Environmental Indicators for Resource Managers

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Introduction

The ecological-economic interface is best illustrated by economic activities which make use of renewable natural resources such as forests, fish, fertile topsoil, water.. The production functions behind the availability (incorporating aspects of quality and quantity) of these resources are essentially ecological. However, the results of resource use are generally viewed in monetary and/or economic terms.

Economic activities can be extractive or non-extractive. Forestry, fisheries, aquaculture and agriculture are typically extractive users, and have an immediate impact on quantities of resource stocks and flows. Less direct and longer term impacts on resource quality can occur through cultural selection and poor management practices. Non-extractive resource users include (wild-life) conservation, recreation and waste disposal and primarily affect resource quality. Impacts on resource quantity can also occur, particularly if irreversible damage to an ecological system occurs.

The major social function of an environmental indicator is simplification (Ott, 1978). The same holds for economic indicators. In this respect, the development of indicators is a compromise between an attempt at a scientific account and the social demand for concise information.

This paper introduces some of the indicators which have been developed at the Institute for Environmental Studies. These indicators are targeted towards resource managers at both national and regional levels. Resource managers are key actors in the ecological-economic interface, since they have the responsibility for balancing economic demands with ecological supply.

The following sections discuss the framework within which indicators are considered, two of the fifteen indicators developed to date, their users and the role of indicators within management.

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While everybody knows what an indicator is, the following qualities serve to define indicators in the context of this paper:

1. They should point out changes in environmental systems in socially accessible terms;
2. In the process of developing environmental standards, they should be capable of pointing out, both quantitatively and qualitatively, consequences of a specific policy;
3. In principle they are scientifically based and valid, i.e. they are based on an empirically specified model, in practice however they are often based on correlations or on consensus among experts; and,
4. They should meet current technical requirements as to reproducibility and reliability, making it possible to (prospectively) apply them with the aid of simulation and information systems (Vos et al, 1985).

There are two risks involved In the use of indicators. Firstly, an indicator's necessarily simplistic representation of the 'real world' may come to embody or supplant more detailed and/or comprehensive knowledge. This background knowledge should not be neglected if the indicator is used in policy making. Secondly, an indicator can come to represent something which it was never intended to represent and subsequently lead to inappropriate understanding and action. Both of these risks must be addressed in developing indicators.

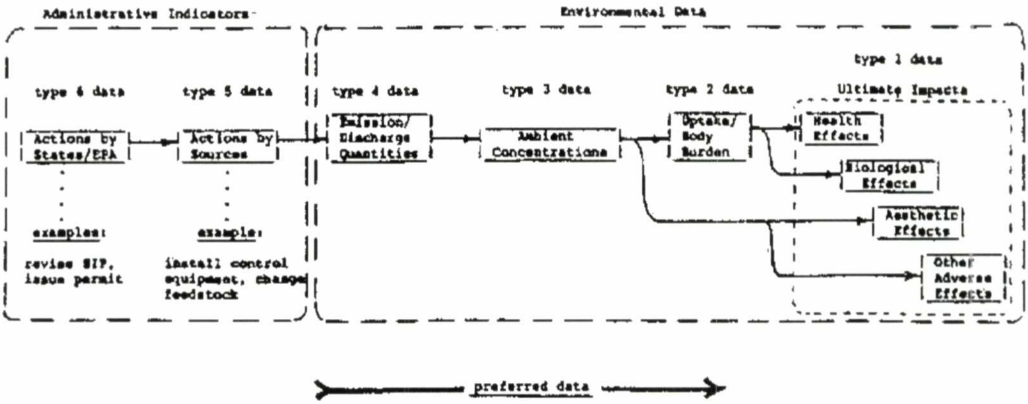
Vos et al.(1985) distinguish between the following indicators: Environmental quality indicators, environmental policy indicators and environmental trend indicators.

One of the characteristics of environmental quality (and therefore environmental quality indicators) is that changes in quality can usually be expressed in a chain of events representing cause and effect (see Figure 1).

From an analytical point of view and in view of social acceptability, effect indicators are to be preferred; *e.g.* change in public health, assuming that the health effects of environmental quality can be separated from the effects of other factors. Where information on such effects is lacking or where these effects do not yet occur, one has to fall back on other steps in the causal chain; *e.g.* the number of people exposed to concentrations of chemical substances considered potentially hazardous to health.

Policy activities can be regarded as cause indicators for environmental quality, although the causal relationship may be difficult to prove. The impact of environmental policy is best illustrated by effect indicators which deal with policy changes. Such policy indicators may have either a discreet form - *e.g.* moment of introduction of reduced lead concentrations in fuel - or a continuous form - *e.g.* annual expenditure on sanitation of waste sites. Although one may assume that at a certain point environmental quality is the result of the policy that was implemented for a number of years, environmental quality indicators do not sufficiently reflect the nature of the policy and its changes.

Figure 1. Overview of data types for indicators in an environmental cause-effect sequence



Source: E.P.A., memorandum: Environmental Reporter, 9-17-82, p.704.

Expressing the social significance of a cleaner environment and the benefits of environmental policy requires a combination of environmental quality and environmental policy indicators. Such a combination is referred to as environmental trend indicators. These indicators are presented as time series in a graphical form and incorporate aspects of both of these constituent indicators.

A Selection of Indicators

From the selection of indicators which have been developed by IES (see Vos et al, 1986) two indicators 'forest vitality in the Netherlands' and 'toxic substances in the North Sea' - are used to illustrate the theme in this paper.

Forest vitality and acid deposition

This indicator uses a spatial representation of forest vitality and production capacity of The Netherlands to indicate damage caused by air pollution in general and acid deposition in particular. Vitality relates to the capacity of an individual tree or a forest to develop aspects of its "life", such as to grow and to diversify. Foresters have generated an index of vitality by combining scores on a series of measurable criteria. These criteria include the number of needles of leaves per branch, leaf colour, shape of the canopy, and light penetration.

Three classes of vitality are defined for the purposes of this indicator: vital, less vital and not vital. Figure 2 shows the distribution and vitality of forests in the years 1984 and 1985. Regions where forests are in poor condition are obvious. They coincide with areas which are 'downstream' from acid gas emissions, where ammonia emissions are high and where soils have a poor buffering capacity.

The use of piecharts in the presentation of this indicator can been questioned: "a table is nearly always better than a dumb pie chart; the only worse design than a pie chart is several of them..." (Tufte, 1983). However, in this case they provide an important advantage. The proportions of the three classes of vitality are left for the viewer to estimate, and so no false sense of precision in this information is communicated. Tables generally give no reference to the accuracy or precision of the numbers contained in them.

Toxic substances in the North Sea

This indicator (see Figure 3) comprises: sources of contaminants, policies implemented and accumulated concentrations in an indicator species. These elements correspond to: cause, management response and effects. This cause-effect chain is obviously not complete nor as simple as the indicator would suggest. However, it serves to highlight trends and key variables in this chain.

Figure 3 presents the indicator for cadmium. It shows that, in 1980, approximately 53% of the cadmium entering the southern part of the North Sea (i.e. the Dutch continental shelf) was derived from rivers, dumping of dredge spoil and deposition of air pollutants. The standard for cadmium in mussels for human consumption was exceeded in 1979 and reached in 1980. However, there appears to have been a definite decrease in cadmium contents since then.

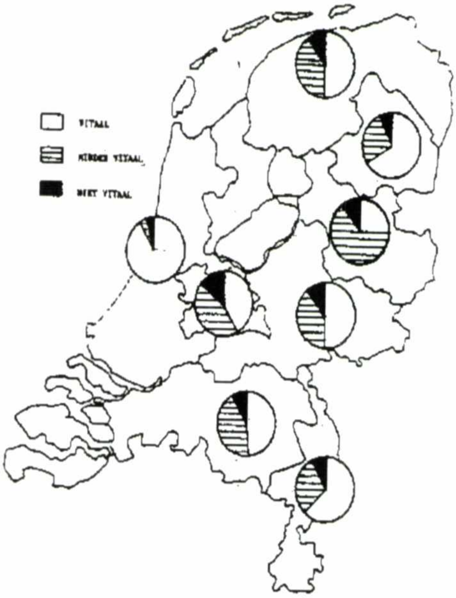
Use and Users

Forest vitality and acid deposition

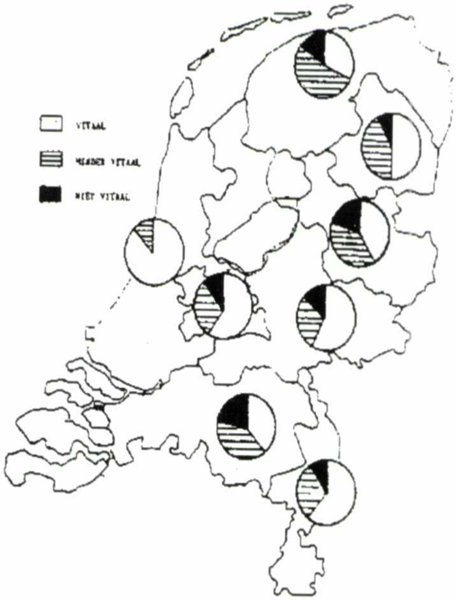
The indicator 'forest vitality and acid deposition' is intended for use in forest management, which is primarily a regional activity. However, it also has implications for national and even international environmental and economic policy. Both the declining vitality of forests and the transboundary nature of S02 and NOx bear on national and international policy.

The concept of forest vitality has proven both to be easy to comprehend and to have some scientific basis. The information contained in this indicator is easily communicated to all parties with an interest in the effects of acid deposition. It communicates no economic information explicitly. However, the

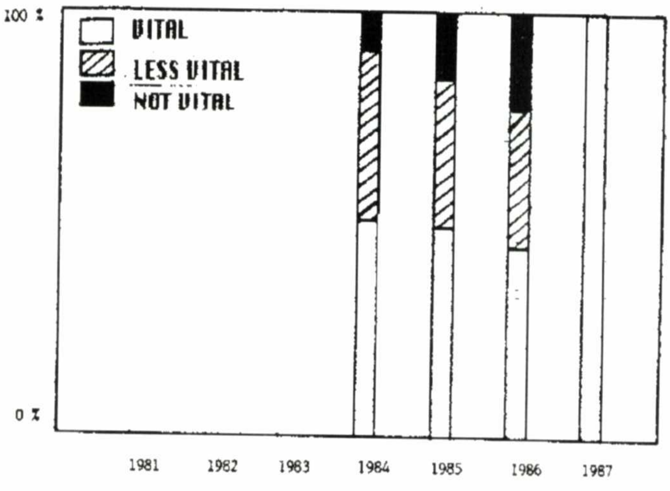
Figure 2. The "Forest vitality" indicator



Forest vitality in the Netherlands in 1984

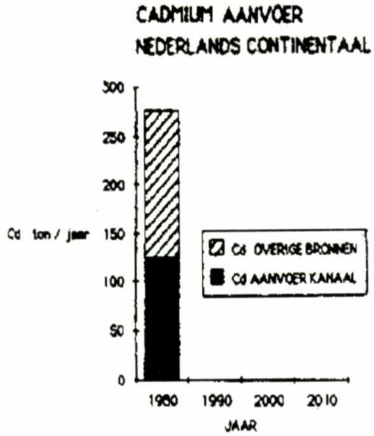


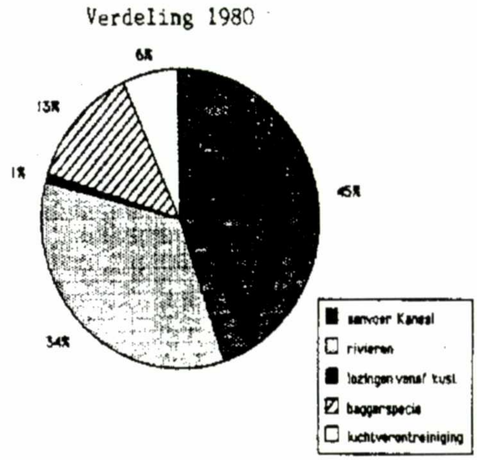
Forest vitality in the Netherlands in 1985



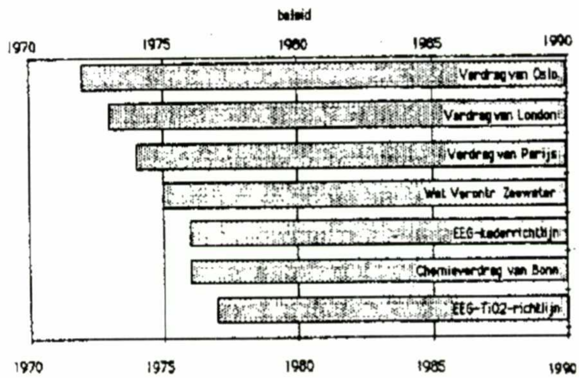
Development of "Forest vitality" in the Netherlands 1984-86

Figure 3. The "Toxic substances in the North Sea" indicator

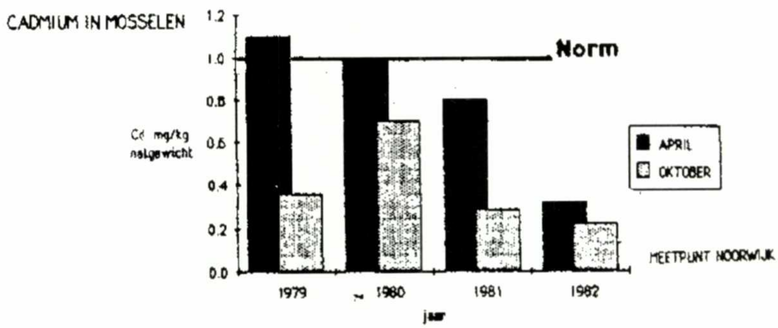




SOURCES OF POLLUTION



POLICY



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economic impacts of declining forest vitality - loss of productivity and costs associated with premature replacement - are difficult to overlook.

There are definite constraints to the use of this indicator. Firstly, acid deposition is not the only cause of reduced forest vitality. Users of the indicator must keep this in mind. Secondly, the indicator as it stands provides no explicit guidance for regional forest management or national environmental policy. It is descriptive of the state of the environment only - it serves to identify the extent of the problem but is of limited use in developing remedial actions.

These limitations demonstrate the need for indicators to be linked with models and other management tools which describe the ecological-economic relationships in more detail and with more precision. IES has developed a number of computer models associated with this problem (*e.g.* Braat et al., 1986).

The Institute has also been involved in the development of a computer system (known as IRENE) for the European Community (Braat et al., 1987; Roberts et al., 1987) which aims to integrate, in the one system, various aspects of management needs (viz. data, information, models, graphics, geographical information systems and interactive software).

Toxic substances in the North Sea

The second indicator - toxic substances in the North Sea - is intended for use at the national level. The national resource manager is identified as the user for two reasons. Firstly, the issue crosses traditional management boundaries - waste disposal, water quality, marine ecosystems and human health - and requires coordination of inputs from these various interests. Secondly, the economic and social aspects of this issue - particularly pollution control costs and costs to fisheries - are of national (and to some extent: international) economic importance, even if the indicator does not deal with them specifically.

The value of this indicator lies in its incorporation of policy elements within the implicit cause-effect chain. However, the information which it imparts - that there is a lag between policy implementation and its effect on ecosystems - is obvious and not particularly helpful for further management. Data constraints, especially the absence of a time series for the various sources, is also a major constraint to this indicator's usefulness in policy making.

This indicator has been developed for use by Dutch authorities. However, the problem crosses national borders and to have a real value or impact, it should be extended to accommodate these other sources and interests. Links with modelling activities are also needed, but IES is not active in this area. However, the problem with its needs for data, indicators, models, etc could, in theory, be handled by the IRENE system developed for the EC (see above).

Discussion and Conclusions

Gross National Product and other aggregate economic indicators generated by the national accounts are probably the best known examples of indicators. The concept of environmental indicators has been developed in part to parallel and complement these economic indicators.

GNP is used in two ways: to monitor current economic activity and to predict future economic activity. The first use is as an indicator derived directly from economic statistics; the second is as a variable in economic modelling. This second use is frequently criticised. These models may be constrained by data availability - they use data easily obtained as substitutes for data required; also, economic models and the conceptual framework behind GNP tend not to incorporate externalities such as natural resource stocks and environmental services adequately. However, this predictive use suggests a need on the part of users and must be carefully considered in the development of indicators.

The environmental indicators presented here are based on environmental statistics. Their monitoring role is clear. The conceptual cause-effect framework behind each indicator is based on scientific knowledge, although this may not be as mathematically specified or consistent as the framework underlying the national accounts and their indicators. The national accounts lend a validity to GNP etc. which environmental indicators to date have not imitated.

There are no specific links between environmental indicators and environmental statistics which correspond to that of the national accounts and their aggregate indicators. However, natural resource accounting is attempting to create such a parallel, although so far with variable success. (A review of these activities is presented in Gilbert and James (forthcoming)).

IES has been active in this area, and a design for a set of natural resource accounts has been developed for inclusion in IRENE (Gilbert and Hafkamp, 1986). This framework permits data to be presented in a range of units and would contain all of the data necessary for the generation of these two indicators. However, such frameworks must be developed with care. They may impart undue credibility to indicators and be inadequate in demostrating the degree of inaccuracy or imprecision inherent in our current understanding of the environement and in such a simplification as an indicator.

The predictive role of environmental indicators is not as clear as is the monitoring role. The predictive role includes: prediction via ecological models of the future state of the environment given certain management inputs and prediction of economic impacts via economic-ecological models. Model output variables should include environmental indicators so that extended time series of this information can be developed to permit communication of model results to managers in a form which is already familiar.

The developers of indicators must be clear about the relative roles of data systems (such as environmental accounts), indicators, and modelling activities in environmental and economic management. As much as possible, indicators should be 'sold' to users as part of a larger, more comprehensive package. This has the obvious advantage of the advancement of science and scientists.

More to the point, however, is that a close working relationship between user and researcher develops to mutual benefit. This relationship facilitates on-going evaluation of the problem and assessment of the management tools.

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