lithosphere: subsurface heat (volcanic sources, thermal potential of ground water, geothermal gradient of earth's crust[36/]).

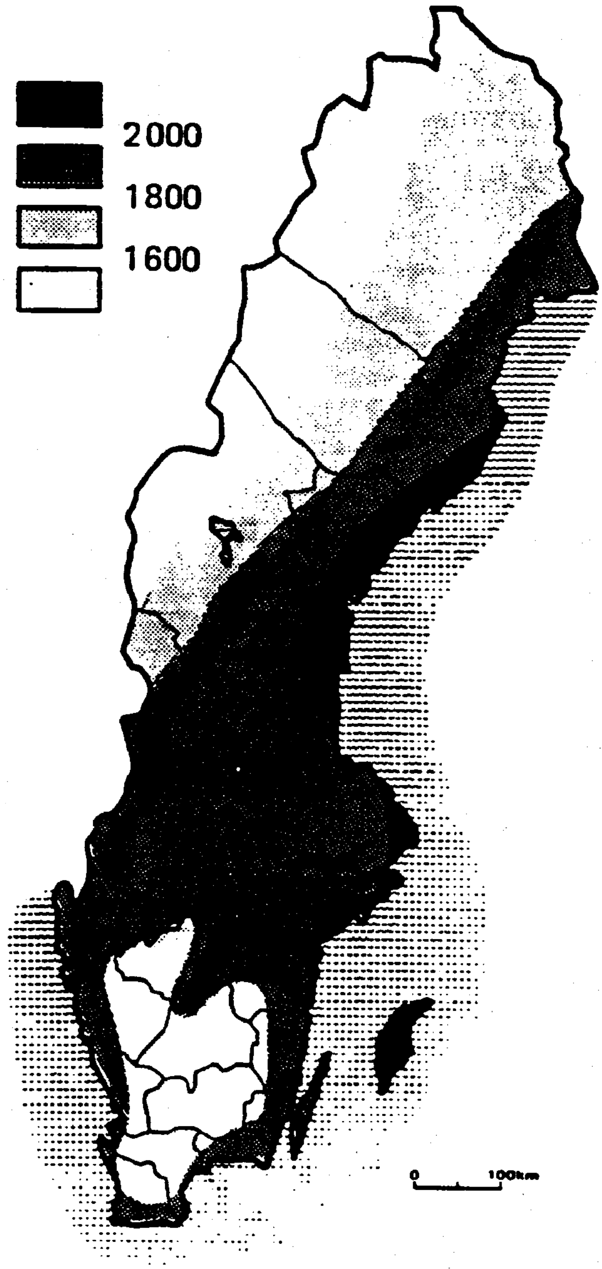
The major interest in developing data on renewable energy sources is to support policies on alternative energy sources. Parameters of renewable energy sources can be displayed in map form. Figure VI presents solar radiation distribution in a country. Solar radiation is the basic form of energy, characterized by the steady inflow of heat from beyond the earth.

Variables	Classifications	Observations
a. Woodland (J/ha)	Type of woodland	Including cultivated and local village woodlots
b. Peat moss (J/ha)	Type of peat moss	
c. Crop residual (J/ha)	Type of crop	Alternative use as fertilizer
d. Streams (kwh)	Type of stream	Potential generating capacity
e. Other hydrological (kwh)	Type of source	Including tidal energy, hot springs
f. Wind (km/hr)	Station	Identify areas of reliable source
g. Solar (J/ha)	Station	Solar power potential
h. Thermal source (J)	Type of source	Including hot springs, volcanic source

D.3.2.2 Energy infrastructure

This database describes the in-place, man-made infrastructure to exploit renewable energy sources, ranging from simple yet fuel efficient wood cook stoves to massive dams for hydro-generation. Electricity from hydropower is by far the most important source of

Figure VI. Average hours of sunshine per year in Sweden, 1931 - 1960



Source: Statistiska Centralbyrån, Naturmiljön i siffror, *Miljöstatistisk Årsbok 1986 - 1987* (Stockholm, 1987).

renewable energy today. Nonetheless, important strides have taken place in harnessing energy potential from biomass (e.g., alcohol gasoline in Brazil) and, largely on an experimental basis, generating electricity from wind and solar sources. In many parts of the world, the major source of (local) energy is wood and burning of other organic matter (e.g., cow dung). There is increasing interest in developing energy-efficient, small-scale technologies based on local renewable energy sources. The availability of energy using facilities in housing is described in D.1.1.d of *Human Settlements Statistics*.

The major concern of statistics on renewable energy infrastructure is to track the change in the nature and scale of harnessing these forms of energy. For example, the average size of dams has increased substantially from those built in the early part of the century, with the subsequent result of large flooded areas and large-scale environmental and social disturbances. Another major technological change has been the increase in kilowattage of transmission lines, enabling the "economic" transmission of electric currents over long distances. One result of this has been the exploitation of hydroelectric power far from the user, such as in the James Bay scheme of Quebec, Canada. Hydro-sites are now found in relatively untouched wilderness areas and have had a substantial impact on wildlife and tribal life.

	Variables	Classifications	Observations
a.	Biomass facilities (kwh, J, nos.)	Type of facility	Including electricity generating and fuel refining facilities
b.	Solar facilities (kwh, J, nos.)	Type of facility	Including electric power generating and household heating/cooking facilities
c.	Wind stations (kwh, J, nos.)	Type of facility	Including large-scale and individual household units and traditional windmills
d.	Water (small scale) facilites (kwh, nos.)	Type of facility	Including watermills and small-scale hydro-facilities
e.	Geothermal (kwh, J, nos.)	Type of facility	Including large-scale heating and electricity generation and small-scale facilities
f.	Hydro-dams (m^3, ha, kwh)	Type of dam, size of dam, size of reservoir, date of construction	Identify multipurpose facilities
g.	Other hydro-infrastructure (kwh)	Type of source	Including waterfalls, tidal and wave facilities
h.	Hydro-transmission (km, kwh)	Capacity	

D.4 ECOSYSTEM INVENTORY

The purpose of an ecosystem inventory is to record the size, diversity and spatial distribution of the natural attributes of the nation. These attributes are increasingly being treated as national assets, and there are several international initiatives to encourage national programmes which designate selected parts of their natural ecosystems as reserves (see sect. C.1.1). An ecosystem inventory may be used for ecological rehabilitation of critical areas, degraded beyond their natural carrying capacity; as a framework for ecological mapping and the development of databases; and for the development of key indicators to assess environmentally sound development. The inventory can be viewed as a holistic database of nature, exhibiting the following characteristics:

(a) Ecosystem or ecozone (see below) classification;

(b) Inclusion of parameters, describing bio-physical characteristics in terms of physiography, vegetation, geology and climate;

(c) Recording of spatial characteristics in terms of area and geographical coordinates;

(d) Assessment of natural attributes by indicators of ecosystem health, including species diversity, habitat carrying capacity and incidence of disease;

(e) Assessment of pertinent human activity, such as land use conversion, removal of biota and environmental protection and rehabilitation.

Although the ultimate objective is to develop a detailed ecosystem classification that can be applied at low (district or county) administrative levels, the first step will usually be to delineate a small number of "ecozones", perhaps 15 - 20, at higher (provincial) levels. Characteristics employed to delineate ecozones are:

(a) Physiography - e.g., hills, plains and coastal zones;

(b) Soils and surface characteristics - e.g., organic soils, rocky and stony surface materials, or alluvial soils;

(c) Climate - e.g., hot humid, cool dry, temperate marine;

(d) Flora and fauna - e.g., species composition, in particular dominant flora, woodlands, grasslands and wetlands.

Table 10 describes the characteristics of ecozones, developed for statistical and analytical purposes in Canada.

Ecosystems or bio-physical classification systems are typically structured in a hierarchical manner. The top level describes global ecozones, or "biome types" (e.g., forestlands, grasslands, tundra and deserts). These in turn are subdivided into increasingly

Table 10. Characteristics of terrestrial ecozones in Canada

Ecozone	Physiography	Vegetation	Soils/surface materials	Climate	Present use
Tundra Cordillera	Mountainous highlands	Alpine and arctic tundra	Cryosolic, brunisolic; colluvium, moraine, rock	Cold, semi-arid, subarctic	Trapping, hunting, recreation, tourism, mining
Boreal Cordillera	Mountainous highlands; some hills and plains	Boreal; some alpine tundra and open woodland	Brunisolic; colluvium, moraine, rock	Moderately cold, moist montane	Hunting, trapping, forestry, recreation, mining
Pacific Maritime	Mountainous highlands; some coastal plains	Coastal, western and mountain hemlock	Podzolic; colluvium moraine, rock	Very wet, mild temperate maritime	Forestry, fishing, urbanization, agriculture
Montane Cordillera	Mountainous highlands and interior plains	Mixed vegetation; conifer stands to sage brush fields	Luvisolic, brunisolic; moraine, colluvium, rock	Moderately cold, moist montane to arid	Forestry, agriculture, tourism, recreation
Boreal Plain	Plains; some foothills	Conifer and broadleaf boreal stands	Luvisolic; moraine, lacustrine	Moderately cold, moist boreal	Forestry, agriculture, recreation, trapping
Taiga Plain[a]	Plains; some foothills	Open woodland; shrub lands and wetlands	Cryosolic, brunisolic; organic, moraine	Cold, semi-arid, subarctic to moist boreal	Hunting, trapping, recreation
Prairie	Plains; some foothills	Short and mixed grasslands; aspen parkland	Chernozemic; moraine, lacustrine	Cool, semi-arid	Agriculture, urbanization, recreation
Taiga Shield	Plains; some interior hills	Open woodlands, some arctic tundra and lichen heath	Cryosolic, brunisolic, moraine, rock	Moist, cold boreal to cold, semi-arid, subarctic	Hunting, trapping, recreation
Boreal Shield[b]	Plains; some interior hills	Conifer and broadleaf boreal stands	Brunisolic; moraine, rock, lacustrine	Cold, moist boreal	Forestry, mining, recreation, tourism
Hudson Bay Plain	Plains	Wetlands, arctic tundra and some conifer stands	Cryosolic; organic, marine	Cold, semi-arid subarctic to cold boreal	Hunting, trapping, recreation
Mixed-Wood Plain	Plains; some interior hills	Mixed broadleaf and conifer stands	Luvisolic; moraine, marine, rock	Cool to mild boreal	Agriculture, urbanization, recreation
Atlantic Maritime	Hills and coastal plains	Mixed broadleaf and conifer stands	Brunisolic, luvisolic; moraine, colluvium, marine	Cool, wet temperate maritime	Forestry, agriculture, fishing, tourism
Southern Arctic	Plains; some interior hills	Shrub/herb/heath arctic tundra	Cryosolic; moraine, rock, marine	Cold, dry arctic	Hunting, trapping, recreation, mining
Northern Arctic	Plains and hills	Herb-lichen arctic tundra	Cryosolic; moraine rock, marine	Very cold, dry arctic	Hunting, trapping, recreation, mining
Arctic Cordillera	Mountainous highlands	Non-vegetated, some shrub/herb arctic tundra	Cryosolic; ice, snow colluvium	Extremely cold, dry arctic	Hunting

Source: Environment Canada, *State of the Environment Report for Canada* (Ottawa, 1986).

a/ The term "taiga" here refers to a zone of forest-tundra transition encircling the Northern Hemisphere.

b/ Boreal refers to the coniferous forest regions that bridge much of the mid-latitudinal belt of Canada.

unique ecological types, such as forestland classified into tropical, temperate and boreal. Further subdivisions identify specific climates, soils, and dominant flora and fauna types of ecosystems such as wet coastal forests, alpine systems or mangrove swamps. These can be further distinguished by human-modified systems, described by dominant agricultural crops and livestock, and human settlements and infrastructures. Ecosystem inventories are an evolving science, addressed in particular by work currently under way in ecological mapping. The ecosystem classification needed for statistical purposes thus requires a level of generalization that is compatible with overlay mapping of socio-economic data.

Notes

1. United Nations publication, Sales No. E.82.XVII.4.

2. United Nations publication, Sales No. E.83.XVII.12.

3. United Nations publication, Sales No. E.84.XVII.12.

4. *Official Records of the Economic and Social Council 1985, Supplement No. 6* (E/1985/26), para. 86 (d).

5. United Nations publication, Sales No. E.88.XVII.14.

6. See World Commission on Environment and Development, *Our Common Future* (Oxford: Oxford University Press, 1987).

7. See, for example, the recent discussions of the Second Independent Conference of the International Association for Official Statistics (Beijing, 16 - 19 October 1990).

8. For example, studies assessing the stocks and changes therein of particular natural resources - e.g., with the help of physical resource accounts (see annex I) - might usefully combine selected elements of the information categories D and B. Similarly, the analysis of pollution flows from the emitting source to loading of environmental media and ambient concentrations therein would have to link variables from sections A.2 and B.2.

9. These actions are more precisely defined as stressors in a stress-response model of the environment. The underlying assumption is that these activities are entopic processes which require energy and material inputs to maintain human production systems. Stress is the result of activities measured as quantities extracted/harvested, land use change, such as drainage of wetlands, and quantities and chemical properties of waste residual loadings, such as SO_2 emissions. The result of stress shows up as symptoms of distress on ecosystems and human health. Measures of distress are indicators of ecosystem health, such as primary productivity and species diversity, measures of the quality of the environmental media, and selected indicators of human health. In the stress-response model, these indicators are referred to as **environmental** responses. FDES, on the other hand, reserves the term "response" to **social** responses, in reaction to environmental impacts.

10. For a thorough analysis of the theoretical underpinning of this approach, see N. Georgescu-Roegen, *The Entropy Law and the Economic Process* (Cambridge: Harvard University Press, 1971).

11. *International Standard Industrial Classification of All Economic Activities* (United Nations publication, Sales No. E.90.XVII.11).

12. There is considerable evidence of public concern over degradation of the nutrient quality of foods from pesticide residues, food additives, the use of irradiation for food preservation and the use of hormones in livestock production (see sect. B.3.1). One response to these concerns is the development of alternative agricultural practices, in particular, the so-called "organic agriculture".

13. Agriculture is an intensive land use activity. In advanced industrial nations, the contribution to GDP of agriculture in terms of value added is in the order of 5 - 7 per cent; yet occupation of land is several orders of magnitude more, compared to the spatial extension of all other economic activities. Its nearest rival, forestry, has generally about 2 - 5 per cent of forestland in intense annual land use.

14. Natural regrowth generally follows distinct generational cycles of dominant species. The first species to establish themselves are characterized by being fast-growing, hardy and thriving in disturbed ecosystems.

These are usually undesirable for commercial harvesting and may establish a different ecosystem to that of the original forest. If this forest is commercially inviable, it is designated as "not sufficiently restocked" in forest inventories. The full cycle eventually leads to "climax forests". These are generally characterized by large trees with a fairly high level of diversity and specialized niche development. It should be noted that climax forests have high biomass but low productivity, whereas new growth forests are characterized by low biomass but high productivity. Complex forests, particularly rain forests, may take many hundreds of years to re-establish climactic conditions. Under commercial "rotation forest management", original forest ecology may be lost forever.

15. In the 1970s many maritime nations expanded their coastal zone from the traditional 12 miles to 200 miles. One of the incentives to establish the so-called "exclusive economic zone" was to manage fish catch on a sustainable basis.

16. Statistical Office, United Nations Secretariat, August 1984. Unpublished manuscript.

17. CES/636, June 1989.

18. Biological oxygen demand (BOD) is a measure of the dissolved oxygen consumed by organic and non-organic materials in water. BOD is a good indicator of potential stress on "oxygen demanding" plant and animal life.

19. Various conventions have been adopted within UNEP's Regional Seas Programme including the Convention for the Protection of the Mediterranean Sea Against Pollution and the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region.

20. In Arctic regions and deserts, dump sites of oil drums, abandoned construction material and vehicles remain perfectly preserved indefinitely. Another form of "litter" is the abandoned weapons, vehicles and other materials, including unexploded shells, bombs and mines of modern technological warfare.

21. There is considerable scientific opinion that human tragedies occur or are exacerbated by inappropriate land use in areas vulnerable to extreme climatic events. In other words, socio-economic activities are being undertaken within a narrower band of expected climate fluctuations than would be warranted by historical observations. The neglect of such expectations due to extreme poverty has been vividly termed as a symptom of "pollution of poverty".

22. It should be noted that, in FDES, man-made disasters such as large-scale industrial accidents or war effects are excluded from the activity statistics. However, as far as such action produces environmental discharges and further impacts, these outcomes could be presented as the loading of environmental media with residuals (A.2.1) and/or as respective environmental impacts in section B. See in particular B.3.2, Impacts of environmental disasters, covering both man-made and natural events.

23. Inventories are traditionally measured at the beginning (opening) and end (closing) of an accounting period. The concept of biological inventories is essentially the growing stock (goods-in-progress) or the amount remaining after depletion. Crops, which are totally harvested after each cycle, would have zero inventories in terms of "standing crops". To get around this dilemma, it is suggested in this report that the inventory stocks of crops be calculated at a point in time just before harvest - i.e., at maximum biomass.

24. The build-up of CO_2 and the thinning of the ozone layer could be considered in this context as physical gains and losses.

25. The distinction between atmospheric pollution, urban air quality and indoor air quality is, in effect, a classification of levels of concentration of ambient air quality. The critical impact is different for each of these categories. Indoor air quality is largely a problem of exposure of and health effects on specific occupational groups. Although this problem is generally associated with an "enclosed" indoor environment, the question of exposure to air quality in the work environment can be extended to "outdoor

work" - e.g., crop dusting, fire fighting and traffic control. Urban air quality is mainly a concern because of the general exposure of urban populations to health hazards. Atmospheric pollution is concerned with the global or transnational questions of acid rain, climate change and destruction of the ozone layer.

26. See annex III, part A, for a listing of polluting substances presented under the draft ECE Standard Statistical Classification of Ecological Freshwater Quality.

27. See, for example, the Register of International Treaties and Other Agreements in the Field of Environment, prepared in 1991 by UNEP (UNEP/GC.16/Inf.4).

28. "Indicators of water quality from an ecosystem perspective", paper submitted by Statistics Canada to the Economic Commission for Europe, Conference of European Statisticians, Informal Meeting on Water Use and Quality Statistics (12-14 December 1983).

29. The forthcoming United Nations Conference on Environment and Development (Rio de Janeiro, 1-12 June 1992) is expected to produce policy recommendations, action plans and conventions on environmentally sound and sustainable development.

30. See P. Bartelmus, C. Stahmer and J. van Tongeren, "SNA framework for integrated environmental and economic accounting", *Review of Income and Wealth*, series 37, no.2 (1991), pp. 111-148; an SNA Handbook on Integrated Environmental and Economic Accounting will be issued by the Statistical Office of the United Nations in 1992.

31. International Union for Conservation of Nature and Natural Resources (IUCN). *World Conservation Strategy* (Gland, Switzerland, 1980). A broader approach, focusing on sustainable development has been proposed in the follow-up "Strategy for Sustainable Living" (IUCN, UNEP, WWF. *Caring for the Earth* (Gland, Switzerland, 1991).

32. Eco-development was originally proposed by UNEP and defined as "development at regional and local levels ... consistent with the potentials of the area involved, with attention given to the adequate and rational use of the natural resources, and to applications of technological styles ... and organizational forms that respect the natural ecosystems and local socio-cultural patterns." See "Proposed programme" (UNEP/GC/3), para. 100.

33. R. E. Munn, "The Design of integrated monitoring systems to provide early indications of environmental/ecological changes", in Proceedings of the State of the Biosphere, Taskent, 1985.

34. Draft ECE Standard International Framework for the Development of Fauna, Flora and Habitat Statistics (CES/548/Add.4/Rev.1), 30 April 1985.

35. The carbonization process to convert biomass into peat takes place in time well beyond human planning horizons. Therefore, strictly speaking, this form of fuel should be treated as non-renewable. Nonetheless, it is included here because of its association with "alternative energy sources".

36. The geothermal gradient is based on the rate of temperature change per kilometre of depth of the earth's outer crust. A potential source of geothermal-generating capacity is cycling water at sufficient depth to obtain steam on return to the surface. Geothermal gradients vary greatly from region to region, but on average tend to be about 30°C per kilometre. Where the crust is thin or where volcanoes or earthquakes have disturbed the underlying rocks, the gradient may be considerably greater. Harvard University Press, 1971).

ANNEXES

Annex I

ENVIRONMENT STATISTICS, NATURAL RESOURCE ACCOUNTING AND THE SYSTEM OF NATIONAL ACCOUNTS

In the wake of the report of the World Commission on Environment and Development[a/] and its concern for "sustainable development", there has been increasing interest in introducing an environmental component into the national accounts. In part, this is a recognition that natural resource stocks and inventories should be treated as "assets", like capital stocks. The depletion and degradation of natural resource stocks could then be subtracted from national income and product as environmental costs to obtain environmentally modified indicators.

The scope of "production" and associated factors of production in FDES is broader than that currently applied in the SNA where stocks of natural resources and natural growth processes are treated as "free goods". For example, natural inputs (i.e., solar energy, water and soil nutrients) are ignored in the SNA, whereas man-controlled inputs of labour, capital and materials/energy are part of the cost of production. In other words, (economic) production in the SNA comes into existence only if it is associated with a market transaction. The exclusion of natural capital assets creates an anomaly in the sense that biological reproduction and growth processes and material flows of natural resources contribute to economic output just as natural mortality and depletion subtract from it.

The introduction to section D above discusses the conceptual framework for the development of natural resource stock/inventory databases in FDES. Section B.1, Resource depletion and increase, identifies the net changes in the stock of biological, cyclical and non-renewable resources. A comprehensive programme in environment statistics thus provides the database for natural resource accounting. This is illustrated for the different information categories of FDES in the figure below. Natural resource accounts also provide the relevant physical database for the environmental dimension in modified (monetary) national accounting.

Natural resource accounting (NRA) reformats the databases of FDES for the purpose of monitoring a country's stock and flow of natural resources. In other words, NRA can be viewed as the aggregation of environment statistics to describe the state and change of state of the nation's natural assets. The basic components of NRA are:

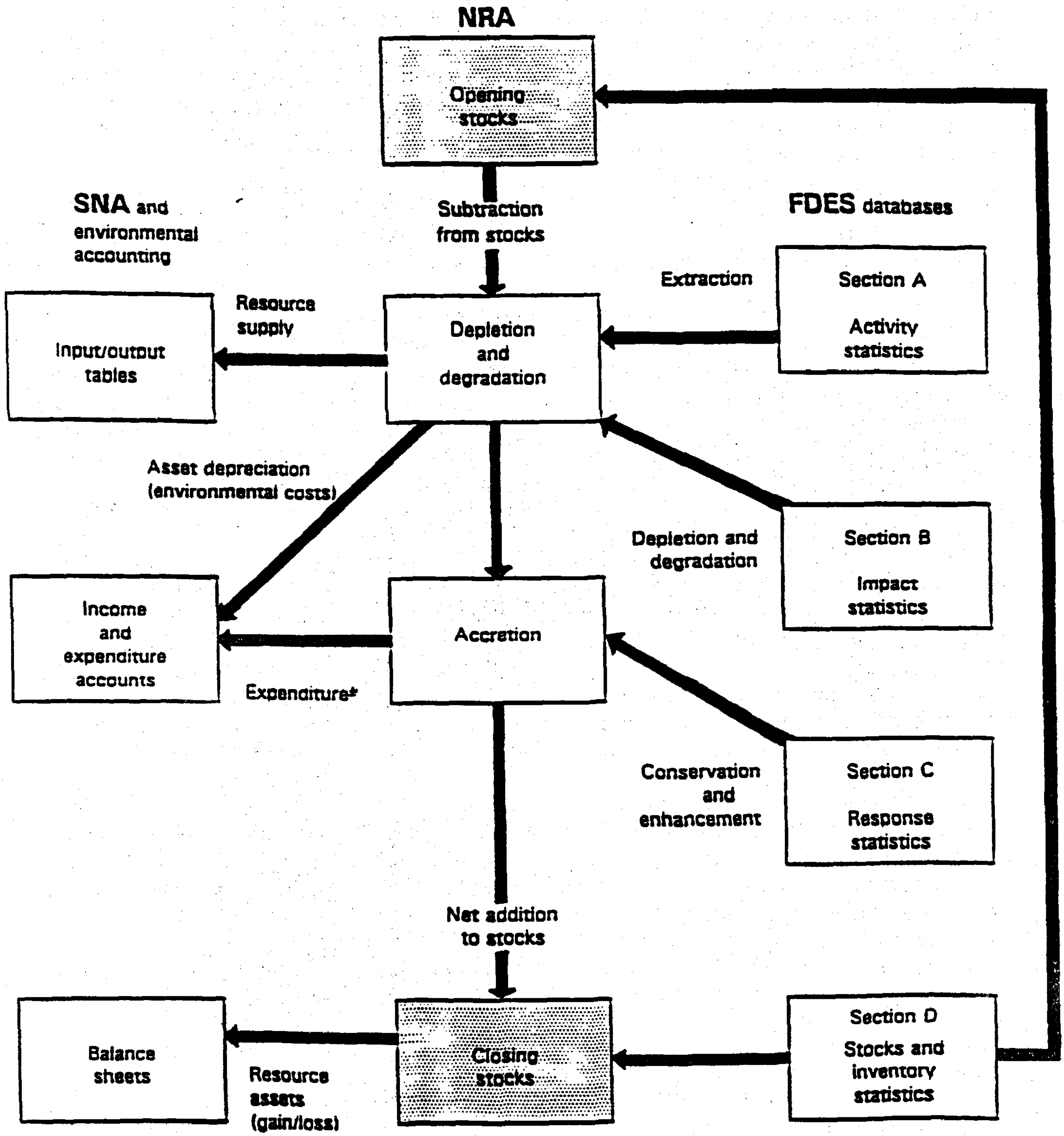
(a) Quantity and quality of natural resource stocks;

(b) Rates of depletion and/or accretion;

(c) Use or supply of natural resources in economic production processes, including international trade;

(d) Contribution of natural resources to human wellbeing, sometimes referred to as "environmental services".

Data linkages between FDES, NRA and the SNA



a/ Includes costs of environmental protection, conservation, rehabilitation, and expenditure to enhance the productivity of biological resources (e.g., afforestation) and exploration and discovery of non-renewable resources.

The (a) and (b) components record the physical stock/flow of the various types of natural resources. Components (c) and (d) are the socio-economic extension of NRA. The quantity and value of resource inputs in the economic processes represent the linkage of NRA with input/output accounts. The valuation of environmental impacts - i.e., changes in the quantity (availability) and quality of environmental assets in terms of costs and benefits of human activities - transforms physical accounts into monetary environmental accounts, proposed as a satellite system of the System of National Accounts, the SNA.[b/]

The three major categories of NRA are:

(a) Biological and ecosystem resource accounts (BERA);

(b) Non-renewable resource accounts (NRRA);

(c) Cyclical systems resource accounts (CSRA).

BERA constitutes the database on "natural productivity". The stock/flow quantities are recorded in terms of (a) population and diversity (numbers), (b) habitat state and area and (c) biomass (weight/volume). The objective is a measure of the total biomass/populations which flow into the human production systems, described under agriculture, forestry, wildlife (hunting) and (commercial) fisheries. The value of the output of biological commodities produced by these activities accounts for an important part of the Gross Domestic Product (GDP). The "environmental services" component (e.g., recreational use of forestlands, aesthetic enjoyment of nature, wildlife habitats), on the other hand, are largely outside the "accounting boundaries" of national accounts, although access to these resources clearly contribute to human wellbeing. While the principle of positive and negative externalities is recognized in economics, the difficulty of estimating, what are essentially "non-market values", has resulted in neglect of this area in the SNA. The complex interdependency of economy, environment and human health suggests to explore methods to evaluate environmental services, particularly as they pertain to ecosystem integrity, climate variables, air/water purification and functional roles in physical and chemical cycles.

NRRA are more straightforward from a conceptual standpoint. Firstly, because the extraction of minerals and hydrocarbons is, in principle, a one-way flow (i.e., depletion only). Secondly, the multi-use aspects do not generally apply to these kind of resources. Thirdly, the one-to-one correspondence between the rate of depletion of reserves and the output of the mining and energy industry makes for direct linkages between the state of these resources and the level of economic activity. In practice, however, the picture is more complicated due to the uncertainty in the knowledge of the actual quantities of these resources. These accounts show therefore also additions to stock based on new discoveries and re-assessments of existing reserves (resulting from changing commodity prices, substitution effects and technological change). The size and (economic) accessibility of reserve stocks can thus be considered as assets in economic accounting.

CSRA record aspects of the atmosphere and lithosphere that are critically linked to economic production, human health and ecosystems. These are more familiarly described in terms of air pollution, water use and quality, land use and soil fertility. Sub-components of the major physical systems also include chemical cycles of the biotic and abiotic environments, such as nutrient, nitrogen, oxygen, ozone and carbon cycles. The high level of complexity, the global nature and the geological time scales of lithosphere cycling systems limit the capacity of statistics to describe these systems with respect to their stock/flow dimensions.

Despite these limitations, meteorological data and pollution statistics can be considered as effective descriptors of the state and change of the state of the atmosphere. Soil mapping and land use data describe the surface state of the lithosphere, and erosion data and land use change are effective descriptors of its change of state. Hydrological cycling systems, on the other hand, do lend themselves to stock/flow dimensions of accounting by measures of the volume of water stored in lakes and reservoirs and by hydrometric readings of daily, monthly and annual flows of rivers and streams. Chemical and nutrient cycles can be observed in controlled experiments in small-scale ecosystems but their transposition to global stock/flow balances have hardly progressed beyond crude models. Nonetheless, monitoring data on the build-up of CO_2 and data on ozone depletion in the stratosphere are examples of statistical methods for recording changes in the stocks and flows of atmospheric cycling systems.

The linkage of NRA and the SNA are critically dependent on the availability of methods of "non-market" (e)valuations. Techniques such as shadow prices, willingness-to-pay, optional values, social discounting (time preferences) and so forth have been developed in the attempt to replicate market transactions. The Statistical Office of the United Nations Secretariat is currently developing a Handbook on Integrated Environmental and Economic Accounting which will propose methods of accounting for environmental (protection) expenditures, environmental assets and changes therein, and the cost and benefits of environmental services and natural resource use. The Handbook will also describe the presentation of NRA in the SNA format which is deemed essential in developing the physical "counterpart" data base for integrated environmental-economic accounting.

Notes

a/ See *Our Common Future* (Oxford: Oxford University Press, 1987).

b/ P. Bartelmus, C. Stahmer and J. van Tongeren, "Integrated environmental and economic accounting, framework for a SNA satellite system", Review of Income and Wealth, Series 37, No. 2 (1991), pp. 111-148.

Annex II

CATEGORIES OF THE ECE STANDARD STATISTICAL CLASSIFICATION OF LAND USE (CES/637, 7 April 1989)

1. Agricultural land

    1.1 Arable land

    1.2 Land under permanent crops

    1.3 Land under permanent meadows and pastures

    1.4 Other agricultural land, n.e.s.

    1.5 Total agricultural land
    of which: Fallow agricultural land

2. Forest and other wooded land

    2.1 Total land under forest and other wooded land
    of which: Stands of exotic species, particularly fire-prone stands

    2.1.1 With wood production the recognized major function
    2.1.2 With protection, conservation and biological use the recognized major functions
    2.1.3 With recreation the recognized major function

    2.2 Land under coniferous forest

    2.2.1,2,3 (same as 2.1)

    2.3 Land under non-coniferous forest

    2.3.1,2,3 (same as 2.1)

    2.4 Land under mixed forest

    2.4.1,2,3 (same as 2.1)

    2.5 Other wooded land

    2.5.1,2,3 (same as 2.1)

3. Built-up and related land (excluding scattered farm buildings)

3.1 Residential land

3.1.1 With mainly one- or two-storey buildings
3.1.2 With mainly three- and more storey buildings

3.2 Industrial land (excluding land classified under 3.3 below)

3.3 Land used for quarries, pits, mines and related facilities

3.3.1 For peat cutting
3.3.2 For other open-cast mining and quarrying
3.3.3 Other, n.e.s.

3.4 Commercial land

3.5 Land used for public services (excluding transport, communication and technical infrastructure)

3.6 Land of mixed use

3.7 Land used for transport and communication

3.7.1 Land under roads
3.7.2 Land under railways
3.7.3 Land under airports and related facilities
3.7.4 Other land used for transport and communication, n.e.s.

3.8 Land used for technical infrastructure

3.8.1 Land used for the disposal of wastes
3.8.2 Land used for water supply and waste-water treatment
3.8.3 Land used for electricity generation and distribution
3.8.4 Other land used for technical infrastructure, n.e.s.

3.9 Recreational and other open land

3.9.1 Parks, green areas, hobby gardens, cemeteries, etc.
3.9.2 Recreational land mainly occupied by camping sites, secondary residences or vacation houses
3.9.3 Land under current construction
3.9.4 Land intended for future construction
3.9.5 Other, n.e.s.

4. Wet open land

4.1 Mires

4.1.1 Ombrogenous mires (upland moors)
4.1.2 Soligenous mires (lowland bogs)

4.2 Wet tundra

4.3 Other wet open land, n.e.s.

5. Dry open land with special vegetation cover

5.1 Heathland

5.2 Dry tundra

5.3 Mountainous grassland

5.3.1 Used for grazing of domestic animals
5.3.2 Not used for grazing of domestic animals

5.4 Other, n.e.s.

6. Open land without, or with insignificant, vegetation cover

6.1 Bare rocks, glaciers, perpetual snow

6.1.1 Bare rocks
6.1.2 Glaciers and perpetual snow

6.2 Sand-beaches, dunes, other sandy land

6.3 Other, n.e.s.

7. Waters

7.1 Inland waters
<u>of which</u>: In harbour areas

7.1.1 Natural watercourses
7.1.2 Artificial watercourses
7.1.3 Inland sea (freshwater or saline), lakes, ponds, coastal land-locked bodies of water

7.1.4 Artificial water impoundments
7.1.5 Other inland waters, n.e.s.

7.2 Tidal waters
of which: In harbour areas

7.2.1 Coastal lagoons
7.2.2 Estuaries
7.2.3 Other tidal waters, n.e.s.

Annex III

DRAFT ECE STANDARD STATISTICAL CLASSIFICATION OF ECOLOGICAL FRESHWATER QUALITY (CES/688, 15 March 1990)

Part A: List of Polluting Substances

1. Selected overall measures [tons]

   1.1 Biochemical oxygen demand of discharges (BOD_5)

   1.2 Chemical oxygen demand of discharges (COD-Mn)

   1.3 Total suspended solids

   1.4 Total dissolved solids

2. Nutrients [tons]

   2.1 Total phosphorus

   2.2 Total nitrogen

3. Harmful substances [tons]

   3.1 Arsenic

   3.2 Cadmium

   3.3 Chromium

   3.4 Copper

   3.5 Lead

   3.6 Mercury

   3.7 Nickel

   3.8 Zinc

   3.9 Aluminum

3.10 Other harmful inorganic substances

3.11 Petroleum hydrocarbons

3.12 Organic chlorinated hydrocarbons

3.13 Other organic compounds

4. Microbiological discharges [number/100ml]

4.1 Thermo-tolerant coliforms

4.2 Faecal streptococci

Part B: Water Quality Classes

The annex table contains water quality variables and quality ranges by class. Values for flowing water are given in parentheses. Unbracketed values refer to both stagnant and flowing water bodies, or, if accompanied by bracketed values, to stagnant water.

The overall quality classes are defined as follows:

Class I: Excellent (blue)
Clear, oligitrophic water in natural state or with a very slight, occasional anthropogenic pollution with organic (but no inorganic) matter. Constant near-saturation of oxygen content, low nutrient and bacteria content; provides spawning grounds for salmonids. The buffering capacity of the water is very good.

Class II: Good (green)
Slightly polluted, mesotrophic water receiving small discharges of organic matter from municipal waste-water treatment plants or from diffuse loading. The oxygen saturation of water bodies is good throughout the year. The loadings may lead to slightly increased primary productivity. The buffering capacity of the water is good. Possible influents do not contain harmful substances.

Class III: Fair (yellow)
Moderately eutrophic water receiving considerable amounts of discharge of organic matter and nutrients. Oxygen deficiencies may occur in the hypolimnion. The level of primary production is considerable, and some changes in community structure, including fish species can be observed. The buffering capacity is weak but keeps the acidity of the water at levels which are still suitable for most fish. Loading by harmful substances and microbial pollution are evident. Concentrations of harmful substances vary from natural levels to levels of chronic toxicity for aquatic life.

<u>Class IV</u>: Poor (orange)

Strongly eutrophic, polluted water, receiving discharges of organic matter, nutrients and harmful substances. Oversaturation of oxygen occurs in the epilimnion, and oxygen deficiencies are frequent in the hypolimnion. Algal blooms are common. Increased decomposition of organic matter together with stratification of water bodies may entail anaerobic conditions and fish kills. Mass occurrences of more tolerant species; populations of fish and benthic organisms affected. The buffering capacity is exceeded, leading to considerable levels of acidity which affect the development of spawn. Microbial pollution prevents the use of water for recreation. Harmful substances either discharged or released from sediments affect the quality of aquatic life. Concentrations of harmful substances vary from levels of chronic to those of acute toxicity for aquatic life.

<u>Class V</u>: Bad (red)

Extensively polluted, hypertrophic water. Major problems occur in oxygen regime - i.e., oversaturation in the epilimnion and oxygen deficiency leading to anaerobic conditions in the hypolimnion. Decomposers dominate over producers. Fish or benthic species do not occur permanently. The water is without buffering capacity and its acidity is harmful for many fish species. Concentrations of harmful substances exceed acute toxicity levels for aquatic life.

Annex table. Variables and concentration ranges by quality class

	Class I Excellent (Blue)	Class II Good (Green)	Class III Fair (Yellow)	Class IV Poor (Orange)	Class V Bad (Red)
Oxygen regime					
DO (%) epilimnion	90-110	70-90, 110-120	50-70, 120-130	30-50, 130-150	<30,>150
hypolimnion	90-70	70-50	50-30	30-10	<10
total	90-70	70-50, 110-120	50-30, 120-130	30-10, 130-150	<10,>150
DO (mg/l)	>7	7-6	6-4	4-3	<3
BOD5 (mg O2/l)	(<3)	(3-5)	(5-9)	(9-15)	(>15)
COD-Mn (mg O2/l)	<3	3-10	10-20	20-30	>30
Eutrophication					
Total P (µg P/l)	<10(<15)	10-25(15-40)	25-50(40-75)	50-125(75-190)	>125(>190)
Total N (µg N/l)	<300	300-750	750-1500	1500-2500	>2500
Chlorophyll a (µg/l)	<2.5(<4.0)	2.5-10(4-15)	10-30(15-45)	30-110(45-165)	>110(>165)
Acidification					
pH	6.5-8.5	6.5-6.3	6.3-6.0	6.0-5.3	<5.3
Alkalinity (mg CaCO3/l)	>200	200-100	100-20	20-10	<10
Harmful substances					
Heavy metals and cyanides					
Aluminum (µg/l, pH:<6.5)	-		<5	5-75	>75
(µg/l, pH:>6.5)	-		<100	100-500	>500
Arsenic (µg/l)	<10		10-50	50-100	>100
Cadmium[a/] (µg/l)	<0.07		0.07-0.7	0.7-1.8	>1.8
Chromium[b/] VI (µg/l)	<1		1-11	11-16	>16
Copper[a/] (µg/l)	<2		2-6.5	6.5-9.2	>9.2
Lead[a/] (µg/l)	<0.1		0.1-1.3	1.3-34	>34
Mercury[b/] (µg/l)	<0.003		0.003-0.012	0.012-2.4	>2.4
Nickel[a/] (µg/l)	<15		15-88	88-790	>790
Zinc[a/] (µg/l)	<45		45-59	59-65	>65
Cyanides (µg/l)	<0.5		0.5-5.0	5.0-22	>22
Others					
Dieldrin (µg/l)	0		<0.0019	0.0019-2.5	>2.5
Chlordane (µg/l)	0		<0.0043	0.0043-2.4	>2.4
DDT and metabolites (µg/l)	0		<0.001	0.001-1.1	>1.1
Endrin (µg/l)	0		<0.0023	0.0023-0.18	>0.18
Heptachlor (µg/l)	0		<0.0038	0.0038-0.52	>0.52
Lindane (µg/l)	0		<0.08	0.08-2.0	>2.0
Malathion (µg/l)	0		0	<0.1	>0.1
Parathion (µg/l)	0		<0.013	0.013-0.065	>0.065
Pentachlorophenol[c/] (µg/l)	0		<3.5	3.5-5.5	>5.5
PCBs (µg/l)	0		<0.001	0.001-2.0	>2.0
Toxaphene (µg/l)	0		<0.2	0.2-730	>730
Radioactivity[d/]					
Microbial pollution (median No/100 ml)					
Thermo-tolerant coliforms	<10	10-30	30-100	100-1000	>1000
Faecal streptococci	<10	10-30	30-100	100-1000	>1000

a/ Calculated for standard hardness of 50 mg CaCO3/l. Adjustment for different levels of hardness.

b/ Calculated for standard hardness of 50 mg CaCO3. Adjustment formula for different levels of hardness currently under development.

c/ Calculated for standard pH of 6.5. Adjustment for different pH values.

d/ Ranges will be specified according to test results.

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