ADVICE

TOWARDS A MORE ECOLOGICALLY SUSTAINABLE LAND USE

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This advice was formally approved at a meeting of the Technical Committee on Soil Protection on 4 June 2003.

On behalf of the Committee

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Many forms of land use in the Netherlands are not sustainable. The consequences of this unsustainable use can be seen for example in land subsidence, the accumulation of nutrients in the environment, a reduction in the useful organic matter in agricultural land, an impoverishment of our flora and fauna and the loss by crops of natural resistance to disease and pests. Land use in the Netherlands can be made more sustainable by adopting an ecosystem approach to managing the soil. Soil management can be instrumental in making land use more sustainable, and refers to all activities consciously performed in order to put land to a particular use, now and in the future.

Introducing an ecosystem approach to soil management makes it easier to identify and anticipate the adverse effects of present land use. This prevents these effects merely being displaced, improves the chances of changing to other forms of land use and reduces the costs to society, both long and short term, associated with using land unsustainably. The ecosystem approach, by strengthening the ecological basis for land use, will ensure that the soil retains its value to society in the long run. An ecosystem approach to soil management also makes it clearer which parties must be involved in land use planning and development.

Ecosystem-based soil management is based on three principles:

7 **Sustainable use of soil and water**

The use to which an ecosystem is put is related to its quality and ability to support that use. The effects of intervening in or changing the land use are evaluated at the spatial and temporal level of the ecosystem to prevent problems associated with reduced quality or a change in quantity being merely displaced or deferred, to surface elsewhere or later.

8 **Multisectoral approach**

A multisectoral approach leads to a process of ongoing coordination between the different policy areas (e.g. spatial planning, water management, the environment) and the various planning levels: international, national, provincial and local (municipal and water board). All agencies/persons with a management function, as well as other stakeholders, take part in the planning process within the framework of long term objectives.

9 **Integrated management structure**

The responsibilities for managing the ecosystem should be assigned and coordinated at the policy, planning and operational levels. The relevant agencies should actively assume these responsibilities.

SUSTAINABLE USE OF SOIL AND WATER

The existence of a healthy ecosystem suggests that the soil and water are being used sustainably. The health of an ecosystem can be inferred from properties such as its activity levels, stability, resilience and organisation. These properties cannot yet be expressed in well-defined, measurable indicators. The Technical Committee on Soil Protection therefore proposes that the functioning of the ecological services is taken as a proxy for the health of an ecosystem. Ecological services are the properties of and/or processes in an ecosystem which are of use to man. The main ecological services are: soil fertility, adaptability & resilience, buffer & reactor functions, biodiversity, resistance to disease and pests and physical structure. These ecological services are important for all forms of land use and are interdependent. It is assumed that a healthy ecosystem can provide these ecological services as appropriate.

Land use was once always based on the ecological services provided by the soil, but these have gradually been displaced by technical and chemical expedients which are often harmful to ecosystems and the environment, and to the functioning of the ecological services themselves. For example pesticides harm the organisms which control pests naturally. The Committee is convinced that land use can be made sustainable by maintaining and nurturing the ecological services, as this will reduce the need to use detrimental expedients. It has formulated a number of guidelines by which this can be done.

The ecosystem not only provides ecological services for a particular land use, but also imposes constraints on that use. These constraints are frequently ignored, leading to adverse ecological and environmental effects and, often, problems with the use of the land, for example when a woodland type with a high transpiration rate is planted on drought-prone land. More common is where technical or chemical techniques are used to adapt an ecosystem to a particular use, with the same negative consequences, for example draining peatlands for agricultural purposes. Land use can be made much more sustainable by respecting these constraints, and ensuring in planning decisions and development projects much more than at present that the soil is suitable for the use proposed.

In managing the ecological services a distinction is made between the local level and the level of the catchment. Ecological services are important for all forms of land use, but not in equal measure. The difference in importance for different land uses will increase as we look at specific aspects of the ecological services. Ecological services directly relevant to the local land use must be managed at the local level. Large-scale ecological services such as water buffering and the fixing of greenhouse gases must be managed at the catchment level.

MULTISECTORAL APPROACH

Ecosystem-based land use planning requires the integration of policies on land use, water, nature conservation, agriculture, the environment in its wider sense and spatial planning. Although this integration is beginning to take place, the regulations which affect the management of the soil continue to display many sectoral features. If an ecosystem approach is adopted, these rules can be improved and better coordinated. More sustainable land use will mainly be achieved by means of non-regulatory means. Stimuli should certainly have a good chance of succeeding at the local level because local managers are also dependent on the ecological services. The measures envisaged by the Committee include public information, demonstration projects, and the development and provision of tools such as sustainability screening, more sustainable tillage methods, environmental benchmarking and simple monitoring tools. The ecological services which need to be maintained at the catchment level are those of more general importance. It will be more difficult to convince local managers that they should contribute to the maintenance of these general ecological services, and regulation will produce better results.

INTEGRATED MANAGEMENT STRUCTURES

All the relevant persons/institutions should be involved in the management structure when an ecosystem-based approach to soil management is being taken. Who these are will depend on the issue involved and the spatial scale on which the issue operates. At present there is no forum which brings together all the relevant managers to consider land use management issues. The Committee considers that such a forum can be established through better coordination and organisation of existing institutions. In specific cases, such as De Kempen, consideration could be given to setting up a separate management organisation.

The responsibility for implementing soil policy can in principle vest locally. The Committee summarises in its advice the ecological services (or aspects of these services) locally relevant for agriculture, nature area, public open space, allotments and domestic gardens. Local authorities should make clear to land users their dependency on ecological services, and the importance and benefits of preserving these services. This can be done either directly or in cooperation with private and semi-governmental organisations involved with land use and soil management issues. It will in any case be necessary to cooperate with these organisations, since they play a major role in supervising and managing land use.

At the catchment level the authorities need to concentrate on the ecological services which need to be maintained and supervised at a higher spatial level, e.g. water buffering and the storage and emission of greenhouse gases. Authorities at the catchment level need to deal with local authorities and other organisations involved with land use and soil management, or with the local users directly, on matters related to soil management which act on a larger spatial scale.

In development projects all government agencies should take account of the constraints on use imposed by the ecosystem, or more specifically the soil. These should be dealt with if possible by matching land use to soil type rather than by using artificial expedients to enable the land to be used in the desired way. Knowledge is needed for this. In the view of the Committee this knowledge is available, but is not being sufficiently deployed at present. The Committee recommends that this knowledge is made more available, and that spatial planners, developers and land users should continue to be made aware of the need to match land use to the characteristics of the ecosystem.

MONITORING

In order to determine the condition of the ecological services and to monitor whether the policy adopted has produced the desired result, monitoring needs to be carried out using indicators. The Committee considers that an indicator set for ecological services developed in the Netherlands (BISQ) and with which some experience has already been acquired offers the best prospects. Following comparison with a Danish system of microbiological indicators of ecosystem health, it is considered that a number of additional elements ideally still need to be added to the BISQ. Routine monitoring with the BISQ would be costly, however. Priorities need to be set regarding the scale of the monitoring effort, the number of indicators to be measured and how the effort should be apportioned between the different parties involved with soil management. The Committee proposes a smaller indicator set for different forms of land use at the local and catchment level, partly based on the BISQ. It also recommends that standards for the indicators are not set at this time. More experience first needs to be acquired with ecosystem-based management and indicator-based monitoring.

RECOMMENDATIONS

Sustainable use of soil and water

- Land use needs to be made more sustainable in order to reduce existing - and prevent new – environmental problems and the costs these bring with them, to maintain the ecological basis of land use, thereby maintaining the economic and socio-cultural value of the soil in the long term.

- Land use will be made more sustainable by nurturing and developing the ecological services and ensuring that the soil is suitable for its present or future use.
- Policy should in the first place seek to maintain the ecological services if they are sufficiently developed to support the land use sustainably, or to develop the ecological services in the 'right' direction if not.
- In land use planning and development projects account must be taken of the constraints which the ecosystem imposes on land use.

Multisectoral approach

- Land-use in the Netherlands has for many years had damaging effects, thereby imposing costs on society. There are currently many social and political trends which are affecting land-use, including the intensification of land-use, increasing use of underground space, the changing climate, the increasing need to tackle flooding, falling water tables and land subsidence, changes in agricultural methods in the Netherlands and in the European agricultural policy and the development of the EU land-use strategy. These trends are both reasons and pointers to the government to begin to promote a more ecologically sustainable use of land along the lines described in this advice.
- The Committee would like to see the main elements of this advice reflected in the proposed *Nota Ruimte* (Spatial Planning Memorandum), the national agenda for a vital countryside and the soil policy letter.
- The ecosystem approach here recommended, including assessing the suitability of the soil for present or future land use, is relevant or applicable to the Water Framework Directive, the EU soil strategy, the planned European agricultural policy and the increasing integration of water policy and land-use planning. The Committee recommends that policy-makers should endeavour to apply these ideas in new policy initiatives.
- Underground space also needs to be actively managed, with both qualitative and quantitative characteristics being protected. At present, clear management responsibilities and rules for the use of underground space are lacking.
- Land use planning exercises such as national spatial plans and regional development plans should include a cost-benefit analysis in which the local benefits of a particular land use are weighed against the costs (which usually emerge in the long term and on a larger spatial scale), adopting an ecosystem approach.
- The suitability of the soil and subsoil, seen as components of a wider ecosystem, for the present or future land use should be one of the main criteria used in spatial planning and development plans.

- Existing Dutch legislation which affects land use should be analysed to check whether the ecosystem approach can be applied, and amended if necessary. Better coordination of this legislation is also needed, also based on an ecosystem approach.
- The Committee recommends that stimuli are devised to encourage local land users to manage and develop the ecological services. Existing policy instruments can be used to some extent, but new instruments may also have to be developed.
- The Committee recommends that local land users contribute to the maintenance and development of the ecological services which are important on a larger spatial scale. Regulations will probably be needed to achieve this.
- The Committee considers that the Netherlands should endeavour to introduce sustainable land use practices into the European *Good Agricultural Practice*.
- More room needs to be made available for experimental purposes, so that more sustainable uses of land can be developed, though this sometimes runs counter to existing legislation and regulations.
- The Committee would like to be involved in granting special dispensations for the purpose of research into the development of more sustainable forms of land use.
- The Committee recommends the introduction of a system of indicators for ecological services in order to monitor the condition of and trends in the ecological services and the results of the policy adopted.
- The Committee considers that it is not yet opportune to set standards for the indicators for ecological services; more experience should first be gained with an ecosystem-based approach to soil management and the use of the indicators.

Organisation

- In considering soil management issues, a distinction needs to be made between the local, regional and river basin levels. The regional level is less important in the management of ecological services, but it is important for spatial planning and development projects.
- Cooperation and coordination needs to be implemented between the various government agencies and with umbrella organisations and environmental protection / nature management organisations.
- The local soil managers must be made responsible for implementing sustainable soil management practices.

Developing and disseminating know-how

The Committee considers the following actions necessary to develop and disseminate know-how on using land more sustainably:

- Establish an ongoing survey of sustainable management instruments and the reasons for using land sustainably.

- Develop and implement criteria for testing the sustainability of land uses.
- Continue development of an indicator-based monitoring system for ecological services on different spatial scales.
- Continue development of more sustainable forms of land use, for example more sustainable land cultivation plans.
- Develop and promote the use of environmental benchmarking systems.
- Promote the transfer of traditional know-how and of the lessons learned from the demonstration projects.
- Give more prominence to the role and functioning of ecosystems in technical education, for example in civil engineering and agricultural production systems.
- Develop, ultimately, targets for indicators for ecological services relative to economic and socio-cultural values.

The Committee has drawn up a considerable number of recommendations, and would appreciate being kept informed of progress.

1 INTRODUCTION

In a letter dated 30 March 2000 the Minister of Housing, Spatial Planning and the Environment (VROM) requested the Technical Committee on Soil Protection (TCSP) for advice on the role and significance of soil ecosystems for land use (see Annex 1). We have drawn up two advices on this subject [1, 2][1] and indicated that we wished to prepare a third advice on the way the soil ecosystem could play a more central role in land use policy and spatial planning. In his response the Minister of VROM indicated that the first two advices provide support for the policy already being pursued and were helpful in orienting future policy [3]. At the request of the Ministry of VROM we did not draft our third advice until the 'Soil & Ecology' review [4] had been completed. This review, commissioned by the Ministry, was drawn up by a nucleus of experts in soil science and ecology, including a number of TCSP members. The Ministry of VROM intends to inform Parliament in 2003 by means of a policy letter on sustainable land use. We understand that this letter will contain the government's long-term vision on the soil ecosystem and how we should deal with it. Regard will be had to our third advice in drawing up this letter.

The *Soil and Ecology* review has now been published [4]. This review contains recommendations on how the ecology of the soil in rural areas can be described and used to promote a more sustainable land use in spatial planning, land development and environmental protection policy in the Netherlands. In concrete terms, the main recommendations are summarised below.

- Policy to conserve the ecological quality of the soil should focus on preserving and maintaining ecological cycles.
- A natural supply of nutrients, resistance to disease and good soil structure require the careful management of organic matter, measures to counter contamination and that soil structure enhancing organisms and antagonists are introduced into the soil and nurtured.
- Before undertaking habitat creation projects, the suitability of the soil should be examined.
- Soil biodiversity should be protected.
- Programmes for monitoring whether policy is effective should make use of judiciously chosen physico-chemical and biological indicators of the quality of the soil ecology.

TERMS

[1] These are appended as Annexes 5 and 6 to this document.

This advice supplements our earlier advices and the review referred to above. As requested we have focused mainly on the functioning of the ‘soil ecosystem’ in relation to land use. The advice presents our vision on how the living component of the soil should be approached in the context of land use. The accent will be on the surface layer because this is the most biologically active and intensively used component. The surface layer is difficult to delineate precisely, and depends on the particular land use in question and the situation being considered. In our earlier advices we have treated the top 150 cm as being an adequate definition for practical purposes; this is the layer which is important for the above-ground part of the ecosystem [5, 6, 7].

In referring to spatial matters the terms ‘soil system’, ‘soil ecosystem’ and ‘ecosystem’ usually mean the same thing. In the mainly ‘abiotic’ disciplines (soil science, geology) the term soil system is more common, while in ‘biotic’ subjects (biology) the term (soil) ecosystem is preferred. In this advice we shall emphasise the living, time- and space-dependent process side of the system, of which the surface vegetation is a part. In this connection the term ‘soil ecosystem’ used in the advice request is too limited, and we prefer the term ecosystem. The ground and surface water are definitely considered to form part of the ecosystem.

In this advice land use relates to the physical use of land by society, this land forming part of the ecosystem. Major land uses include: agriculture, forestry, construction, infrastructure (above and below ground), recreation, nature area, the extraction of water and minerals. A large proportion of Dutch land is used for ‘green functions’ such as agriculture and area. The emphasis in this advice is therefore on rural land, but it also considers land use in urban areas, since even urban ecosystems are indispensable for a number of forms of land use, namely gardens and public green space. Furthermore small scale sustainable land use, including in urban areas, contributes to sustainable land use on a larger scale.

STRUCTURE OF THIS DOCUMENT

The first part of this advice (chapters 2 - 4) describes the reasons and basis for sustainable land use. The second part (chapters 5 - 6) begins to look at how the concept of ecologically sustainable land use might be operationalised. Chapter 2 presents our vision of a more sustainable land use and the role of the ecosystems in this vision. Chapter 3 introduces the concept of ecosystem health. It is proposed that sustainable land use be based on implementable criteria for the health of ecosystems, referred to as ‘ecological services’. Sustainable soil management should seek to maintain and nurture the ecological services and ensure that the ecosystem is suitable for the desired use. We regard soil management as an instrument for implementing a more sustainable land use. Chapter 4 describes the role played by soil management in a more sustainable land use, and considers the principles underpinning soil management, the managers and the spatial scales relevant for soil management. Chapter 5 presents our views on how the public authorities can encourage the sustainable use of land. The relationship between the ecological services, forms of land use and the managers at various levels is central to this issue. Chapter 6 considers how ecological services can be monitored using indicators.

2 MORE SUSTAINABLE LAND-USE

This chapter considers what is meant by sustainable land use and the role of the ecosystem in sustainable land use.

The Fourth National Environmental Policy Plan 4 (NEPP4) [8] used the term sustainable development to embrace not only environmental and ecological considerations but also the economic and social dimensions. Sustainable development essentially means, according to the NEPP4, finding the right balance in managing and protecting these three dimensions.

The Advisory Council on Government Policy (WRR) issued an advice on sustainable development in response to the exploratory policy studies on a national strategy for sustainable development [9, 10]. The term sustainable development was coined by the Brundtland Commission in 1987 in the report *Our common future* [11], where it was defined *inter alia* as development that meets the needs of the present without compromising the ability of future generations to meet their own needs[2]. According to the WRR the Brundtland Commission formulated the concept of sustainable development in two different ways: (a) as a new value expressing the fact that we cannot permit ecosystems to be jeopardised by human activity, (b) as a 'metaterm', a principle according to which all values, needs, institutions, temporal and spatial scales are interrelated, from which the right balance needs to be found.

The WRR considers that the term sustainable development is used in the exploratory studies mainly as a metaterm, and is concerned that it will lose its normative significance. "If all possible government actions are qualified by the adjective 'sustainable', this suggests a quality not necessarily related to sustainability in an ecological sense". It pleads for sustainable development to continue to be seen as a value, based on an ecological substrate, and indicating the need to strike the right balance between the needs of rich and poor, now and later. The WRR considers that sustainable development must remain limited to the ecological aspect and the trade-offs which, **from an ecological starting point,** have to be made with economic and socio-cultural values. This suggests a certain hierarchy, with ecology at the top.

We echo the WRR in focusing in this advice on the ecological basis of sustainable land use, from which starting point, trade-offs can be made with economic and socio-cultural values.

The quip *'Ecology is economy in the long term'*[3] refers to the fact that damage to ecosystems will ultimately impact on the economy, and therefore also the social dimension of land use [13].

Some consider that ecosystems can be regarded, in relation to land use, simply as a utility which must be properly maintained. On this view, only those properties of ecosystems need to be preserved which provide society with its needs. In our view, however, society also has a stewardship function in regard to ecosystems, implying that preserving only the useful properties is not enough, and that regard must also be had to the intrinsic value of the ecosystem.

It is difficult to define the term 'sustainable' precisely. We therefore favour using it in a relative sense, and seek to implement land uses which are at least more sustainable than at present and which recognise both the utilitarian functions and the intrinsic value of ecosystems.

Some current land uses in the Netherlands are intrinsically unsustainable given present management practice. These uses cannot be maintained in this manner in the long term (see Box 1). We also noted in our previous advices on the role and significance of soil ecosystems that land use now no longer maintains an appropriate balance between economy and ecology. Ecosystems are suffering in consequence [1, 2].

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2 See [11].

[3] We have not been able to verify the source of the quotation; it may be: E.T. Odum, *Ecology and society* [12].

Box 1. Examples of unsustainable forms of land use

Land use can be unsustainable when an establishment and the manner in which it uses land are not in harmony with the surrounding ecosystem. Damage occurs, sometimes then and there but often later and elsewhere. Examples include housing on land with a high water table, or the planting of trees with high transpiration rates on land subject to drought. Other examples include locating industrial estates on greenfield sites while there is an abundance of brownfield land available.

An ecosystem is often made 'suitable' using physical and/or chemical artifices which can themselves have ill effects on the soil, for example the use of windmills and pumps to dry land in order to make it suitable for housebuilding or agriculture, resulting in a considerable lowering of the water table, a loss of elasticity by the soil system and its compaction. The benefit is immediate: housebuilding or cultivation in early spring become possible. The negative consequences only become apparent many years later: drainage becomes increasingly expensive, the surrounding dikes have to be raised, the ground becomes more difficult to work because of compaction, the gardens around the houses (built on deeper, stronger foundations) sink, and groundwater-dependent ecosystems suffer parching.

A specific example is peatland [14]. Drainage and working of these lands results in large-scale sinking of the land surface. As a result of the fall in the water table, the peat becomes compacted. Oxygen also gains access to the peat, resulting in its decomposition. These are irreversible processes. The nutrients and pollutants stored for thousands of years in the peat are released, for example to surface water. These nutrients and pollutants ended up in the peat through soil weathering, groundwater, atmospheric deposition, manuring and the influx of water from other areas. Some farmers in peatland areas are able, through good soil management practices, to limit settlement and to maintain better environmental quality than neighbouring farms [15]. In 2002 the Council of State ruled that the municipality of Vlist (Krimpenerwaard) should put a stop to the cultivation of maize in the peatlands around Stolwijk. This was justified by the vulnerability of this area to tillage and eutrophication [16].

An overemphasis on maximising benefits without due attention for the conservation of ecosystems can lead to unsustainable land use. The use of pesticides and intensive cultivation, for example, can harm useful ecological processes, such as natural resistance to pests or the functioning of the organic matter cycle. Another example is the excessive use of fertilisers, resulting in ammonia emissions into the air and the leaching and runoff into ground and surface water of nitrate and phosphate, with a variety of secondary effects. These include, for example, the spreading of undesirable vegetation in nature conservation areas (colonisation of heathland by grass, colonisation of other land by nitrogen-loving plants such as brambles and nettles, the development of rush clumps on land where the water table is being restored), the threat that groundwater used for drinking water will become contaminated by nitrate or metals mobilised as a result of the underground oxidation of pyrite.

3 ECOLOGICAL SERVICES AND SUITABILITY FOR USE

INTRODUCTION

The local benefits of a particular land use impose costs on others (external costs), often here and now, but also elsewhere and later, on a larger geographical scale (see also Box 1, Chapter 1). These costs should be imputed to the local land use. They can, in our view, be internalised by adopting an ecosystem approach to land use.

It is not strictly necessary to treat the ecosystem as paramount in land use planning as far as the ecosystem itself is concerned. Ecosystems are able to adapt continuously to changing circumstances, and when unmanaged, gradually change of their own accord. They develop in a manner optimally adapted to the conditions, even where these are unfavourable. Human intervention in the ecosystem is primarily intended for human benefit. In order to assure this benefit or avoid having to face escalating costs to continue to enjoy the same benefits, regard must be had to the ecological dimension of sustainable land use.

In order to ensure that sufficient weight is attached to the ecosystem in land use planning, we need to know what precisely constitutes ecologically sound land use. The Soil Protection Act describes the purpose of soil protection as: to prevent, limit or reverse changes in the quality of the soil which reduce or jeopardise its functional properties for humans, plants or animals: soil protection is directed at the functional properties of the soil for humans, plants or animals. Ecologically sound land use should therefore involve preventing, limiting or reversing impairment of these functional properties in relation to the requirements of the ecosystem.

ECOSYSTEM HEALTH

In order to decide whether a given land use is ecologically sound, i.e. takes sufficient account of the ecosystem, use can be made of the concept of ‘ecosystem health’. This concept broadens out the term health (usually applied to humans) to apply to ecosystems, thereby referring to the state of an ecosystem which has been affected by human activity. A discussion document commissioned by the TCSP on soil ecosystem health explores this concept in detail [17].

Ecosystem health is a normative concept; it requires values and standards which have to be regularly re-evaluated. It opens the way for policy-makers to set a target quality for the ecosystem in relation to the economic and socio-cultural dimension of the land use. Figure 1 uses an **example** to illustrate how this might work.

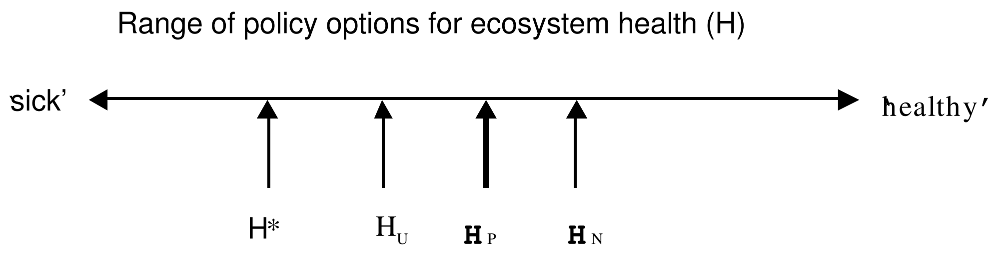

Figure 1. Diagram representing the range of policy options for ecosystem health in relation to a particular land use[4]. The relative positions of the H(ealth) values on the scale from 'sick' to 'healthy' are site-dependent and the positions are **examples**.

H*: minimum health level for a specific local use as estimated by experts;

H_U: health level which would apply if the use were implemented without any government action to deal with the health effect;

H_P: the present health level;

H_N: the health level regarded as desirable or optimal by stakeholders who are not beneficiaries of the local use.

The range of policy options therefore extends theoretically between:

1. the minimum ecosystem health as rated by experts for a given use (H*). Below this value the soil must be regarded as unsuitable for this use; and
2. the health level which in the view of interested parties who are not beneficiaries of the local use would be desirable or optimal given the use (H_N).

The present health (H_P) results from the present land use; the example represents a situation where sustainability is aimed at. The present health usually lies between H_N and H*. H_U is the health which would apply if no sustainability objective were associated with the use. Assuming that a sustainability objective is adopted which promotes healthy ecosystems in order to achieve a sustainable land use, H_U will remain to the left of H_P. In the absence of enforcement or in the event of a disaster H_P and H_U can actually move to the left of H*. The position of H_P is affected by policy in this area. Where efforts are made to make land use

[4] This diagram is adapted from a diagram in OECD *Agri-biodiversity indicators: background paper* [18]. In the original diagram the situation was applied to agro-biodiversity.

more sustainable H_P should move towards H_N; this needs to be considered, however, in relation to the economic and social dimensions of the land use.

The concept of ‘ecosystem health’ also has a number of disadvantages. It is not a very appropriate concept for completely natural ecosystems, because a system uninfluenced by man cannot be healthy or unhealthy, it is merely at a specific stage in its temporal development. Such ecosystems are not to be found in the Netherlands, however. Furthermore defining what constitutes a healthy ecosystem when that system is subject to human influence is not value-free, but is related to what one expects from that ecosystem. The perception of what constitutes a healthy ecosystem can therefore vary over time and depends on the type of ecosystem. Some scientists would prefer an absolute evaluation system and therefore reject the concept of ‘ecosystem health’. Our view, however, is that for complex systems such as ecosystems which are in a state of constant temporal and spatial flux it is virtually impossible to devise an absolute system.

Box 2 lists a number of criteria which can be used to evaluate the health of soil ecosystems. Most of the research on these criteria has been carried out in the field of traditional systems ecology. The list is not exhaustive. Research is currently being conducted into the practical use of the criteria in the context of ecosystem health in the Netherlands [19], but is not yet at the stage where it can be applied shortly. We indicate below the activities which will be needed in order to develop the concept ‘ecosystem health’ into a practical tool for soil policy.

Box 2. Criteria for ecosystem health

These are criteria which could be used to define and evaluate ecosystem health, and are arranged in order of decreasing naturalness:

- *Activity level*. This criterion refers to the energy flows within the ecosystem, measured in terms of nutrient cycles and biomass production. The activity of a healthy ecosystem depends greatly on the type of ecosystem.
- *Carrying capacity*. This criterion refers to the specific capacity of an ecosystem to cope with stress (stability) and to recover after a period of stress (recovery capacity).
- *Organisation*. This criterion refers to the complexity of the ecosystem. Complex systems exhibit greater interaction between species, greater biodiversity and a less prominent role for opportunistic species. It is assumed that a healthy ecosystem is more complex than an unhealthy ecosystem; this of course depends on the development stage of the ecosystem.
- *Absence of pathological symptoms*. A healthy ecosystem is characterised by the absence or near absence of characteristic pathologies, such as a reduction in biodiversity, inhibited primary production, increased occurrence of opportunistic species and pests.
- *Dependency on external inputs*. The dependency of a healthy ecosystem on external inputs (for example energy, organic matter, fertilisers, water, pesticides) to maintain the activity of the ecosystem reduces over time, whereas this dependency increases in an unhealthy ecosystem.
- *Damage to adjacent systems*. An unhealthy ecosystem tends to cause damage or risks to adjacent systems (including humans). Examples include the leaching out of nitrate to shallow groundwater and of nitrogen, phosphate and toxic substances to surface water from agriculture.

Source: reference 17.

ECOLOGICAL SERVICES

The concept of 'ecosystem health' and the criteria listed in Box 2 cannot be evaluated directly in practice. We can take as a proxy criterion for ecosystem health the *ecological services*. Ecological services are properties and/or processes within the ecosystem which are useful to humans. Soils delivers use naturally ecological services, which support to a greater or lesser extent certain forms of land use. The capacity of an ecosystem to provide ecological services is easier to evaluate in practice than ecosystem health. It can be supposed that a healthy ecosystem will provide the appropriate ecological services. The maintenance and development of ecological services corresponds well to the objective of the Soil Protection Act, i.e. the protection of the functional properties of the soil. Further research will be needed to determine whether the presence and development of ecological services is a sufficient condition for a completely healthy ecosystem. **On practical grounds we therefore recommend that soil management practices aimed at sustainable land use should in the first place be directed towards the maintenance and development of ecological services in the ecosystem.**

Box 3 lists a number of ecological services which are more or less important for all forms of land use. These services are interdependent, and cannot therefore be considered separately from one another. The ecological services listed can be subdivided into a large number of separate ‘aspects’ (see Annex 2) which may or may not be relevant, depending on the land use. Some of the services listed in Box 3 and separate aspects (Annex 2) can also be regarded as products of ecological services, for example clean groundwater, agricultural products or healthy air. The distinction between services and products is rather vague, however, and depends on the context. We shall therefore refer only to ecological services.

Box 3. Ecological services

1. **Soil fertility:** the capacity to provide nutrients and produce biomass (including soil structure, organic matter, all essential nutrients for plant and animal):
2. **Adaptability and resilience**: the capacity to adapt, or the fragility in the face of disturbance or a change of land use;
3. **Buffer and reactor function**: ability to store and buffer water, gases, substances, energy (storage of heat and cold), cation exchange capacity, ability to decompose and synthesise substances and compounds (detoxification, humification);
4. **Biodiversity***: genetic, functional and structural biodiversity;
5. **Resistance to disease and pests**: the natural capacity to prevent and fight disease and pests;
6. **Physical structure**: carrying capacity, historical archive, landscape identity.

*See explanation below.

The term biodiversity in Box 3 covers a group of parameters, the different aspects of which are shown in Box 3 as genetic, functional and structural biodiversity [see also reference 20]. Genetic biodiversity here refers to the diversity of the gene pool, functional biodiversity to the diversity of functions (processes) in the ecosystem and structural biodiversity to the number of different species in the ecosystem. The genetic biodiversity of a system represents its potential for both functional and structural biodiversity. In relation to the ecological services, the functional biodiversity is particularly important, that is, the various different processes the system can perform. Structural biodiversity plays an important role in the above-ground part of the ecosystem, but also for example in the stability of the food-webs in the soil. The soil is host to a multiplicity of invisible organisms. There is assumed to be a positive correlation between biodiversity and the health of an ecosystem [21, 22, 23].

In the distant past all land use depended on ecological services. In order to allow the land to be used more flexibly, many extraneous technical and chemical tools have been developed: foundations, piles, material layers to raise ground level, changes in the level of the water table, dikes, fertilisers and pesticides. Some of these tools have deleterious effects on the ecosystem itself, particularly when used intensively; these usually involve damage to the ecological services, for example a reduction in the carrying capacity of the soil, a reduction in organic matter in the soil, the contamination of groundwater, a reduction in pest resistance or in the buffer capacity of the soil. Modern intensive use of land and the large-scale use of artificial expedients undermines the functioning of the ecological services, so that ever increasing quantities of these expedients are needed to continue use, resulting in mounting damage to the ecological services.

We believe that land use will become more sustainable if it is supported by the ecological services (rather than by extraneous physical and chemical expedients). Soil management would then seek to make land use less dependent on these environmentally harmful devices, and more reliant on the ecological services of the soil. The use of many chemical and technical expedients on the land has helped to make the Netherlands prosperous. Reduced dependence on these techniques by placing more reliance on the ecological services might mean reduced returns on some forms of land use to begin with, which would in turn have social consequences. To set against this, there would be less environmental damage. There would also be a reduction in the costs of pollution prevention and control and the costs of the expedients. The picture in the longer term is therefore more favourable.

The implications for land use in the short and the long term therefore depend heavily on how it is used and how intensively. Land use should in any case be ultimately re-oriented so as to take optimum advantage of the ecological services specific to the local soil system. It will be vital to determine in advance whether the soil (the ecosystem) is suitable for a desired use (see following section). In order to take optimum advantage of the ecological services, it is worth reiterating the guidelines formulated in our first advice on this subject [1]:

- Use of the ecological services[5] should not lead to their exhaustion or destruction locally.
- In using a specific ecological service, the other services should as far as possible remain intact.
- The recovery capacity of the soil should remain intact; this means that the services temporarily absent, possibly for a protracted period, must be able to return. This means that that all the organisms important for the ecosystem must be kept available.
- The rate of recovery should be commensurate with the rate at which the use is being changed. A recovery period of centuries is too long where the changes took place over 30 years, for example.

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[5] Since then we have somewhat modified our terminology. We refer to ‘ecological services’ rather than ‘ecological functions’ as this corresponds to current scientific usage, and avoids confusion about the word ‘functions’.

- All ecological services must have the requisite space; this limits the scale on which use can occur.
- The use of the ecosystem must not harm its surroundings, e.g. the groundwater and other contiguous ecosystems.

Managing the soil for sustainability means making extensive use of natural methods of pest control, maintaining soil structure, closing nutrient cycles, preventing contamination from atmospheric deposition and chemicals. Closer account needs to be taken of the constraints imposed by the ecosystem on land use. This approach also requires technological innovation to ensure that human activity is more ecologically friendly. The conclusions of the Soil and Ecology review also provide a basis for this type of management of agricultural soil. Specific recommendations made include: improve the organic matter cycle in the soil, nurture soil biota, limit pesticide use, reduce excessive application of nitrogen and phosphate. Some of the concrete ways in which government can promote more sustainable land use will be examined in chapter 5.

SUITABILITY FOR USE

Land use places requirements on the ecosystem, but the ecosystem also constrains land use. Land use which respects these constraints is more sustainable.

In an ecosystem-centred approach to land use the criterion of suitability for use is an important element in spatial policy and development. Attention is paid in our second advice [2] and in the Soil & Ecology review [4] to the problems presently arising with land use. These analyses show that many problems are caused by the belief that ‘anything can be done anywhere’. As a result of the operation of the market and the vested interests involved in relation to a given use, the question of whether the soil is suitable for its present or proposed use, and whether there might not be a more suitable place to locate a particular activity is usually overlooked. The result is that society establishes activities on unsuitable land, i.e. land where the ecosystem imposes inappropriate constraints on land use, leading to hydrological problems, groundwater contamination, excess nutrients, disease and pest infestation. The soils are subjected to physical and chemical treatments to correct this, and these often have an adverse effect on the ecosystem.

We obviously acknowledge man’s need to live safely. This safety may relate to health, land or food. We do not oppose interfering with ecosystems for reasons of safety, e.g. dike-building, the reclamation of habitable land by poldering and drainage, the control of disease (e.g. malaria) or artificially enhancing soil fertility. Our point is that in deciding on the type of intervention or where it is to be located we should think more carefully about the suitability of the location (some locations are more suitable than others), its impact on the ecosystem, and whether we cannot use the ecosystem itself to help solve the problem. Debate is currently being rekindled, for example, about the Delta project, now regarded by some as an inflexible safety structure which works against the ecosystem. There is an increasing body of opinion which argues that in seeking to protect ourselves from water we should place more reliance on harnessing natural processes and helping them to help us. Allowing sedimentation to occur in estuaries and river mouths, and allowing more water temporarily onto the land form enormous challenges: in the present situation such measures can be virtually ruled out.

Evaluating the suitability of ecosystems for specific land uses, and allowing for this suitability to influence land use planning and development can substantially reduce soil-related problems. Soil experts are now agreed that a prior evaluation of suitability of use is necessary. This conclusion emerges from our advice on system-based groundwater management [24, 25] and from the Soil & Ecology review [4], and plays a role in habitat creation issues and in cases of *in situ* remediation of contaminated land, where the potential of the soil to break down the contamination is first studied, so that the missing components (nutrients, organisms, etc.) can be added.

There is also a clear relationship between suitability for use and making optimum use of the ecological services; the more ecological services the soil offers for a specific land use, the more suitable the land is for that use.

The practice of examining whether an intended land use is suited to the local ecosystem should be reinstated as 'normal' in planning, development and land use decisions. This is already being done to some extent in habitat creation projects by testing beforehand whether the desired development is consistent with a number of characteristics of the local situation. Where the requirements imposed on the ecosystem by a particular land use are inconsistent with the characteristics of that ecosystem, possible alternative locations should be considered. Inconsistent combinations would include, for example:

- Intensive animal husbandry in soils prone to leaching.
- The cultivation of nutrient-hungry crops on nutrient-poor land (usually also prone to leaching).
- The cultivation in clayey soils of crops which thrive in sandy soils; bulb cultivation is moving from sandy to clayey soil, and the topsoil is being prepared by mixing in large quantities of sand.
- The cultivation of pest-sensitive crops in land where such pests thrive.
- The cultivation of crops in soils which cause extensive disease and pest infestation.
- Large-scale construction on land subject to compaction or desiccation.
- Construction on land with a high water table.

- The construction of industrial estates on greenfield sites when there is sufficient brownfield land available.
- Arable farming using heavy machines on soil where the soil structure is prone to compaction.
- The planting of trees subject to high transpiration rates on drought-prone land.
- Habitat creation projects which depend on seepage water at locations where the seepage water cannot be restored to a satisfactory standard, either quantitatively or qualitatively.
- Habitat creation projects at locations where the necessary environmental quality cannot be restored.

Agencies with experience in habitat creation, builders of housing estates and infrastructure and farmers have between them accumulated a considerable body of knowledge on which land use/ecosystem combinations are appropriate and which are not. In our view, the reason why proper account is not being taken of the suitability of the ecosystem for the use concerned is not so much to do with a lack of sufficient knowledge. Rather the knowledge which does exist is not being properly used. The developer or manager is not aware of the knowledge, the knowledge base (computer model) he uses is inadequate or the knowledge is disregarded. This is possible because expedients are available for adapting ‘unsuitable’ ecosystems: e.g. water table lowering, pesticides, foundations. The failure to optimise land use as a function of the soil properties has environmental consequences which result in ‘external’ costs which, partly because they are external, are inadequately reflected in planning and development.

4 ECOSYSTEM-BASED SOIL MANAGEMENT

Soil management is not new, but needs to take a more systems-based approach and pay more attention to sustainability

It was indicated in earlier advices and in chapter 2 that many forms of land use are not sustainable. In chapter 3 it was stated that land use can be made more sustainable by giving priority to the management and development of ecological services. When land is used, activities are performed on and in the soil and these have an impact on the soil. More sustainable land use will involve modifications in soil management. This chapter sketches some ways in which this can be achieved. We also consider who the managers of the soil are and the spatial level at which soil management issues act.

WHAT IS SOIL MANAGEMENT?

Society uses the soil for many purposes, and these uses inevitably have an impact on the soil. **Soil management is defined as all activities carried out with the intention of influencing the soil to meet the needs of its present or future use**. These activities may be of all kinds, ranging from a farmer ploughing a field to a province assigning certain types of use to a specific area. Soil management activities are carried out by government, organisations or persons which are the competent authority, owner or user. Soil management is usually an ongoing activity. The manager decides within a framework (scientific recommendations and rules) on the actions most appropriate in the situation based on his own practical knowledge. Soil management aimed at more sustainable land use is not a new activity as such; it just uses a different criterion.

The soil is managed by different land users with different objectives, and on different spatial scales. Since many forms of land use are not sustainable, present-day soil management regularly results in conflicts between land users. These conflicts usually lead to a deterioration in the possibilities of at least one of the parties to use the land [2, 25]. Such conflicts are bound to increase as land use intensifies.

SYSTEMS APPROACH

A systems approach to soil management can help to resolve conflicts of interest in land use [25, 26]. In a systems approach, account is taken of the fact that the soil forms part of the ecosystem. The ecosystem can be regarded as comprising the totality of mineral components, dead organic matter, air, water, micro-organisms, fauna and flora. There are many interactions in this system between the various organisms and between the organisms and the abiotic components. The system reacts to the environment. The lateral boundary of the system depends on the question being asked. In the context of soil management a river watershed[6] or a polder may define the appropriate boundaries (see also the section 'Spatial scale of management'). A systems approach recognises that land use can have an impact on the whole system, as well as other and future land uses. And conversely, that the system imposes constraints on use.

A systems approach pays particular attention to the dynamic interactions of all the component parts of the system in space and time. Although the dynamicity of soils are regarded as low, they are interrelated in space and time through:

- groundwater and surface water flows. Materials, biota, precipitation and sediments are transported through the soil;
- organisms, the biosphere;
- interactions between people who may - or may be not - physically close to one another (e.g. market transactions, movements of soil or manure sales contracts);
- their origins;
- the cultural identity of the landscape.

These interrelations mean that interventions (management) must be considered in the light of the impact they will have later or elsewhere. It is vital that against the benefits of a land use for one (often local) user are weighed the costs for another (possibly elsewhere or later). By managing the system as a whole rather than its component subsystems, the effects which occur later and elsewhere can be identified more quickly. A systems approach allows different management systems acting on different spatial scales to be integrated. It is also easier to identify the managers relevant for a particular policy issue, since the scope of an intervention can be better appreciated if the soil is regarded as part of the ecosystem.

In our advice on a systems approach to groundwater management and the underlying report of the TCSP working party on groundwater [24, 25] we enunciated three principles underlying the systems approach to soil management:

1. Sustainable use of soil and water

[6] Following the introduction of the European Framework Water Directive, the term river basin is reserved for the basins of the major European rivers. We use the terms catchment and watershed for smaller rivers, which might vary from the level of a small stream to the tributary of a major European river. In a poldered area a polder is a comparable unit.

- A relationship is established between the quality and the use of an ecosystem. The (desired) use takes account of the suitability of the ecosystem to support that use.
- The effects of an intervention or change of land use are assessed on the spatial and temporal scale of the ecosystem in order to show up and prevent the displacement of qualitative or quantitative problems to 'elsewhere or later';

2. Multisectoral approach
   - A multisectoral approach results in a process of continuous coordination between the different policy areas (e.g. spatial planning, water management and the environment) and the various planning levels (international, national, provincial and local municipal/water board). All agencies and persons involved in soil management and other stakeholders participate in the planning process within the framework of long-term objectives.
3. Cohesive management structures
   - The responsibilities for ecosystem management need to determined and coordinated at the policy, planning and operational levels. The relevant agencies must actively assume their responsibilities.

MANAGERS

In order to implement more sustainable land use it is important to know who manages the soil. There are no executive government agencies in the Netherlands charged with managing the surface soil in the way the water boards manage surface waters. Land is largely privately owned, and ownership is very fragmented. In practice the surface layer is mainly managed by the owner and/or user. Farmers work the land to grow crops. Nature conservation organisations manage land so as to develop or preserve particular types of ecosystem. Land in urban areas is managed mainly by private owners and municipal departments. The obvious step is therefore to seek to implement sustainable soil management through the owner and/or the user of the land. In addition, land is subject to spatial management, i.e. spatial planning and development. This form of management is primarily the responsibility of government.

Subsurface soil is also increasingly being used, for example for buildings, storage of heat and cold and *in situ* groundwater remediation. There is an urgent need to extend management to underground resources, and in particular a systems approach to the management of groundwater [24, 25].

SPATIAL SCALE OF MANAGEMENT

A river watershed is seen as one of the most natural physical entities for delimiting ecosystems. In areas where the hydrology is intensively managed, e.g. in the West of the Netherlands, polders or polder complexes can fulfil this role. In an earlier advice [27] we indicated that water and soil management in the Netherlands should be organised at the level of the river catchment, based on units similar in size to the modern water boards. This is consistent the approach taken in the European Water Framework Directive [28]. The catchment is a meaningful level for soil management when considering material cycles, hydrological cycles and landscape development. A second level for soil management might be the regional level, which is important for spatial planning. The third level which is meaningful for practical implementation of soil management can be described as the user level, which corresponds to the level of the existing local land use.

When looking at soil management in the context of sustainable land use, the appropriate spatial unit is the largest unit of land which imposes homogeneous requirements on the ecosystem and on which the ecosystem imposes similar constraints. A polder chiefly used for arable crops can be managed on a larger scale than an area in which agriculture alternates with nature area. Soil management in natural habitat depends on the type of habitat involved and on its size. In addition, soil type and the natural water table level impose conditions on the management regime. The spatial scale appropriate for management must be based on the purpose of the management and the spatial units of land use, e.g. gardens, farm plots, polders, habitats or landscapes of a particular type, catchments and regions.

TOWARDS MORE SUSTAINABLE LAND USE

Land use can be made more sustainable by tending to the health of the ecosystem. In practice this means:

1. nurturing and working with the ecological services and
2. having regard to the suitability of the soil for the desired use.

In our view the way for government to make land use more sustainable is for it to influence soil management practices. In chapter 4 the principles of ecosystem-based management were summarised as:

- Sustainable use of soil and water;
- Multisectoral approach;
- Cohesive management structures.

These points are developed in greater detail below.

MORE SUSTAINABLE USE OF SOIL AND WATER: TYPES OF LAND USE AND ECOLOGICAL SERVICES

Chapters 3 and 4 explored ways of implementing a more sustainable use of the soil and water. This section puts these ideas in more concrete form by examining the importance of ecological services for the different forms of land use. The object is to manage the soil so as to maintain and stimulate the ecological services important for the land use. We focus particularly on land uses in which the soil remains at least partly accessible to be worked and managed. As far as underground space is concerned, the reader is referred to our advice on systems-based groundwater management [24][7].

About 87% of the total surface area of the Netherlands (including water) is devoted to open land uses (see Annex 3). Between 5 and 10% of the total surface area is (mainly) sealed (buildings and pavement) [29]. In the analysis below, the following open land use types will be distinguished[8]: agriculture (56.3%, excluding glass horticulture), nature areas (nature parks (3.3%), forest (7.8%) and extensive recreation parks), public open space (parks, public gardens, open sports and recreational areas), allotments (some in residential areas) and domestic gardens (in residential areas (5.3%)). This typology was also used in the policy review on the remediation of contaminated land [30]. Small-scale forms of land use, e.g. domestic gardens, are much smaller in size than agriculture and nature area. They are

[7] And the related report of the TCSP working party on groundwater [25].

included in the analysis below, however, as they fulfil an important ecological role in areas which are mainly sealed (pavement and buildings) Ecological services are important in urban areas for some forms of land use, e.g. gardens, public parks, and allotments. These small-scale forms also contribute to the functioning of the large-scale ecological services, such as water buffering and structural biodiversity (diversity of plant and animal species).

Relevant spatial scales

Three different spatial scales for soil management are distinguished in chapter 4: a local level, a regional level and a catchment level. In administrative and political terms the regional level is the most important for spatial planning. If the surface layer[9] ecosystem were to become the main focus of soil management, then the catchment level would become the most relevant scale for spatial planning. This is the most natural scale for ecosystems. As far as ecological services are concerned, a distinction can again be made between the local and catchment scales. At the local level the aspects of ecological services which are important are those which contribute to the land use being successful locally, i.e. where the local use depends on the ecological service. However there are also aspects of ecological services which are of more general importance to society as a whole, for example water buffering and the fixing of greenhouse gases. These more general aspects usually operate on the catchment or larger scale. In the discussion below a distinction is therefore made between the local and the catchment scales; the catchment scale can be regarded as indicative for the regional scale in this context.

Ecological services and land use

The following ecological services were mentioned in chapter 3:
- Soil fertility;
- Adaptability & resilience;
- Buffer & reactor function;
- Biodiversity;
- Resistance to disease and pests;
- Physical structure.

These ecological services are interdependent and relevant for all forms of (open) land use. In Table 1 we indicate the extent to which we regard local land uses as being dependent on the various ecological services. This is based on the goal of sustainability, i.e. we looked at the

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[8] The figures in brackets are the surface area as a percentage of the total Netherlands area including water.
[9] Surface layer is a term used in the Fifth Spatial Planning Policy Document; it relates to the soil characteristics and the geohydrological system, and is regarded in that document as a basis for further planning [31].

extent to which land use should and could be supported by ecological services instead of environmentally harmful expedients. These ecological services would be managed at the local level by the local managers.

Table 1. Estimated dependency of the **local** land use on ecological services (- = not relevant, + = not very important, ++ = very important).

	Land use				
Ecological service	Agriculture	Nature areas	Public open space	Allotments	Gardens
Soil fertility	++	++	+	++	+
Adaptability & resilience	++	++	+	-	-
Buffer & reactor function	++	++	++	-	-
Biodiversity	-	++	++	-	++*
Resistance to disease and pests	++	-	+	+	-
Physical structure	++	++	+	+	-

* specifically structural biodiversity, i.e. a wide variety of plants (and animals); this is usually a property sought by the users.

In drawing up Table 1 the following considerations applied.

1. Between-use differences in the dependency on fertility result directly from the desired productivity and vegetation. Soil fertility needs to be relatively high for agriculture, whereas for nature areas it is variability in fertility that is important.
2. Differences in the importance of the adaptability & resilience and buffer & reactor functions are mainly due to differences in the scale and production level of the different uses.
3. For biodiversity the scores reflect not only the conservation and aesthetic aspects of a given land use, but also the physical scale.
4. Resistance to disease and pests affects productivity; in nature areas land disease and pests are regarded as a normal phenomenon. There appears to be a close relationship between resistance to disease and pests and biodiversity, with high biodiversity increasing resistance.
5. In the case of the physical structure, scale and productivity both affect the dependency level.

Table 2 shows our estimate of the extent to which local soil management can contribute to general ecological services which need to be maintained at the catchment level. This contribution is mainly a function of scale: is the scale on which the use occurs relevant for the larger system? For agriculture and nature areas there is an overlap with Table 1 because allowance has already been made in this table for the scale involved. Table 2 relates however to the ecological services on which the agency responsible for management at catchment level would have to focus.

Table 2. Extent to which local land use contributes to the management of the ecological services at **catchment** level (- = not relevant, + = not very important, ++ = very important)

	Land use				
Ecological service	Agriculture	Nature areas	Public open space	Allotments	Gardens
Soil fertility	++	++	-	-	-
Adaptability & resilience	++	++	+	-	-
Buffer & reactor function	++	++	++	+	+
Biodiversity	++	++	++	+	+
Resistance to disease and pests	++	++	+	-	-
Physical structure	++	++	++	-	-

In drawing up Table 2 the following considerations applied.

7 Nutrient flows at the catchment level are mainly determined by the relative presence of agriculture, nature areas and the various urban uses in the catchment. The fertility of the soil determines, both directly and indirectly (land fertilised according to need), the size of the nutrient flows.

8 Adaptability & resilience are mainly important, in relation to the possibilities for changing land use, for large-scale uses.

9 Small-scale forms of use can contribute to the buffer & reactor functions, for example the ability of gardens to purify and store water, or of larger public open spaces to fix Carbon.

10 Small-scale forms of land use can also contribute to large-scale structural biodiversity.

11 Small-scale functions are considered of little relevance for resistance to disease and pests at high level, i.e. gardens are not regarded as an important source of organisms which can control sickness and pests on a larger scale. But the control of disease and pests is locally important for allotments (see Table 1). The opposite applies to nature areas: resistance to disease and pests is not important at the local level (Table 1) but on a larger scale natural habitats may act as a reservoir both of organisms being able to control disease and pests, but also of pathogens.

12 As far as the physical structure is concerned, the scale of the land use is the key parameter.

The differences between Tables 1 and 2 become more pronounced if the ecological services are broken down into their component aspects. A more specific determination can then be made of the aspects of the ecological services which are important for the various forms of land use, and which must be maintained and developed by the soil manager. Annex 2 of this advice contains a (non-exhaustive) list of the aspects of ecological services and their linkages with land use. Those listed for the local level are the aspects of ecological services on which the land use depends. Those listed for the catchment level are the aspects which contribute to general ecological services.

There is a large body of knowledge amongst soil managers and researchers about measures which can be taken to enhance the performance of the ecological services. But it will not **always** be clear which measures should be taken and to what extent intervention is needed [32]. Further research into the relationship between soil management (the knobs and how far they should be 'tweaked') and the health of the soil ecosystem, as reflected by well functioning ecological services, is necessary. It should be appreciated, however, that ecosystems are difficult to manage, and that it is more profitable to work *with* natural processes [23].

MULTISECTORAL APPROACH

Integrated policy

In our advice on systems-based groundwater management and the report of the working party on groundwater [24, 25] which underpinned this advice, the term *multisectoral approach* is used to mean that there is continuous coordination between the various policy areas (soil protection, spatial planning, water management) and the various planning levels (international, national, provincial, municipal, water boards). Different regulatory approaches and types of policy instrument are chosen which interface well, sometimes specially for a particular issue. The recent legislation designed to restructure the pig farming industry is given as an example of policy which cuts across sectoral boundaries [25].

Ecosystem-based soil management means integrating policy on soil, water, nature conservation, agriculture, the environment (in a broader sense) and spatial planning. This need has been articulated in recent policy documents such as the Fourth National Environmental Policy Plan, the Fifth Policy Document on Spatial Planning, the Second Green Space Structure Plan and the policy document *Natuur voor mensen, mensen voor natuur* (Nature for people, people for nature) [8, 31, 33, 34]. The European Water Framework Directive [28] is based on the close integration of these policy areas, although soil is not explicitly included.

Instruments

The present regulations which affect soil management still exhibit many sectoral characteristics because they are not based on a systems approach (see Annex 4). We do not favour implementing a more sustainable land use by enacting extensive new regulations, for the following reasons:

1. Soil management is organisationally complex, and is related to many policy areas. The present sectoral regulations which affect soil management can be greatly enhanced by adopting an ecosystem approach. This will lead to integration and coordination of the regulations.
2. Soil management is an everyday activity, and takes place in a very complex environment. The way the soil is managed is affected not only by regulations but also many other factors including the weather, local soil conditions, the market price of the crop or of land. Because of this complexity it is virtually impossible to devise generic measures for soil management which will cover all cases. Tailor-made solutions and a decentralised approach are what is needed.
3. We think it better, also given present deregulatory sentiment, to encourage more sustainable land use by non-regulatory means. Local land use, certainly in the long term, will depend on the ecological services being managed sustainably. The local manager can be expected to be aware of the importance of these ecological services, and non-regulatory stimuli should be sufficient to guide land use in a sustainable direction. There are many encouraging social trends[10] which suggest an awareness of the need for sustainable development. By exploiting and supporting these trends the government can enhance progress towards more sustainable land use.

It is therefore vital that managers at the local level are shown the advantages to be gained by a more sustainable land use (less environmental damage, easier to comply with statutory standards, less management needed to maintain the ecological services, less problems arising from changes in land use, enhanced landscape value). Nature conservation in agricultural areas could also be looked at in this way. The effectiveness of this kind of nature conservation is being debated in relation to biodiversity. However it is of unquestioned benefit to ecosystem health because it involves a less intensive use of the land and various measures can be taken to enhance resistance to disease and pests. Nature conservation in agricultural areas demands extra efforts from the manager, and another way of looking at his/her production system. It is this other way of looking which can lead to a sustainable approach to dealing with the ecosystem.

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[10] See, for example, LEADER, VEL and VANLA, Koeien and Kansen [35, 36, 37].

However there are also costs associated with sustainable land use. Local restrictions or additional measures may be needed in order to realise benefits at the catchment level, reducing the benefits of the land use locally. Fears of loss of earnings may lead to resistance. We would normally expect a local soil manager to implement a basic level of sustainability higher than the minimum level. This basic level might be set, for agriculture for example, using the EU guidelines on *Good Agricultural Practice* (GAP). It could subsequently be developed further into a basic level of sustainable land use.

Those implementing soil management locally will also be expected to contribute to the ecological services of benefit on a larger scale, i.e. at the catchment level (referred to, in agriculture, as green and blue services). Local managers may perceive such action as irrelevant or limiting. The required effort is unlikely to be made of its own accord. A regulatory system here is likely to be more effective than mere exhortation.

One possibility would be to compensate managers who go further in implementing sustainable soil management than expected on purely local considerations. This is consistent with, for example, EU plans to modify its agricultural policy to subsidise incomes rather than marketable products.

Research and dissemination of know-how

In order to promote more sustainable use of land it will also be necessary to foster research and the dissemination of know-how. There are numerous research projects on more sustainable land use, for example the agrobiodiversity programme and research projects at the De Marke experimental farm. It is recommended that a survey be made of the tools being developed for sustainable land use, and of the motives which drive sustainable land use projects. In chapter 6 a number of research projects are mentioned which are looking at methods for evaluating the surface soil ecology, and which could be used to determine whether the soil is suitable for a planned use. Some recommendations are also made with regard to this type of research.

As part of an ecosystem approach we consider it desirable that soil management techniques (for example tillage methods) should be developed which contribute to land being used more sustainably. Issues to be explicitly addressed would include the fact that the soil forms part of the ecosystem, how ecological services are dealt with, and how to prevent the spatial or temporal displacement of problems arising from land use. In our view greater flexibility is needed so that scientific experimentation can be conducted into sustainable land use; the law does not allow for such experiments at present [15, 38].

A methodology could be developed for evaluating the sustainability of soil management measures based on an ecosystem approach, that is, which would reflect the effects of measures on the ecological services not only locally but also on a larger scale (catchment level) and in the future. It would be desirable to integrate this procedure with other water management and environmental instruments such as the procedure for testing the impact of spatial plans on the water system and EIA[11]. A number of systems already developed in specific areas for assessing environmental effects (for example for choosing the least environmentally harmful pesticide) could be helpful.

There is a substantial body of useful practical knowledge vested in local soil managers, particularly farmers, which is no longer being passed on to others. We recommend that more is done to ensure that this knowledge is recorded, compiled and disseminated.

Education will play an important role in the development of soil management skills. Many courses, particularly in technical disciplines, pay little attention to ecology, and the soil is seen as a lifeless base on which activities are superposed. In the agricultural sector farmers used to be supported by experimental farms and government information services. These activities are now much less important as a result of the high level of education of farmers, their specialisation and the setting of other social priorities, and have been partly taken over by the purchasers of agricultural products, who set requirements with regard to quality and farming methods. We advocate that courses in technical subjects such as civil engineering and farming be widened to include the systematic study of soil ecosystems.

COHESIVE MANAGEMENT STRUCTURES

All relevant institutions and persons should be involved in soil management and implementation issues. Who these are will depend on the issue involved and the spatial scale on which the issue operates. At present there is no forum in the Netherlands which brings together all the relevant managers, each with his/her/its own dynamic and approach, to consider land use management issues. We consider that such a forum can be established through better organisation of existing institutions. For specific large-scale problems, such as the contamination at De Kempen, a separate management structure could be established.

Soil management could be based on the ecosystem, taken as the catchment, since this accords with the notion that the ecosystem should be the guiding principle and main focus of

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[11] See also our advice *Systeemgericht grondwaterbeheer* (Systems approach to groundwater management) and the associated report [24, 25].

land use and soil management [see also the Water Framework Directive, 28]. The management, and therefore the managers, of the catchment set the tone for the management and the managers at a more local scale. Day-to-day management can in principle be made the responsibility of the local level except where larger-scale issues are involved. This approach is also recommended for the proposed UNEP[12] ecosystem approach [39].

Table 3 shows the organisations/persons who implement soil management measures and the government agencies responsible for supervising soil management for each of the five different land use categories. The implementers at the local level are those who actually use the land. They are supervised at the local level by the lowest applicable government tier. This level largely depends on the scale on which the use takes place. There are departments within the municipalities, provinces and water boards which implement at the local level, but these authorities also have supervisory tasks: spatial planning, development, public information, regulation and licensing, which may be carried out on different spatial scales. At the macro level the soil (ecosystem) is managed by central government and the European Union through their spatial planning and regulatory activities.

Table 3. Soil management: implementation and government supervision on different spatial scales.

Type of use	Agriculture	Nature areas	Public open space	Allotments	Gardens
Execution, local level	Farmers	Nature management agencies	Municipal and provincial departments	Users	Users
Supervision, local level	Municipalities and provinces	Municipalities and provinces	Municipalities and provinces	Municipalities	Municipalities
Supervision, catchment level (or larger)	Water boards, provinces, central government, EU	Water boards, provinces, central government, EU	Water boards provinces	Water boards, provinces	Water boards, provinces

It should be appreciated that supervisory activity is not the exclusive domain of government. There are private and semi-governmental organisations which influence soil management, for example the Natuurmonumenten Association, the provincial landscape organisations, the Association of Woodland Owners, the Forest Management Agency, the Nature and Environment Planning Office, the Netherlands Waterworks Association, agricultural and horticultural organisations, purchasers' and suppliers' associations. Because of our role as government adviser, this advice concentrates on the role of government in soil management. Consultation and coordination between government agencies and other parties involved in soil management is necessary, however.

12 United Nations Environmental Programme.

Supervising soil management at the catchment level is the job of the public authority with competence on a larger spatial scale. They need to supervise the local implementers (if necessary through the local supervisory authorities and organisations) in relation to aspects of soil management which are important for ecological services at the catchment level. This might be water storage in the case of gardens, the fixing of carbon for public open spaces, nutrient losses and the leaching and run-off of pesticides for agriculture, or restoring the water table for nature areas. It must be remembered that the costs and benefits may occur at different spatial levels. Where issues are important at the catchment (or higher) level the local manager (or executor) needs to be asked to perform tasks which might seem irrelevant or excessive (too costly or time-consuming). Resolving conflicts between the local and catchment levels is one of the major challenges in achieving a sustainable land use. This means that the authorities at the catchment level have management tasks not only in regard to spatial planning and development. Managing the aspects of ecological services which are important on a catchment scale can be seen as promoting a common good, and as an area in which government agencies need to take a more directive role.

RECOMMENDATIONS FOR SUPERVISION

In view of our advisory role, our recommendations relate to the role of the public authorities in regard to sustainable land use. It is generally the municipalities and provinces who supervise soil management activities at the local level. It is they who should determine which ecological services (or aspects of ecological services) are relevant for and constrain land use locally. Monitoring systems should be used to determine the relationship between ecological services and land use. If the ecological services are sufficiently developed to support the land use sustainably, this situation should be maintained. If not, then the ecological services should be further developed. This maintenance or development will be the job of the local soil management implementers with the help of other parties involved, such as associations representing local interests and nature conservation and environmental organisations. This activity can be supported by various measures, including the provision of information on tillage methods and soil treatment, the provision of do-it-yourself packages for soil assessment, demonstration projects, etc. Land use plans and regional development plans should take better and systematic account of the suitability of the proposed ecosystem for the desired land use.

At the catchment (or higher) level the water boards, provinces, central government and the European Union all play a major role in supervising soil management. Activities at this level should relate to the ecological services which are of general importance and operate at a high level, e.g. water buffering, gas fluxes between the ecosystem and the atmosphere, biodiversity (general), landscape and geological features. These are ecological services in which local land users do not have a direct interest, but which do need to be maintained and developed by them. It is not expected that the authorities will be able to ensure that these services are maintained purely by means of information and exhortation, and a regulatory system is likely to be necessary. The role of the authorities in spatial planning at this level, in which suitability criteria will be applied to land use, will be crucial.

6 MONITORING USING INDICATORS

The best indicator for ecological services is observing the possible failure of one or more services.

It was concluded in chapter 3 that ecological services offer the best prospects in the short term for developing an operational monitoring system. In order to describe the current state of the ecological services and to monitor whether soil management is producing the desired results, criteria need to be formulated for evaluating the ecological services. Because the processes involved are relatively complex, there is no simple observable parameter which measures the state of the system. Indicators have to be devised which reflect the state of the ecological services.

Various systems have been proposed to assist in assessing the state of the ecological services using biological and abiotic indicators (see Box 5: Examples of systems for the ecological assessment of the surface layer). The first 7 methods listed seek to evaluate the current quality of the surface layer. Depending on the question being addressed, however, it is not sufficient just to evaluate the quality of the surface layer. If a systems approach is taken then the quantity and quality of the surface water, groundwater, infiltration water, as well as of the air and the precipitation are also important. Methods 1 and 2 involve directly assessing the ecological services, and will be discussed further below. The third method (Soil Biological Site Classification) describes the biological quality of the soil in terms of the biotic community in the soil and its interactions with the abiotic soil properties and reference values, but does not try to describe the functioning of the soil. Methods 4 and 5 (Sustainable Soil Management Project, Soil Foodweb Incorporated) are tools which give farmers and horticulturalists insight into the functioning of the soil and how it can be improved. Methods 6 and 7 (integrated environmental effect modelling, OTUs & DNA fingerprints) involve more fundamental research into the health and functional diversity of the soil. Some of the lessons learned and techniques acquired in these studies have already been incorporated into the Biological Indicator for Soil Quality (method 1) and Microorganisms as indicators of soil health (method 2).

The other methods relate to the suitability of the surface layer for one specific use, i.e. nature areas (methods 8 to 12 in Box 5). The method has not yet been developed for other forms of land use but a great deal is known about suitability for use. It is desirable that this knowledge be compiled into a database or decision support tools. Recent developments in risk assessment for ecosystems or contaminated land, designed to determine whether risk reducing measures or remediation of contaminated land is necessary, are not included in Box 5 [40, 41, 42, 43].

Box 5. Examples of systems for the ecological assessment of the surface layer

1. *Biological indicator of Soil Quality (BISQ).* Based on measurements of a number of biological parameters in the surface layer, so-called amoeba diagrams are constructed. The parameters are closely related to ecological services. The monitoring is linked to the national soil quality monitoring network. The indicator system was tested for agricultural land, but can be extended to other forms of land use. The indicator can be used for monitoring at the national level [44, 45].
2. *Microorganisms as indicators of soil health.* Based on 7 characteristics of healthy soil, various soil ecosystem parameters are identified, together with microbial indicators for these parameters; together these form a minimum dataset for assessing the health of the soil. The soil ecosystem parameters are aspects of the ecological services. The report makes specific recommendations on the design of a monitoring system and identifies gaps in knowledge [20].
3. Soil Biological Site Classification. This system uses ecotype based on soil fauna, a 'functional parameter (bait lamina) and abiotic parameters. The ecotypes act as reference types and are based on a desk study of the 'normal values' for the parameters; soil samples are analysed and compared with the normal values of the ecotype to which the sample should belong. The deviation is related to the ecological quality of the surface layer, but no direct relationship with the ecological services is established. The system takes explicit account of land use, and is still being extended. This work is being conducted in cooperation with the BISQ project of the RIVM. This indicator system can be used for monitoring at the national level [46].
4. Project Sustainable Soil Management. The introduction of MINAS has meant that practical interest in soil quality is strongly oriented towards soil chemistry. However there is an increasing realisation that physical and biological aspects are also important. In this project practical tools for sustainable soil management were developed on the basis of physical, chemical and biological indicators. The tools were developed for farmers, and comprise: courses, a kit for testing soil quality, guidelines for manure use and soil management (including: green manure, urea, organic matter management, grass/clover management), CD ROMs on nutrient management, organic matter in soil [47].
5. Soil Foodweb Incorporated. The SFI laboratory defines a 'healthy soil' using biological (foodweb) and abiotic parameters, determines on the basis of samples whether the soil is healthy and gives advice on soil treatments, e.g. adding certain organisms to it. SFI is mainly active in organic farming, and focuses on ecological services in the surface layer which are important for agriculture. The system was developed for assessing individual fields or farms. There is a Dutch subsidiary active under the name Soil Foodweb Europe [48].
6. *Integrated environmental effect modelling: Ecosystem health indicators.* This is a fundamental approach which uses the traditional ecological concepts listed in Box 2. This approach is still under development. Would be suitable for evaluating the health of surface layer ecosystems on any scale from a field right up to national level. See for example the TRIAS project [19].
7. *OTUs & DNA fingerprints.* Soils are analysed for the number of species of organism they contain using molecular techniques. An unexpected finding was that soils contain very many different operational taxonomic units (OTUs), often up to several thousand. This diversity of species and its distribution appears to depend heavily on the treatment of the soil and its heterogeneity. The new molecular technology (including DNA fingerprinting) and analysis using micro-arrays of several thousand

phylogenetic or functional genes simultaneously) permit soils to be compared and trends in their genomic diversity to be documented and computerised [see for example 49].

8. '*Natuurplanner*'. This is a tool by which the effects at national level of the main environmental problem areas or 'themes' (eutrophication, acidification, groundwater depletion and habitat fragmentation) can be described and predicted. The system can be used to answer policy questions, evaluate conservation and environmental policy and warn of changes in ecosystems at the national level. The system characterises terrestrial habitats by their main physical parameters, i.e. soil pH, nitrogen availability, water table level, metals content, and consists of a series of models. The system provides results at the national level, for natural habitats only [50].
9. Ecological classification of soils. Humus profiles are used to describe the ecological quality of the soil, and the associated prospects of developing particular types of habitat. The classification is not linked to ecological services and is based on a limited concept of an ecosystem. This system is applicable only to natural habitats, and can be used to assess the suitability of land for habitat creation projects [51, 52].
10. Ecological knowledge-based system (EKS) for peatlands. An interactive computer program that uses the habitat requirements of plants to provide the user with insight into the properties of the habitat and help him/her to manage it. The factors which affect plant growth at a particular site are the supply of water, the presence of nutrients and the acidity. Based on the result of the habitat analysis, the EKS helps the user to manage the site, e.g. identify conservation measures, choose the target vegetation and the appropriate development measures. Since the EKS is aimed mainly at the individual user, the program is particularly used by managers of nature areas and agroecology projects, and for educational purposes [53].
11. Soil assessment system for habitat creation in former farmland contaminated with nutrients and heavy metals (Dutch acronym BONANZA): A decision support system which can be used, for example, to assess possible land purchases for inclusion in the national ecological network. The system is still in development, and the emphasis so far has been on soil chemistry. It is not linked to ecological services and has only limited ecosystem representation. It is suitable for the assessment of individual sites [54].
12. Vulnerability analysis of nature objects on contaminated land. Based on ecological knowledge of 'target species' of Dutch nature conservation policy, this approach looks at the effect on vulnerability of heavy metals and DDT having regard to exposure pathways, sensitivity and population dynamics. The system is a decision support tool which allows soil managers and developers to select the most feasible habitat creation alternatives by identifying the most vulnerable target species in a particular type of ecosystem. The method can also help identify the parameters to be monitored and appropriate risk reduction measures. The intention is that this methodology should eventually be incorporated into BONANZA [55].

Methods 1 and 2 in Box 5 are best suited to monitoring the ecological services over larger spatial areas. The indicators relevant to ecosystem health which can be monitored in the soil using these methods are listed in Table 4. These indicators all relate to the ecological services. A one-to-one correspondence between ecological services and indicators would make it easier to choose which indicators should be monitored where, on the basis of Tables 1 and 2 and Annex 2. Such a correspondence can only be achieved very partially, however, because most of the individual indicators refer to several ecological services. The quantity and structure of organic matter in the soil, for example, affect soil fertility, resistance to disease and pests and the physical structure of the soil. This is because, as mentioned earlier, of the interdependency of ecological services. It is all the indicators taken together which provide an indication of system health. For more information on the linkages between indicators and ecological services the reader is referred to [20, 44 and 45].

The Biological Indicator for Soil Quality (BISQ) [44, 45] was developed in the Netherlands by the RIVM and Alterra. It is still partly in the research stage. The system is linked to the national soil monitoring network. The BISQ is the most complete of the indicator systems listed, since it describes virtually the entire food web in the soil ecosystem. This is important in understanding the stability, resilience, and also the functional biodiversity of the ecosystem. Fungi, including mycorrhizae, are considered crucial for the decomposition of resistant organic material in the soil and the development of vegetation in natural systems. Fungi were initially included in the BISQ but have not yet been monitored, due to their lack of relevance for farmland, and also for budgetary reasons. In future, fungi will be included in the monitoring programme, particularly when applied to nature areas [56]. The quality of the organic matter (composition and structure) can also be important, particularly in nature conservation land.

Table 4. Biological indicators for soil quality and a set of microbial indicators of soil health suggested by an expert working party.

Biological Indicator for Soil Quality [44, 45]	Micro-organisms as indicators of health of the soil [20]
pH	Microbial diversity (genetic, functional and structural)
Organic matter content	Soil respiration
Lutite	Decomposition of organic matter
Available phosphate	Soil enzymes
Large livestock units	Methane oxidation
Heavy metals	Nitrogen mineralisation and fixation, (de)nitrification
Bacterial growth rate	Microbial biomass
Genetic diversity bacteria	Biomass protozoa
Potential carbon mineralisation	Bacterial DNA/protein synthesis
Potential nitrogen mineralisation	RNA measurements
Functional microbial diversity	Bacteriophages
Numbers, individuals, species and sexes, maturity index nematodes	Mycorrhizae Pest resistance
Numbers, biomass, species and diversity white worms	Human pathogens Biosensor bacteria
Numbers, biomass, species and diversity earthworms	Plasmids
Numbers and numbers of species of micro-arthropods, proportions in various food groups	Antibiotic-resistant bacteria Catabolic genes

Unlike the microbial indicators listed, the BISQ does not include any indicators for:

- fluxes of gases between the soil and the atmosphere (transpiration, methane oxidation, nitrogen fixation and denitrification) which are important in connection with climate change;
- presence of pathogens, antibiotics and pesticides;
- the presence of pests.

Indicators of the physical structure of the soil and the buffer and reactor capacity are also missing (e.g. cation exchange capacity).

Ideally a monitoring system oriented towards ecological services in the soil should include all the biological indicators of soil quality, as well as the missing data referred to above. The monitoring should also focus on the conditions needed to ensure the ecosystem functions well, e.g. air quality, quality and quantity of groundwater, surface and seepage water. However monitoring the biological indicators and additional data will be costly. Priorities will have to be set. It is desirable that the monitoring costs should be shared between the different parties. The scale of the exercise can be limited by using random sampling or monitoring in pilot areas. The number of indicators could also be reduced (see below).

A lot of data are already being collected which can help to describe ecosystem health. In our previous advice on the role of the ecosystem in land use [2] we pointed out that there are many research and monitoring programmes in the Netherlands which routinely determine the quality of ecosystems, some of which in relation to land use. Data on the desirable characteristics of ecosystems are collected, e.g. vegetation, plants, birds, mammals, butterflies, insects and geological features, as well as data on land area sown with different crops, damage in agriculture due to drought and flooding, pests, the health of forests and the quality of the landscape. Examples of the latter are the system for monitoring small landscape features and a study just completed of differences in landscape quality between organic and normal agriculture [57, 58]. By drawing together and compiling the results of these programmes and monitoring activities, significant advances could be made in our understanding of the quality of soil ecosystems. In our previous advice we recommended the establishment of a planning office which would report on the state of and trends in ecosystems in relation to land use [2]. The nature and environment planning office now carries out this function.

We need to bear in mind the purpose of monitoring. Monitoring provides information which allows the management regime to be modified. It can also be used to check whether the policy being pursued is leading to the desired results. At the local level the user or manager (see Table 3) should monitor those aspects of ecological services which are directly relevant to the local use (Table 1 and Annex 2). The local manager can promote monitoring of this kind by providing appropriate information and making monitoring methods available. Methods 4 and 5 in Box 5 may be helpful in this regard. The results of monitoring can also be used to answer higher-level questions. The resulting data would then need to be made available to managers not only at the local but also at the catchment level. Readily accessible databases, for example on the Internet, would be helpful in this regard. Table 5 contains suggestions for a number of indicators for the different land uses which could be determined at the local level. Because of the costs of monitoring, a smaller set of indicators is proposed than in the BISQ plus the additions mentioned above. This is based on the need for particular ecological services (or aspects of them) for the use concerned and on ensuring balance relative to all the ecological services. The latter applies particularly to large-scale forms of land use.

Table 5. Suggestions for indicators for monitoring at local level the condition of the ecological services. These are the ecological services on which the local use depends.

Agriculture	Organic matter (quantity), nitrogen (quantity, mineralisation and leaching to shallow groundwater), phosphate (available, total accumulated and leaching/runoff), pH, cation exchange capacity, copper, zinc, maturity index nematodes, biomass and biodiversity earthworms, biomass micro-organisms and functional microbial biodiversity, disease and pest resistance.
Nature areas	Organic matter (quantity and structure), pH, cation exchange capacity, carbon/nitrogen ratio organic matter, nitrification rate, bacteria/fungi ratio, maturity index nematodes, biomass and biodiversity earthworms or white worms, biomass micro-organisms and microbial biodiversity (general).
Public open space	Organic matter (quantity), pH, maturity index nematodes, biomass earthworms.
Allotments	Organic matter (quantity), pH, nitrogen and phosphate (if appropriate), biomass earthworms.
Domestic gardens	Organic matter, pH.

Notes on Table 5:

- Biomass micro-organisms: measure of microbial activity. This allows the bacteria/fungi ratio – an indicator of the functioning of the system - to be derived.
- Functional microbial biodiversity: indicator of the diversity and microbiological activity in the soil (including mycorrhizae, potential for converting farmland into nature conservation land, ability to break down complex compounds, soil fertility).
- Cation exchange capacity: indicator of the chemical buffering capacity of the soil.
- Carbon/nitrogen ratio organic matter: indicator of the degradability of organic matter.
- Copper, zinc: indicator of eutrophication, atmospheric deposition of metals.
- Nematode Maturity Index: indicator of pollution in the system, its adaptive capacity and balance.
- Nitrification rate: buffering capacity to nitrogen deposition from the atmosphere.
- Organic matter (quantity): indicator of structure, humidity regulation, resistance to disease and pests, richness in nutrients, buffering capacity.
- Resistance to disease and pests: indicator of capacity of the soil to resist disease and pests.
- Earthworms: indicator of soil fertility, toxic compounds, biodiversity, soil structure.
- Nitrogen and phosphate: indicators of soil fertility, but also of ‘leaky’ nutrient cycles.
- pH: indicator of soil fertility, level of lime in soil, but also of acidification.

In our view, soil pathogens need to be measured in agricultural land and allotments for food safety reasons; it would be interesting to know whether this indicator is measured in any other connection.

Although Table 5 lists indicators for nature areas, this form of land use should not be a priority for monitoring. The vegetation and other ‘external’ characteristics such as the presence of certain indicator species themselves give a good indication of the condition of the ecosystem.

It may not be necessary to delve deeply into the workings of the ecological services. There should be greater emphasis, in the case of nature conservation, on prior testing of the location to ensure it is suitable for the desired use. The function of management would then be ensure the site is made/kept suitable. Use can be made in this regard of methods 8 to 12 given in Box 5.

At catchment level the managers (Table 3) should concentrate on monitoring and adjusting the ecological services of general importance (see Table 2 and Annex 2). At this level this often involves monitoring fluxes and balances, for example of nutrients, greenhouse gases and pollutants. For large-scale land uses (agriculture and nature conservation) some of the indicators are already being monitored at the local level (see Table 5). The monitoring data collected at local level therefore need to be made available to managers at catchment level. Table 6 lists indicators for large-scale uses, thereby complementing Table 5.

Not much experience has yet been acquired of monitoring biological indicators. We recommend that a start is made with a number of pilot areas or random samples. To start with, trends in the indicators can be monitored, so as to build the necessary knowledge base. It is usually known whether high values correspond to good or poor functioning of the ecological services. The results can be used to evaluate the suitability of the indicators and the required monitoring frequency.

Table 6. Suggestions for indicators for monitoring the condition of ecological services at catchment level (or larger). These are ecological services which must be managed at the catchment level.

Agriculture	Water buffering capacity, carbon fixation, methane oxidation, biodiversity (general), landscape features, geological features
Nature areas	Water buffering capacity, carbon fixation, methane oxidation, pest-resistance, landscape features, geological features
Public open spaces	Water buffering capacity, carbon fixation, methane oxidation, biodiversity (general), landscape values, geological features
Allotments	Water buffering capacity
Domestic gardens	Water buffering capacity

Notes on Table 6:

- Geological features: indicator of special geological elements, archaeological sites, ability to ‘read’ landscape (descriptive rather than an indicator).
- Biodiversity (general): contributions to genetic, functional and structural biodiversity in the Netherlands.
- Landscape features: indicator of attractiveness of landscape, characteristic elements in the landscape of the Netherlands (descriptive rather than an indicator).
- Methane oxidation: indicator of the capacity to fix methane or discharge it to the atmosphere.
- Carbon fixation: indicator of the sequestration of carbon in the soil and/or discharge it to the atmosphere.

- Water buffering capacity: indicator of the capacity to store water temporarily and gradually release it, and indicator of potential drought and water damage.

We do not recommend that standards are set at present for the indicators. Experience should first be acquired with ecosystem-based management and the use of indicators to monitor the functioning of the ecological services. We fear that a discussion on standards for indicators will distract attention from and undermine support for ecosystem-based management. We consider that ultimately it is desirable that the authorities should set targets or goals for the indicators, as this will help them optimise ecosystem health. Target values reflecting ‘good or desirable’ values of indicators are one element, which need to be considered alongside the economic and social dimension of the land use. Decisions must be taken on the basis of sound information. These decisions are complex, and there may be a role for decision-supporting instruments [59].

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ANNEX 1

The letter of the Minister of Environment has not been translated.

ANNEX 2

LINKAGES BETWEEN ECOLOGICAL SERVICES AND LAND USES: SEPARATE ASPECTS

In chapter 5 linkages were established between the ecological services and various types of land use. It was concluded that all the ecological services are important for nearly all forms of land use at both the local and catchment levels. It may however be possible to increase the discriminatory power for the various forms of management by subdividing the ecological services into separate aspects. We present below a non-exhaustive list of aspects of the ecological services linked to land use, at the local level in terms of the services needed and at the catchment level in terms of ‘contributions to’ (cf. Tables 1 and 2 in chapter 5).

The ecological services are:

1. Soil fertility
2. Adaptability and resilience;
3. Buffer and reactor function;
4. Biodiversity;
5. Resistance to disease and pests;
6. Physical structure.

The separate aspects distinguished are (the number of the appropriate ecological service is shown in brackets; the first part only will be used in the Tables):

- Adaptability: capacity to adapt to another use (2)
- Autonomy: development of nature (1 and 4)
- Biodiversity (general): all aspects of biodiversity considered (1, 2, 3, 4, 5)
- Soil archive: geographical and archaeological features (6)
- Soil structure (1 and 6)
- Greenhouse gases: conversion of gases such as carbon dioxide, methane, volatile organic compounds (3)
- Firmness: ability of the soil to withstand subsidence and settlement, particularly in peatlands (3 and 6)
- Functional biodiversity: diversity of functions/processes in an ecosystem (1, 2, 3, 4, 5)
- Genetic biodiversity: diversity/stock of genes in an ecosystem (2, 4, 5)
- Groundwater: quality and quantity (3)
- Landscape: quality and diversity (4 and 6)
- Air: self-purifying capacity (3)
- Organic matter (1, 3, 5, 6)
- Resistance to disease and pests (5)
- Production: agricultural products (1)

- Structural biodiversity: number of different species and interactions between species in an ecosystem (2, 6)
- Transport: water inflow and outflow (ability to transport water) (3)
- Water buffering: capacity to store water temporarily, and gradually release it (3)
- Self-purification: ability to break pollutants down (3)