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Incorporating ecological sustainability into landscape planning

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Abstract

The ecological component is crucial in landscape planning according to the principles of sustainable development. We define "ecologically sustainable landscape" and develop a tool to measure how ecological sustainability is incorporated in landscape plans. This method acknowledges the critical role of spatial scale and pattern to the conservation of biodiversity. The metapopulation concept is used as a spatially explicit ecological theory, appropriate to describe the relation between biodiversity and the pattern of ecosystem patches ("ecosystem network") in intensively used regions. We propose that ecological sustainability is achieved if quality, area and configuration of the ecosystem network permit target species to persist. A simple decision-making model represents a theoretical framework for a tool comprising two sets of ecological indicators. One set indicates the awareness of actors to consider ecological principles of sustainable planning. The other set indicates their performance to apply these principles quantitatively in designing the ecosystem pattern. The method is applied on a sample of reports on Dutch landscape development plans. A majority of the reports shows awareness of the importance of spatial conditions for achieving planning goals, but perform inadequately on the quantitative indicators. We conclude that the tool could be developed as a guideline and assessment method for the ecological sustainability of landscape plans.

Keywords: Ecological planning; Biodiversity; Ecological networks; Decision-making; Stakeholder involvement; Sustainable development

1. Introduction

In Western Europe, as in other urbanised regions of the world, land use functions strongly compete for space. In decision-making processes about land use change, functions related to the ecological integrity of the land (biodiversity, ecosystem services) and the quality of life (recreation, landscape scenery, environment) are often regarded as non-compatible with expanding technologically driven functions (Cairns, 1999). Short-term goals related to economic values tend to dominate over public values related to landscape and ecosystems. By contrast, sustainable development is widely accepted as a strategic framework for decisions on the future use of land (IUCN, 1992). The principles of sustainable development imply that in developing land, ecological, social and economical functions are balanced in space and time to maintain their potential to deliver goods and services to future generations (WCED, 1987; Linehan and Gross, 1998). Therefore, in the context of sustainable development, decisions on landscape change must take into account the three dimensions of the landscape concept, each of them representing a different way of looking at the function and pattern of landscapes (Leitão and Ahern, 2002; Opdam et al., 2006). These dimensions are: the *eco-physical* dimension, defined by geographical patterns and ecological processes; the *social* dimension, defined by parameters of human perception, land use and physical and mental health; and the *economic* dimension, defined by the landscape's capacity to produce economical values.

Understanding these dimensions and their interrelations, such as adverse effects as well as synergy and trade-offs, is the key to sustainable development (Pope et al., 2004). This holds in particular in decision-making on landscape development. The way people decide about landscape change and how they use knowledge of the eco-physical, social and economic dimensions for those decisions are crucial components that determine whether the outcome of the development is sustainable. In this context, decision-making is, in the first place, on attributing targets for nature conservation, quality of life or economic welfare to the landscape region. Secondly, it includes the assessment of ecolog-

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ical, social and economic values and their interactions. Thirdly, decisions are made on the allocation of land use functions.

This study focuses on the relation between the eco-physical dimension of landscape and decision-making on ecological functions in the context of landscape (i.e. spatial) planning. Many land use decisions affect the spatial pattern of ecosystems or the intensity of human land use. These changes may have major implications for the ecological functions of landscape. Much literature indicates that the persistence of many populations in a region depends to a great deal on the area and spatial configuration (connectivity) of good quality habitat (Soulé and Terborgh, 1999; Opdam et al., 2003). Habitat loss and fragmentation are major causes of loss of biodiversity (Saunders et al., 1991; Turner, 1996). Therefore, landscape planning should include the changes in area and configuration of the ecosystem pattern in a region, as well as their consequences for biodiversity. This focus is consistent with the aims of most nature conservation agencies (Redford et al., 2003).

Although we focus on the eco-physical dimension, we have no intention to neglect or put in the background the importance of the social and economic dimensions and their relation to decision-making in landscape planning. In our view, however, the ecological functions of the landscape have not been given the same level of attention in decision-making as the economic and social functions. For example, definitions of and indicators to measure ecological sustainability are hard to find in scientific literature. One possible reason for this paucity is the limited transfer of knowledge between the eco-physical and the landscape planning domains (Moss, 2000; Antrop, 2001; Opdam et al., 2002; August et al., 2002; Wu and Hobbs, 2002). Ndubisi (2002) concludes, in his extensive overview of approaches in ecological planning, that landscape ecology potentially has a lot to offer to improve the ecological basis to spatial planning, but that it has not yet succeeded in developing procedures for the systematic integration of concepts into planning. The imperfect definition of ecological sustainability can also be a reflection of the preliminary state of defining sustainable development (Pope et al., 2004). In the mid 1990s the countries of the European Union had hardly proceeded with incorporating sustainability in spatial planning and policies (European Commission, 1997). We have found no evidence nor have we reason to assume that things have changed considerably since.

We argue that the transfer of landscape ecological knowledge towards planning will be improved by developing a science-based tool for incorporating principles of ecological sustainability into landscape planning situations. Such a tool should make these principles measurable and debatable. An important condition is that non-ecologists must be able to use it. Another requirement is that the tool should be a general one, i.e. it should be applicable to different kinds of plans (strategic plans, master plans, regulatory plans, etc.) on different scale levels (national, regional, local). The aim of this paper is to develop this tool. To that end, we need a framework for building the decision-making on scientific research evidence. This framework should include an operational definition of ecological sustainability and a decision-making model with corresponding indicators, which can be derived from that definition. We will construct such a framework as a basis for the tool and analyse the possibilities of applying the tool in concrete landscape planning situations. Our target group is the group of planners, i.e. those who are responsible for developing a landscape plan. As we see it, they need a tool to assess the ecological quality of their plans and adapt the plans when quality standards or not met. They could also use it to report systematically to decision-makers and the public.

The structure of this paper is as follows. After developing a definition of ecological sustainability suitable for landscape planning, we analyse the ecologically sustainable conditions that could be related to this definition and propose a set of indicators to incorporate ecological sustainability into a landscape planning context. Subsequently, the applicability of the tool is analysed. To that end, we use a sample of landscape plans taken from recent Dutch planning cases. A discussion of the theoretical considerations underlying the proposed tool and of its practical applicability concludes the paper.

2. Goal-setting in planning ecologically sustainable landscapes

Modern policy-making demands the formulation of verifiable and therefore concrete and measurable targets (Smith and Sheate, 2001; Pope et al., 2004). With such quantitative targets the money spent on ecosystem conservation can be checked on criteria for effectiveness and added value. What scientific basis is available for goal-setting and how could a goal-setting procedure be made operational?

Recognising the preliminary state of defining the concept of sustainable development (Pope et al., 2004), assumptions are inevitable. Let us assume that sustainable development implies that landscapes are changed and exploited in a way that ensures they will remain in a healthy state and their services are available for use by subsequent generations (IUCN, 1992; Pullin, 2002). Gobster (1994) proposed that ecological sustainable land management aims to restore and maintain the ecological structure and function of ecosystems and to preserve and enhance the health and diversity of species and ecological communities. Building on this and recognising that landscape planning is often practised in multifunctional landscapes, we propose to focus on semi-natural and natural ecosystems and ecosystem mosaics, including the populations and communities supported by them. However, this focus is not yet practical enough for goal-setting in landscape planning. Functioning of ecosystems is connected to ecosystem type, area, configuration and abiotic conditions. Hence, goal-setting should be equal to choosing a certain level of ecological functioning, the ambition level, in a way permitting a translation into spatial dimensions of the ecosystem pattern. We explore two options for determining ambition levels: one based on the life-support functions and other ecosystem services, the second one based on proxies of biodiversity.

Cairns (1999) summarised why human society depends on the life-support functions provided by ecosystems. Ecological sustainability requires that the sum of benefits people derive from the landscape is maintained (Haines-Young, 2000).

Existing concepts like natural capital and ecosystem services (Costanza et al., 1997; Edwards and Abivardi, 1998; Haines-Young, 2000) are based on this notion. However, as far as we see it, the progress in this field of ecology is not far enough yet to permit quantification of the required levels of ecosystem services for a planning area and certainly not in a way that is manageable and understandable for regional actors in the planning process. Moreover, the valuation of ecosystem services and the quantitative relation between such values and the characteristics of ecosystem pattern characteristics is poorly understood (Chee, 2004).

The second option starts from the notion that biodiversity is a conservation focus in itself. This goal, expressed in terms of lists of species to protect, is the basis for many nature conservation acts and policy declarations worldwide. Examples are the U.S. Endangered Species Act (ESA) of 1973 (Redford et al., 2003) and the IUCN red lists (Hilton-Taylor, 2000), the Birds and Habitats Directives of the European Union (European Commission, 1979, 1992) and the sustainability principles defined by the Western Australian government (Pope et al., 2004). This is a strong argument to build goal-setting on the basis of species mentioned in conservation acts. Therefore, for the time being, we assume that a list of protected species is a species diversity proxy. Biodiversity has been functionally linked to ecosystem services. For example, species diversity generates ecological stability at the ecosystem and landscape level, particularly in changing environments (Gunderson, 2000; Loreau et al., 2001). However, as expressed above, research on ecosystem services needs to evolve considerably before the role of biodiversity in delivering ecosystem services can be specified. Another argument for using species diversity is that operational methods exist to relate population performance to dimensions and shapes of ecosystem patterns in landscapes quantitatively (Verboom et al., 2001; Opdam et al., 2003). Therefore, we conclude that goal-setting for ecological sustainable landscape planning based on biodiversity proxies is possible in practice. As a workable proxy, we recommend a list of focal species (Lambeck, 1997) or ecoprofiles (Vos et al., 2001) for a particular region.

The final question to answer here is how to choose the ambition level. Fig. 1 illustrates the principle that species can be ranked according to the amount of area they need and the distances they can move between spatially separated ecosystem units in the landscape (Vos et al., 2001). Consequently, the more species are included in the conservation goal, the more conservation effort, public support and finances are required. Hence, the ambition level can be defined as a certain point in the graph, which is chosen as the ecological planning goal for a landscape region. In planning situations, of course, decision-makers will balance this ambition level to the aims set for the social and economic dimensions of the landscape. In doing so, they will also need to incorporate conservation goals defined at a higher administrative level, for example international and national conservation goals in case of regional or local planning. The role of scientists is to provide the actors in the planning process with the information and tools that allow them to found goal-setting upon the principles of sustainable landscape development.

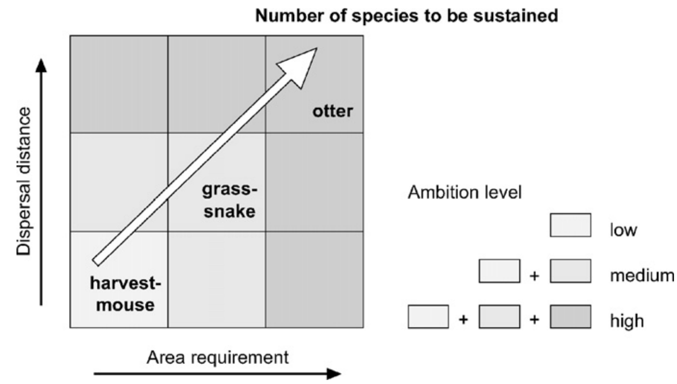

Fig. 1. Representation of ambition levels as points in the graph of dispersal distance and area requirement with corresponding example species. Every grey square includes the species of that ambition level and of lower ambition levels (based on Van Rooij et al., 2003).

We conclude that goal-setting in landscape planning (given the state of the art of science) can best be made operational on the basis of focal species or ecoprofiles. It implies that the physical conditions of the landscape allow populations of targeted species to persist in the planning area in the long term. To develop a method by which actors in a regional planning process can define a feasible target for ecological functions, including both species diversity and ecosystem services, is a challenge in itself and outside the scope of this paper.

3. Deriving ecologically sustainable conditions from the planning goal

In a sustainable landscape, as discussed in the previous section, the spatial pattern of ecosystems should permit populations of targeted species to survive. It is the population that must be conserved, not the individual. For defining a persistent population we need to be explicit on the probability by which the population survives within a certain time span. Verboom et al. (2001) used a minimum threshold of 95% chance of survival in 100 years. To reach this threshold, the population should hold a minimum number of individuals, which equals a minimum amount of ecosystem area consisting of habitat for the species. If this area cannot be achieved as one continuous ecosystem area, as is often the case in landscapes where nature has become fragmented, an alternative option is to ensure that scattered ecosystem patches function as an ecological or (as a preferred synonym) ecosystem network (Opdam, 2002; Hobbs, 2002, Jongman et al., 2003). A functional network is possible if the flow of individuals between the ecosystem patches is strong enough. The resulting “network of populations”, inhabiting the ecosystem network, is called a metapopulation (Verboom et al., 2001). This spatially structured population typically shows a dynamic distribution pattern in the ecosystem network, resulting in extinctions in occupied patches, local absences, and reestablishments in patches that were unoccupied by the species. A particular ecosystem network can provide appropriate spatial conditions to a range of species (Soulé and Terborgh, 1999; Cairns, 1999; Opdam, 2002; Jongman et al., 2003; Opdam et al.,

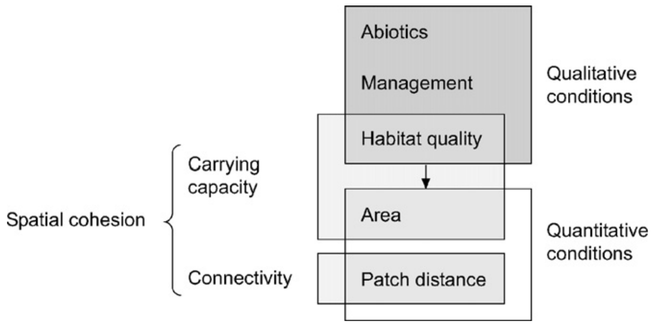

Fig. 2. Items that determine the quality of ecological networks, represented by a scheme of the parallels between the concept of spatial cohesion, dependent on carrying capacity and connectivity, and the distinction of qualitative and quantitative conditions. The qualitative conditions influence the quantitative conditions.

2003). Ecosystem networks are an appropriate physical structure for populations to survive in intensively used landscapes, where single large ecosystem areas with enough habitat to ensure persistence to many species do no longer occur (Kinnaird et al., 2002; Myers, 2003). Therefore, we will use the ecosystem network concept to link the planning goal, expressed as the persistence of target species, to the spatial pattern of ecosystems in the planning area. As a practical measure for this link, we will use the "spatial cohesion" concept (Opdam et al., 2003) to describe the physical characteristics of an ecosystem network in an ecologically significant way. Spatial cohesion encompasses two structural components: carrying capacity and connectivity. Carrying capacity, related to the maximum number of individuals a network can sustain, includes habitat quality and network area. Connectivity, including network density and matrix permeability, controls the flow of individuals between the patches. Carrying capacity assumes a minimum habitat quality level (main items: vegetation type and disturbance by, for example, recreation and traffic noise). Together with abiotic conditions (main items: hydrology and soil) and management of the area, these factors encompass the qualitative conditions of the network (Fig. 2). In addition, sustainable populations need a minimum network area and a minimum connectivity, the quantitative conditions of the network. The combined qualitative and quantitative conditions need to meet the demands of each target species. To some extent, these conditions are mutually exchangeable in their effect (Opdam et al., 2003). For example, when the habitat quality of an ecosystem network decreases, the carrying capacity can be kept at the same level by enlarging the network area.

In summary, we assume that a landscape is ecologically sustainable if the qualitative and quantitative conditions of the ecosystem pattern are in balance with a chosen target, expressed in terms of a list of species. This definition excludes the use of other proxies of ecosystem functioning as a planning target than those linked to species diversity. For example, "ecosystem type" or "nature" is not specific enough to serve as a quantitative goal in planning; "ecosystem type" is independent of network area and connectivity, whereas the target "nature" is even more ambiguous.

4. A tool to balance biodiversity goals and spatial conditions in planning

For a landscape plan to be ecologically sustainable, not only the spatial conditions of the ecosystems need to be in balance with the chosen biodiversity goal, but also these two aspects together need to be made concordant with the realisable conditions in the planning area. How can this be achieved by landscape planners? We propose to develop a tool, as mentioned in the introduction, which helps to focus on the most important aspects of ecological sustainability. Such a tool includes a set of indicators that are easy to understand to a broad variety of disciplines and translate the key characteristics of ecologically sustainable landscapes into items useful for landscape planning. These indicators should be specific for different steps in the decision-making process. Hence, we need to extend our theoretical framework by defining these steps first.

In Fig. 3, we propose a conceptual model of decision-making for ecologically sustainable landscape development. Although we operate in a multifunctional context, this model is limited to the eco-physical dimension of the landscape for the sake of simplicity. The dashed frame represents the administrative level of the planning area. At this level, the nature conservation targets are chosen. This choice is influenced by the boxes outside the dashed frame. One box refers to including nature conservation targets of higher administrative levels. A second box involves conditions required for persistence of populations of target species, provided by scientific research. Such conditions are compared to the feasible and acceptable conditions for the planning area, which may result in a reassessment of the targets chosen originally. A third box represents the inclusion of ecosystems outside the planning area, which may contribute to a larger scale ecosystem network, allowing targets of a higher ambition level. The steps in the decision-making process are explained in further detail below.

At the start of the decision-making process, a spatially explicit goal has to be chosen, for example based on species diversity. Conservation targets of higher administrative levels provide an important input and need to be incorporated. In addition, arguments related to socio-cultural values may play a role in decision-making on biodiversity goals (McCool and Stankey, 2004), but we neglect those in our model. Subsequently, it needs to be checked whether the required spatial conditions for the planning goal (i.e. the selected species or ecoprofiles) are realisable within the planning area. If the ambition level turns out to be too high, a potential solution is to consider the spatial conditions of the neighbouring areas and to develop the local network as a part of a larger scaled network. In this way, higher ambition levels can be pursued than when restricting planning within the limits of the planning area. However, by extending the decision-making process beyond those limits, cooperation with other administrative units becomes necessary. If the spatial conditions for the chosen target species are not realisable within the planning area and if including the neighbouring areas is not an effective or preferred option, a lower ambition level has to be determined: the decision-making process becomes cyclic.

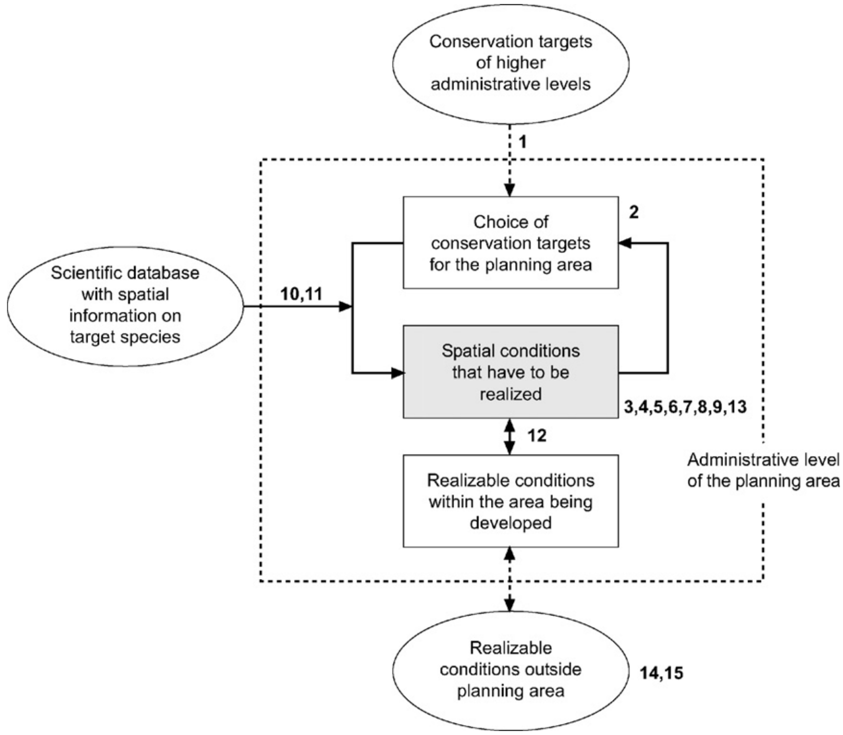

Fig. 3. Schematic visualisation of decision-making on spatial conditions for biodiversity targets. The numbers represent ecological planning indicators as explained in the text.

In this paper, we distinguish indicators for the ecological functioning of the landscape (ecological indicators) from indicators for the use of ecological criteria and values in the planning process (which we call ecological planning indicators). Ecological indicators mirror the ecological functioning of the landscape, for example indicators related to ecosystem services (Luck et al., 2003) or ecosystem fragmentation (Vos et al., 2001). These ecological indicators belong to the eco-physical dimension of landscape (Dale and Beyeler, 2001). Alternatively, ecological planning indicators inform about the outcome of the decision-making process; they are representative for the link between ecology and landscape planning. Such indicators measure the degree to which decisions about landscape development contribute to ecological sustainability, for example: has a verifiable target been chosen and is the planned ecosystem network adequate for the target? Literature abounds on the ecological indicators (European Environment Agency, 2002), but we could not find examples of the latter type.

Therefore, we extend the decision-making model with a set of simple, measurable ecological planning indicators. Most arrows and boxes of the model include one or more indicators, represented by the numbers in Fig. 3. Since the set of indicators has to be usable for communication and discussion, we propose a limited number large enough to cover all relevant items for ecological landscape planning. We propose generic formulations of the indicators, assuming that they will have to be made operational for specific aims.

The indicators measure the performance of decision-makers with respect to dealing with ecological sustainability. In its simplest form, these indicators have a binary notation, meaning that a step in the decision-making model has been taken or not. We propose to distinguish two sets of indicators: awareness indicators and key indicators. The awareness indicators tell us on which aspects the decision-makers have the awareness of conditions required for ecologically sustainable plans. The key indicators assess on which aspects they succeeded in making the plan sustainable. The key indicators tell us whether both qualitative and quantitative conditions are appropriate for a verifiable conservation target. A positive score on the awareness indicators is a necessary but not sufficient requirement for ecologically sustainable plans. A positive score on the key indicators is also needed. Both sets of indicators are linked in such a way that a positive score on the awareness indicators is prerequisite for a positive score on the associated key indicator. For example, in the list below, indicators 9–12 are prerequisites for indicator 13. The following ecological planning indicators, with awareness indicators A and key indicators K, are proposed:

- *Choosing targets*
  - Indicator 1 (A): Targets of higher administrative levels are used for choosing nature conservation targets for the planning area.
  - Indicator 2 (K): Verifiable nature conservation targets are chosen.
- *Qualitative conditions*
  - Indicator 3 (A): The abiotic conditions are taken into account in the planning process.
  - Indicator 4 (K): The (planned) abiotic conditions are appropriate for the nature conservation targets.

- Indicator 5 (A): The management of ecosystems (including physical development) is taken into account in the planning process.
- Indicator 6 (K): The (planned) management of ecosystems (including physical development) is consistent with the required habitat for the conservation targets.
- Indicator 7 (A): The habitat quality is taken into account in the planning process.
- Indicator 8 (K): The (planned) habitat quality is appropriate for the conservation targets.

- *Quantitative conditions*
  - Indicator 9 (A): "Ecological networks" is used as a spatial concept.
  - Indicator 10 (A): Spatial information on target species is used to determine which spatial conditions have to be realised.
  - Indicator 11 (A): The habitat quality is taken into account to calculate the quantitative spatial conditions that have to be realised.
  - Indicator 12 (A): The planned nature is spatially defined.
  - Indicator 13 (K): The planned configuration and area of nature are appropriate for the ambition level.
- *Areas beyond the limits of the planning area*
  - Indicator 14 (A): The adjacent areas are taken into account in the planning process.
  - Indicator 15 (K): The spatial conditions of the ecosystems in adjacent areas are known and (in combination with the conditions in the planning area) appropriate for the conservation targets.

5. The tool in practice: a case study

To explore the applicability of the tool and the kind of results that can be expected, we applied it on a sample of Dutch landscape plans. The legal planning system in the Netherlands is embodied in the Spatial Planning Act and in a number of sector laws, such as those on nature protection, land consolidation, rural land management and water management. All three tiers of government (national, provincial, municipal) have planning powers. National and provincial land use plans are broad strategic framework plans and policy guidelines. The municipalities have the statutory power to make framework plans as well as binding land allocation plans (Van der Valk, 2002). Plans that are based on sector laws can be found on all levels of government. These plans usually focus on the implementation of policies. To come into effect they must comply with or give rise to an adaptation of the land allocation plan. Another characteristic of the planning system is that plans of lower administrative levels must conform to plans of higher levels, although the ability of the higher levels to direct the lower levels is increasingly limited and subject to negotiations.

To gather the required data about the plans, different methods can be used. One way is to obtain detailed information by studying every document available and talking to the commissioners and those responsible for the planning process. Another way is to use only the information mentioned in the final report. The second method gives a less thorough assessment of each plan,

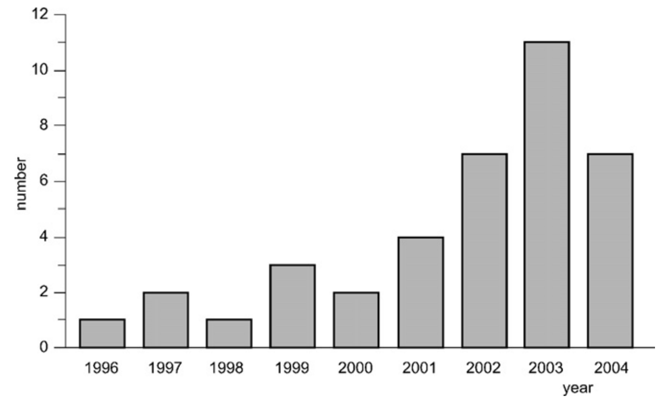

Fig. 4. Distribution of years of publication of the plan reports in the sample of the case study.

but more plans can be handled. In this case study, we have used the second option, because the tool is meant to play a role in communication about ecological quality of landscape plans and therefore must be applicable without a time-consuming analysis. Additionally, the tool must be able to deal with a variety of landscape plans. Therefore, we maximised the size of the sample to get a representative view of the variety of Dutch landscape plans and the applicability of the tool. Initially, the sample consisted of 62 landscape plans. We asked all kinds of consulting companies and advisory bodies to send plan reports to us. All selected plans were multifunctional, including nature related goals (ecosystem area, corridor, ecological network, etc.) as well as goals with respect to other functions, like recreation, housing projects, industry and infrastructure. No more than four plans per consulting company or advisory body were used, excluding the surplus plans from the sample. Plans in which no nature was assigned to new areas (plans restricted to nature management) and operational plans (blueprints) were not taken into account. Draft plans were also excluded. Hereafter, the sample consisted of 38 landscape plans. Most plans were dealing with planning problems at the local level (up to 100 km^2), whereas 18% pertained to larger (regional) planning areas. All plans were of a recent date, because "ecological networks" is a relatively new concept in The Netherlands (launched in 1990 as the Dutch National Ecological Network). Plans had been commissioned by provinces and other regional authorities (42%) or local authorities (48%), for example municipalities, and some by national authorities. Eighty-two percent of the plan reports were published in the year 2000 or later (Fig. 4).

All plan reports in the sample have been examined to find out whether the requirements of the ecological planning indicators 1–15 were fulfilled. These results per plan were combined and expressed in percentages. As said before, to apply the generic list of ecological planning indicators in a specific case, it has to be specified. We adapted the indicators to the limited information provided by the plan reports. The specified indicators are described in Box 1. In this respect, "nature" is defined as areas of specific types of natural and semi-natural ecosystems, such as dry forest, wet grassland and marsh. Box 2 provides additional information on how to check the quantitative conditions of a landscape plan.

Box 1. Specification of the ecological planning indicators for the case study

- *Choosing targets*
  - Indicator 1 (A): The plan report states that one or more elements of the planned nature are adopted from nature conservation targets of higher administrative levels, i.e. European, national and regional targets for local plans and European and national targets for regional plans.
  - Indicator 2 (K): In the plan report, target species are systematically mentioned per ecosystem for all the nature in the planning area, for part of the nature, or only some species are mentioned. Target species should be mentioned for all the nature in the planning area to be able to verify the results. If not, what is the progress in the process of learning to define target species? Are species mentioned for part of the nature area or are only some species mentioned or none at all?
- *Determining qualitative conditions*
  - Indicator 3 (A): It is mentioned in the plan report that soil and hydrology are considered during the planning process.
  - Indicator 4 (K): The abiotic conditions described in the plan report, which are narrowed down to the conditions of soil and hydrology, are appropriate for (the ecosystem types of) the nature conservation targets.
  - Indicators 5 (A) and 6 (K): Not applied, because we excluded nature management planning.
  - Indicator 7 (A): It is mentioned in the plan report that at least two of the three items recreation, noise/traffic and nutrient emission, are considered during the planning process.
  - Indicator 8 (K): The habitat quality described in the plan report, which is narrowed down to the aspects recreation, noise/traffic and nutrient emission, is appropriate for the nature conservation targets.
- *Determining quantitative conditions*
  - Indicator 9 (A): It is mentioned in the plan report that either a spatial concept "ecological networks" is used or a combination of areas and corridors. Alternatively, the use of this concept may appear from the map, which is included in the report.

Box 1. (*Continued*)

  - Indicator 10 (A): The required quantitative conditions, represented by needed habitat sconfiguration and necessary area of nature for the target species, are mentioned in the plan report.
  - Indicator 11 (A): It is mentioned in the plan report how the abiotic conditions and the habitat quality of the planning area affect the area needed by the target species.
  - Indicator 12 (A): The planned nature types are described on a map.
  - Indicator 13 (K): The quantitative conditions described in the plan report or on a map are appropriate for the ambition level. To check this, a practical method based on the principles as described by Verboom et al. (2001) and Opdam et al. (2003) is useful (see Box 2).
- *Including adjacent areas*
  - Indicator 14 (A): It is mentioned in the report that it is assumed, either implicitly or explicitly, that there is a functional ecological connection between the ecosystems in the planning area and the ecosystem pattern of the surrounding area.
  - Indicator 15 (K): The ecosystems in the planning area together with the ecosystems in the surrounding area are appropriate for the nature conservation targets. See indicators 3–8 for the qualitative conditions and indicators 9–12 for the quantitative conditions.

Applying the thus specified indicators to the plan reports in the sample, we found the following results for the awareness indicators (Fig. 5). The majority of the reports, but not all of them, included nature targets of higher administrative levels (indicator 1): in 74% of the reports one or more elements of the planned nature were adopted from nature targets of higher administrative levels. Most reports (84%) took soil and hydrology into account in the planning process, in 11% only one of these items was mentioned (indicator 3). Planners were much less aware of the potential impacts of land use activity on habitat quality (indicator 7). Of the three items recreation, noise/traffic and nutrient emission, 37% of the reports considered two of these items (not explicitly mentioning that the third one was not important). In 45% only one item was given attention. The importance of a spatial approach based on ecosystem networks was recognised in 87% of the reports (indicator 9). Nevertheless, in only 8% this awareness was translated into specific minimal area and configuration guidelines for the target species (indicator 10). This information could be indirectly acquired from maps in 63% of the reports, because they included a map on which

Box 2. How to check the quantitative conditions of a landscape plan

To evaluate the ecological sustainability of ecological networks landscape cohesion assessment tools, for example LARCH (landscape assessment rules for the configuration of habitat; Chardon et al., 2000; Groot Bruinderink et al., 2003), can be used. This tool needs a lot of data input and expert knowledge to work with it. The tool is also time-consuming, since data have to be digitised. Therefore, such tools are not useful in a planning process with strict deadlines, little money for ecology and executed by people without an ecological background, despite the good results. A more practical method, executed by hand, does not exist, but could be developed, according to the following steps (based on Verboom et al., 2001; Opdam et al., 2003):

- For practical reasons, simplify the concept of connectivity to the distance between patches that is covered by most dispersing individuals (dispersal distance).
- Put the target species with the same habitat, dispersal distance, area requirement and barrier sensitiveness together in a group: an ecoprofile (Van Rooij et al., 2003). The group with the highest dispersal distance and area requirement represents the highest ambition level. Determine the quantitative spatial conditions belonging to this ecoprofile (Verboom et al., 2001; Vos et al., 2001), if possible taking into account the habitat quality.
- Use the dispersal distance, barrier sensitiveness and presence or absence of ecological corridors to determine which patches of the ecosystem type can be clustered into an ecological network for the ecoprofile.
- Determine whether there is an area large enough in the ecological network to allow a minimum viable population.
- If not, determine whether there is an area large enough to allow a key population. If present, the network is sustainable when it is large enough to allow a viable metapopulation.
- If a key area is not present, the network is still sustainable when it is large enough to allow a viable metapopulation, but more network area is needed.

planned ecosystems or more detailed descriptions of nature were spatially defined (indicator 12). However, this result also shows that one third of the landscape plans did not include such information in the report. Moreover, none of the reports mentioned the effect of habitat quality on the area needed by the target species

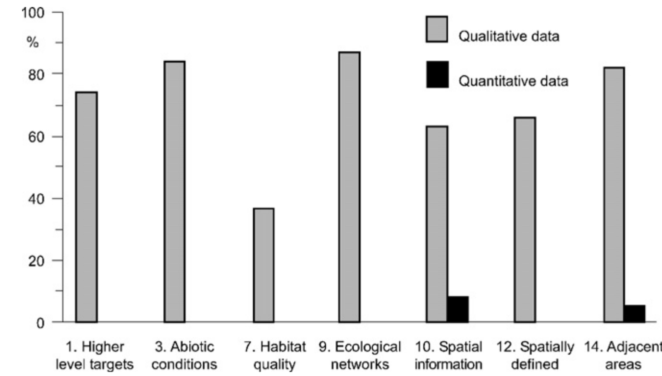

Fig. 5. Scores found for the awareness indicators. The numbers refer to ecological planning indicators explained in the text.

(indicator 11). Awareness that the areas surrounding the planning area were part of the ecological system was demonstrated in 82% of the reports, but just 5% went beyond this notion by presenting quantitative data for total area and/or configuration (indicator 14).

For the key indicators we found the following results. The only key indicator that could be determined is the one on goal-setting. It appears that in only 24% of the plan reports target species were mentioned for all the nature in the planning area, in 29% for part of the nature and in 11% only some species were mentioned (indicator 2). We could not obtain results on the other key indicators (indicators 4, 8, 13, 15), because of insufficient data in the reports. For example, only a few reports mentioned target species for all the nature in the planning area and also described the spatial conditions in a verifiable way on a map or in the report. On none of these reports the check on quantitative conditions could be performed (indicators 13 and 15), due to the lack of information on specific species, habitat quality and adjacent areas.

This case study also illustrates the kind of results that can be obtained by applying the tool. If we consider the sample to be representative, these results can be interpreted as an indication of the ecological quality of recent Dutch landscape plans. It is significant that a definition of verifiable nature targets is present in only a quarter of the sampled plans, while knowledge on quantitative conditions was hardly applied, if at all. A positive sign is that 87% of the plan reports showed awareness that spatial cohesion of nature sites in the planning area is an important feature to consider. On the other hand, the sample suggests that the quantitative implementation of ecosystem networks is still in its infancy. Therefore, the case study indicates that the competence to incorporate principles of ecological sustainability in landscape planning still needs to be developed.

6. Discussion

We proposed a *tool* to make principles of ecological sustainability in landscape planning measurable and debatable and used a case study on a sample of Dutch landscape plans to test the practical value of the tool. The tool is embedded in a *framework* for building decision-making on scientific research evidence. The urgency for the development of this framework and the tool is suggested by research showing that most decisions in conservation management are not based on evidence, but on advice from other, secondary resources (Sutherland et al., 2004). The results of the case study are in support with this conclusion, suggesting that not much progress has been made since the European Commission (1997) made their statement on *incorporating principles of sustainability* into landscape planning. The question is how our results can improve this situation. We will organise our discussion along three issues: the tool, the framework and the implementation into planning practice.

What did the case study learn about the practical value of the *tool*? It was shown that the generic indicators can be specified for a particular set of plans and that the application of the tool permits a concrete and measurable interpretation of how principles of ecological sustainability are incorporated into landscape plans. We believe that such an interpretation will be helpful and necessary to decide upon improving the ecological quality of landscape plans. Whether the generic formulation of the indicators is flexible enough to cope with a variety of landscape types and planning methods must be revealed by further research.

While the plan reports always included enough information to examine the awareness indicators, only one key indicator could be assessed. The reason for this could be found in current weaknesses of the tool as well as in shortcomings in the current state of Dutch landscape planning. The landscape plans we investigated did not provide enough information to assess the quantitative planning indicators we proposed. Since what is written in the plan report not necessarily covers all available information, it remains possible that quantitative spatial conditions for target species were implicitly and, therefore, not transparently incorporated into a plan. We suggest that our tool might be developed as a guideline for providing the proper information on the ecological basis used in a landscape plan. To be able to play a role in the public debate on the plan's effectiveness and implications, the report must provide explicit and unambiguous information on the goal-setting and the measures proposed.

A proper measuring of the key indicators may also require improvements on the side of ecological methods. There is a shortage of spatially explicit guidelines at the landscape level, based on ecological thresholds (Moss, 2000; Boothby, 2000; Opdam et al., 2002). For example, scientific ecological information for many species is still not available and ecological indicators for sustainable landscape patterns are in a preliminary state. An issue for further research is whether the set of key indicators we proposed is flexible enough to cope with these insufficiencies. A potential solution might be adding a third, intermediate group of indicators, which reflect whether or not quantitative ecological data were used, irrespective of the outcome of the design. Assessing whether the plan is based on quantitative spatially explicit ecological data is a task less demanding than determining, by using the key indicators, whether the plan includes a sustainable ecosystem network design. However, extending the list of indicators might lower the effectiveness of the tool in practice (Spangenberg et al., 2002).

The *framework* encompasses two scientific domains, landscape ecology and landscape planning. Consequently, both for practical and theoretical reasons, we had to limit the scope of the framework and make a number of simplifications, both in the ecological and in the planning domain. For example, the decision-making model is limited to ecological aspects of the plan. Of course, in most, if not all, planning situations the decision-making process is much more complicated. Planning is about solving spatial conflicts between different land use interests under conditions of uncertainty (Faludi and Van der Valk, 1994). The social and economic dimensions play an important role in the planning process. An answer to the question whether plans will work and consequently contribute to ecological sustainability, depends largely on the effect they have on negotiations and decisions in the successive phases of the planning process (Hopkins, 2001). Therefore, a point for further research is how the simplifications we made affect our definition of ecological sustainability and our choice of ecological planning indicators.

A key issue of the framework is the definition of ecological sustainability. How dependent is our approach on this particular definition? Would another definition require a new set of indicators? Our definition uses a species list and qualitative and quantitative conditions of ecosystem networks. If ecosystem services are chosen, the chosen ambition level based on target species is substituted by desired quality levels of one or several ecosystem functions. This service level still demands enough ecosystem area and is probably also liable to constraints in configuration. Therefore, we believe that with another basis for goal-setting, the proposed indicators for decision-making might still be appropriate. Further research may reveal the need to add some other indicators, for example, indicators measuring whether the implementation of the landscape plan improves the ecological sustainability of the region. Another example is an indicator for the planning period (plan preparation and implementation) in relation to the development time of ecosystems.

How could the framework and the tool stimulate the *incorporation of ecological sustainability into landscape planning*? A first perspective we see, is to develop the tool as a guideline for ensuring the ecological quality of landscape plans. A second perspective is to develop the tool as an instrument for assessing the ecological quality of planning. For example, one could determine the progress made in improving ecological quality of landscape plans for an administrative unit, by repeating the assessment every 5 or 10 years. Moreover, one could compare plans from different administrative units or even countries. On this basis, a benchmarking procedure may reveal which administrative units or countries could learn from each other. An issue to be addressed in this context is how to make a sample which is representative for the average state of the art in landscape planning in a region or period. For example, in our sample biases may have been introduced by planners sending their ecologically 'best' plans for evaluation or by a disproportionately large representation of planners attributing a high importance to ecological sustainability. A check based on interviews could reveal such biases.

A critical condition for a prosperous career of our framework and tool in the planning domain is that planners recognise their added value. A prerequisite for an effective implementation is that the criteria will be acceptable for a variety of public and private stakeholders. Furthermore, they need to be appropriate in the context of the organisational and procedural arrangements of the decision-making process, such as planning approaches and procedural concepts (Beunen et al., 2004). Planners and decision-makers often lack time or money for a thorough investigation of the ecological features of the planning area on the basis of scientific evidence (Pullin et al., 2003). That is why we proposed a flexible, generic tool, which can be tailored to the demands of various planning situations. However, the tool is not yet used by planners. Issues which remain to be explored are for example: do planners agree with the need of verifiable ecological targets and ecologically sustainable designs, and what is their view on the practical assets of the tool we proposed?

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