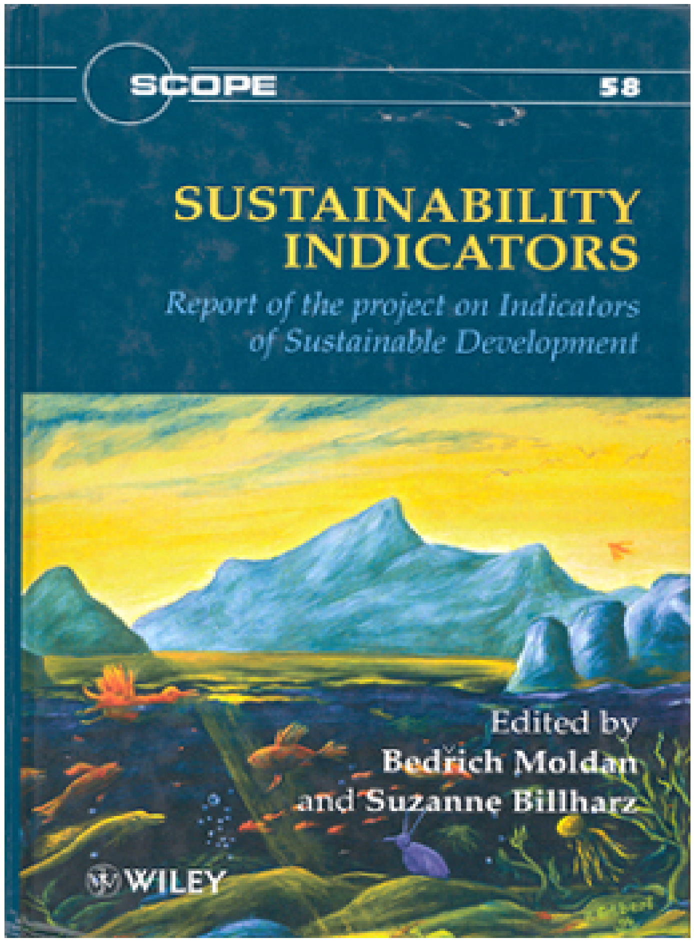

Gallopín, G.C. 1997. “Indicators and Their Use: Information for Decision-making. Part One-Introduction”; pp.13-27 in: Moldan, B. and S. Bilharz (Eds.) “Sustainability Indicators. A Report on the Project on Indicators of Sustainable Development”. SCOPE 58. Wiley, Chichester.

1. Indicators and Their Use: Information for Decision-making

PART ONE - INTRODUCTION
Gilberto Carlos Gallopín

WHAT IS AN INDICATOR?

Indicators are an essential component in the overall assessment of the progress towards sustainable development. The general principles of this assessment were developed at Bellagio in 1996 (**Box lA**).

Initially, most indicators are constructed using information that is readily available, or can be obtained at a reasonable cost. Therefore indicators are unavoidably biased at least in two senses: availability of information is much greater in industrialized countries than in developing countries, and environmental factors are under-represented in the information routinely collected and reported. The cost of gathering and processing additional relevant information may be a constraint in many cases. This makes it all the more important to avoid any unnecessary narrowing of options when defining potential indicators, and particularly when trying to identify a common set of indicators for international action.

Current definitions of indicators and the use of terminology in this area are particularly confusing (Bakkes *et al*. 1994). Some clarity and consensus is required about the definition of what an indicator is, as well as in the definition of related concepts such as threshold, index, target, and standard. This consensus cannot be based solely on political agreement; logical and epistemological soundness is also necessary. Different authors define indicators differently. This problem pertains not only to environmental issues. There are many ambiguities and contradictions regarding the general concept of an indicator.

Some specific definitions of indicators in the literature include: a variable 'hypothetically linked to the variable studied which itself cannot be directly observed' (Chevalier *et al*. 1992); a 'measure that summarizes information relevant to a particular phenomenon, or a reasonable proxy for such a measure' (McQueen and Noak 1988); 'a parameter, or a value derived from parameters, which points to/ provides information about/describes the state of a phenomenon/environment/area with a significance extending beyond that directly associated with a parameter value' (OECD 1993, which also defines 'parameter' as 'a property that is measured or observed'); 'a measure of system behaviour in terms of meaningful and perceptible attributes' (Holling *et al*. 1978, p. 106).

A wider survey of publications on environmental indicators shows even more meanings assigned to the concept. An indicator has been defined as a *variable* (Chevalier *et al*. 1992, Holling *et al*. 1978 p. 53), a *parameter* (OECD 1993, Bakkes *et al*. 1994), a *measure* (McQueen and Noak 1988, World Bank 1995 p. 80, Dever 1979, Holling *et al*. 1978 p. 106); a *statistical measure* (Tunstall 1992); a *proxy* for a measure (McQueen and Noak 1988); a *value* (OECD 1993, Bakkes *et al*. 1994), a *meter or measuring instrument* (implied by Adriaanse 1993, p.7 in his example of the clock and the thermometer as indicators); a *fraction* comparing a quantity (the numerator) with a scientifically or arbitrarily chosen measure (the denominator) (Adriaanse 1993); an *index* (implied by Hammond *et al*. 1995, p. 8 when they call the WRI's green-house index an indicator); a *subindex* or component of an index (Ott 1978 p.8; implied by Adriaanse 1993, implied by Hammond *et al*. 1995, p.16); '*something*' (Hammond *et al*. 1995); a *piece of information* (Bakkes *et al*. 1994); a single *quantity* derived from one variable and used to reflect some attribute (Ott 1978, p. 8); an *empirical model* of reality (Hammond *et al*. 1995); a *sign* (Marcus 1983).

The examples above also suggest that there is a need to develop a more unified, generic and rigorous definition of indicators. In its most general sense, an indicator is a *sign*. In semiotics (the general theory of signs), a sign is defined as something which stands for something to somebody in some respect or capacity. The concept of indicator as something that points out, or stands for, something else, is clearly a particular form of the concept of sign.

At a more concrete level, it has been shown (Gallopín 1996) that indicators are *variables* (not 'values', as they are sometimes called). A variable is an operational representation of an attribute (quality, characteristic, property) of a system. It is our image of an attribute defined in terms of a specific measurement or observation procedure. Each variable is associated with a particular set of entities through which it manifests itself. These entities are usually referred to as states (or values) of the variable. The whole set of possible states is called a *state set* (the meaning of value in this case is different from the axiological one implied, e.g. in 'value judgement'). The pragmatic interpretation of a particular variable as indicator is usually made on the basis that such a variable conveys information on the condition and/or trend of an attribute(s) of the system considered. This information is important for the purposes of decision-making at some level.

In a general sense, any variable 'indicates' an attribute. It is not the real attribute of a real object, but an image or abstraction of the attribute. How closely the variable reflects the attribute, and how meaningful and relevant for decision-making is the chosen attribute is a question related to the expertise and insight of the investigator, as well as to the purpose and constraints of the investigation.

In this context, any variable (and therefore any indicator, whether 'descriptive' or 'normative') has a significance besides its face value, or beyond what is directly obtained from observations. The significance of the variable, or of its values, arises from the *interpretation* made about them, assigning a meaning to the variables.

Obviously, a variable that is associated to an attribute of fundamental interest for decision-making, or to a cluster of such attributes, or that simplifies or summarizes a number of important properties is more useful as an indicator than a variable that is associated to a superficial or isolated characteristic of the studied system. But this represents a pragmatic[1], rather than a semantic[2], distinction. On the other hand, this pragmatic aspect is precisely the *'raison d' etre'* of the search for indicators and it defines their usefulness. The most important feature of indicators compared to other forms of information is relevance to policy and decision-making. To be relevant in this sense, the attributes represented by the indicators must be considered important by the decision-makers and the public.

Desirable indicators are variables that summarize or otherwise simplify relevant information, make visible or perceptible phenomena of interest, and quantify, measure, and communicate relevant information. As discussed later on, some of those properties are not universal requisites (e.g. qualitative indicators may be used in some situations), but a matter of convenience. In addition, some indicators may be used to *evaluate* a condition or phenomenon (e.g. those indicators of environmental quality as opposed to environmental condition).

The major functions of indicators are (modified from Tunstall, 1992, 1994):

- to assess conditions and trends;
- to compare across places and situations;
- to assess conditions and trends in relation to goals and targets;
- to provide early warning information;
- to anticipate future conditions and trends.

INDICATORS AND RELATED CONCEPTS

Indicators are variables; *data* are actual measurements (or observations, in the case of qualitative indicators) of the values of the variables at different times, locations, populations, or combinations of these. A collection of quantitative data is usually referred to as *statistics*. At a given level of aggregation or perception (such as local or global), indicators can be defined as individual variables or as variables that are a function of other variables. The function may be as simple as a *ratio* (including the concept of *index number*, measuring the change in the values of a variable relative to some base value), an *index* (a single number which is a simple function of two or more variables, usually a weighted summation of individual variables, a multiplication, or a maximum operation -Ott 1978), or as complex as the outcome of a large simulation model.

The values of the indicators may be sometimes observed or measured directly at the level of aggregation required for decision-making (e.g. by using satellite images; by measuring the millenary changes in concentration of atmospheric carbon dioxide in Antarctic ice-cores, then extrapolated to the planet). However, in most cases indicators are derived from the primary data that are processed (e.g. averaged, added, etc.) and analysed to estimate the values of more aggregated variables which are used as indicators. An indicator of the air pollution of a city must be based upon a number of individual measurements that are averaged and added, and usually also corrected for inconsistencies. It is not directly measured at the level of the whole city. Therefore, in most cases, indicators are variables representing complicated functions of the primary data. Indices are simple functions of lower-level variables (sometimes called subindices). Although some authors put indices at a higher level of aggregation than indicators (Hammond *et al*. 1995, see their Figure 1, the 'Information Pyramid') this is not generally correct. The distinction between indices and indicators lies in the complexity of the function by which they are obtained, not in their hierarchical level: the 'Greenhouse Gas Index' (World

Resources Institute 1990) belongs to the same level as the GNP.

A *proxy* in the context of indicators can be defined as a variable assumed to be correlated (or otherwise linked) to some attribute which is not directly observable (or, for some reason, cost, for example, is not directly observed or measured). For instance, one could approximate the emission of a country's greenhouse gases by using the generally available national industrial profile. It gives information on the type and volume of industrial activities, and assumes or estimates an emission coefficient for each type of industry, e.g. as in the Industrial Pollution Projection System (IPPS) developed by the World Bank (available on the Internet).

Indicators can adopt different values or states. Some of those values are given special significance, and are often allocated a subjective value judgement. Those include the terms: 'threshold', 'standard', 'norm', 'target', 'reference value' and 'benchmark'. While each of those terms can have different meanings, they are not interchangeable. To some extent within the context of ISDs, standards and norms are rather similar. They refer in their fundamental aspect to any value or state established as desirable by authority or societal consensus ('a means of determining what a thing should be' - MWCD). Sometimes, standard is also used in a less normative sense, as in 'something set up and established by authority as a rule for the measure of quantity, weight, extent, value, or quality' (MWCD), as a technical reference value. In this sense, a standard becomes similar to a benchmark (defined as 'something that serves as a standard by which others may be measured or judged' , or as 'a point of reference from which measurements may be made' (MWCD).

Targets, on the other hand, allude explicitly to intention, representing a specific value (or set of values) to be achieved. The target is set in the context of a decision-making process and is expected to be achievable. Progress towards the targets should be measurable or observable.

Some use the terms target and goal interchangeably, but in the general usage, as well as in theories of organizations, goals are usually rather qualitative terms indicating a general direction rather than a specific state, the end towards which effort is directed (e.g. improving environmental quality, mitigating poverty).

Finally, thresholds are of a more technical nature. They represent values or set of values 'above which something is true or will take place and below which it is not or will not' (MWCD). A threshold may be, for example, the concentration of a pollutant above which health damages become measurable.

CHARACTERISTICS OF INDICATORS

Qualitative and quantitative indicators

Most definitions of environmental or sustainable development indicators rule out the possibility of qualitative indicators, by restricting the concept to numerical variables, either explicitly or implicitly (OECD 1993; Adriaanse 1993; Hammond *et al*. 1995; World Bank 1995; Ott 1978; Holling *et al*. 1978;

Bakkes *et al*. 1994; Winograd 1995). Indeed, it is maintained that one of the essential functions of indicators is to quantify. However, in principle, an indicator could be either a qualitative (nominal) variable, a rank (ordinal) variable, or a quantitative variable. A classic qualitative indicator is the 'indicator species' (Braun Blanquet 1932) which has long been used in ecology, denoting a species so closely associated with particular environmental conditions that its presence is indicative of the existence of these conditions.

Qualitative indicators may be preferable to quantitative indicators in at least three cases: when quantitative information is not available; when the attribute of interest is inherently non-quantifiable; and when cost considerations become determinant. In some cases, qualitative assessments can be translated into quantitative notation.

Indicators should be selected at different hierarchical levels of perception

Sometimes it is assumed (or stated) that indicators must necessarily be developed by the aggregation of lower-level data or variables (Ott 1978; Hammond *et al*. 1995; World Bank 1995). While this approach is commonly used, making it a general requirement is an unnecessary restriction that would eliminate from consideration potentially important indicators.

Different kinds of indicators may be relevant at different scales (and meaningless at others). Hierarchical systems theories show that different indicators of systems performance are usually required at different hierarchical levels of the system (as well as by different levels in the hierarchy of users), and aggregation across levels is not always possible nor meaningful.

As the technology of remote sensing and geographical information systems (GIS) advances, more and more indicators will be generated directly at the scale of interest. See examples by Langaas in **Box lB** and Winograd and Eade in **Box lC**. A fruitful line of research could be developed around the question of which indicators are appropriate at different scales, and which of them can be obtained directly and in a cost-effective way at the desired scale.

Indicators may be scalars or vectors

A number of indicators presented simultaneously to give a picture of environmental conditions (but not aggregated) is defined as an 'environmental quality profile' (Ott 1978, p. 8). An environmental quality profile (or in general, an environmental profile) is a vector. A vector is a natural generalization of a 'variable'. By contrast, an index is a scalar (a single number generated by aggregation from two or more values). The difference between indexes and profiles is also apparent from the viewpoint of the users. This is called the 'classic dichotomy' of views towards indices: one viewpoint prefers data in the most complete form possible (environmental profile) but is willing to accept the resulting complexity, while the other viewpoint prefers data in as simple a form as possible (an index), but is willing to accept the distortion introduced in the simplification process (Ott 1978).

It should be noted that the profile is by itself an indicator, a variable that is a vector. The individual component variables are ordered, often linearly or radially. Therefore, profiles provide information not only on the values of the individual variables included, but also a Gestalt view of the whole. This holistic function of profiles raises a research question related to human perception that requires attention: what is the best structure of the profile in terms of the apprehension of the total pattern? An advantage of visualizing the profiles as vector indicators is that the mathematical tools of abstract algebra and vector analysis can be applied to make more holistic comparisons and inferences.

The need to address inter-linkages

Complex interlinked problems such as those associated with sustainable development require integrated approaches and solutions. There is a need to move beyond the usual, more or less exhaustive, lists of individual indicators to integrated or interlinked sets of indicators. This is particularly important regarding the uses of indicators for early warning and for forecasting (the issue of interlinked indicators should not be confused with that of indicators of inter-linkages).

Inter-linkages in socio-ecological systems may be physical flows of matter or energy or causal influences that are not adequately described as material or energy flows. Linkages may exist among variables within a subsystem, among different subsystems (e.g. among the economy and the environment), and among whole systems (e.g. among countries). From another viewpoint, linkages may exist among systems or subsystems of roughly the same hierarchical or aggregation level (either internal or external to the considered socio-ecological system). Those can be referred to as 'horizontal' linkages (Gallopín 1994). 'Vertical' or interlevel linkages, on the other hand, are those existing between socio-ecological systems belonging to different levels of organization (such as local, regional, global) or between subsystems belonging to different levels of the system, if the latter is defined as a hierarchical system.

The recognition of the existence of significant linkages in socio-ecological systems highlights the limitations of the usual procedures (often as simple as summation or averaging) for aggregating indicators into a single index. Those may be useful for assessing progress, but usually not for understanding early warning and forecasting. For the latter purposes, it is not enough to choose indicators having some correspondence (e.g. iso- or homo-morphism) with meaningful attributes of the object studied. In addition, it is necessary to insure that some minimum correspondence exists between the functional inter-linkages among the attributes and the procedure linking or aggregating the individual indicators. A set of indicators (variables) and a set of assumed relations among them constitute a 'model' of the original system. This model may be only a blurry mental image about how indicators are interconnected causally, or it may be a highly formalized mathematical model.

The need for indicators of fundamental whole system properties

The systemic nature of many aspects of sustainable development points to the importance of searching for fundamental whole-system attributes for which appropriate indicators could be devised. Those indicators would be holistic themselves, representing directly basic underlying properties at the total system level (not only elements, not only inter-linkages). This will require more fundamental scientific research, both empirical and theoretical, on the behaviour of complex socio-ecological systems, in order to identify the basic attributes, mechanisms, and necessary measurements. Systemic vulnerability and resilience, ecosystem health, socio-ecological self-reliance, etc. are examples of whole-system attributes critical for sustainability. The need for a holistic approach is pointed out in Box lA.

The general concept of indicator is not limited to the case of a time-varying variable

While it is clear that in most cases the main interest will be to assess changes over time (e.g. trends and future conditions), indicators used for cross-sectional studies and other types of synchronic comparisons have space (such as in the case of indicators of soil quality in a landscape) or population (such as static indicators for countries - total size, mountain areas, etc.) rather than time, as a distinguishing property. Those indicators are still variables, adopting different states or values not in time, but in space or population, and are very useful for some purposes in policy-making. Therefore, the requirement that indicators should show trends over time is a convenient, but not a universal requirement for environmental or socio-economic indicators. It is obvious, however, that indicators of sustainable development must be able to show changes through time, because of the inherent temporal dimension imbedded in that concept.

Value judgements may enter indicators at different levels

The term 'value' has two common meanings relevant to the discussion of indicators: the first is that of 'relative worth, utility or importance' (the axiological definition associated to value judgements). The second meaning essentially alludes to a state of a variable in the general systems contexts. The state (which can be a numerical quantity or non-numeric) is allocated through observation, measurement, calculation, inference or, in the case of System Design, *a priori* designation.

Ultimately, all indicators are used normatively, insofar as they are selected to fulfil the purpose of policy and, more generally, decision-making. The important point is whether the associated value judgement is built into the indicator or is external to it. Here one could point to a second 'classical dichotomy' of views towards indicators: one viewpoint prefers to have value judgements internalized, reducing decision-making to quantitative comparisons of a single measure such as cost-benefit ratio, and the other viewpoint prefers to have the indicators laid out and to perform the evaluation of their condition (in terms of worth or utility) explicitly.

Explicit value judgements can appear in indicators in the following ways:

(a) Directly in the measuring or observation process (such as for indicators of aesthetic value of a landscape, preferences, etc).
(b) Added to the observed or measured condition such as when a value of quality is assigned to each concentration of a pollutant, or the desired value (standard, target, etc.) is combined with the indicator to

define a new indicator such as the ratio between the current and desired condition, or as the distance from the current condition and the target.
(c) As relative weights in an aggregation function combining several indicators (or subindices); a weighted linear sum or a weighted product are common examples. The allocation of weighting coefficients to each indicator introduces a value judgement reflected in the value of the total indicator or index.

Alternatively, value judgements may be kept confined to targets, norms or standards, and the current condition (value or state) of the indicators (and their trajectory of changes through time) can be compared with them in order to evaluate performance. The distinction between 'descriptive' and 'policy performance' indicators (Adriaanse 1993) is therefore not an essential, but a pragmatic differentiation.

Value judgements include both explicit and implicit values. Explicit value judgements, those made consciously, comprise part of the basis for creating indicators, but implicit values are also involved. Implicit value judgements are based upon factors that are not easily revealed, as they are mostly subconscious and relate to personal and societal characteristics, such as one's background, associations, culture, and environment. Although it is often difficult to distinguish the influence of implicit value judgements in the selection of a set of indicators, they directly affect qualities of the indicator sets, such as which indicators are chosen, the time and geographical scale deemed to be relevant, and the issues of concern (poverty, non-renewable resource depletion) (see chapter 2). Thus, it is important to recognize that any indicator set is inevitably biased to some extent.

The aggregation problem

Wall *et al*. (1995) note that:

> 'The development of highly aggregated indicators is confronted with the dilemma that, although a high level of aggregation is necessary in order to intensify the awareness of problems, the existence of desegregated values is essential in order to draw conclusion for possible courses of action. This dilemma particularly affects highly aggregated approaches which do not have a disaggregated substructure. Moreover, highly aggregated systems still have substantial conceptual problems. In approaches that follow the calculation of the national product, relevance is limited by limitations in the monetizing of external costs. In approaches that envisage an aggregation of individual elements, it constitutes a methodological barrier. Distance-to-target methods only appear to bypass the problems of valuation; in addition, they are often dependent on the existence of target values. Altogether it is noticeable that the status of discussion on the aggregation of indicator systems is lagging far behind the analogous discussion on the evaluation of life-cycle analysis. It would therefore be appropriate for the knowledge gained in this latter field to be received by, and transferred to the field of indicator systems.'
>
> 'There is a basic need for further conceptual development regarding inter-linkages between the individual aspects of sustainable development. This problem crops up in all the proposals analysed. However, there are also instances where the existing state of knowledge is just not yet integrated into the indicator system. This is true, for instance, for the interconnections between

social and economic phenomena (for example: nutrition problem-work productivity, lack of state provision for old people, children as an 'insurance' for old age, population pressure-unemployment, the discussion of the 'vicious circle of poverty' in development theory) and for the interactions between social problems (poverty) and environmental problems. In this area, it will be a necessary task to build existing knowledge into the indicator systems (Wall *et al*. 1995).'

INDICATORS FRAMEWORK

Sustainable development embraces many issues and dimensions. In order to organize the different indicators relevant to sustainable development, some kind of conceptual framework is required.

As the conclusions of the workshop in Ghent state:

> Indicator frameworks, organizing individual indicators or indicator sets, in a coherent manner, have several additional uses. They can guide the overall data and information collecting process. They are useful communication tools to decision-makers, summarizing key information derived from many different sectors. They suggest logical groupings for related sets of information, promoting their interpretation and integration. They can help to identify important issues for which adequate information is lacking, thus identifying data collection needs. Finally, indicator frameworks can help to spread reporting burdens, by structuring the information collection, analysis and reporting process across the many issues and areas that pertain to sustainable development (UNEP-DPCSD/Ghent Report 1995, p6).

Different analytical frameworks have been used to identify, develop, and communicate indicators. In the particular case of environmental indicators, several approaches have been used including: the 'media approach' (air, water, land, and living resources); the 'goals approach', used to select indicators according to legal and administrative mandates; and the 'sector approach' , examining indicators of environmental impact from the perspective of economic sectors (transportation, industry, urbanization, agriculture, and so on) (from Tunstall 1992, p5).

In the field of environment and development, some of the major frameworks are (Bartelmus 1994):

- integrated environmental-economic accounting systems or other national accounts-based recordings of stocks and flows of natural resources and environmental services, in most cases expressed in monetary terms;
- frameworks of environmental statistics, such as the United Nations Framework for the Development of Environmental Statistics (FDES), which lists statistical variables in a systematic manner but without attempting to establish accounting or functional relationships among those variables. The contents of the FDES are 'statistical topics' , or those aspects of environmental and related socio-economic concerns that are amenable to statistical description and analysis;
- ad hoc nomenclatures or listings of environmental indicators, using selected 'themes', 'issues', or 'subsystems' of models;
- overall policy frameworks or more limited conventions, which were not designated for data

> collection but reflect the concerns to be monitored (notably Agenda 21).

A framework that is rapidly gaining international prominence is the 'Pressure-State- Response' framework derived from the stress-response framework applied to ecosystems (Friend and Rapport 1979). As noted by Bakkes *et al*. (1994), 'response' used to stand for ecosystem response originally. But in the pressure-state-response framework, as used by the OECD (1993), SCOPE (Ghent Report), and other current users or developers, 'response' is used to denote the response of society (e.g. environmental protection expenditure). The United Nations (1995) replaced the concept of 'pressure' by that of 'driving forces' in an attempt to accommodate more accurately the addition of social, economic and institutional indicators.

In the original PSR framework as used by the OECD (1993) and SCOPE (1995 Ghent Report), 'pressure' means human activities that exert a pressure on the environment and change its quality and the quality and the quantity of natural resources (the 'state'). Society responds to these changes through environmental, general economic and sectoral policies (the 'response'). The latter forms a feedback loop to pressures. The PSR framework is obviously based on a concept of causality (OECD 1993).

It should be noted that in this framework, the notion of 'state' refers only to the state of the environment, reflecting the fact that it was used for assessing environmental performance, 'for measuring and reporting on the environment in the context of sustainable development' (see title of SCOPE Discussion Paper 1995- Ghent Report). When the focus shifts from environmental indicators to indicators of sustainable development, both the state or condition of the environment (or ecological subsystsem) and the state of the human subsystem have to be considered. The driving force-state-response (DSR) framework adopted by the United Nations (1995) clearly addresses this issue, as described by Mortensen in **Box 1D**. There, 'state' indicators indicate the state of sustainable development and 'response' indicators indicate policy options and other (societal) responses to the changes in the state of sustainable development. The framework is applied to the following categories: social, economic, environmental, and institutional, each with indicators of driving forces, state and response. The indicators are directly related to the chapters of Agenda 21.

Closely related to the question of frameworks are the linkages between indicators and various models. This issue was stressed, among others, by Joke Waller-Hunter at the second Ghent Workshop on Indicators of Sustainable Development (1995):

> Modelling can be a useful tool for understanding the inter-linkages between various indicators. UNEP, UNU and DPCSD have recently taken the initiative to establish a Global Modelling Forum for Sustainable Development, following decisions taken by the CSD. It brings together modelers from within the UN system and from various research centres. It will contribute to a substantive multi-year programme on long- term forecasting and modelling, aiming at an integrated modelling framework for sustainable development, drawing on a variety of existing models. Projections generated by the selected models will be expressed in terms of various indicators, such as energy demand and supply, land use, water demand and others. The purpose will be to develop a range of possible scenarios and response strategies which explore the inter-

linkages between trend projections and policy options at the global and regional level. The work on modelling may help building aggregated indicators or indices. Developing such indices reduces the number of indictors and adds analytical and interpretive value to the process. It also, however, increases the value content (Waller-Hunter 1996).

Although these issues are not covered in great detail in this book, some of the issues are indicated in **Box lE** (Rutherford).

The causality assumption

As noted before, the PSR, as commonly used, subsumes a notion of causality: a pressure modifies the state of the environment, and this triggers a response from society. The OECD itself warns that the PSR framework 'tends to suggest linear relationships in the human activity-environment interaction. This should not obstruct the view of more complex relationships in ecosystems and in environment- economy interactions' (OECD 1993, p.5). By contrast, the DSR framework explicitly states that there is as yet no implied causality among indicators between cells, either horizontally (driving force-state-response) or vertically (social-economic-environmental- institutional). The CSD recognizes that significant work must be undertaken on the question of inter-linkages among indicators before causal relations can be understood and expressed (United Nations 1995, p. 5; see Box 1D). However, users of the PSR (and also of the DSR) are easily tempted to use them within a mechanistic, Newtonian world view, seeing the pressure as the cause, the state as the effect, and the response as a feedback regulator. And, given that the early uses of this framework concentrated on biophysical variables such as carbon emissions (pressure), the atmospheric concentration of greenhouse gases (state), and energy intensity (response), this conception may seem natural.

The elementary features of any socio-ecological system are enough to show that the environmental subsystem is not a passive receptor of human influences. Both environmental and human subsystems exhibit rich internal dynamics that result in effects (or outputs) that are not simple direct functions of inputs. The consequence is that, in most cases, it is very difficult to identify cause-and-effect chains in socio-ecological systems without detailed studies. The risk of viewing the PSR (or any other framework) as representing a causal sequence in terms of policy-making is that invalid inferences are likely to be drawn, leading to wrong policy recommendations. Another consequence is that if the internal dynamics and the contextual aspects of different socio-ecological systems are ignored, recommended policies (or societal 'responses') that work in some situations (e.g. industrial countries), might fail or backfire if applied indiscriminately.

In summary, the PSR, even for the case of environmental indicators, is best perceived as a useful taxonomy for ordering indicators, but without an underlying functional causality. The search for immediate and ultimate causes, and the indicators of these, is a very important enterprise, that should not be trivialized through oversimplification and straight-jacketing.

THE USE OF INDICATORS

The basic use of indicators of sustainable development is to support and improve policy and decision-making at different levels. Particularly applicable to national and international policy-making (but also to other levels of decision-making) is the concept of the 'decision-making cycle', by which different phases in the decision-making process are recognized. Different indicators may be required in the different phases, and indicators may be used in different ways in each phase. An overview of the concept is given by Moldan in **Box 1F** .

Users of indicators may vary much, across societal, geographic and cultural dimensions and across scales from the global to the local. The broadest level is the *international* or *global* level. In this context, recent global conventions and protocols, such as the climate, biodiversity, desertification, and ozone agreements, are extremely important. It is becoming increasingly clear that unless specifically tailored indicators are developed and monitored, the implementation of these conventions will not be possible. Both the secretariats of the conventions and international agencies are working intensely not only to identify and develop appropriate indicators but, most importantly, to give them acceptability in the eyes of the international community.

Most indicators are devised for their use at the *national* level (see chapter 4). However, the differences among individual countries (size, level of industrialization, etc.) as well as the heterogeneity within countries (particularly the large ones) are often very great and represent serious constraints to the meaningful use of same national level indicators (e.g. what would be the meaning of an air quality indicator at the level of a country?). Because of these and other reasons, many experts and policy-makers are strongly encouraged to develop indicators at subnational levels (down to the community or local level indicators).

For a number of important sectors such as agriculture, forestry, energy, transport, industry, and urbanization specific sets of indicators (sometimes very advanced and sophisticated) have been developed or are already being used, as will be shown in Chapter 3.

An important and often neglected prerequisite for the usefulness (and acceptance) of indicators is that the users must understand them. Indicators are also a means of communication. Any form of communication requires understanding by all partners participating in the dialogue in order to move towards sustainable development. The indicators should ideally be fully transparent, and the users should be empowered in order to be able to grasp their meaning and their significance in terms of their own values.

Some pragmatic considerations

Various authors have proposed certain requirements that indicators should meet (Adriaanse 1993, OECD 1993, Turnstall 1994). Some of the requirements are tied to a particular framework, or otherwise restricted to some particulars.

Only the more universal requirements or desirable (from a practical point of view) properties are listed below:

1. The values of the indicators must be measurable (or at least observable).
2. Data must be either already available or they should be obtainable (through special measuring or monitoring activities).
3. The methodology for data gathering, data processing, and construction of indicators must be clear, transparent and standardized.
4. Means for building and monitoring the indicators should be available. This includes financial, human, and technical capacities.
5. The indicators or sets of indicators should be cost effective, an issue often overlooked. The situational indicators described in **Box lG** address this issue for a class of indicators.
6. Political acceptability at the appropriate level (local, national, international) must be fostered (indicators that are not acceptable by decision-makers are unlikely to influence decisions).
7. Participation of, and support by, the public in the use of indicators is highly desirable, as one element of the general requirement of participation of the broader society in the quest for sustainable development.

NOTES

1 Involving the relationships of signs to things other than signs by which some use is ascribed to the signs.
2 Involving the relationship of signs to things other than signs by which a meaning is given to the signs (e.g. words, variables) but without reference to their use.

REFERENCES

Adriaanse, A. (1993) *Environmental Policy Performance Indicators*. SDV Publishers, The Hague.

Bakkes, J.A., van den Born, G.J., Helder, J.C., Swart, R. J., Hope, C.W., and Parker, J.D.E. (1994) *An Overview of Environmental Indicators: State of the Art and Perspectives*. UNEP/EATR.94-01; RIVM/402001001. Environmental Assessment Sub-Programme; UNEP, Nairobi.

Bartelmus, P. (1994) *Towards a Framework for Indicators of Sustainable Development*. Working Paper series No.7, Department of Economics and Social Information and Policy Analysis, ST/ESN1994/WP.7, United Nations, New York.

Braun-Blanquet, J. (1932) *Plant Sociology. The study of plant communities*. Hafner Publishing Co., New York, 1972 (copy of 1932 Edition).

Chevalier, S., Choiniere, R., Bernier, L. *et al*. (1992) *User Guide to 40 Community Health Indicators*. Community Health Division, Health and Welfare Canada, Ottawa.

Dever, G.E.A. (1979) *Community Health Analysis*. Aspen Systems Corporation. Germantown, Mary town.

Friends, A. and Rapport, D. (1979) *Towards a Comprehensive Framework for Environment Statistics: A Stress-Response Approach*. Statistics Canada, Ottawa, Canada.

Gallopín, G.C., Gutman, P. and Maletta, H. (1989) Global Impoverishment, Sustainable Development and the Environment. A Conceptual Approach. *Int. Social Science Journal* **121**: 375-397.

Gallopín, G.C. (1994) *Impoverishment and Sustainable Development. A Systems Approach*. International Institute for Sustainable Development (IISD), Winnipeg, Manitoba, Canada.

Gallopín, G.C. (1996) Environmental and sustainability indicators and the concept of situational indicators. A systems approach. *Environmental Modelling & Assessment* **1**: 101-117.

Gill, A. (1969) Finite-state systems., pp.43-94, In: L.A. Zadeh and E. Polak (eds.) *System Theory*. McGraw-Hill, New York.

Hammond, A., Adriaanse, A., Rodenburg, E., Bryant, D., and Woodward, R. (1995) *Environmental Indicators: A systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development*., World Resources Institute, Washington, D.C.

Holling, C.S. (ed.) (1978) *Adaptive Environmental Assessment and Management*. John Wiley & Sons, Chichester.

Marcus, S. (1983) *Towards a Semiotic Approach to Social Indicators*. Paper presented at the International Congress of Logic, Methodology and Philosophy of Science, Salzburg, Austria, July 11-16,1983.

McQueen, D., & Noak, H. (1988) Health Promotion Indicators: Current status, issues and problems. *Health Promotion* **3**, 117-125. (MWCD)

(MWCD) Merriam-Webster Collegiate Dictionary, l0th. Edition

OECD (1991) *The State of the Environment*. OECD, Paris.

OECD (1993) *Organization for Economic Cooperation and Development Core Set of Indicators for Environmental Performance Reviews. A Synthesis Report by the Group on the State of the Environment*. OECD, Paris.

Ott, W.R. (1978) Environmental Indices: Theory and Practice. *Ann Arbor Science*, Michigan.

Tunstall, D. (1992) *Developing Environmental Indicators: Definitions, framework and issues*. (Draft paper). Background Materials for the World Resources Institute. Workshop on Global Environmental Indicators, Washington, D.C., December 7-8, 1992. World Resources Institute, Washington, D.C.

Tunstall, D. (1994) *Developing and Using Indicators of Sustainable Development in Africa: An Overview*. (Draft paper). Prepared for the Network for Environment and Sustainable Development in Africa (NESDA). Thematic Workshop on Indicators of Sustainable Development, Banjul, The Gambia, May 16-18,1994.

United Nations (1995) W*ork Programme on Indicators of Sustainable Development of the Commission on Sustainable Development*. ID:2129634260, United Nations Department for Policy Coordination and Sustainable Development, New York.

UNEP-DPCSD (1995) *The Role of Indicators in Decision-making*. Discussion paper prepared for UNEP for the Indicators of Sustainable Development for Decision-Making Workshop, 9-11 January, Ghent, Belgium.

Wall R., Ostertag, K. and Block, N. (1995) *Synopsis of selected indicator systems for sustainable development. Report for the research project*, 'Further development of indicator systems for reporting on the environment' of the Federal Ministry of the Environment. Fraünhofer Institute for Systems and Innovation Research, Karlsruhe.

Waller-Hunter, J.H. (1996) *Testing Indicators of Sustainable Development: Building on a Strong Foundation*. Second Ghent Workshop on Indicators of Sustainable Development.

Winograd, M. (1995) *Environmental Indicators for Latin America and the Caribbean: Toward Land-Use Sustainability*. GASE-IICA/GTZ-OAS-WRS (Printed by the World Resources Institute, Washington, D.C.).

World Bank, The (1995) *Monitoring Environmental Progress*. The World Bank, Washington, D.C.

World Resources Institute (1990) *World Resources* 1990-91. Oxford University Press, New York, pp. 383.