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Natural Resource Accounting - the search for a method

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NATURAL RESOURCE ACCOUNTING

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This report, commissioned by the Ministry of Housing, Physical Planning and Environment as project no. 80725 summarizes the discussions on Natural Resource Accounting and formulates a proposal on the issue. In the context of the Dutch environmental policy there is a connection with the policy theme 'squandering', that deals with elaborating the notion that environment has the character of a resource.

CENTRUM VOOR MILIEUKUNDE
DER RIJKSUNIVERSITEIT LEIDEN

CONTENTS

0. Summary

Natural Resource Accounting (NRA) is needed to provide the data for integrated environmental and economic accounting and to derive relevant policy performance indicators. This study tries to find a theoretical base for NRA. The study was commissioned by the Ministry of Housing, Physical Planning and Environment, as part of the NIMIOK project. The NIMIOK project brought together representatives of various departments to prepare the dutch standpoint on NRA and environmental indicators, to be submitted for discussion at the OECD-GEP meeting in Paris, 1-2 february, 1993. Apart from this paper there were contributions from the Central Bureau of Statistics (CBS), RIVM and Rijkswaterstaat. The project was presided over by dr. A. Adriaanse.

The search for a method of Natural Resource Accounting is based on the macro-ecological insight that the environment contributes to the economy with goods and services, i.e., by providing materials, by storing or processing waste, by keeping material cycles going, by conversion of solar energy and by generally maintaining optimal conditions for human life. Following customary terminology the environmental functions can be analyzed as those of source, sink and life support system.

Any system of national accounts that fails to reflect these contributions is deficient and misleading as indicator of policy performance. A widely accepted method of monetary valuation of the environmental contribution is not in sight or maybe not possible. This means that the natural resources and their use must be accounted in physical units.

The meaning of 'natural resources' differs in time and space. What constitutes a natural resource for a society is largely dependent on the society and its dominant mode of production. Some natural resources are vital in any society, like water, while others are only of importance during a relatively short span of time, like oil.

Natural resources are either exploited by diverting material cycles between the total ecological system and the economic subsystem, or by tapping energy chains that convert solar energy. The timescale of the ecological cycles can be larger than that of human societies by an order of magnitude, in which case the resource can be said to be exhaustable. Natural Resource Accounting should both reflect the physical exchanges crossing the boundary between the ecological and the economic system and the strength of the energy chains. Both stocks and flows should be accounted.

Use of various natural resources may result in environmental problems, depending on way of use and the characteristics of the resource. To cover the problems of exhaustion, extinction and conditional renewability, we propose a distinction into live, dead and non-living resources. As photosynthesis is the main process to convert solar energy and it is the only one to start food chains, NRA should contain information on the health and diversity of flora.

This report does not treat the ethic and aesthetic value of nature and the environment, as these are not usually considered to be resources as such. Neither does the report pronounce a judgement on the possible similarities or difference of Natural Resource Accounting and closely related concepts as Satellite Accounting.

The content of this report was discussed in a working group, in which, apart from the writers, took part:

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Egbert de Bloeme, VROM/HIMH
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Ruud Stevers, RWS, Directie Zuid Holland, Afdeling VPM
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The authors thank the working group for their critical comments. Of course, the authors take the full responsibility for the contents of the report.

1. Introduction

More than two hundred years after Adam Smith we have to ask ourselves again: what are the nature and causes of the wealth of nations? The traditional answers no longer satisfy as they do not take into account the threatening environmental collapse and its heavy repercussions on health and wealth of the human population. The environment has been a tireless supplier of goods and services, till recently free of charge. As Costanza, Daly and Bartholomew write in their summary of the first congress of the International Society for Ecological Economics (ISEE), held in May 1990 in Washington DC:

> "We now have entered a new era in which the limiting factor in development is no longer manmade capital, but remaining natural capital." (Costanza, p 16)

Traditional economic indicators like GNP fail to reflect the environmental contribution to the economy, or even worse, misrepresent environmental deterioration as increase in national wealth. This is hardly wise and serves none but the most shortsighted political goals.

> "A country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers, and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared." (Repetto et al 1989, p2)

A reform of the aggregate economic performance measures is very much needed (MacNeill, 1991, p 43; World Development Report, 1992, p 287). Since 1986 the System of National Accounts (SNA: Gross National Product, National Income, etc.) has been under attack for excluding economically relevant data on the state of the environment. Various solutions have been proposed, ranging from supplementing the SNA with environmental data to the development of a completely new Integrated System of Environmental and Economic Accounts (SEEA). Our study deals with possible theoretical foundations of Natural Resource Accounting and will not treat the discussions around SNA.

The 'Stockholm declaration on the human environment' (1972, article 21) states that the nations have the right of ownership over the natural resources in their territory and in 1992 the UNCED reaffirmed the right. The responsibility for the natural resources should involve the introduction of Natural Resource Accounting. Natural Resource Accounting (hereafter: NRA) can provide the data on which to found policy indicators relating to environmental aspects. The United Nations framework for a recommended System for Integrated Environmental and Economic Accounting (SEEA) describes Natural Resource Accounting as one element of integrated environmental and economic accounting.

The last decade the OECD, the World Bank, The UN Statistical Office, the World Resources Institute and various nations have put forward practical and theoretical suggestions for the accounting of natural resources, each based on considerations of intended use, availability of data and economic and ecological soundness. The discussions deal with three fundamental questions:

a. what are the natural resources to be accounted?
b. how are these to be accounted?
c. how are these to be valuated?

Of these three questions, the last one is the most difficult to tackle. We agree with the generally taken position that no widely acceptable method of valuation yet exists and that NRA should be done in physical units.

> No easy solution is to be expected for the valuation of natural resources, as a simple example illustrates. The value of the dead tree can be equated with the value of the wood and traditional economic reasoning is valid as soon the tree is felled. To assess the value of a tree that is alive requires intricate economic and ecological reasoning.
>
> If the conditions are right and the tree is left alive long enough it could beget a forest. Should the tree be valued as the future value of the wood to be grown? The tree might bear fruit. Should the tree be valued as the discounted value of the harvest? The tree might be the habitat of a swarm bees, should the value of the honey be included? The tree keeps the soil in place, gives shade, regulates cycles of water and nutrients, grows, bears fruit, multiplies: the tree is a complex of processes with direct or indirect economic and ecological value. In short, it is alive and it is part of an ecosystem.
>
> As long as the supply of trees may be considered to be boundless the tree is a gift of nature. However, the limits of the supply are now well within sight and the laws of marginal value go into effect. This one felled tree should be valued as the sum of the losses of all the extra goods and services that this one tree did and potentially could provide.

In chapter 2 we describe the ecological-economic point of view, expanding on the concepts of source, sink and life support system. The approach is closely linked to that in the writings of the International Society for Ecological Economics (ISEE).

In chapter 3 we describe the practical achievements of international institutions and nations. Realizing there is no time to wait for the completion of the theoretical construction they started collecting and publishing data on natural resource accounting. In chapter 4 we derive a set of resources that should be accounted. Chapter 5 offers the tentative accounts of the natural resources gas, nitrogen compunds and biodiversity.

2. Theoretical analysis

Though the recent literature on the relationship between economy and the environment tries to combine both disciplines, the two approaches are still separate. The ecologist analyze the relationship in the terms of their trade: material cycles and energy chains. The economists are easily recognizable by the emphasis they give to the term 'natural capital'.

The two disciplines have not always been seperate. Only after the emergence of the neoclassical school the distinction was strictly made, before that the economic and ecological discussions were intertwined. There is a difference though in the topics discussed. In the 19th century the main question was the exhaustibility of resources, while now the disturbance of the life suport system by economic activities is the main issue.

2.1 The ecological approach

Ecologists generally specify the contribution of the environment to the society in terms of functions. Various lists of functions are found in the ecological literature. These lists are not contradictory; generally they can easily be translated into each other. In the accepted opinion the environment adds to the economy by delivering materials, by storing or processing waste, and by generating optimal conditions for life. After E.P. Odum, E. Barbier and others we use the following terms for these functions 'Source', 'Sink', and 'Life support system'.

As a <u>source</u> the environment delivers both biotic and abiotic resources, such as minerals, metals, wood, water and fish. Actually, all materials withdrawn from the environment are part of cycles, though some cycles take place on a time-scale far beyond that of human societies. Biotic resources are renewable to a certain extent, but the extinction of a species is irreversible.

The <u>sink</u> function of the environment refers to the function of garbage can and purification installation. Waste can be stored or incinerated. In the last case the resulting gases are dumped. On the other hand waste can be decomposed by micro-organisms. In all cases the environment delivers the service of taking unwanted materials out of the economic cycle.

Human life on earth is only possible when temperature, level of radiation, acidity, composition of the atmosphere do not exceed certain boundaries. The environment regulates the conditions of the biosphere to a large extent by keeping the global material cycles going. These cycles could possibly be run by labour and man-made capital but there is no doubt that it would be much more expensive. Lately, a growing body of evidence is found that lifeforms and ecosystems play a crucial role in maintaining these cycles. The total of all processes maintaining conditions for life is referred to as the <u>life support system</u>.

Environmental problems arise (a) by depletion of sources, (b) by exhausting the waste-storing and cleaning capacity of the environment, and (c) by unsettling the life support system. A natural resources accounting system must contain information on these aspects. A useful way of considering these problems in their context and with their mutual relations is (at least for materials related problems) by regarding the transformation of the Earth's resources as cycles. This view is presented in the Netherlands Environmental Policy Plan (NEPP, 1989) in a picture:

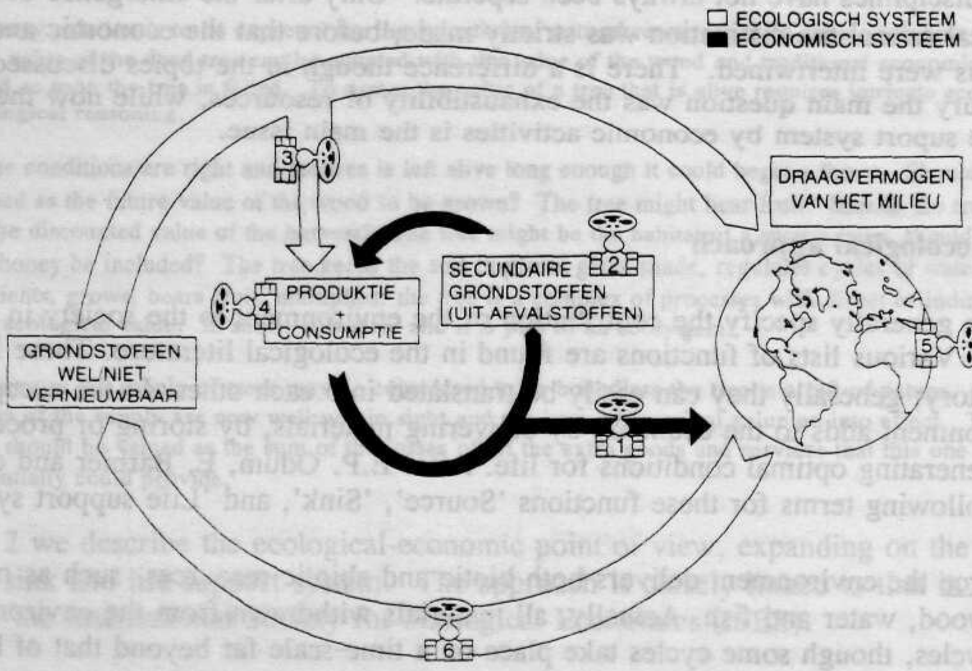


Figure 1: The Earth's ecological system and economic system as interdependent cycles. (figure copied from *Signaaladvies* for technical reasons)

This figure represents the flows of materials in the system Earth, the related environmental problems, the mechanisms involved and the possibilities for control. The two crucial aspects of the figure are:

- the distinction between ecological and the economic cycles,
- the presentation of pollution/depletion problems as disturbances of the ecological cycle caused by the economic cycle.

The economy influences the ecological cycle by extraction and by emission of materials. In terms of the functions of natural resources, both interactions may result in two types of environmental problems that can be characterized as unsettling of ecological cycles: depletion of sources, and interference with the life support system. As will be shown in Section 5, this figure can be made applicable to a broader range of resources. A system of NRA should contain information on the state of the ecological cycles and the influence exercised on them by the economic cycles.

We propose a slight modification of the picture for the purpose of Natural Resource Accounting. Instead of the Earth, we would like to put a certain resource in the central place. Both the natural and the economical cycle make use of and/or contribute to the central resource; and on top of that there are interactions between the natural and economic cycle. Figure 2 is a representation of this. In chapter 5 the figure will be specified for the examples gas, nitrogen, and biodiversity.

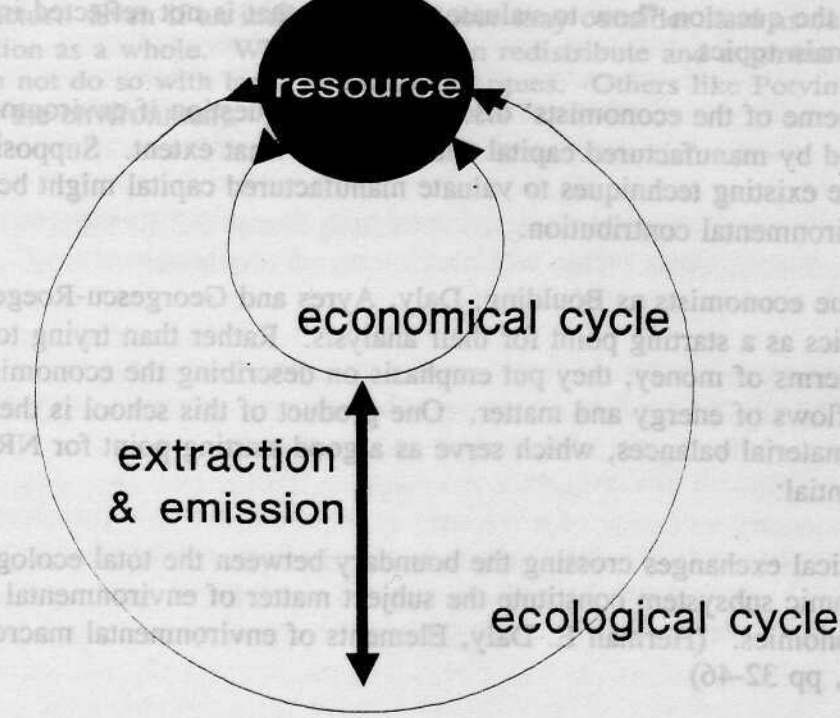


Figure 2 Natural and Economic Cycles Related to a Central Resource

2.2 The economic approach

Economists have been grappling since the 19th century with the question of the environmental contribution to production, from the physiocrats that considered land to be the only truly productive agent to Daly, who considers the environment to be the restricting factor on the economy. For some decades the environmental production factor was disregarded, as it was thought to be available in near endless quantities. In the last decades, the finite character of the environment has been recognized and, as a consequence, the environmental production factor was seen as potentially 'scarce'. Thereby is became a legimate object for economic study, the question "how to valuate a scarcity that is not reflected in a market" being of of the main topics.

One recurring theme of the economists' discussion is the question if environmental factors can be substituted by manufactured capital and, if so, to what extent. Supposing substitution to be possible the existing techniques to valuate manufactured capital might be useful to measure the environmental contribution.

To avoid the issue economists as Boulding, Daly, Ayres and Georgescu-Roegen take the laws of thermodynamics as a starting point for their analysis. Rather than trying to express the environment in terms of money, they put emphasis on describing the economic system in physical terms: flows of energy and matter. One product of this school is the careful construction of material balances, which serve as a good starting-point for NRA. Daly even considers it essential:

> The physical exchanges crossing the boundary between the total ecological system and the economic subsystem constitute the subject matter of environmental macroeconomics. (Herman E. Daly, Elements of environmental macroeconomics, in Costanza, pp 32-46)

Kneese and Herfindahl in their book *Economic theory of natural resources* (1974) take the stand that capital is "anything which yields a flow of productive services over time and which is subject to control in production processes." The authors define the role of the environment mainly as source of natural resources and as sink of waste products. Their emphasis on the controllable nature of natural and manufactured capital implies a high degree of substitution between the two. Air-conditioners, in their view, can take over the self-cleansing natural processes that keep the air breathable.

Dasgupta and Heal in *Economic theory and exhaustible resources* (1979) concentrate on the theory of resources that are running out. They conclude that "even in the absence of any technological progress, exhaustible resources do not pose a fundamental problem", as substitution is always sufficiently possible. With technological progress and substitution, an expanding economy is sustainable, even in a finite world.

Members of what Victor, Kay and Ruitenbeek call 'the London school', consisting of Pearce and his colleagues from the London Centre for Environmental Economics, deny that a substitution between natural and manufactured capital is always possible. They point out that manufactured capital is dependent on natural capital and that natural capital fulfils basic life support functions. Natural capital is multifunctional in a way that manufactured capital is not. Moreover, in contrast to manufactured capital changes in natural capital can be irreversible. The authors conclude that the stock of natural capital should not be diminished.

However, it is not without contention that the environment can be analyzed as comparable to manufactured capital. The argumentation is founded on the work of Marshall on land as production factor. Even if an individual producer may consider land as capital, this is not true for a nation as a whole. While a nation can redistribute and augment its manufactured capital, it can not do so with land, so Marshall argues. Others like Potvin extend this conclusion to the environment.

2.3 Both approaches: keeping the house in order

Neoclassical economists saw the environmental contribution as an externality and a gift. In terms of systems analysis this is only too right: the environment of a system is deemed to be of no influence. But in the last decade the global economies are seen more as a subsystem of the global ecosystem: the economic processes influence the environment and are in turn influenced by the environmental processes. An integration of the disciplines economics and ecology is urgently needed. The International Society for Ecological Economics (ISEE) has been explicitly founded for this purpose.

The economic approach and the ecological approach are not contradictory. The method of approach has been different: economics has restricted itself to those processes that transform scarcities, while ecology usually restricts itself to processes beyond human control. But both disciplines, as by now has been pointed out too often, contain the same root *eco* and teach us how to keep our house in order. The ecologists' *functions* are the economists' *goods and services*. It would be useful for an integration of both disciplines to express economy and environment in common terms. This will not be easy, for various reasons (Lone, 1987). In this report, it will not be elaborated further.

Until now only the 'source' type of resources has qualified for a place in the economic system. It might be argued, however, that the 'life support' resources are more crucial for the economy and that the neglect of these is a serious matter.

As long as no monetary valuation of a resource is required, the only justification needed to include a natural resource in a natural resource account is that it fulfills a (potential) function for society.

3. Recent applications

Clearly, policy making can not wait till the theoretical base for environmental accounting is complete and generally accepted.

In 1985 the member governments of the OECD adopted a "Declaration on environment: resources for the future". They recommended to develop appropriate mechanisms and techniques, including more accurate resource accounts (Repetto et al, 1989, p 8). Since then, the recommendation has been repeated by the World Commission on Environment and Development, by the World Bank, by the World Resources Institute and by the United Nations Environmental Programme. Various systems of Natural Resource Accounting (hereafter NRA) are being tried out in Norway, Canada, Japan, the Netherlands, the United States and France. Norway and France put the emphasis on material and biotic stocks, while the United States and Japan emphasized pollution and environmental quality.

In 1990 and 1991 the OECD meetings concerning environmental accounting discussed 3 main approaches to improve accounting as an indicator for policy performance:

a. adjustment of the national accounts
b. developing satellite accounts outside the system of national accounts
c. natural resource and environmental accounts to be linked to the national accounts.

As this study only considers natural resource accounts, we will disregard the first two.

Though there are many NRA systems under development, we restrict ourselves to those of Norway, France and the Netherlands for a more detailed description. Our description of the Norwegian and French endeavours is largely derived from the study ERL Nederland did in 1992.

3.1 Norway

Norway started the end of the seventies an experimental system of accounting physical stocks and flows. The following classification was used (source: Central Bureau of Statistics of Norway (1981), as cited in ERL 1992):

resource	physical classification	physical properties
material resources	mineral resources * basic matters * minerals * hydrocarbons * stone, sand, gravel	non-renewable
	biotic resources * life in the air * life in the water * life on land	conditionally renewable
	inflowing resources * solar radiation * the hydrological cycle * wind * ocean currents	renewable
environmental resources	status resources * air * water * soil * land	conditionally renewable

ERL continues:

> "In practice this classification no longer has a descriptive or a prescriptive function for the resource accounts; rather the accounts now include a limited number of important resources:
> * energy resources
> * air pollution
>
> and to a lesser extent:
> * forests (chiefly forest health)
> * minerals (iron, titanium, copper, zinc and lead, plus sand and gravel accounts at desegregated/local levels).
> * fish."

The system of accounting was motivated at first by concern over ending supplies of resources, in accordance with the then prevalent views. Now resource scarcity is no longer considered to be the major environmental problem. (ERL, p 9).

3.2 France

The development of the French system of natural resource accounts was started in 1978 as a system to account "the natural heritage". The natural heritage is "...all goods inherited from previous generations and which must be passed on to future generations without altering their essential properties" (Cornière, cited in ERL, p 16).

Weber (1991) describes four hypotheses that were formulated in the development of the French accounts (quoted in ERL, p 17):

1 The natural heritage is regarded as fulfilling at least three functions
  * economic
  * ecological
  * social/cultural.

2 The main effort should be concentrated on the development of physical accounts but monetary accounts should be developed for
  * actual expenditures
  * activities where natural resources are exploited
  * the value of natural assets
  * assessment of damages.

3 The general principles of double-entry accounting could be relevant to physical data.

4 Implementation could be achieved by bringing into widespread use the methods of those bodies responsible for natural resources.

The first two are still considered valid, the third is doubted and the fourth hypothesis has been abandoned after the information systems of selected bodies were found to be too specific to be used for a general framework (ERL, p 17).

ERL gives an overview of the data to be included in the French natural heritage accounts (pp 18-19): elements accounts, ecosystem accounts and actor accounts.

The element accounts are similar to the Norwegian accounts, recording changes in stocks and flows over time. The ecosystem accounts record changes in land cover and internal changes of the state of health of ecosystems, in terms of diversity, vegetation indices, water turbidity etc.

CLASSIFICATION	COMPONENTS
element accounts	
1. non-renewables	fossil fuels uranium metallic ores non-metallic ores quarried resources (including sand) other non-renewables
2. physical environments	soils continental waters (surface,groundwater, snow, glaciers) ocean waters (coastal and open sea) atmosphere
3. living organisms	animal species (wild and domestic) plant species (wild and domestic) microorganisms
ecosystem accounts	
1. water ecosystems	open sea coastal ecosystems inland ecosystems
2. terrestrial ecosystems	forest woodland and pastureland heath meadow and land under cultivation turf pioneer ecosystems
3. other ecosystems	
actors accounts	
according to the traditional distinction of the systems of national accounts	households business firms administrations other (such as foreign entities)

The French system (ERL, p 19)

3.3 The Netherlands

The Dutch Central Bureau of Statistics published in 1992 a tentative account of natural resources as part of the annual environmental statistics 1992 (Algemene Milieustatistiek, 1992). It chose the resources to be accounted by considering the criteria scarcity, environmental damage and availability of data. The following set is presented:

- sources of energy
- surface water and groundwater
- metals: aluminium, copper, lead, tin, zinc, iron, chrome, nickel, mercury en mangane
- quarried resources: gravel, sand, marl en clay
- wood, including tropical wood
- soil

These are accounted in physical units. The account of metals is presented in the form of balances, following, not wholeheartedly, the system proposed by Eurostat (1990).

The CBS is an active contributor to the preparations for a Dutch proposal on NRA, to be tabled at the OECD conference.

3.4 Evaluation

The Norwegians now limit the accounting to energy and air pollution and use the data as input for macroeconomic models. The French system is set as a detailed information system, but "to date there is little evidence of the use of the system" (ERL, p 21). The Netherlands, starting from available data, offer a workable account, but it lacks a theoretical basis and is limited in scope.

Lacking in all three is the living and dynamic component: the contribution of the services delivered by self-organizing and self-maintaining ecosystems. The French and the original Norwegian systems do pronounce the importance of these, but have not as yet offered an accounting method. Even though resource scarcity is no longer considered to be the major environmental problem, practical accounting still tends to reflect only the real or presumed exhaustion of resources. This is a least partly caused by the fact that the efforts of establishing a natural resource accounting system were underestimated.

The prime conclusion of ERL is that NRA is only viable if it is quite clear what purpose the collecting of data is going to serve. A system of natural resource accounts should be motivated by the goal and not by the data.

4. Accounting natural resources

4.1 Why accounting natural resources

An accounting of natural resources may serve more than one purpose. In the literature several are mentioned:
- calculation of a 'green GNP'
- more balanced cost/benefit analyses
- information on the state of the environment
- evaluation of environmental policies

The sole use of NRA for direct economic purposes suggests

(a) a translation of the resources in terms of money

and, therefore,

(b) taking into account only the 'source' type of resources.

This would make the use for other goals impossible: it disregards the resources that cannot be translated into monetary terms. Information on the state of the environment is dependent on data on the 'life-support' type of resources.

In our opinion, an NRA system must give an insight in the state and changes of resources connected to both the goods and the services the environment produces for us.

NRA should present data on the state of the environment as a result of economic activities, as well as on the state of the economy as a result of the use of natural (environmental) resources. This choice has several consequences:
- the account itself cannot be presented in terms of money
- the account must, whenever possible, be presented in terms that are translatable into monetary terms
- the account must, whenever possible, be presented in terms that are translatable into environmental terms, for instance environmental quality indicators.

These requirements have to be met in order to give NRA a proper place in the total of e-conomic/environmental data and accounts, a place between the enormous amounts of statistical, monitoring and other data available on the one hand, and the highly condensed indicators for economic and environmental well-being on the other.

4.2 What natural resources must be accounted

The meaning of 'natural resources' differs in time and space. What constitutes a natural resource for a society is dependent on the society and its dominant mode of production. The natural resources of the Amazon indians are different from those of the citizens of the United States. The use of natural resources by the Western world has changed dramatically in the last centuries and it will continue to change in the future as technology develops. However resources such as breathable air and drinking water are needed in every society. To avoid an NRA that includes all possible resources an assessment will have to be made the contribution of a resource to human society, or, in other words, of the risk or damage that their loss would entail.

The availability of fossil fuels was of no importance at all two hundred years ago, nor will it be two hundred years hence, but in the industrial societies of today it is of overriding importance. Fossil fuels will have to be accounted though, because the loss or exhaustion will necessitate a thorough transformation of the human society and a careful exploitation of the resource lengthens the time available for the transformation.

Generally a practical approach is taken and after a rough classification a list is made of accountables.

> The earlier classifications were based on renewability as sole distinguishing concept. This has proved to be unsatisfactory, especially as it seemed to recommend a shift from the use of non-renewable to the use of renewable resources. Such a shift is not always environmentally safe. Lifeforms, for example, are classified as 'renewable', but species can be exhausted irreversibly. On the other hand, non-renewable matter, especially on the elementary level, never disappears as the first law of thermodynamics tells us, but it may be dispersed and therefore it may cost more energy to render it available. To solve this dilemma the distinction into three categories has been made: renewable, conditionally renewable and non-renewable (Lone, p 13). Life forms are classified under 'conditionally renewable', thus bringing in some caution in the use of these resources.

In Chapter 2 we introduced a distinction, based on the functions (or goods and services) of the environment for human society: source, sink, and life support. Although this is a useful approach for specifying the contribution of nature to society, it is insufficient from the point of view of resource management. In order to manage resources, we must look at their characteristics rather than to their functions. **We propose here a distinction into live, dead and non-living resources**, which we find attractive because it emphasizes the role of life. We suspect that this classification might be translatable into Lone's one, or at least does not lead to different outcomes in practical applications.

The department of Strategic Planning of the Dutch Ministry of Housing, Physical Planning and Environment introduced a partition of resources into renewable, non-renewable and environmental. It interprets quality of air, water and soil as environmental resources. This distinction is at least partly motivated by policy considerations. As this report is only concerned with the academic discussion, we do not discuss considerations pro and contra the distinctions proposed by Lone and VROM-SP.

Below, we present a description of the various types of resources.

Sources

The environmental resources we use as materials or products are numerous and widely varying. A distinction can be made between living, dead and non-living sources.

Non-living resources

Among *non-living sources* we count ores, minerals, water, oxygen, surface mined minerals. The ores and minerals themselves can be exhausted, but the elements that make them interesting from an economical point of view cannot be exhausted but only dissipated. Resources such as water and oxygen are part of a global cycle. Their availability on a certain time and place depends on the earth's chemical and biological processes, and therefore on the life support system discussed below. Both the World Bank and the CBS already make accounts concerning resources of water.

Dead resources

Dead sources originate from living sources but as a source they are dead. In this case it is not the elements they contain but the molecular structure that make them economically interesting. These molecules store solar energy (fossil fuels) or can be used as building blocks in chemical syntheses (ethylene in polyethylene). If the processes that produce these resources take place on a time scale incomparable to that of human society the resource can be said to be exhaustible.

Living resources

Trees, fish and game, medicinal herbs and wild animals are *living sources*. Ivory is dead, when it is used to produce billiard balls, but it can be produced again by living elephants on a time-scale relevant for human economy. The same holds true for the resource 'wood'. These are the so-called 'renewable resources': being living, they multiply themselves. Unlike the elements, 'renewable resources' can be exhausted; once a species is extinct it is gone forever. For this reason, attention is shifting to this type of resources (McNeill et al., 1990). The use we make of these resources is derived from two parameters: biomass, and genetic information. These two may be viewed as the most important living sources. It needs no emphasis that the availability of living resources depends strongly on the life support system.

Sinks

The sink function of the environment refers to our using it to dispose of our waste products, as solid waste, as liquid waste and as gaseous waste. This use of the environment (or rather, the environmental compartments soil, water and air) as a garbage can has two aspects: the space we occupy, and the influence we have on the environmental quality.

Ecologically speaking the environmental sink is just one link of the cycle. Generally the service is provided by bacteria, that decompose dead matter and make available the nutrients.

Economicaly speaking the sink is the end of the market. Rubbish cannot be sold and hopefully disappears. It has been argued that the economy influences the environment far more by using it as a sink than by using it as a source. (Patterson, 1991).

Clearly, economists reasoning in chains with a dead end and ecologists working with cycles should find material here for discussion. The difference can be said to be one of the most important ones dividing both disciplines.

It is not clear if and how the sink function should be included in an NRA. Pollution, arising out of the use of the environment as a sink, is well documented in data on environmental quality, climate change or ozon depletion. Data on health of bacteria are scarce, but hard to collect. Use of space as dumping grounds is accounted by mapmakers.

In short, though the data on the use of the environment as sink possibly are the most complete, and though we feel it to be of importance to reflect the use of sink in a resource accounting, we are not sure how these should be introduced in an NRA.

Note that 'space' does not fit into any category of living, dead or non-living. We can't destroy or exhaust it, only occupy it to nature's loss. De Groot (1992) argues that space is the basic measure of the environment, but doubts have been voiced about the fruitfulness of this approach. (Loo et al, 1992).

Life support system

The life support function (LSS) of the environment refers to the 'thermodynamic machine', which maintains optimal conditions for life forms: a proper temperature, acidity, level of radiation, sufficient availability of crucial sources as oxygen and water, sufficient absence of toxic substances.

The LSS is an intricate complex of processes. In general the life support services are generated by regulating the composition of the three major environmental compartments: atmosphere, surface water, and soil. On a global level, the biogeochemical cycles are of crucial importance for the composition of the environmental compartments. These cycles are maintained by both biotic and abiotic (physical/chemical/geological) processes, generally driven by solar energy in chains of energy conversion.

The LSS can also be described by analyzing the elements which keep the machine going. These, rather than the processes mentioned above, are translatable into terms of 'natural resources'. Again, a categorization can be made into non-living, dead and living resources.

non-living resources

Important physical elements are abiotic entities such as the ozone layer and the abiotic part of the great material cycles. In terms of resources, it seems the most appropriate to restrict ourselves to the physical entities involved in keeping the processes running, and therefore either the materials or the vital parts in terms of abiotic factors, or both. Most important materials in global cycles are: water, carbon, oxygen, nitrogen, phosphorus, sulphur.

dead resources

Dead resources such as fossil fuels or organic based limestone probably have a life support function, but these play a role only on a geological time scale. By using those resources we may influence the life support system in a negative way; however, not the depletion of dead resources but the affecting of other parts of the life support system causes the problems.

living resources

Obviously, living resources are of great importance for the life support system. Biological processes form the bulk of the processes involved in keeping the great material cycles running. Not the species diversity (very important as a source) but the presence of healthy ecosystems is the crucial aspect of living resources from the point of view of the life support system. Not only global cycles, but also regional, national and local cycles are important for a healthy environment. Therefore, the presence of healthy ecosystems is necessary on any scale level. The diversity of ecosystems then is another requirement on the global level.

In Appendix 2 a list of important resources is given. Based on the argumentation presented in this paragraph, a selection of this list that we think should be included in a system of NRA is presented below, divided into the three main categories source, sink, and life support.

Table 1: Selection of important natural resources

Source

Non-living resources

- metals (resources on an elementary level)
  - bulk metals (Fe, Al)
  - metals (Pb, Zn, Sn, Ni, Cr, Cu, Cd, Hg, Mn)
  - trace elements (Ga, Ge)
- nutrients
  - macro nutrients (P, mineralised N, K, (S), O, H_{2O}): as these are part of global cycles the account can be integrated with that under 'Life Support System' (below)
- surface minerals
  - grit, sand, marl, clay

Living resources

- biomass
  - forests
  - fish
- information
  - genetic diversity

Dead resources

- fossil fuels: natural gas, mineral oil, coal (hard, soft, lignite)

Sink

Land-surface

- in categories of use:
  economy: for example: industry, housing, infra-structure (roads, railway, airports, harbours, waterways) agriculture, recreation
  nature: natural forest, heathland, coastal dunes, wetlands
- in types of soil, regardless of use, for example: peat, sand, clay

Life Support System

Non-living sources

- global cycles of water, C, N, O, P, S
- the ozone layer (possibly a part of the O cycle, but deserving separate attention)

Living sources

- natural ecosystems: quantity (biomass), therefore, special attention for forests and wetlands and quality (vitality, species composition)

4.3 How should we account natural resources

For the techniques of resource accounting, that is, which data should be presented in what conjunction in an NRA system, several starting points are formulated.

First, we (humans) are free to use natural resources, of every type and for any function. However there are limits to this use, we must not use more than is dictated by those limits. This must be expressed in the way we set up an NRA system. **Apart from a 'stock accounting', there must also be information about 'flows', or in other words the use we make of the stocks in time.**

Second, the resources we have can be accounted for on different scale levels. Most resources, such as wood and minerals, are in fact global resources. Some resources are even purely global or at least international, such as the atmosphere, the oceans or the ozone layer; these are very difficult to account for in a national NRA system. Accounting for those on a global level therefore must be strongly recommended. However, we are dealing now with resource accounting on a national level. **For global resources, a national accounting should express**
(a) the contribution of the nation to the global resource stock, and
(b) the contribution of the nation to the global use or consumption of the resource.
The contribution of a nation to both the worlds stock and its consumption may best be described by a (yearly) balance, wherein not only production and use but also import and export are included. In the account, if we take the example of wood, therefore not only the raw materials must be visible, but also the finished products, in fact the whole materials life cycle. It also means that a picture is required of the nations consumption of resources not recovered or produced within the nation itself.

Third, resources can be accounted in more detail on a national level than on a global level. **Information can be included not only about quantity, but also about quality.** If we are, for instance, accounting 'forest' (and not 'wood', the global level resource), we not only include figures on wood production but also on the vitality, the types of forest, the species composition, the undisturbed areas, and suchlike. Such a further classification of resources based on qualitative aspects is very probably very relevant.

Fourth, a national resource account should have its proper place among other accounts. **This means that no express information must be included that is already presented elsewhere.** Therefore, a system of NRA must not go into any details with regard to
- environmental quality aspects, i.e. concentration levels of chemicals in the environment in relation to environmental standards
- emissions and pollution levels related to environmental policy themes (acidification, ozone depletion, etc.),

otherwise than directly related to contribution to and use of a certain resource.

Fifth and last, it would be sensible if the way of resource accounting were be related to the 'sustainable management' of a resource, if any such management can be defined, and therefore not to its function but to its characteristics. **In fact, what is needed is a specification and quantification of the natural cycle in relation to the economic cycle** (Figure 1 and 2). This will be worked out in further detail below. The information on mitigations of the stocks over time can be used to make predictions for the future and if necessary reformulate resource management policy.

Natural resources may, as is pointed out in section 4.2, be divided into three character-based categories: living, dead, and non-living. As a fourth, space is distinguished as a type of resource. In the following, some general recommendations will be made with regard to the contents and shape of the accounts of the various resources, based on both functions and characteristics of resources.

Non-living resources:
Here, the distinction between ore-type resources (very often chemical elements) and resources that are a part of biogeochemical cycles (mostly compounds) is relevant. These two types of resources are treated separately below.

Ore-type resources of elements
Elements present in ores are not environmentally available. If they are part of a cycle, it is a geological one and as such a cycle with a time-span that is outside the scope of human use. Elements cannot be depleted, but transgress from an economically beneficial and environmentally harmless state (ores) into an economically useless and environmentally harmful state (pollution). This could be expressed in a yearly balance, wherein the extraction of a certain element inevitably leads to emissions. Information is needed not only on the in- and outflows of the economic system but also on the flows within the economic system in order to be able to relate the emissions to their (ultimate) origins. Here, too, the information on the nations contribution to and use of the worlds stock can be extracted from the balance figures if these are complete, and therefore also include finished products wherein the elements occur. The emphasis in this type of account should be strongly on the economic side, as there is no natural cycle to speak of.

Resources as a part of biogeochemical cycles
Non-living resources such as water, that are a part of biogeochemical cycles, cannot be extracted to any desired amount. The maximum extractable amount, in terms of the disturbance of the biogeochemical cycle, must be defined. This then can be related to the actual extracted amount in order to get an indication of the state of the resource. This step is needed in order to do justice to both the source and the life support function of these resources.
Here, too, a distinction must be made between the accounting of the nations stock and its contribution to the worlds stock, c.q. the consumption of the worlds stock.
For the national resources account, quality aspects are important: usefulness of certain stocks or flows of water for various functions (salt/sweet, presence and concentrations of contaminations, CO_3-content, temperature, trophication level, etc.)

For some non-living resources, humans are able to create a more or less detached economic cycle. An example is nitrogen: most nitrogen used nowadays in western agriculture is derived from a technical process conversing atmospheric N_2 into ammonia. Problems then do not arise from the extraction of nitrogen from a natural cycle, but from the leaks from the economic cycle leading to disturbances of the natural cycle by adding large amounts over a short period of time. For agriculture in developing countries this is not true. In those countries, extraction of agricultural products does lead to soil exhaust, because more nutrients are extracted than are added from natural processes and fertilizer together.

In a natural resource account, information is needed

- on the stocks, or sinks, of the natural cycle (to stick with the water example, the amounts of water stored in biomass, captured as ground water, staying overyears in large water bodies etc.)
- on the flows of the natural cycle: amounts of rain, rivers flowing into the seas, evaporation, extraction by life forms
- on (stocks and) flows of the economic cycle: human production, consumption and emissions

Again, this suggests the use of yearly balances. For the national account, it would be useful to link the actual extraction and emission to maximum levels for any stage of the cycle.

As a global resource, the ozone layer account must certainly be specified on a global level. It is a bit problematical how to conduct such an account on a national level. The only relevant way this could be realized is by specifying the nations contribution to the degradation of the ozone layer. It is possible that this is already done within the framework of the separate policy themes, of which ozone depletion is one. Another such account then would be superfluous.

Dead resources:

Dead resources can be exhausted, contrary to elements. Because these dead resources originate from living resources, the possibility of suppliance is not excluded. In the case of fossil fuels however the time span involved is too large to be useful for human use. This means that every use of dead resources is extracted from the worlds stock, and that continued use inevitably leads to depletion. In order to preserve these resources therefore they must not be used at all. If there is no direct life support function (as is the case with fossil fuels), the pace of use could be linked to the time we expect to have need of the resource, always keeping in mind that it is inevitable to find new resources to fulfil the functions of these ones.

Living resources:

Additional starting points for the account of living resources are:

a. living resources renew themselves. The use we make of them must keep pace with the capability for renewal. In the RA therefore not only stocks and flows, but also the potential for generating new stock must have a place in order to signal loss of stock.

b.it might be a good idea to use living resources as little as possible as a source of biomass and to confine ourselves to making use of the information. In fact, we do just that in agriculture: using information to economically produce biomass from minerals and water. In our account, both biomass and information must therefore be noted.

c. the NRA should include accounts for both species and ecosystems. Species diversity is important as a source of genetic information, and the presence and good quality of ecosystems for the life support function of the environment.

Together with the general starting points formulated above, this leads to the following accounts:

1. <u>specification of the environmental and economic biomass cycles:</u>
- natural biomass production and human use of wood and fish as the most important biomass sources, and the changes in time. On a national level, this again could be presented in the shape of a mass balance, including import and export and also including finished products.
- natural biomass production and biomass stock of natural ecosystems as a crucial factor for the life support system, and changes over time. In order to narrow down somewhat, we could confine ourselves to the account of the most important ecosystems, generally forests (stock) and wetlands (production).
- economic biomass production (i.e., agriculture) and the leaks to the environmental biomass cycle, and changes over time.

2. <u>specification of the genetic information source:</u>
- natural biodiversity: species diversity on a national level, family diversity on a global level, And, of course, changes over time (extinction, loss of genetic information within families)

3. <u>specification of the ecosystem presence and quality:</u>
- presence of ecosystems: surface of natural areas as a whole for the global level, and areas of specific types of ecosystems for the national level, and changes over time
- quality of ecosystems (only on the national level): vitality (for forests or for all ecosystems?); species composition in relation to a characteristic species composition (ecodistricts); changes over time; undisturbed areas.

Space occupation:
The occupation of air and water is very much related to environmental quality aspects. For that reason (along with practical purposes related to the 'ownership' of these fluent environmental compartments) the accounting on a national level does not appear to be very useful. Water itself is treated, as a source and as an important global cycle, in the water balance and stock specification for the nation (including both surface water and ground water; see above under non-living resources). Emission accounts are very useful indeed, but are carried out in another framework and are hardly to be characterized as natural resources. Within a system of NRA as proposed here, emissions are only included as losses from the economic cycle to the natural cycle; no relation is presented to any environmental effects.
The occupation of soil, or land surface, can be accounted more easily. A nation possesses a certain, very well defined area of space that does not change. The land surface occupation quantitative account must in the first place make a distinction between 'natural' and

'economic' surface. There will certainly be border problems (a production forest, the use of a natural area for recreational purposes), but these may be solved in a practical manner. Within the main categories 'economic' and 'environmental' subcategories may be distinguished, as presented in Table 1. Another classification might be included with regard to the usefulness of the soil for specific purposes depending on the pollution level. This borders on environmental quality aspects but it is relevant for a soil account.

4.4 Indicators for Natural Resource Management

A rather separate part of this study is the investigation of possibilities for linking policy indicators to the Natural Resource Accounting. The indicators, as is suggested by the term 'policy indicators', should provide information relevant for governmental policy.

The indicators should appealingly represent policy relevant information, to be constructed out of data by reproducible methods of aggregation (Adriaanse, 1992, p 9). In this case, when we speak of policy we mean the policy related to the proper management of natural resources. Therefore, the indicators would have to be constructed out of the data presented in the NRA system. As aggregation always entails loss of information the design of the method to construct NRA indicators takes some consideration. It will not be easy to choose relevant points of reference and in some cases this point will be the object of heavy scientific discussion.

Obviously, the indicators would be different for the widely varying types of resources that they will have to cover. However, on an abstract level something can be stated about the information the indicator could present in general terms:

1. information on the state of the natural resource
2. information on the changes in the state of the resource over time
3. information on the influence of the economy on the state of the natural resource
4. information on the influence of natural resource management policy on the state of the resource.

For all four types of indicators this could include both quantity (the amount of the resource) and quality (composition, information, contamination, extractability, ...), or the changes therein, depending. The information could be interpreted better if the actual state or changes in the state of the resource was in some way related to the desirable state (or changes..) of the resource. This will not always be possible; there will be cases where no desirable state can be defined. It is relevant, however, for policy concerning the use of natural resources to refer to some sort of a standard. Then we can measure the actual life index of a certain resource in years against the time we will be needing the resource, or the speed of depletion against the possibility for recovery. It may turn out that the search for such indicators leads us to the realization of the lacking of these standards, and also of the need for them.

In the next chapter, suggestions are made for the natural resource account for three example resources: natural gas, nitrogen, and biodiversity. Added to the accounts, proposals are made for natural resource management indicators for each of the examples, wherein the above is specified in more detail.

5. Examples

5.1 The case of natural gas

5.1.1 Natural gas as a resource

In general, fossil fuels can be accounted both as a source of materials and as a source of energy. Apart from that, the combustion of fossil fuels results in a major disturbance of natural carbon-cycle. By interfering with the natural carbon-cycle the use of fossil fuels has a negative impact on the Life Support System. The latter effect however should be discussed within the framework of the carbon account, of which fossil fuels are a part.
In the Netherlands the most important stock of fossil fuels is the stock of natural gas. The size of this resource can be accounted both as a source of materials, i.e. the amounts of the different components, and as a source of energy. The composition of the natural gas, and therefore also its contribution to both source aspects, varies considerably from one location to another.

When the size of the natural gas resource is estimated a number of terms are commonly used:

- technically extractable reserve
- commercially extractable reserve
- expected reserve
- proven[1] reserve

The Dutch Central Bureau of Statistics (CBS) states that if the exploration of a certain reserve is commercially not feasible the size of the reserve is equal to zero. Therefore economical and technical developments will have a direct impact on the size of a stock as reported by CBS. Theoretically, not the (commercially) extractable but the existing reserve would be appropriate to mention in an NRA: when accounting for resources the ease with which they can be recovered is a quality aspect and does not affect the quantity. In practice, however, the only existing complete figures refer to commercially extractable amounts. For that reason these figures are used here. As will be shown later, this has certain consequences for the use of this numbers in the composition of indicators.

Because natural gas represents both a stock of materials and a stock of energy, the amount of natural gas left as a reserve can be (and are in fact) expressed several units:

- m^3
- kg
- J
- tonnes of oil-equivalents.

[1] The probability that the actual reserve is larger than the proven reserve is more than 90%.

Within the Natural Resource Account both aspects of natural gas are of interest. Moreover, the influence of the use of natural gas on the life support system is important and should be deductable from the account. **As our resource in this case is 'natural gas' and not 'energy' or 'methane', it is suggested that the basic account be expressed in cubic metres of natural gas.** In order to enlighten the various aspects mentioned above, it is recommendable to translate the m^3 data into:

- Joules, to express the contribution to the energy supply
- kg CH_4, to express the contribution to the methane market (this can also be done for other materials extracted from natural gas, which are deemed economically or environmentally important)
- kg C, in order to be able to specify the contribution of the use of natural gas to (the Dutch part of) the global carbon cycle.

The translation from cubic meters into Joules is already commonly made. For this purpose, a conversion factor is introduced, which is determined for each field separately. Such conversion factors must be part of the NRA, too. The conversion-factors which are used are dependent on the composition of the natural gas: e.g. the energy-content decreases with an increasing fraction of nitrogen. Furtermore the amount of energy per m^3 of gas is sometimes given as a calorific upper-value or as a calorific lower-value (Van Gool p 70,76 and 77). The calorific upper-value or burning-value is used if the water which is produced during the combustion is emitted as a gas. The calorific lower-value is used when the water is released as a liquid. The calorific lower-value is in general about 10% less than the calorific upper-value. The calorific uppervalue of natural gas from the Dutch concessions varies between 18.8 and 40.0 MJ/m^3 (102.325 kPa ; 273.15 K)(Van Gool table 4.4).

The translation into kg methane or C is also dependent on the composition of the gas. Such conversion factors can easily be deducted, and also presented within the NRA. In the basic account therefore, not only the quantity but also the composition of natural gas must be given. As this varies per field, the basic account must give the information for each field. (It would be imaginable to present only three tables: Groningen, the offshore production, and the rest. At this moment, Groningen represents over 90% of the current stocks as well as flows).

5.1.2 The natural gas account

The Natural Resource Account for natural gas, as follows from the above, contains data on:

- the various reserves in m^3
- the flows through the economy: from import/production to export/consumption in m^3
- the quality of the different reserves:
  - composition of the gas
  - ease of recovery
- the conversion factors for the various reserves, to be able to translate the cubic metre data into kg methane (or other materials) or kg carbon.

Almost all information needed for the account of natural gas is already available in the current CBS energy account. It varies from this account in some aspects:

- the basic account is presented in cubic metres, not in Joules which is considered to be a translation (with concurring loss of information)
- two other translations are suggested: in kg CH_4 (or other materials), and in kg C. The first one expresses the other source function while the last one specifies the contribution to the (decline of the) life support function of the environment.

Some of the information which is needed for an NRA is presented as an example in Tables 2, 3 and 4, and in Figure 3 below.

Table 2 Natural gas reserves in the Netherlands as at 1st January 1992

	remaining proven reserve (10^9 m^3 st)	remaining expected reserve (10^9 m^3 st)
'Groningen' concession	1364	1483
other onshore territory	109	256
continental shelf	185	347
Total Netherlands	1950[2]	2086

[2] This figure was obtained by probabilistic summation of the proven reserves in the individual fields.

Table 3 Composition of natural gas from the 'Groningen' concession in ml/l

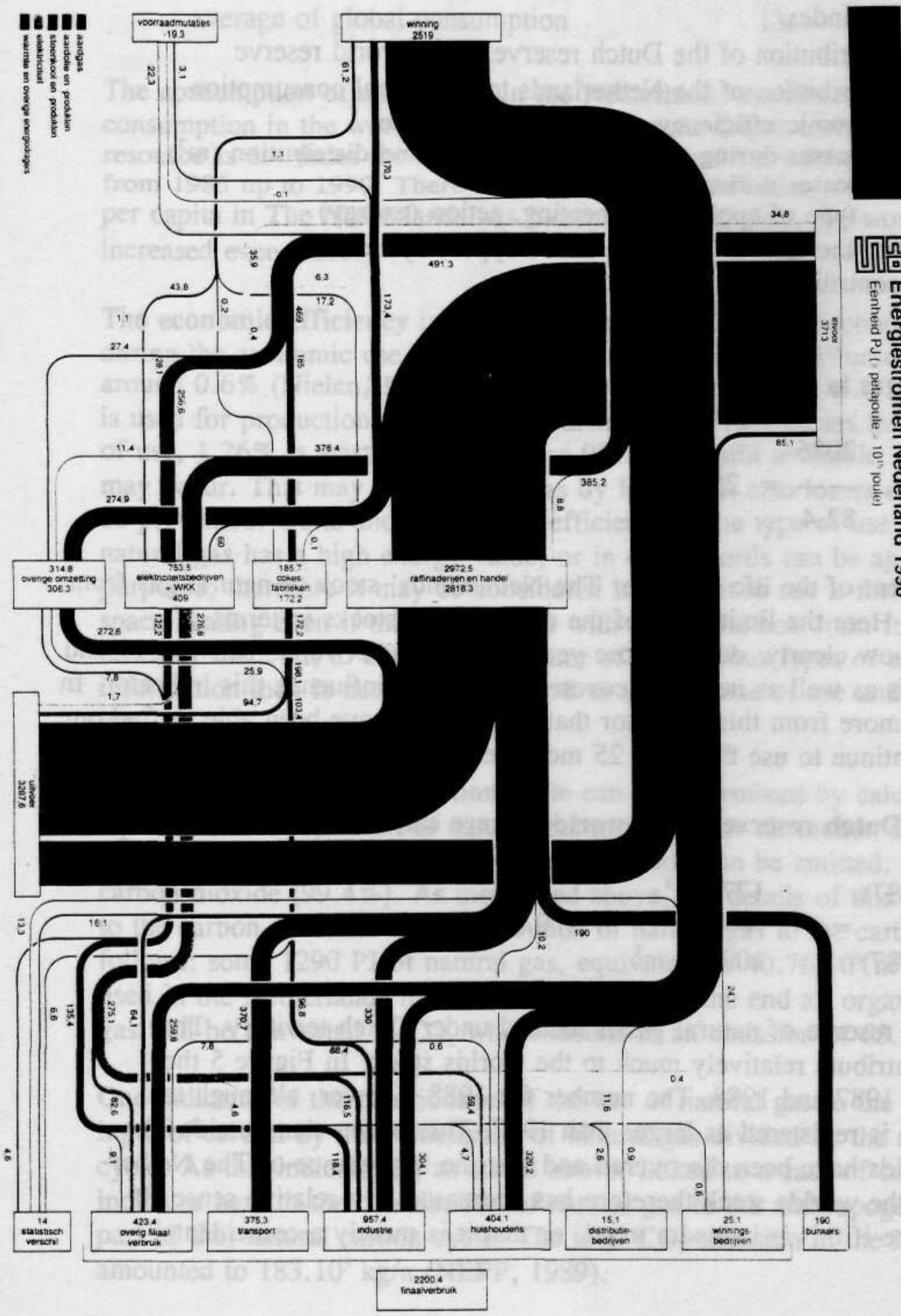
methane	814
ethane	28
propane	3.8
butane and higher	2.2
nitrogen	142
carbondioxide	10
TOTAL	1000

Source : table 4.4 Van Gool

Table 4 Conversion factors for the 'Groningen Concession':

energy-content:	31.65 MJ/m^3
methane fraction:	0.59 kg CH_4/m^3
carbon fraction:	0.45 kg C/m^3

Figure 3 Energy flows in The Netherlands, 1990. Source: CBS, Algemene milieustatistiek 1992. In PJ/year. (the original figure is in colour)



5.1.3 Indicators for natural gas resource management

The indicators must have significance for the management of the natural resource. Therefore they must illustrate:

* The source functions of natural gas:
  - the number of years we can continue the present rate of consumption: the life-index
  - the contribution of the Dutch reserve to the world reserve
  - the contribution of the Netherlands to the global consumption
  - the economic efficiency of our natural gas use:
    - losses during production, transport and distribution (m^3)
    - losses during use (J)
    - type of application: heating, action (exergy)
* The contribution to the disruption of the Life Support System
  - the contribution to the carbon-cycle

The **life-index** of natural gas in 1991 in the Netherlands is equal to :

$$\frac{\text{reserve}}{\text{production}} = \frac{2086}{82.4} = 25 \text{ years}$$

In Figure 4 the development of the life index for The Netherlands' stock of natural gas from 1975 to 1991 is pictured. Here the limitations of the definition of stocks in terms of economic extractability show clearly: during those years the life index varies between 25 and 30 years. Newfound fields as well as newly discovered techniques influence this indicator. In practice, we cannot read more from this indicator that we seem to have been able to find our stocks at need, and to continue to use them for 25 more years at least.

The **contribution of the Dutch reserve to the world reserve** can be expressed simply by:

$$\frac{\text{Dutch reserve (1987)}}{\text{global reserve (1987)}} = \frac{1770 \text{ m}^3}{109326 \text{ m}^3} = 0.016$$

Some 1.6% of the global reserve of natural gas is located under Dutch territory. The Netherlands therefore contribute relatively much to the worlds stock. In Figure 5 the indicator is presented for 1987 and 1988. The number for 1988 is lower, although the absolute reserve for 1988 is registered as larger than 1987. This means that outside The Netherlands more gas fields have been discovered and that the importance of The Netherlands as a contributer to the worlds stock therefore has decreased in a relative sense. It would be interesting to see if this is indeed a trend, or that it is merely a coincidental fluctuation.

The **contribution of the Netherlands to the global consumption** can be expressed by relating the consumption per capita in the Netherlands to the world average consumption per capita:

$$\frac{\text{consumption in the Netherlands}}{\text{average of global consumption}} = \frac{86{,}000}{13.4} = 6.4$$

The consumption of natural gas in the Netherlands therefore is 6.4 times the average consumption in the world. This indicates that the Dutch contribution to the depletion of the resource is 6.4 times the worlds average. Figure 6 shows the development of this indicator from 1985 up to 1990. There is a slight general decrease, although the absolute consumption per capita in The Netherlands has increased. Apparently, the worlds average consumption has increased even more.

The **economic efficiency** is related to both the bulk of the economic use and to the losses during the economic use. In the Netherlands transport/distribution losses are estimated to be around 0.6% (Nielen, 1991). Furthermore 0.66% (Blok et al., 1988) of the amount produced is used for production, transport and distribution. This means that before it reaches the stage of use, 1.26% is wasted and therefore 98.74% is still available. During use, further losses may occur. This may be losses of gas by leaks, but also losses of heat or energy that could be prevented. Quite another type of efficiency is the type of use that is made of the resource: natural gas has a high exergy value, or in other words can be applied for high value purposes; therefore it may be considered inefficient to use it for low-value purposes such as space heating even if this is executed with very little heat loss. It is probably possible, however difficult, to create an indicator of the various types of efficiency. Additional information then is needed with regard to the purpose of use and the losses that occur during use.

The **contribution to the carbon cycle** can be determined by calculating the amount of carbon equivalent to the amount of natural gas produced. A distinction should be made however between the different forms in which the carbon can be emitted: as natural gas (0.6%) or as carbon dioxide (99.4%). As mentioned above, the details of this discussion should be linked to the carbon account. The contribution of natural gas to the carbon cycle can be pictured as follows: some 1290 PJ of natural gas, equivalent to 40.76 10^9 m^3 of 'Groningen m^3', was used in the Netherlands in 1990 (CBS 1992). In the end all organic fractions of the natural gas will be converted to CO_2 which results in an emission of 65.10^9 kg CO_2/a.

One indicator of the contribution of the use of natural gas to the carbon cycle would be the input of carbon by the combustion of natural gas divided by the amount of C in the natural cycle. As this indicator is, as stated above, linked to a case of carbon, we will confine the indicator here to the contribution of natural gas to the anthropogenic input into the (Dutch part of the) natural carbon cycle. The total CO_2-emission in the Netherlands in 1989 amounted to 183.10^9 kg/a (NEPP, 1989).

$$\frac{\text{CO}_2 \text{ equivalent of natural gas}}{\text{total Dutch CO}_2\text{-emission}} = \frac{65.10^9 \text{ kg/a}}{183.10^9 \text{ kg/a}} = 0.36$$

About 36% of the total Dutch CO_2 emission can be accounted to the consumption of natural gas. Figure 7 shows the developments from 1985 to 1989. The relative contribution of natural gas to the national CO_2-emission has decreased. Because the use of natural gas has increased, this means that the CO_2-emissions from other sources have increased even more: the total CO_2-emission has risen from 138.10^9 kg (Zorgen voor Morgen I, RIVM 1988) to 183.10^9 kg in three years time. Again, the implications of this are part of the case of carbon and will not be further discussed here.

Figure 4 Development of the life index for the natural gas stock on Dutch territory from 1975 to 1991. Source: Annual Review 'Oil and Gas in the Netherlands, exploration and production 1991'.

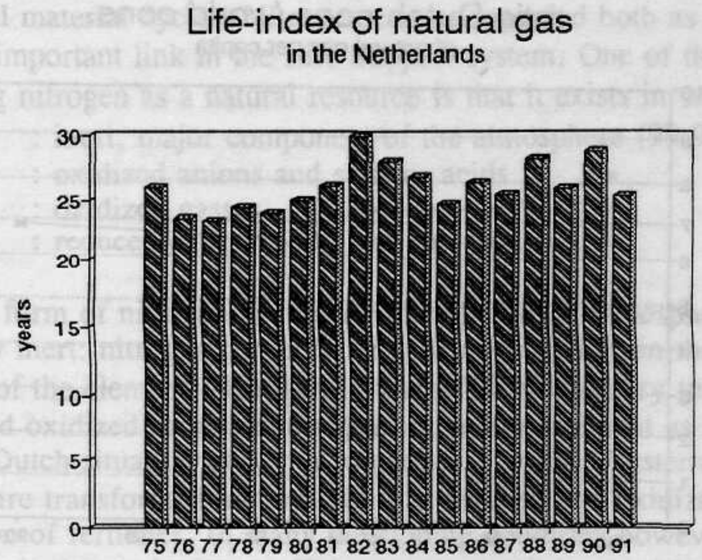


Figure 5 The Netherlands contribution to the global reserves of natural gas. Source: United Nations Energy Statistics Yearbook 1988, 1990.

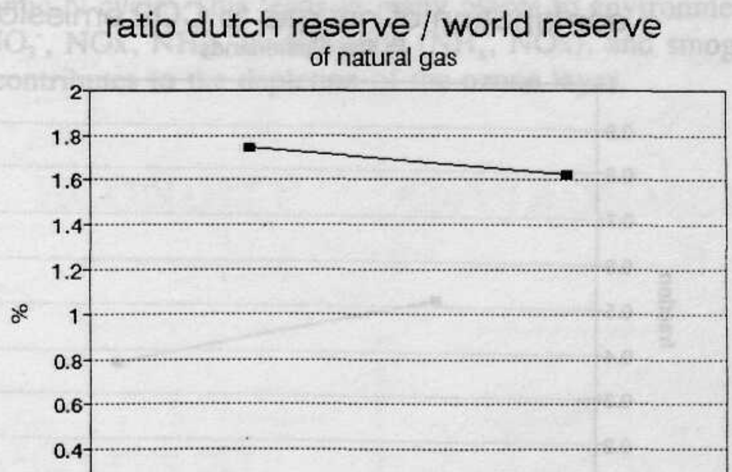


Figure 6 The Netherlands contribution to the consumption of natural gas per capita. Sources: CBS, 1993 and United Nations Energy Statistics Yearbook.

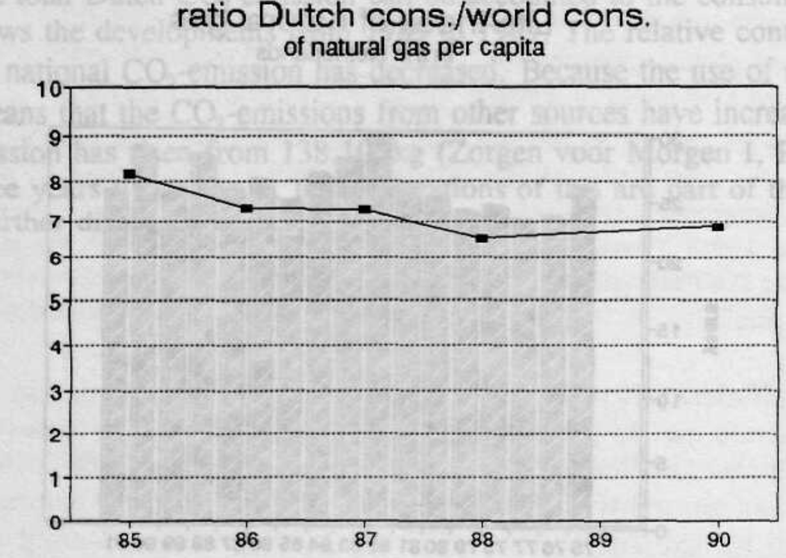
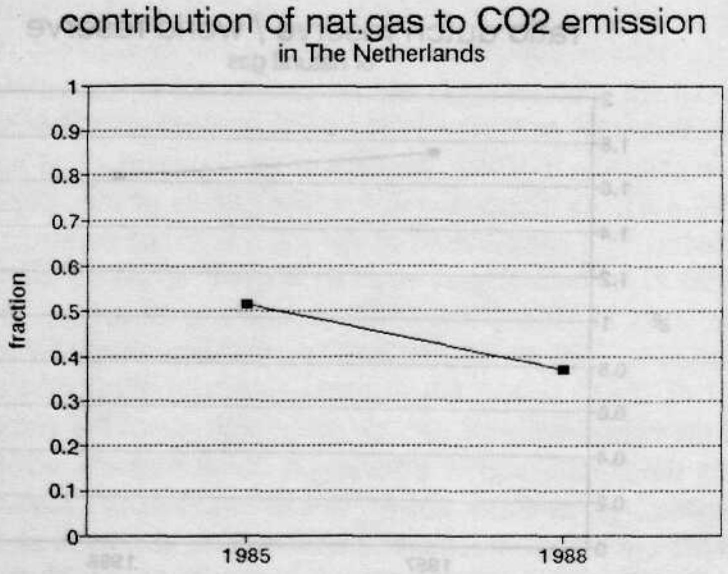


Figure 7 The contribution of the use of natural gas to the carbon dioxide emissions in The Netherlands. Sources: CBS, 1993; NEPP, 1989; Zorgen voor Morgen I, RIVM 1988.



5.2 The case of nitrogen compounds

5.2.1 Nitrogen compounds as a natural resource

Nitrogen is one of the major nutrients. The nitrogen cycle is therefore one of the most important ecological material cycles. Nitrogen can be regarded both as a source of the material and as an important link in the Life Support system. One of the most important aspects of regarding nitrogen as a natural resource is that it exists in several different forms:

N_2 : inert, major component of the atmosphere (99.9998%)
NO_3^- : oxidized anions and salts or acids
NO_x : oxidized gasses
NH_x : reduced cation (NH_4^+) or gas (NH_3)
organic N

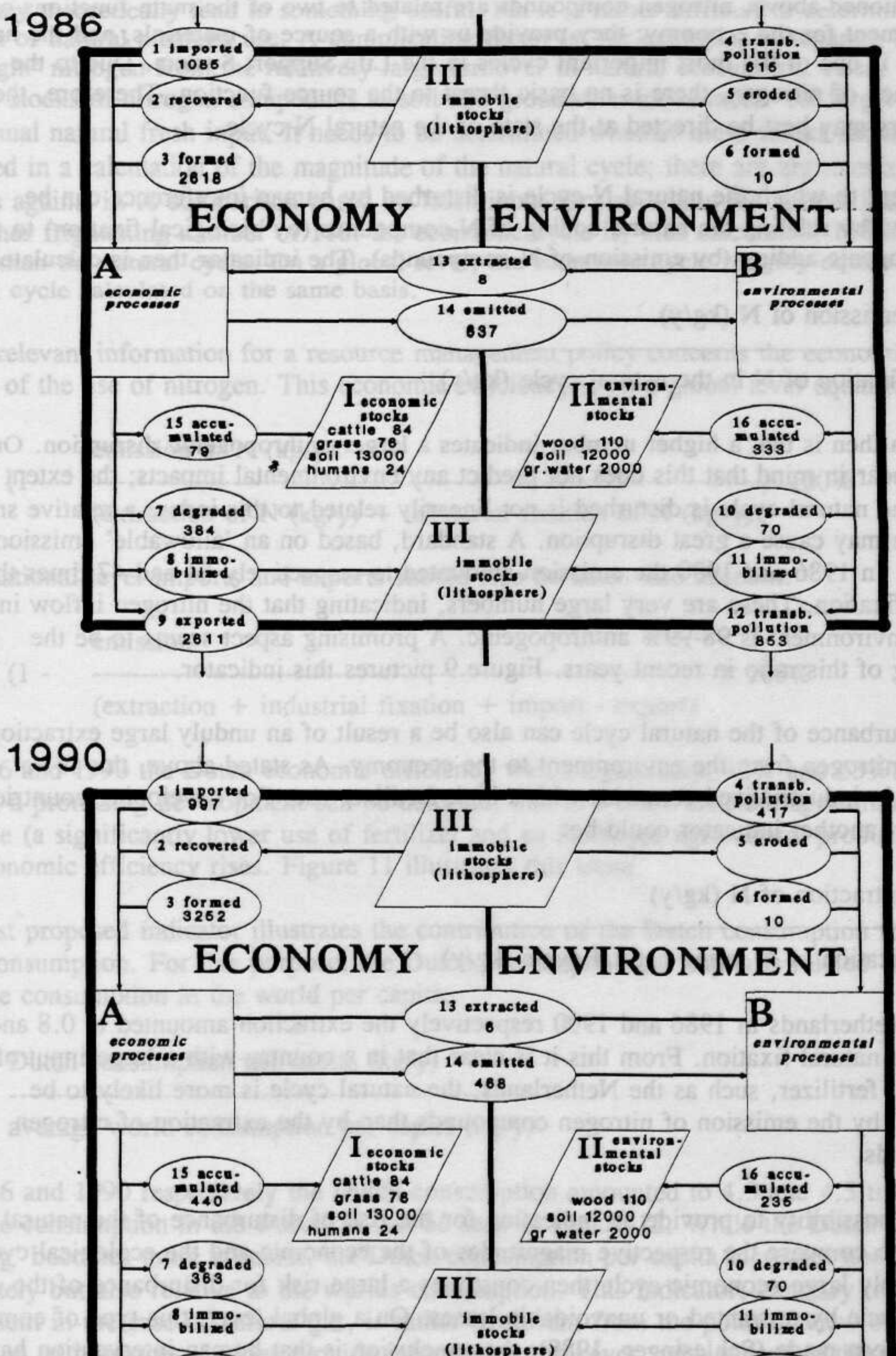
The most abundant form of nitrogen in the environment is the atmospheric N_2 gas. However, nitrogen gas is very inert: nitrogen can only be used as a nutrient in the oxidized, reduced, and organic forms of the element. Nitrogen in these forms, contrary to N_2, can be become scarce. Reduced and oxidized forms of nitrogen in the environment as a source of the materials is in the Dutch situation of minor importance. In the Western World large amounts of atmospheric N_2 are transformed industrially into reduced and oxidized forms in the economic production of fertilizer. In many developing countries however, the main source of nitrogen compounds is the environment. This source may become exhausted as a result of over-exploitation of the soil and erosion.

The natural nitrogen cycle is an important cycle in the Life Support System. All forms of nitrogen are present in the natural N-cycle. Disturbances of the natural N-cycle are caused by exhaustion, as mentioned above. In western countries, the natural nitrogen cycle is most often disturbed by large and concentrated addings of nitrogen compounds as a result of "leaks" in the economic N-cycle. This leads in many places to environmental problems such as eutrophication (NO_3^-, NOx, NH_x), acidification (NH_x, NOx), and smog-forming (NO_x). In the form of N_2O it contributes to the depletion of the ozone layer.

5.2.2 The nitrogen compounds account

The Natural Resource Account must inform on both stocks and flows. It can be presented in the form of a material balance for nitrogen in the Netherlands. In this material balance information is available on the flows of all forms of nitrogen except N_2 (which is considered as the outside source) into, through and between both the economy and the environment. The flows are expressed in kg N. The materials balances of nitrogen for the Netherlands in 1986 and 1990 are given below in Figure 8. More information could be provided by specifying the stocks and flows within economy and environment, especially with regard to the contribution of certain economic sectors to the various disturbances of the natural N-cycle. Whether this information is needed in an NRA system is disputable. One may take the point of view that since the information is available it might as well be presented. However, this detailed information is not presented in this report.

Figure 8 Balances of nitrogen compounds in The Netherlands in 1986 and 1990. Based on CBS balances (Olsthoorn, 1989 and Olsthoorn, 1993). Numbers in kg.10^6 N/year.



5.2.3 Indicators for nitrogen resource management

As mentioned above, nitrogen compounds are related to two of the main functions of the environment for the economy: they provide us with a source of materials, and the natural N-cycle is one of the most important cycles in the Life Support System. Due to the abundancy of nitrogen, there is no basic threat to the source function. Therefore, the indicators may best be directed at the state of the natural N-cycle.

The extent to which the natural N-cycle is disturbed by human interference can be expressed by relating the natural adding of N-compounds (by biological fixation) to the anthropogenic adding (by emission of N-compounds). The indicator then is calculated by:

$$\frac{\text{emission of N (kg/y)}}{\text{fixation of N in the natural cycle (kg/y)}}$$

The idea then is that a higher number indicates a larger anthropogenic disruption. One should bear in mind that this does not predict any environmental impacts; the extent to which the natural cycle is disturbed is not linearily related to this index: a relative small emission may cause a great disruption. A standard, based on an 'allowable' emission, is missing. In 1986 and 1990 the emission amounted to respectively 64 and 47 times the natural fixation. These are very large numbers, indicating that the nitrogen inflow in the Dutch environment is 98-99% anthropogenic. A promising aspect seems to be the lowering of this ratio in recent years. Figure 9 pictures this indicator.

The disturbance of the natural cycle can also be a result of an unduly large extraction: the flow of nitrogen from the environment to the economy. As stated above, this is not relevant in industrialized countries with a high fertilizer use. For developing countries however, another indicator could be:

$$\frac{\text{extraction of N (kg/y)}}{\text{fixation of N in the natural cycle (kg/y)}}$$

In The Netherlands in 1986 and 1990 respectively the extraction amounted to 0.8 and 0.6 times the natural fixation. From this it is clear that in a country with a large input of industrial fertilizer, such as the Netherlands, the natural cycle is more likely to be disrupted by the emission of nitrogen compounds than by the extraction of nitrogen compounds.

Another possibility to provide an indication for the risk of disturbance of the natural N-cycle is to compare the respective magnitudes of the economic and the ecological cycles. A relatively large economic cycle then constitues a large risk for disturbance of the natural cycle by unwanted or unavoidable losses. On a global level, this type of comparison has been made (Schlesinger, 1988): the conclusion is that human intervention has doubled the total nitrogen fixation. Eventually, all of this extra nitrogen ends up in the environment, threatening to disrupt the natural cycle. In this case, the measure has been the industrial N-fixation compared to the biological fixation. On a national level, import and export both in the economy and in the environment complicate the case. The comparison then could be made on the basis of anthropogenic versus natural nitrogen use. This may theoretically lead to something useful, but it is rather difficult to determine the amount of natural nitrogen use. A complicating factor is, for example, to separate the use of 'virgin' nitrogen from the relatively large turnover in natural ecosystems. Also, the natural stocks of nitrogen compounds in soil and groudwater are a factor 10^7 larger than the annual natural fresh input. It needs to be determined whether these stocks should be included in a calculation of the magnitude of the natural cycle; there are arguments for as well as against it. A comparison based on fresh input for use within the system leads to the rather frightening number of 110: the economic cycle is, thus calculated, 110 times larger than the natural cycle. On a global level, the economic cycle roughly equals the natural cycle calculated on the same basis.

Other relevant information for a resource management policy concerns the economic efficiency of the use of nitrogen. This economic efficiency is on a global level equal to:

$$\left(1 - \frac{\text{emission of N (kg/y)}}{\text{(extraction of N (kg/y) + industrial fixation of N (kg/y))}}\right) * 100\%$$

On a national level imports and exports should also be taken into account:

$$\left(1 - \frac{\text{emission}}{\text{(extraction + industrial fixation + import - export)}}\right) * 100\%$$

In 1986 and 1990 the Dutch economic efficiency was, respectively, 42% and 63%. Again, a promising development can be detected: due to a more efficient agricultural practice (a significantly lower use of fertilizer and an increased agricultural production) the economic efficiency rises. Figure 11 illustrates this trend.

The last proposed indicator illustrates the contribution of the Dutch consumption to the total consumption. For this purpose, the Dutch consumption per capita is related to the average consumption in the world per capita:

$$\frac{\text{Dutch consumption per capita (kg/y)}}{\text{average world consumption per capita (kg/y)}}$$

In 1986 and 1990 respectively the Dutch consumption amounted to 4.3 and 4.5 times the average consumption in the world, as can be seen in Figure 12. While the Dutch 'housekeeping' becomes more efficient, the Dutch consumption per capita increases not only absolutely but also relative to the worlds consumption. This indicator, contrary to the equivalent in the case of natural gas, is rather irrelevant from the point of view of depletion of resources. It does provide information, however, with regard to the equal sharing-side of the management of natural resources.

Figure 9 Anthropogenic versus natural contribution of nitrogen compounds to the Dutch natural nitrogen cycle

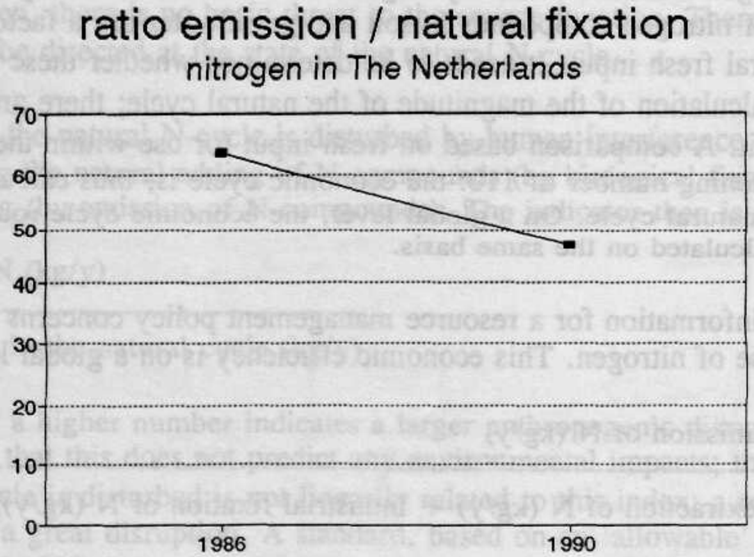


Figure 10 Economic efficiency of the use of nitrogen compounds in The Netherlands

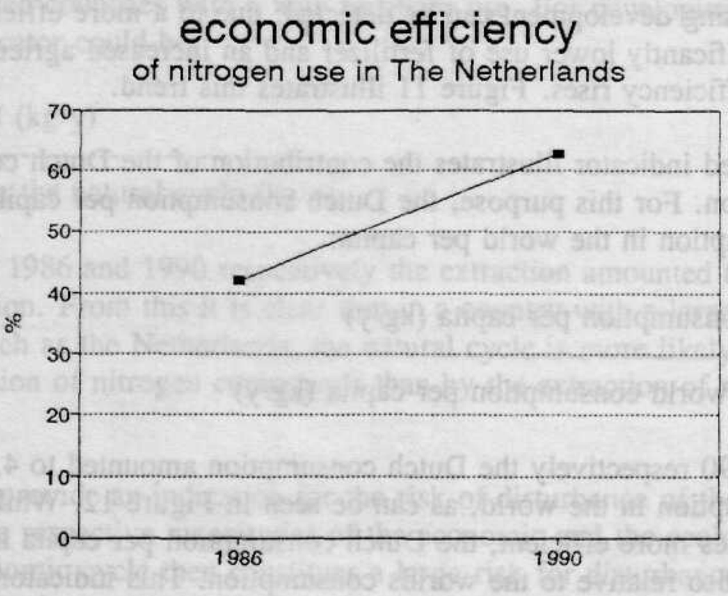
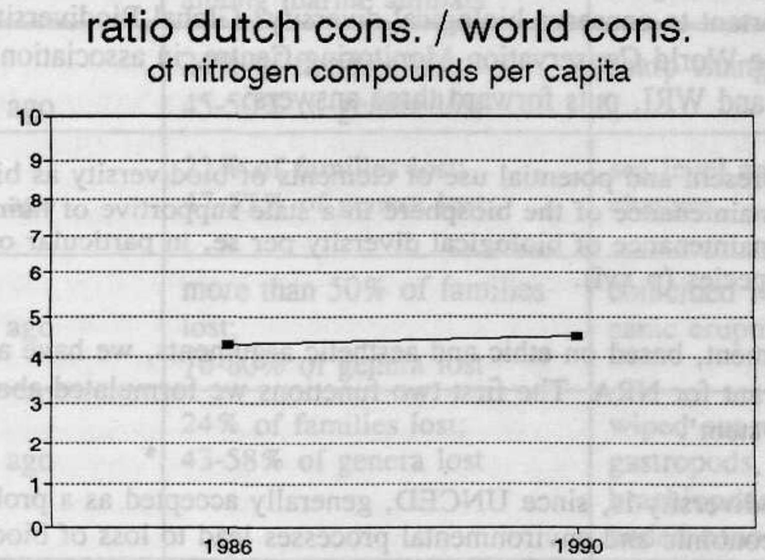


Figure 11 Consumption of nitrogen compounds in The Netherlands compared to the worlds average consumption. Source, apart from the account in figure 8: United Nations Yearbook Industrial Production.



5.3 The tentative case of biodiversity

5.3.1 Biodiversity as a resource

Biodiversity loss as a global environemntal problem

Why is it important to conserve biological diversity? Global Biodiversity (1992), a report compiled by the World Conservation Monitoring Centre, in association with the IUCN, UNEP, WWF and WRI, puts forward three answers:

1. the present and potential use of elements of biodiversity as biological resources
2. the maintenance of the biosphere in a state supportive of human life
3. the maintenance of biological diversity per se, in particular of all presently living species (p xvi).

The third argument, based on ethic and aesthetic arguments, we have already discarded as not being relevant for NRA. The first two functions we formulated above as 'source' and 'life support system'.

The loss of biodiversity is, since UNCED, generally accepted as a problem of mondial dimensions. Economic and environmental processes lead to loss of biodiversity and loss of biodiversity in its turn has, with a revenge, serious environmental and economic consequences. Clearly the biodiversity of the earth is an asset and will have to be accounted. As the total amount of species on earth is not known (May, 1992), and even the order of magnitude is under discussion, it is going to be no easy bookkeeping. Less work has been done on the accounting of life resources than on the accounting of dead and non-living resources. Our analysis is tentative.

It should be kept in mind however, that loss of biodiversity on any scale is by far the most frightening of environmental threats. Lack of data is no reason for comfort. Extinction of species is absolutely irreversible. Mass extinction is a downhill ride, unstoppable and catastrophic. Moreover, mass extinctions have occurred before in the history of the earth: at least ten are known. In the five greatest mass extinctions half or more of the marine genuses died out (see table). About terrestrial genera less is known, as the fossil record is not as complete as that of the marine genuses. After each extinction new species filled the opened ecological niches. Also it should be noted that the mass extinctions coincided with climate change, or massive volcanic emissions. Human induced emissions now approach a magnitude comparable to those of natural cycles, thereby creating another catastrophe on a global scale. Some hope may be derived from the fact that the process of extinction often took a few hundred thousands years, though there is no guarantee the same span is allowed for us humans.

Table 5 The five greatest mass extinctions in the history of the Earth. Source: International Herald Tribune, december 17, 1992, p 8: "Extinction Theories", by Malcolm W. Browne.

Time of occurrence	Magnitude of extinction among marine animals	Coinciding disaster
Final Ordovician 435 million years ago	24% of families lost; 45-50% of genera lost	sharp changes in sea levels
Late Devonian 357 million years ago	22% of families lost; 47-57% of genera lost	sea level and climate changes
Final Permian 250 million years ago	more than 50% of families lost; 76-80% of genera lost	coincided with great volcanic eruptions;
Late Triassic 198 million years ago	24% of families lost; 43-58% of genera lost	wiped out many reptiles, gastropods, bivalves and brachiopods; ended conodonts
Final Cretaceous 65 million years ago	16% of families lost; 34-46% of genera lost	coincided with Siberian eruptions and possibly with impact of asteroids or comets. demise of dinosaurs.

The extent of an extinction is measured by the percentage of marine animal families that became extinct; many more genera and individual species were reduced or wiped out. Marine animals are used as the index because the fossil record in marine sediments is far more complete than that for land animals. Families are counted because larger categories are easier to gauge.

The nature of biodiversity as a natural resources

Strictly speaking, biodiversity is not a resource, but a characteristic of a resource. A population, a region or an ecosystem has a certain measure of biodiversity; the actual resource then is the total number of organisms within the population, region or ecosystem. This spatial dimension of biodiversity complicates the account. The problems are many. When can living entities be said to belong to a region? Animals move around, sometimes over considerable distance and are not easily related to a specific region. A stopover with good feeding facilities may be crucial on a long flight and its conservation may greatly contribute to the biodiversity of migratory birds, even though the birds stay at the place only a few days every year. Plants at least keep their place, but some are more fussy than others and will only grow under quite specific circumstances, while others will grow almost anywhere.

There is such a thing as 'too much biodiversity': areas poor in nutrients may lose their characteristic flora by eutrophication leading to a local increase in species variety. Colloquially the phenomenon of an undesirable increase in biodiversity is known as 'thistles on the heather'. A high level of biodiversity is valuable in as far as the population is seen as a source of genetic information, but it may be detrimental in the future as it threatens the diversity of ecosystems and thereby the heart of the life support system. Clearly, a distinction must be made in different varieties of biodiversity: genetic, species and ecosystem diversity.

We follow the definitions as given in World Resources, 1992-1993 (p 128):

genetic diversity	the variation of genes within a species
species diversity	the variety of species within a region
ecosystem diversity	the variety of ecosystems within a region

Genetic diversity is the main issue in the continuation of the existent production of domesticated flora and fauna. Species diversity has a potential significance as new products might be developed, and as a root of speciation under new environmental circumstances. Species diversity and ecosystem diversity both are crucial in maintaining the life support system.

Genetic diversity within species

This feature of biodiversity is commonly linked to domesticated species. Problems arise from the large scale growing of crops in monocultures. Eventually any monoculture will be attacked by a specialized disease or predator that has found its niche. The all-resistant plant or animal does not exist and cannot exist for evolutionary reasons. Consequently varieties have to be changed regularly to keep ahead of the pests. The loss of genetic diversity in a species, called 'genetic erosion', makes it vulnerable. "The average life of a new crop variety is now roughly equivalent to the life of a new pop record," Al Gore quotes in Earth in the Balance (p 131). It follows that the presence of variety of species is a resource with direct economic value, the more so as new traits will be required during the impending climatic and environmental changes. Analysis of the medicinal use of flora and fauna is analogous. The commercial value of genetic varieties is pretty well known to the big pharmaceutical and seed industries and supposedly the loss of genetic variety in domesticated crops is the least of worries. Although, the United Nations International Board for Plant Genetic Resources produces a frightening list of the crops being most at risk form genetic erosion: apple, avocado, barley, cabbage, cassava, chickpea, cocoa, coconut, coffee, eggplant, lentil, maize, mango, onion, pear, pepper, radish, rice, sorghum, soybean, spinach, sugarbeet, sugarcane, sweat potato, tomato, wheat and yam (Gore, p 137).

Species diversity and taxonomic diversity

Which species should be conserved in a region? Is the loss of one species 'worse' than the disappearance of another, i.e., can one species be 'more of a resource' than another? Dollo's Law states that once a species, a unique combination of genetic characteristics, is lost it is lost forever. The potential future value of a specific feature cannot be known in advance and we should conclude that extinction of any species is an immeasurable loss. The only basis of comparison then is the probability that the disappearance of a species from a region means that it is extinct worldwide. From this the conclusion should be drawn that endemic species should always be protected, as their loss is absolute. It has been argued that conservation priorities should not be founded on the number of species only, but also on the degree of difference among them (Williams et al, 1991). It may be advisable to put more effort into the conservation of species that are genetically distant than in safeguarding two related species. One justification for this opinion is that it provides a better starting point for new speciation.

For species diversity that takes into consideration the relatedness of the species the term 'taxonomic diversity' has been introduced. This approach means that the extinction of a species from a monospecies family is to be considered as worse than the loss of a species with many relatives. The argument behind this is that the single species contains more unique genes and gene patterns than a species with many close relatives. On a family level, it appears to be a possibility at least for vascular plants to calculate the contribution to the worlds gene pool or, in other words, the family's taxonomic diversity (...).

ecosystem diversity

Costanza, Daly and Bartholomew state, in their summing up of the first ISEE conference: "Sustainability is the maintaining of our life support system." (Costanza p 7). The life support system itself is largely dependent on life in all its diversity. So, plants, animals and micro-organisms - interacting with each another and with the physical environment in ecosystems - form the foundation of sustainable development (Global Biodiversity Strategy, p1). Accounting the ecosystems supporting the life support system is not easy, theoretically nor practically, and it is dependent on the assumptions about the life support system. As ecosystems as scientific term are not beyond discussion it seems unadvisable to propose an accounting of ecosystem diversity as part of biodiversity. Intuitively however one feels that the Waddenzee, for example, should be visible as an asset in an NRA. Functioning of ecosystems from a life support point of view, for example by keeping the nutrient cycles going, is dependent on both quantity and quality of ecosystems. The role of separate species in the life support system is less clear. It is very well possible that individual species may be interchangeable from this point of view, and that the completeness of foodchains, the filling in of a variety of niches, and the mere stock and production of biomass within ecosystems is more important.

5.3.2 A biodiversity account

To construct a list of accountables we analyze the importance of biodiversity for the environmental functions of sink, source and life support system. We stress again that our effort is highly tentative.

sink

The function 'sink' is above all fulfilled by bacteria. A large-scale extinction of bacterial life will lead to a complete environmental collapse within days. That this will happen is not unthinkable. A high level of acidity might pickle the soil and effectively stop the decomposition of organic material. The nutrient turnover cycle is stopped and a forest on poor soil, dependent on the nutrients freed from its fallen leaves, will rapidly starve. An account of the presence and health of the multiplicity of strains of bacteria might be useful in an NRA, but the practical problem of the account is impressive. We are not competent to suggest a solution and can only voice the feeling that the state of the bacteria population should be reflected in an NRA.

source

Domesticated animal and plant species generally cannot survive without human intervention and should be considered an economic resource instead of a natural resource. The accounting of domesticated species belongs to agricultural economics and is well taken care of by that discipline.

Of the wild species, either the genetic information is used or the biomass. Using the biomass means the destruction of the population, unless careful harvesting is practised. Genetic information can be used without destruction of the individual.

Biomass

We suggest that accounting sources of biomass can be restricted to fish and forests. Data on both flows and stocks of wood as well as fish are available for The Netherlands, as specialized institutions have been doing high quality research for quite some time. It is to be expected that an account of fish along national borders will prove to be impossible or useless. In that case as supranational account will have to be maintained.

Genetic information

When regarding biodiversity, or rather the total of living organisms within an area, as a source of genetic information, we are in fact considering the taxonomic diversity. As a first approach, taxonomic diversity may be accounted as species diversity. The account of species diversity should be based not only on presence but also on frequency of species occurrence. A time series of frequency data furnishes information on the biodiversity in a region, though the exact translation is not straightforward. Continuing existence of a species is dependent on the size of a population and a drift towards lower frequencies of observation may be interpreted as a threat to species diversity. A general drift towards higher frequencies can only mean that a region is losing differentiation in physical and chemical conditions, leading to a loss of diversity in ecosystems and eventually to loss of species.

In case the information on species frequency is lacking or incomplete data may be collected on higher taxonomic entities, as families for flora. As the genetic distance between families may be considered equal an account of families can be used as measure of taxonomic diversity. No systematic study has been done yet on the biodiversity of the Netherlands. Availability of data on the Dutch flora and fauna is good. The absence of biodiversity accounting is not due to lack of data, but to lack agreement on the theoretical foundations of such accounting. Some work has been done on the frequency of plant species, notably by Plate, working for the CBS. We suggest that her work would be a good point to start with.

The Netherlands have been divided into a grid of about 1600 squares of 5x5 km, called Hour Blocks (5 km being the distance a biologist is supposed to cover in one hour). Observations of flora are placed in this grid. Occurrence of plants is measured in Hour Block Frequency Classes, which are defined as follows:

HBFC	description	number of hour blocks in which a species is observed
0	absent or extinct	0
1	extremely rare	1 - 3
2	very rare	4 - 10
3	rare	11 - 29
4	fairly rare	30 - 79
5	less common	80 - 189
6	fairly common	190 - 410
7	common	411 - 710
8	very common	711 - 1210
9	extremely common	1211+

Plate compared frequency data of 1940 and 1990:

HBFC	0	1	2	3	4	5	6	7	8	9
1940	79	73	107	160	187	217	209	171	165	80
1990	71	126	115	153	183	178	165	141	191	125
change	-8	+53	+8	-7	-4	-39	-44	-30	+26	+45

This table is summarized in Figures 12 and 13.

There is a clear tendency to squeeze out the middle groups: both the most rare and most common have increased in the period between 1940 and 1990. On the left side of the figure, there is a development towards a greater scarcity of the already not very frequent species. This is most likely linked to the disappearance of certain habitats, and therefore might be interpreted as a sign of danger for future extinction. On the right side, there is a development in the direction of a greater abundance of species already more common. Putting it rather grossly, the modern Dutch landscape develops a homogenous flora, with the same plants occurring everywhere. More analysis is needed before these data can be used as an indicator for species diversity.

life support system
As stated above, for the functioning of the life support system not the presence of individual species but the presence of a certain amount of well functioning ecosystems is the most important demand. Accounting ecosystems runs into heavy theoretical problems, as the term is far less well defined than species. As a first approach we suggest to account the quantity of ecosystems by collecting data on the state and changes of

- natural areas: areas dominated by non-domesticated species
- nature reserves: areas of protected areas
- stocks and production of biomass within natural ecosystems.

On the first two issues, information is available. The definition of 'areas dominated by non-domesticated species' will most probably present difficulties, which might be solved in a practical manner. The biomass stocks and flows are known for forests at least. It may be possible to arrive at a rough approximate number for biomass stocks in other areas, but it is questionable whether this information will be detailed enough to link it to data on biomass flows and changes over time, otherwise than directly linked to the areas.

For information with regard to the quality and health of ecosystems several accounts are possible:

- vitality
- species composition
- completeness of foodchains

Vitality data for forests are already collected regularly in The Netherlands. Data on species composition of ecosystems are only relevant when confronted with a reference for specific types of ecosystems. It will be very difficult to approach this from a scientific point of view: which species 'belong' naturally in certain ecosystems is not very easy to decide. However, it is possible and has in fact been practiced for years (...) to make a list of species linked to certain combinations of abiotic and climatic factors. This has led to the division of The Netherlands into ecoregions on various scale levels. For a national account, the ecodistrict level seems to be the most appropriate. It seems to be possible or at least imaginable for environmental policy makers to be able to define a certain reference list of species indicating healthy ecodistricts. This list then could be compared to the actual species present. As stated above, data on species occurrence and frequency are, at least for plants, available for The Netherlands.

5.3.3 Indicators for biodiversity management

Following from the above, many indicators for biodiversity management, or rather for the management of the natural resource of living wild organisms within a region, can be thought of just by ordinary common sense. To mention a few possibilities:

- contribution of a nation to the global stock and to the global consumption of wood
- presence of endemic species as a contribution to the global biodiversity
- changes in presence and frequency of species
- percentage of species threatened with extinction
- changes in natural areas and natural biomass
- changes in vitality of forests
- changes in presence of certain indicator species
- changes in coinciding of actual species presence with desired species presence in certain ecosystems

All these and possibly many others may be significant as biodiversity indicators. However, the development of each of these indicators and even the determination of the usefullness of each will be a study in itself. We do not propose to make choices and come up with solutions in this report. Our recommendation would be to start investigations in this area; the more so because the accounting of living organisms and the interpretation of these data lags seriously behind compared to other types of natural resources.

Figure 12 Development of the frequency of occurrence of species within The Netherlands between 1940 and 1990. Source: Plate (1992).

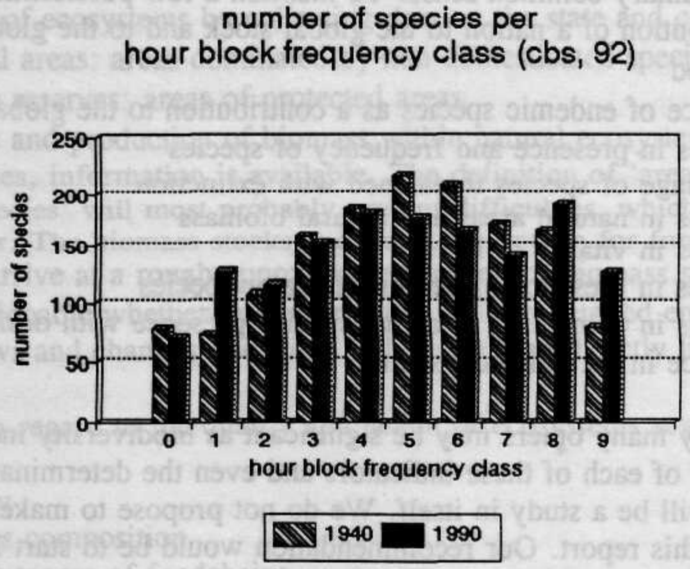
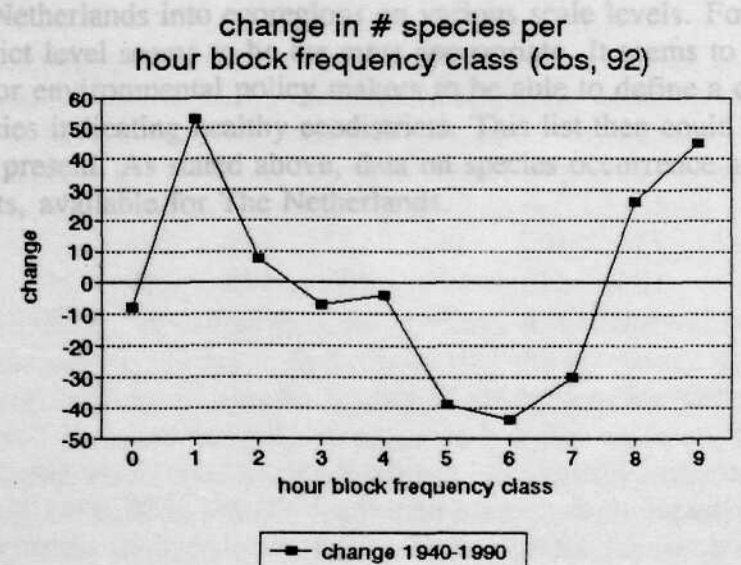


Figure 13 Changes in frequency of occurrence of species within The Netherlands between 1940 and 1990. Source: Plate (1992).



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Appendix 1: A walk-through of the argumentation

The following is a careful walk-through of the argumentation offered in this paper, and as such consists of the bare skeleton of the study.

Legend:

Ax: arguments, to be founded on accepted scientific literature

Cx: conclusions, to be drawn from the arguments, generally also to be found in the body of scientific literature

Px: propositions, with political significance; actually beyond the researchers competence, but offered here as a logical consequence of the arguments and conclusions.

Considering:

A1. The natural environment is a supplier of goods and services to the national economies; these goods and services are the natural resources. Careful management of these limited resources is needed to guarantee future benefits and to avoid squandering them.

A2. The economic indicators as defined in the SNA exclude the contribution of nature and the environment to the national economy.

A3. Existing environmental indicators fail to reflect the utilisation of natural resources.

We can conclude that:

C1. In the absence of reliable economic and environmental indicators policymaking is based on incomplete information.

Which brings us to the proposition that

P1. Natural resource accounting is needed to present a more balanced account of the economic and environmental policy performance of a nation.

However, also considering:

A4. The theories and policies of economics and the environment are still widely seperated and knowledge of their interaction is limited.

A5. Many environmentally significant phenomena are not registered in the market.

We take the position that:

P2. The natural resources to be accounted should not be restricted to those traded on a market.

Which means that:

C2. The natural resources account should be measured in physical units.

On the scope and use of NRA we take the position that:

P3. The National Resource Account should contain the information in physical units which will be needed to construct economic and environmental policy performance indicators.

Analyzing the use of natural resources we find:

A6. Ecological literature states that natural resources are exploited by
a. benefiting from or by tapping the big and small cycles that are maintained by biological, chemical or physical processes
b. using the energy or information as contained in lifeforms.

A7. The economic literature translates the ecological view into terms of goods and services and formulates the three basic functions of natural resources as those of source, sink, and life support system.

C3. NRA should reflect the contribution of the environment:
a. as providing a source of living, non-living or dead materials
b. as disposing waste, either by storing it, or by biological, chemical or physical decomposition
c. as maintaining the conditions favourable to life in all its diversity.

And so propose:

P4. NRA should contain data on the quantity of the natural resources of a nation, from which over time the following information is to be derived:

a. change in quantity of living stocks: decrease by direct use of materials and rendering them unavailable for potential future use; increase by growth

b. change in quantity of non-living or dead stocks: direct use of materials and rendering them unavailable for potential future without expenditure of energy for recycling or re-use

c. change in the quality of the natural resources: degradation as depreciation of natural capital, q.e. diminished capacity of future production; improvement as increase in capital value, q.e. increased capacity of future production

d. changes in the quantity and qualtity of the natural resources in as much as they necessitate more or less investment to keep the conditions for life favourable.

Comments, notes, sources

A1, A2 MacNeill, Repetto, Gore, Daly, World Bank, WRI, Pearce, Goldsmith, Grundmann, who not. In short, these really are generally accepted. No contention to be expected here.

A3 Environmental indicators are generally based on policy themes or accepted environmental problems. Though these indices are a convenient tool for formulating problem oriented policy they do not describe the resulting state of the natural resources.

C1 Repetto is the most explicit representative of the view that SNA underestimates the economic performance of a nation.

P1 It is tempting to introduce the term 'sustainable' in defining the need for NRA. However, though 'sustainability' is a politically widely accepted term, scientifically it is pretty hopeless (Report "Duurzaam gebruik van milieuvoorraden", VROM-SP). It seems advisable to avoid the concept.

A4 The formulation is derived from Jan van der Straaten. The standpoint is shared by the same general ecology-economy literature as mentioned above. Clearly these arguments can and will be used as delaying techniques. Principally, there is as yet no consensus on a methodology of monetarisation of the environmental contribution to the economy. However, it should be possible to avoid the discussion on monetarisation by emphasizing the physical units of NRA.

P2 We suggest that care should be taken to distinguish Natural Resource Accounting from Environmental Accounting, Environmental Policy Performance Indicators on the one side and Satellite Accounting or Green GNP on the other. Some of the concepts may prove to be identical.

Environmental Accounting and Environmental Policy Performance Indicators reflect, in our opinion, information on the state of the environment and on the success or failure of environmental policies.

Satellite Accounting and Green GNP aim at supplementing the SNA with environmental data.

It seems that Norway shifted from a view of NRA as information on the natural resource as wealth to that of environmental policy indicator. The French have taken NRA as a system to monitor the management of the natural heritage, eventually to be linked to other aggregate welfare indicators.

C2 In accordance with CBS, and the logical consequence of A3, A4 and P2. The USA seems to be in agreement, as the NRA's by the department of agriculture includes forestry and that of the department of interior includes flora, fauna and mines (bgnimiok, 02/6, p 5).

P3 This states the position of NRA as opposed to environmental policy indicators and satellite accounts. It is a succinct formulation of the comment to P2. Moneratisation is equal to constructing an economic index.

A5 This is an ecological purists view, as found in Boyden, Mannion, White et al, Kormondy, Ayres, Simmons. The agricultural approach to the value of nature concentrates on the genetic information contained in wild varieties of domesticated species and is to be found in Doyle, Prescott-Allen, Spedding, Wilson. Obviously some cycles have a time scale that are far beyond the human experience and can for all practical purposes be regarded as stocks. The importance of the argument lies in the emphasis on cycles and on the inclusion of life as a very significant natural resource. As the disturbance of the ecocycles and the endangering of life forms are the most pressing environmental issues these should absolutely be reflected in NRA. It is our central argument against restricting NRA to the measuring of the depletion of mineral and fossil fuel stocks. It is in accordance with the original design of the Norwegian NRA.

C3 Ecological consequence of A5, largely following Barbier. 'The cycles maintaining favourable conditions for life' is generally found as Life Support System in the literature (Barbier, Odum), but here avoided as jargon.

P4 The implementation of C3.

a. 'Natural stocks' means the stocks of minerals, fuels and other materials to be mined. Wood, as dead trees, should be included. Clearly problems will arise in determining the magnitude of stocks as the market decides if a stock is economically exploitable. Examples: burning fossil fuels, killing all herrings, cutting the complete forests.

b. Example: mining, use and dispersal of minerals.

c. 'Natural capital' should be regarded as the potential to produce goods and services in the future. A tree is both a stock of wood when cut down and a producer of fruit and new trees when left standing. Diversity of life forms or ecosystems and viability or health of populations are both characteristics of natural capital and should be accounted in NRA.

d. The economic worth of the life support system is enormous, as a simple calculation on the cost of artificial climate control will show. Two complex issues loom here: the earths life support system is mostly supranational and the cycles maintaining it are not well known. So either a way will have to be found to include the use of the life support system, or it will have to be explicitly decided that NRA is not the place to reflect damage to it by economic activities.

Possibly the cost of cleaning water may be used as a proxy to the value of self-cleansing water systems. As a problem of monetarization it is beyond the scope of NRA.

Use of health indicators and the value of human life, derived from expected income, might lead to the dubious recommendation of exporting polluting industries to low income countries. (World Bank leaked memo, discussed in "Why it's cheaper to poison the poor", in New Scientist, 1-2-1992)

Appendix 2: List of natural resources

Source

Non-living resources

* metals (resources on an elementary level)
  - bulk metals (Fe, Al)
  - metals (Pb, Zn, Sn, Ni, Cr, Cu, Ag, Cd, Pt, Au, Hg, Co, U, V, ...)
  - alkali metals (Li, Na, K, Rb, Cs)
  - trace elements (Ga, Ge, W,...)

* nutrients
  - macro nutrients (P, mineralised N, K, (S); see also Life Support System)
  - micro-nutrients (Mg, Ca, Mn, Cl, ...)

* grit, marl, sand, clay

Living resources

From a biomass point of view; see also Life Support System

- wood
- fish
- game

From a biodiversity point of view
(in order of increasing number of species)

- fungi
- producers
  - algae
  - plants
- animals
  - mammals
  - amphibians
  - sponges
  - echinoderms
  - reptiles
  - coelenterates
  - birds
  - earthworms
  - roundworms
  - flatworms
  - fish
  - protozoa
  - mollusc
  - noninsect arthropods
  - insects

Dead resources

* fossil fuels
  - natural gas
  - mineral oil
  - coal (hard, soft, lignite)
* peat
* sediments
* shells

Sink

land-surface (in categories of use)

- industry

- housing
- infra-structure (roads, railway, airports, harbours, canals (?))
- agriculture
- recreation

environmental compartments

- water (in types of water: fresh water, groundwater, ocean, sea
- air

Life Support System

Measured in output of the LSS

- mean temperature
- acidity
- humidity
- amount of uv radiation reaching the earth surface
- concentration of toxic substances in various compartments

Measured in building blocks of the LSS

- biomass within natural ecosystems, especially forests and wetlands
- vitality of natural ecosystems
- diversity of natural ecosystems
- undisturbed areas of natural ecosystems
- global cycles (water, C,N,O,P,S)
- ozone layer

Appendix 3: Inschatting van de stikstof-voorraad in Nederland

Bij het berekenen van de voorraad aan stikstof in Nederland zijn de volgende posten onderscheiden:

- Bodem
  - Terrestrisch:
    - * agrarische bodem (bouwland, grasland)
    - * overige (natuur, bebouwd land etc.)
  - Aquatisch:
    - * sediment
- Biomassa
  - * bos
  - * gras (niet afgevoerd landbouwgewas)
  - * veestapel
  - * mens
- Water
  - * grondwater
  - * oppervlakte water

In onderstaande tabel staat voor elk van de posten de stikstofvoorraad in Nederland samengevat. Voor een meer gedetailleerde beschrijving van de posten en hun stikstofvoorraad wordt verwezen naar de tabellen 1-3. Tevens staan in de tabel inschattingen gemaakt door RIVM (RIVM, 1992)

DE STIKSTOF VOORRAAD PER COMPARTIMENT IN NEDERLAND		
COMPARTIMENT	VOORRAAD STIKSTOF (mln kg N)	
	RIVM studie	CML studie
atmosfeer	$30 * 10^7$	-
onverzadigde bodem		
diepte 1 m	$70 * 10^3$	
diepte 30 cm		$25 * 10^3$ ($33 * 10^3$)
verzadigde bodem/ grondwater 20-25 m	$20 * 10^2$	-
biomassa		290
veestapel		84
mensen		24
bomen		110
gras		76

Voor het berekenen van de voorraden in de diverse posten zijn de volgende gegevens noodzakelijk:

a) voorkomen van (de elementen uit) bovenstaande categorieën in Nederland (areaal, aantal stuks)

b) Omrekeningssleutel naar (bio)massa (van areaal of stuks naar gewicht (kg); bv produktie cijfers per hectare of gemiddeld gewicht van een element uit de categorie

c) N-gehaltes van elementen uit bovenstaande categorieën

In onderstaande wordt per post kort ingegaan op de aannamen en bronnen gebruikt bij het berekenen van de stikstof-voorraad in Nederland.

BODEM

* Terrestrische bodem

1. De stikstof voorraad in de bodem wordt met name gevormd door organische stikstof. Het organische stof gehalte in de bodem is het grootst in de toplaag van de bovengrond. De stikstof voorraad is daarom berekend voor de bouwvoor (wortelzone) van de bovengrond. Aangenomen is dat deze 30 cm bedraagt.
2. Het oppervlak van de diverse bodemsoorten in Nederland (veen, klei, zand) is overgenomen uit de ecoserie-bodem reeks ontwikkeld op het Centrum voor Milieukunde.
3. Voor de inschatting van het organische stof gehalte en de dichtheid van de diverse bodemtypen is gebruik gemaakt van de "Staringreeks" (Wösten et al, 1987), waarin de fysisch/chemische karakteristieken van diverse bodemtypen zijn opgenomen.
4. De hoeveelheden organische stof in de diverse bodemtypen zijn uiteindelijk omgerekend in stikstofvoorraden met behulp van de C/N ratio van de diverse bodemtypen (Locher en de Bakker, 1987). Daarbij is aangenomen dat 58% van het organische stof bestaat uit koolstof.

In tabel 1 staan per bodemtype de stikstofvoorraad en de bij de berekening gebruikte gegevens opgesomd.

Opmerking:
Het gehalte aan organische stof in de bodem wordt bepaald door het moedermateriaal (veen, klei en zand) en het bodemgebruik (bouwland, grasland en overige) Vooralsnog is geen onderscheid gemaakt in bodemgebruik, dwz. agrarische bodem en niet-agrarische bodem. Momenteel ontbreken namelijk gegevens mbt organisch stof gehaltes en C/N ratio van de bodem bij bepaalde typen grondgebruik.
Bovendien is de spreiding in organische stof gehalte en C/N ratio, zoals die zijn gebruikt in deze studie al enorm groot, mogelijk valt de spreiding door bodemgebruik hierbinnen.

* Sediment

Het grootste oppervlak aan sediment bevindt zich onder de Waddenzee en het Ijsselmeer. Er zijn nog geen gegevens beschikbaar.

BIOMASSA

* bos

1. Areaal (ha), voorraad (m^3/ha), oogst (m^3/ha) en bijgroei (m^3/ha) van het Nederlandse bos (situatie 1989) is per boomtype overgenomen uit het rapport " Houtoogst, voorraad en bijgroei in het Nederlandse bos" (Begeleidingsgroep houtoogststatistiek en prognose oogstbaar hout, 1991).
2. Het gewicht van de diverse boomtype per volume eenheid (kg/m^3) is overgenomen uit het Houtvademecum (Wiselius, 1990).
3. De verhouding tussen biomassa boven- en ondergronds is ingeschat op 8:2 (Schlesinger, 1991)
4. De C/N ratio van hout bedraagt 160 (Schlesinger, 1991). Koolstof bedraagt 58 % van het organisch stof gehalte.

In tabel 2 staat per boomsoort de stikstofvoorraad en de bij de berekening gebruikte gegevens opgesomd.

* gras

1. Het areaal grasland in Nederland bedroeg in 1989 ca. 1007000 ha (LEI/CBS, landbouwcijfers 1991).
2. Aangenomen is dat de totale graslandproduktie (inclusief oogst en beweidingsverliezen) 11000 kg ds/ha bedraagt (Van Eerdt et al, 1991 in: CBS, 1992).
3. Het stikstof gehalte in vers weide gras bedraagt 37.7 gr/kg ds (CBS, 1992).
4. Afvoer van stikstof in graslanden via hooi, graskuil en vers weide gras bedroeg in 1989 ca. 342 mln kg. (CBS, 1992).
5. Aangenomen is dat de totale stikstof vastlegging in gras minus de afvoer van stikstof via hooi, graskuil en vers weide gras een inschatting geeft van de stikstof voorraad in het overblijvende gras.

De stikstofvoorraad in het gras bedraagt ca 76 * 10^6 kg stikstof.

* veestapel

1. De omvang van de Nederlandse veestapel wordt jaarlijks geïnventariseerd. Voor deze studie zijn de aantallen voor 1990 overgenomen uit de landbouwcijfers 1991 (LEI/CBS, 1992).
2. Met behulp van het slachtgewicht en aanhoudingspercentages is voor iedere diersoort een inschatting gemaakt van het totaal levendgewicht (CBS/LEI, 1991 en CBS, 1992 en Pelser, 1988).
3. Het stikstofgehalte van de diersoorten is ontleent aan 'Mineralen in de landbouw' (CBS, 1992)

In tabel 3 staat per diersoort de stikstofvoorraad en de bij de berekening gebruikte gegevens opgesomd.

* Nederlandse bevolking

1. Er zijn 15 mln mensen in Nederland.
2. Het gemiddelde gewicht van een volwassene is 65 kg.
3. Voor het gemiddelde stikstofgehalte van vlees is uitgegaan van 0.025 kg/kg. (zie veestapel varkens)

De stikstofvoorraad in de Nederlandse bevolking bedraagt ca. 24 * 10^6 kg stikstof.

WATER

* Grondwater
RIVM gegevens

* Oppervlakte water
Verwaarloosbaar

TABEL 1 De stikstofvoorraad in de bodem en voor de berekening gebruikte bodemkarakteristieken.

ECOSERIE-BODEM	OPPERVLAKTE (ha)	DICHTHEID (gr/cm3)	ORGANISCHE STOF (uitgedrukt in %) min	ORGANISCHE STOF (uitgedrukt in %) max	C/N ratio max	C/N ratio min	BOUWVOOR (30 cm) ORGANISCHE STOF (in 1000 kg) min	BOUWVOOR (30 cm) ORGANISCHE STOF (in 1000 kg) max	STIKSTOF (in 1000 kg) min	STIKSTOF (in 1000 kg) max	gemiddeld
primair oligotroof veen	76131	0.15	90	96	60	35	30833055	32888592	298052.9	545011	421531.9
primair meso-eutroof veen	147706	0.15	70	83	35	15	46527390	55168191	771025.3	2133170	1452098
veen met kleidek	104249	1.4	4	15	9.6	9.6	17513832	65676870	1058127	3967978	2513052
veen op zand	9144	0.45	28	48	60	35	3456432	5925312	33412.18	98190.88	65801.53
veen op zand met zanddek	9252	1.3	3	10	19.5	19.5	1082484	3608280	32196.96	107323.2	69760.08
lichte klei	699405	1.3	2	5	9.6	9.6	54553590	1.36E+08	3295946	8239865	5767906
zware klei	319903	1.1	3	5	9.6	9.6	31670397	52783995	1913420	3189033	2551226
moerige zeeklei	20643	0.5	38	62	9.6	9.6	11766510	19197990	710893.3	1159879	935385.9
kalkverweringsgronden	4785	1.3	2	5	9.6	9.6	373230	933075	22549.31	56373.28	39461.3
oude sterk verweerde kleigronden	31885	1.3	2	5	9.6	9.6	2487030	6217575	150258.1	375645.2	262951.6
oude sterkverweerde kleigronden met zanddek	8367	1.4	3	10	19.5	19.5	1054242	3514140	31356.94	104523.1	67940.04
buitendijkse kleigronden	58414	1.1	3	5	9.6	9.6	5782986	9638310	349388.7	582314.6	465851.7
moerige zandgronden	155168	0.45	28	48	60	35	58653504	1.01E+08	566983.9	1666238	1116611
zandgronden met eerdlaag of matig dik humeusp	527754	1.4	3	10	19.5	19.5	66497004	2.22E+08	1977860	6592865	4285362
kalkloze zandgronden met dunne bovengrond	35005	1.4	3	10	19.5	19.5	4410630	14702100	131188	437293.2	284240.6
lemige zandgronden	88460	1.3	4	13	19.5	19.5	13799760	44849220	410454.4	1333977	872215.6
niet lemige zandgronden	673157	1.5	1	4	19.5	19.5	30292065	1.21E+08	900994.8	3603979	2252487
zandgronden met kleidek	68586	1.3	2	5	9.6	9.6	5349708	13374270	323211.5	808028.8	565620.2
buitendijkse gronden	30981	1.4	3	10	19.5	19.5	3903606	13012020	116107.3	387024.2	251565.7
lossgronden	46805	1.3	4	13	19.5	19.5	7301580	23730135	217175.2	705819.4	461497.3
TOTAAL	3115800						3.97E+08	9.45E+08	13310602	36094531	24702566

TABEL 2 De stikstofvoorraad in het Nederlandse bos en voor de berekening gebruikte karakteristieken.

NAALDBOOMSOORTEN (1989)

BOOMSOORT	AREAAL (ha)	HOUT VOORRAAD (m3/ha)	OOGST (m3/ha/jr	BIJGROEI (m3/ha/jr	VOLUMIEKE MASSA vers (kg/m3)	vocht 12 (kg/m3)	droog (kg/m3)	C/N RATIO	TOTAAL VOOR NEDERLAND HOUT VOORRAAD (m3))	STIKSTOF VOORRAAD (kg)(boven	STIKSTOF VOORRAAD (boven en ondergronds)
grove den	113880	168	4.6	6.8	450-1000	510	455	160	19131840	31555579	39444473
overige den	18840	160	4.7	9.5	450-1000	510	455	160	3014400	4971876	6214845
douglas	15800	197	5	13.1	640	530	473	160	3112600	5336941.8	6671177
lariks	18065	187	6.9	11.6	800-900	600	536	160	3378155	6563755.2	8204694
overige naaldhout	17113	177	5.5	13.5	450-1000	510	455	160	3029001	4995958.5	6244948
naaldboom totaal	183698								31665996	53424110	66780138

LOOFBOOMSOORTEN (1989)

BOOMSOORT	AREAAL (ha)	HOUT VOORRAAD (m3/ha)	OOGST (m3/ha/jr	BIJGROEI (m3/ha/jr	VOLUMIEKE MASSA vers (kg/m3)	vocht 12 (kg/m3)	droog (kg/m3)	C/N RATIO	HOUT VOORRAAD (m3))	STIKSTOF VOORRAAD (kg)(boven	STIKSTOF VOORRAAD (boven en ondergronds)
inlandse eik	44531	186	3.4	7	900-1200	700	625	160	8282766	18765642	23457052
beuk	8481	285	6.1	12.8	960	720	643	160	2417085	5633923	7042404
populier/wilg	20411	150	7.3	14.6	880	450	402	160	3061650	4461589.5	5576987
overige loofhout	32400	127	2.9	8.4	880	450	402	160	4114800	5996292.3	7495365
loofboom totaal	105823								17876301	34857446	43571808
TOTAAL BOS	289521								49542297	88281557 (bovengronds)	1.1E+08 (boven:onder = 8:2)

TABEL 3 De stikstofvoorraad in de veestapel en voor de berekening gebruikte dierkarakteristieken.

VEESTAPEL

RUNDVEE (1990)	AANTAL	GEWICHT PER DIER (geslacht)	GEWICHT TOTAAL	AANHOUDNGS PERCENTAGE	GEWICHT TOTAAL (levend)	GEHALTE STIKSTOF (kg/kg)	VOORRAAD STIKSTOF (kg)
jongvee (< 1 jaar)	806000	100	80600000	50	1.61E+08	0.025	4030000
vrl. jongvee (> 1 jaar)	880000	269	2.37E+08	58	4.08E+08	0.025	10203448
melk- en kalfkoeien	1878000	290	5.45E+08	56	9.73E+08	0.025	24313393
stieren (> 1 jaar)	43000	328	14104000	59	23905085	0.027	645437.3
mestkalveren	602000	154	92708000	62	1.5E+08	0.0302	4515777
ander jongvee v. mesterij	598000	100	59800000	50	1.2E+08	0.025	2990000
mest- weide- zoogkoeien	120000	290	34800000	56	62142857	0.025	1553571
totaal rundvee	4927000		1.06E+09		1.9E+09		48251627

PAARDEN (1990)	AANTAL	GEWICHT PER DIER (geslacht)	GEWICHT TOTAAL	AANHOUDINGS PERCENTAGE	GEWICHT TOTAAL (levend)	GEHALTE STIKSTOF (kg/kg)	VOORRAAD STIKSTOF (kg)
< 3 jaar	17340	215	3728100	50	7456200	0.025	186405
> 3 jaar	32591	284	9255844	50	18511688	0.025	462792.2
pony's	19661	215	4227115	50	8454230	0.025	211355.8
totaal paarden	69592		17211059		34422118		860553

SCHAPEN EN GEITEN (1990)	AANTAL	GEWICHT PER DIER (geslacht)	GEWICHT TOTAAL	AANHOUDINGS PERCENTAGE	GEWICHT TOTAAL (levend)	GEHALTE STIKSTOF (kg/kg)	VOORRAAD STIKSTOF (kg)
lammeren	884000	26	22984000	52	44200000	0.025	1105000
ooien	790000	26	20540000	55	37345455	0.025	933636.4
rammen	28000	26	728000	55	1323636	0.025	33090.91
geiten	61000	13	793000	55	1441818	0.025	36045.45
totaal schapen en geiten	1763000		45045000		84310909		2107773

VARKENS (1990)	AANTAL	GEWICHT PER DIER (geslacht)	GEWICHT TOTAAL	AANHOUDINGS PERCENTAGE	GEWICHT TOTAAL (levend)	GEHALTE STIKSTOF (kg/kg)	VOORRAAD STIKSTOF (kg)
biggen bij zeug	2397000	25	59925000	79	75854430	0.024	1820506
biggen niet bij zeug	2794000	25	69850000	79	88417722	0.024	2122025
mestvarkens (20-50 kg)	3142000	83	2.61E+08	79	3.3E+08	0.024	7922613
mestvarkens (> 50 kg)	3883000	83	3.22E+08	79	4.08E+08	0.024	9791058
fokvarkens (20-50 kg)	160000	83	13280000	79	16810127	0.024	403443
fokvarkens (> 50 KG)	225000	83	18675000	79	23639241	0.024	567341.8
fokvarkens (zeugen, gedekt)	958000	83	79514000	81	98165432	0.024	2355970
fokvarkens (zeugen, bij big	252000	83	20916000	81	25822222	0.024	619733.3
fokvarkens (zeugen, overige	62000	83	5146000	81	6353086	0.024	152474.1
fokvarkens (beren, opfok)	14000	83	1162000	81	1434568	0.024	34429.63
fokvarkens (beren, dekrijp)	28000	83	2324000	81	2869136	0.024	68859.26
totaal varkens	13915000		8.54E+08		1.08E+09		25858454

PLUIMVEE (1990)	AANTAL	GEWICHT PER DIER (geslacht)	GEWICHT TOTAAL	AANHOUDINGS PERCENTAGE	GEWICHT TOTAAL (levend)	GEHALTE STIKSTOF (kg/kg)	VOORRAAD STIKSTOF (kg)
slachtkuikens	41172000	1.82	74933040	100	74933040	0.0304	2277964
moederdieren (< 5 mnd)	2882000	2.5	7205000	100	7205000	0.0304	219032
moederdieren (> 5 mnd)	4391000	3	13173000	100	13173000	0.0304	400459.2
leghennen (< 18 wkn)	11121000	2.5	27802500	100	27802500	0.0304	845196
leghennen (> 18 wkn)	33199000	3	99597000	100	99597000	0.0304	3027749
totaal pluimvee	92765000		2.23E+08		2.23E+08		6770400
TOTAAL VEESTAPEL							83848807

Nederlands standpunt over Natural Resource Accounting zoals ingebracht in de desbetreffende workshop van de OESO–group on the State of the Environment op 28 januari 1993

Natural Resource Accounting (NRA)
The Netherlands' views and modes of applications

1. The need for NRA

The UNCED conference, as worded in e.g. Principle 2 of the Rio Declaration and in Agenda 21 chapter 8,. section D concerning: "Establishing systems for integrated environmental and economic accounting", recognized the need for NRA as an instrument to advance sustainable development. Hereto, in paragraph 8.41 "A programme to develop national systems of integrated environmental and economic accounting in all countries is proposed".

2. The main approaches to NRA

Traditional economic approaches state that generally the environment is considered as natural capital.
In this context one can state that economists have been grappling since the 19th century with the question of the environmental contribution to production, from the physiocrats that considered land to be the only truly productive agent to Daly (1980, 1990), who considers the environment (and no longer man-made capital) to be the restricting factor on the economy. There is disagreement on how the environmental issue should be included in economic analyses.

The recurring theme of the economists' discussion is the question if environmental factors can be substituted by manufactured capital and, if so, to what extent. Supposing substitution to be possible the existing techniques to valuate manufactured capital might be useful to measure the environmental contribution.

To avoid this issue economists as Boulding, Daly, Ayres and Georgescu-Roegen take the laws of thermodynamics as a starting point for their analysis (Boulding, 1980 ; Daly, 1980 ; Ayres & Kneese, 1989 ; Georgescu-Roegen, 1980). Rather than trying to express the environment in terms of money, they put emphasis on describing the economic system in physical terms: flows of energy and matter. One product of this school is the careful construction of material balances, which serve as a good starting-point for NRA.

In order to achieve an integration between environment and economy in this perspective a reform of the aggregate economic measures is advocated (MacNeill, 1991, p 43; WORLD BANK, 1992, p 287).

More specifically activities concern:
- development of satellite accounts
- adjustment of the national accounts
- calculation of a "green GNP"

An important matter regards the monetarization of the NRA

The main use of NRA for direct economic purposes has in the past been suggesting
(a) a translation of the resources in terms of money and, therefore,
(b) taking into account only environmental resources with a direct economic use.

This would make the use for other goals very difficult, it disregards the resources that cannot yet be translated into monetary terms. Though considerable work has been done on the monetarization of natural resources there is no agreement on methods and scope.

No easy solution is to be expected for the valuation of natural resources, as natural resources often both represent a direct consumable good (the tree as wood) as capital to produce new goods (the tree as progenitor of trees).

Information on the state of the environment is dependent on data on the 'life-support' type of resources. However, it may be argued that the 'life support' resources are even more crucial for the economy than the 'source' resources, but their scarcity is not reflected in a market. While the sources represent the 'goods', the life support system represents the 'services' delivered by the environment, i.e. the maintaining of viable circumstances by cleaning up and preserving vital material cycles and energy chains, so far for free. As Edward Barbier states "these services are largely provided by common-property resources directly to individuals or economic processes and so lie outside the market mechanism" (Barbier, 1989).

Integrated environmental approaches generally are based on the contribution of the environment to the society in term of functions.

In general three main functions are distinguished, that is the source, sink and life-support functions.

Various lists of functions, some dating back twenty years or more, are found in the ecological literature. These lists are not contradictory; generally they can easily be translated into each other. In the accepted opinion the environment adds to the economy by delivering materials, by storing or processing waste, and by generating optimal conditions for life. The following terms for these functions 'Source', 'Sink', and 'Life support system' (Barbier, 1989 ; E.P. Odum, 1989) can be presented.

As a source the environment delivers both biotic and abiotic resources, such as minerals, metals, wood, water and fish. All materials withdrawn from the environment are part of cycles. For some however the period is far beyond the human time-scale. Biotic resources are renewable to a certain extent. The extinction of a species however is irreversible.

The sink function of the environment refers to the function of garbage can a purification installation. Waste can be stored or incinerated. In the last case the gas of combustion is dumped. On the other hand waste can be decomposed by micro-organisms. In all cases the environment delivers a service.

Human life on earth is only possible when temperature, level of radiation, acidity, composition of the atmosphere oscillate between certain boundaries. The environment regulates the conditions of the biosphere to a large extent by keeping the global material cycles going. Perhaps these cycles could be run by man-made capital and labour but there is no doubt about the fact that it would be much more expensive. In the last few years there is a growing body of evidence that lifeforms and ecosystems play a crucial role in maintaining these cycles. This function is referred to as the providing of the life support system.

Environmental problems arise (a) by depletion of sources, (b) by exhausting the waste-storing and cleaning capacity of the environment, and (c) by unsettling the life support system.

It can be stated that environment and economics are still separate disciplines, though recent activities concentrating on the relationship between economy and the environment try to find a productive combination of the two. The International Society for Ecological Economics has been set up for the this purpose (Costanza, 1991). Furthermore, the work of the United Nations framework for a recommended System for Integrated Environmental and Economic Accounting (SEEA) describing. Natural Resource Accounting as one of the elements of integrated environmental and economic accounting (Statistical Office of the UN, 1992) should be mentioned.

3. The multifunctionality of NRA

Based on the items presented above in our view an accounting of natural resources should serve more than one purpose. The following purposes can be mentioned:
- adjustment of the national accounts
- development of satellite accounts
- calculation of a 'green GNP'
- information on the state of the environment
- evaluation of environmental policies

In our opinion Natural Resource Accounting (NRA) should provide the data needed to integrate environmental and economic accounting and to derive relevant economic and environmental policy performance indicators. Natural Resource Accounting can be developed and discussed without pronouncing judgement if and how the System of

National Accounts will have to be adjusted. Monetarization of natural resources, in our view, is not essential for NRA. The account should be made in physical terms and has a value and purpose in its own right.

Based on the standpoint here presented, NRA should contain data relevant to the state of the environment as a result of economic activities, as well as for the state of the economy as a result of the use of natural (environmental) resources. This choice has several consequences:

- the account should not be presented in terms of money
- the account should be presented in terms that are translatable into market terms, money
- the account should be presented in terms that are translatable into environmental terms, for instance environmental quality indicators.

These requirements have to be met in order to give NRA a proper place in the total of economic/environmental data and accounts, a place between the enormous amounts of statistical, monitoring and other data available on the one hand, and the highly complicated indicators for economic and environmental well-being on the other.

4. Natural resource accounting in practice

Reporting on the international experiences with NRA, ERL concludes, heavily leaning on the Norwegian experience, that (ERL 1992):

- resource scarcity is no longer considered to be the major environmental problem
- analysis is considered as important as data
- the efforts of establishing a natural resource accounting system were underestimated.

The Norwegians now limit the accounting to energy and air pollution and use the data as input for macroe-conomic models.
The French system is set as a detailed information system, but "to date there is little evidence of the use of the system" (ERL, p 21).
The Netherlands Central Bureau of Statistics starting from available data, offers a workable account, but a theoretical base is not presented.
Lacking in all three is the living and dynamic component: the contribution of the services delivered by self-organizing and self-maintaining ecosystems. The French and the original Norwegian systems do pronounce the importance of these, but have not as yet offered an accounting method.

The main conclusion to be drawn from the ERL survey in our view regards the matter that given the efforts needed NRA systems only should be developed whenever a proper use for policy making purposes is identified in advance.

What constitutes a natural resource needs definition and specification. Here the users should be involved.

Generally a practical approach is taken and after a rough classification a list is made of accountables. The earlier classifications were based on renewability as sole distinguishing concept. This has proved to be unsatisfactory, especially for the implications that have been presented for resource management: we should shift from the use of non-renewable to the use of renewable resources. Lifeforms, for example, are classified as 'renewable', but species can be exhausted irreversibly. On the other hand, non-renewable matter, especially on the elementary level, never disappears as the first law of thermodynamics tells us, but it may be dispersed and therefore it may cost more energy to render it available. To solve this dilemma the distinction into three categories has been made: renewable, conditionally renewable and non-renewable (Lone, 1987, p 13). Life forms are classified under 'conditionally renewable', thus bringing in some caution in the use of these resources. A distinction into live, dead and non-living resources, can be presented, emphasizing the role of life. In the context of squandering policy theme (Ministry of Housing, Physical Planning and the Environment, 1989) the distinction has been made into renewable resources, non-renewable resources and environmental (water, soil, air) resources.

The characteristics of a resource determine the way its future use is threatened and the form of an environmentally wise resource management. Recycling and reuse are viable options for metals, for the other resources the terms are meaningless. Biotic resources can be harvested, but only if the population is safeguarded.

5. The Netherlands' views on modes of application

Based on the three ecological functions mentioned above in our view natural resources can have several different functions. A natural resource can be

- a source of materials, energy and information
- a sink for waste products
- a part of the biogeochemical system which supports human life by keeping the chemical and physical conditions on earth optimal for it (life support system).

The specific 'natural resources' used to fulfill the three functions mentioned above, differ in time and space. What constitutes a natural resource for a society is largely dependent on the society and its dominant mode of production. Some natural resources, such as water, are vital for all societies. But the availability of fossil fuels was of no importance two hundred years ago, nor will it be two hundred years from now, but in the industrial societies of today it is of a key resource.

The function that a resource fulfills in current society depends on it's characteristics.
In view of both the abatement of squandering of resources (with the purpose of avoiding environmetal pollution) and the advancement of integral life cycle management different types of resource can be distinguished on a character basis:

- Resources such as those of stocks of metals can not said to become exhausted by use, as the element will continue to exist, though generally in a more dispersed form. Recycling and re-use are viable options for metals, for the other resources the terms are meaningless.
- Resources such as carbon, water and nitrogen are part of global cycles. Tapping these cycles cannot exhaust the materials on the level of chemical elements. However, a magnification or reduction of the cycle can disturb the life support system.
- Resources such as stocks of fossil fuels represent accumulated solar energy. Use of the fuels is equal to conversion of the chemically bound energy into heat, which is then lost into space.
- Resources such as stocks of living entities do renew themselves under favourable conditions, but extinction

of species is irreversible. Careful harvesting of the stock may well continue nearly infinitely.
- The flux of incoming solar energy is a flow-type resource that will last as long as the sun does. Use of solar energy will not diminish the flow, but conversion of the energy may influence the physical properties of the earth.

These different types of resources can be grouped for example in terms of renewability.

Resources can be accounted on different levels of scale. Most resources, such as wood and minerals, are in fact global resources. Some resources are even purely global or at least international, such as the atmosphere, the oceans or the ozone layer; these are very difficult to account for in a national NRA system. Accounting for those on a global level therefore must be strongly recommended.
For global resources, a national accounting should express:
(a) the contribution of the nation to the global resource stock, and
(b) the contribution of the nation to the global use or consumption of the resource (the flow).
The contribution of a nation to both the worlds stock and its consumption may best be described by a (yearly) balance, wherein not only production and use but also import and export are included. In the account, if we take the example of wood, therefore not only the raw materials must be visible, but also the finished products, in fact the whole materials life cycle. It also means that a picture is required of the nations consumption of resources not recovered or produced within the nation itself.
Accounts can be differentiated per type of resource. In the case of non-renewable resources emphasis can be laid on the stocks. In the case of renewable ones accounts of flows are essential since rates of flow can be varied or restricted to manage the stocks.

Resources can be accounted in more detail on a national level than on a global level. Information can be included not only about quantity, but also about quality. If we are, for instance, accounting 'forest' , we can not only include figures on wood production but also on the vitality, the types of forest, the species composition, the undisturbed areas, and suchlike. Such a further classification of resources based on qualitative aspects is most probably very relevant for a natural resource management strategy: while the forest area remains the same, a regression in vitality indicates a future or even present loss of function.

A national resource account should have its proper place among other accounts. This means that no information must be included that is already presented elsewhere, otherwise than directly related to contribution to and use of a certain resource. Therefore, a system of NRA must not present any details with regard to
- environmental quality aspects, i.e. concentration levels of chemicals in the environment in relation to environmental standards

- emissions and pollution levels related to environmental policy themes (acidification, ozone depletion, etc.).

Considering the three functions of resources in our society, the following preliminary list of resources to be accounted can be presented:

Selection of important natural resources

Source
- metals (resources on an elementary level)
  - bulk metals (Fe, Al)
  - metals (Pb, Zn, Sn, Ni, Cr, Cu, Cd, Hg, Mn)
  - trace elements (Ga, Ge)
- nutrients
  - macro nutrients (P, mineralised N, K, (S), O, H_2O): as these are part of global cycles the account can be integrated with that under 'Life Support System' (below)
- surface minerals
  - grit, sand, marl, clay
  - biomass
  - wood
  - fish
- biodiversity
  - genetic diversity: species (flora; if possible fauna and fungi)
- fossil fuels: natural gas, mineral oil, coal (hard, soft, lignite)

Sink
- land-surface in categories of use:
  economy: for example: industry, housing, infra-structure (roads, railway, airports, harbours, waterways) agriculture, recreation
  nature: natural forest, heathland, coastal dunes, wetlands
- land-surface in types of soil, regardless of use, for example: peat, sand, clay

Life Support System
- global cycles of water, C, N, O, P, S
- the ozone layer (possibly a part of the O cycle, but deserving separate attention)
- natural ecosystems:
  - quantity: biomass (therefore, special attention for forests and wetlands); surface/type
  - quality: vitality, species composition of ecosystems

Summary

In conclusion in the first place NRA can be defined as follows

Natural Resource Accounts are collections and manipulations of statistical data describing in physical terms the state and changes in the stocks and flows of natural resources providing the human economies with goods and services.

Secondly the multifunctionality of NRA must be underlined, providing data needed for the integration of economy and environment.
Thirdly a classification in types of recources is advocated in support of processes concentrating on the identification of key resources that need monitoring.

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