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Biodiversity and Deciduous Forest in Landscape Management

Studies in Southern Sweden

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Abstract

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The landscape perspective has come to play an important role in efforts to achieve sustainable forestry, especially regarding the protection of biodiversity. However, introducing such a perspective in forestry planning can be difficult in areas where forestry is dominated by non-industrial private forest (NIPF) owners, such as southern Sweden. In this part of Sweden most of the biodiversity values are associated with deciduous trees, and forest owners as well as society have expressed an interest in increasing the proportion of these tree species. The major objective of the thesis is to achieve a better knowledge and understanding of the problems and possibilities of forest landscape management in southern Sweden. This was approached by addressing problems concerning the setting aside of forest areas, assessment of biodiversity and strategies for increasing the amount of deciduous trees in the landscape.

In the thesis it was concluded that, in two investigated landscapes, a common view existed among the NIPF owners regarding what areas to voluntarily set aside from commercial forestry. It was suggested that such a common view could be the basis of a planning process involving a landscape perspective in areas with NIPF ownership. The process of setting aside areas for biodiversity purposes was scrutinised. It was argued that in areas dominated by NIPF ownership this could be done in a more efficient way if a system for cooperation over the borders of estates was introduced. In the search for methods to assess biodiversity, stand characteristics interpreted in colour-infrared aerial photographs was correlated to the occurrence of epiphytic lichens in a landscape. It was concluded that this methodology could be a useful tool for achieving landscape-covering data on forest biodiversity. Finally, a simulation study of different strategies for increasing the proportion of deciduous trees was performed in two different forest landscapes.

Keywords: Case study, red-listed species, nature conservation, timber production, retention trees, logistic regression, projection model.

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Contents

Appendix

Papers I-IV

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Ask, P. & Carlsson, M. 2000. Nature conservation and timber production in areas with fragmented ownership patterns. Forest Policy and Economics 1: 209-223.

II. Ask, P. & Fredman P. Efficiency in forest protection in multiple landowner areas. (Manuscript)

III. Ask, P. & Nilsson, S.G. Stand characteristics in colour-infrared aerial photographs as indicators of epiphytic lichens. (Submitted manuscript).

IV. Ask, P. & Andersson, M. Strategies for increasing the proportion of deciduous trees. A landscape study from southern Sweden. (Submitted manuscript).

Paper I is reproduced by permission of the publishers.

Introduction

The passed decade has witnessed one of the most revolutionary changes in how forests resources are looked upon since the emergence of custodial forestry. From only the products and utilities we can get from a forest being considered, we have moved on to the view of ethical and moral considerations also needing to be taken into account (Sörlin 1993, Angelstam 2001). The concern for forest biodiversity is perhaps the most obvious example of this. In Sweden, the shift in this direction was manifested in the Forestry Act of 1994, in which the protection of biodiversity is considered to be just as important as the production of timber (Anon 1994, Ekelund & Dahlin 1997). Today the term "sustainability" has become the guiding star for all activities in forestry as well as in forest research. The conception of sustainable forestry often includes many different aspects of forestry and its repercussions, although the profitable production of wood and the preservation of biodiversity are two of the key elements here. They are also the aspects of sustainable forestry upon which the present thesis concentrates.

The landscape approach

In research on the preservation and restoration of biodiversity the landscape perspective often assumes considerable importance (Angelstam & Pettersson 1997, Hunter 1999a, Nilsson et al. 2001). Where does the concept of landscape really come from? To answer this, one needs to search far back in history and in the fields of art and geography. The origin of the term landscape can be found in the Germanic parts of northern Europe. The term denoted a territory or area which often had its own laws and a certain degree of independence (Olwig 1996). In the sixteenth century the concept of landscape as being natural scenery developed in the arts of painting and theatre (Keisteri 1990). This was also the time when the word landscape was introduced into the English language. In geography, ever since the beginning of the 19th century, the term landscape has been used in German literature to describe visible land forms and natural scenery (Keisteri 1990). Views concerning landscape were also developed further during last century by for example Sauer (1925) and Granö (1929).

The concept of landscape ecology dates back to the German geographer and ecologist Carl Troll, who introduced it in the late 1930s (Schreiber 1990). In 1963 he defined landscape ecology as "the study of the entire complex cause-effect network between the living communities and their environmental conditions which prevails in [a] specific section of the landscape". During the 1960s and 1970s landscape ecology became widely used in western and central Europe, especially in practical planning and in landscape architecture (Schreiber 1990, Wiens 1997). At the same time, another branch of biological research began to take an interest in spatial dimensions. In population biology the prevailing view was long that of emphasising the equilibrium and stability of local populations (Hanski & Simberloff 1997), but with a tentative start in the 1930s a more dynamic view began to emerge. With the theory of island biogeography (MacArthur & Wilson 1967) and the introduction of metapopulation dynamics (Levins 1969) spatial dimensions also came into focus in population biology.

In the 1980s when the concept of landscape ecology attracted considerable attention among American scientists the research field expanded rapidly in new directions (Forman 1990, Wiens 1997). It was at this time that debate regarding forestry and its impact on biodiversity emerged in North America. American scientists combined theories of metapopulation dynamics with landscape ecology applying them to forestry planning and to conservation biology in forest ecosystems (Forman & Gordon 1986, Franklin & Forman 1987, Turner 1989, Franklin 1993). When the "biodiversity wind" swept over the world in the early 1990s, as most evident in the Rio Conference in 1992 (UN 1992), the ideas stemming from North America were picked up by the rest of the world, especially in northern Europe the ecosystems of which are similar to those of North America. This is how the term "landscape" found its way into forestry planning, and became a prestigious word in connection with efforts to preserve forest biodiversity.

Forestry and biodiversity in southern Sweden

Southern Sweden is defined in the thesis as the Götaland region of the country (figure 1). This is a region characterised by a relatively flat landscape with altitudes varying between 0 and 350 m a.s.l. The bedrock is dominated by Precambrian granites and gneisses (Lundquist 1994), and quaternary deposits form rather deep soils consisting mainly of various types of till (Fredén 1994). The climate is fairly maritime with mean annual temperatures between 5 and 8° C (Vedin 1995), and an annual precipitation ranging from about 500 mm in the east to about 1200 mm in the west (Alexandersson & Andersson 1995).

The forest resources in southern Sweden have been utilised by man for thousands of years. In prehistoric times the clearing of forests for agriculture and grazing had a substantial impact upon the forest ecosystems (Berglund 1969, Lindbladh et al. 2000). In historic times, tar, potash, charcoal, firewood and leaf fodder were important products of the forests (Sjöbeck 1931, Larsson 1996). Most of the forest land in southern Sweden has been grazed by domestic animals for several centuries (Nilsson 1997a, Lindbladh et al. 2000). Intensive grazing, together with slash-and-burn agriculture, has contributed to the drastic decline in deciduous forests that has taken place during the last 1000 years (Lindbladh et al.2000). Dating back several hundred years for some tree species such as oak (*Quercus spp.*) and pine (*Pinus sylvestris*) (Larsson 1996, Eliasson & Nilsson 1999), the production of timber has gradually became the most important utility in the Swedish forests. Today the vast majority of the forest land in southern Sweden is used for timber production. Only about one percent of all forest is legally protected in terms of having been declared as reserves, although it is estimated that another four percent has been voluntarily set aside from use for timber by the forest owners (Anon 2001).

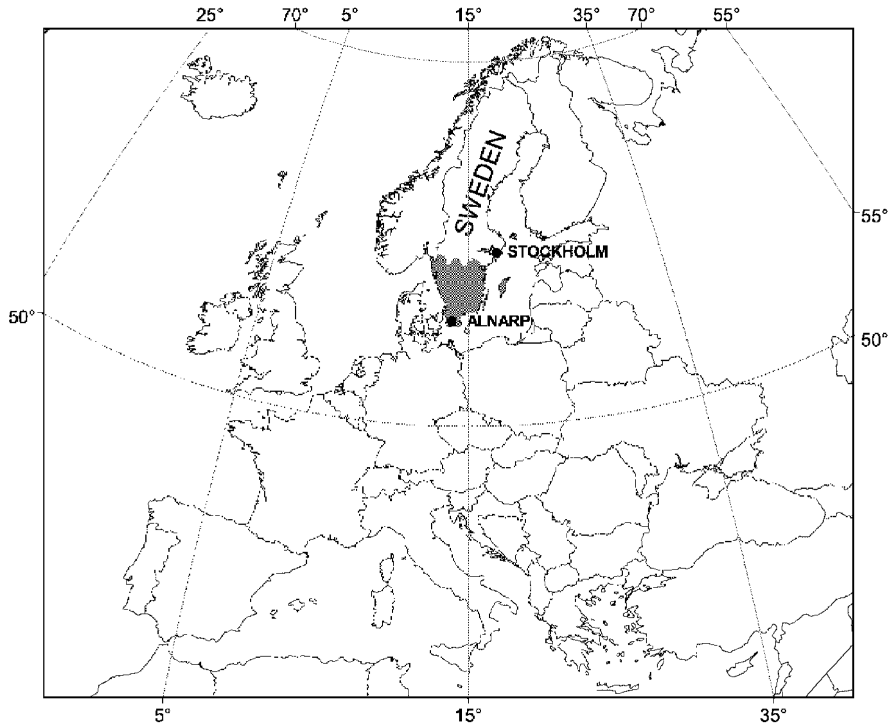

Figure 1. The location of the Götaland region (shaded) in southern Sweden.

Today's forestry in southern Sweden is characterised by a high degree of mechanisation and efficiency in forest operations. The Swedish forest industry is highly developed, the forest sector making an important contribution to the economy (Anon 2000). About 80% of the forest land in southern Sweden is owned by non-industrial private forest owners (NIPF owners), the forest owners' associations being strong actors on the timber market. Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) are the most common species used in silviculture. Of the deciduous trees, birch (*Betula pendula* and *Betula pubescens*) is most common. The Swedish Forestry Act defines eight different tree genera or species as being "southern deciduous trees" (in Swedish: *ädla lövträd*): oak (*Quercus spp.*), beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), elm (*Ulmus spp.*), lime (*Tilia spp*), maple (*Acer spp.*), hornbeam (*Carpinus betulus*) and cherry (*Prunus avium*). These trees have the benefit of special legal protection: They can be managed for timber production, be harvested and be regenerated, but cannot be replaced by species not defined as being southern deciduous trees (Anon 1994). It is also possible to obtain various subsidies for the management of these species. Such protection is provided due to these trees being of great value for biodiversity, for recreation and for landscape scenery.

Southern Sweden constitutes a transition zone between temperate (nemoral) and boreal ecosystems (Ahti et al.1968) and elements from both these vegetation zones can be found there. This creates conditions for a high level of biodiversity in many different groups of organisms (Bernes 1994, Nilsson 1997a, Nilsson 1997b). The total biodiversity present is very difficult to measure (Bernes 1994, Hunter 1999b), and much of the work on biodiversity in Sweden has been concentrated on the species most sensitive to extinction, that is on the red-listed species. The official red-list of Swedish species includes over 4000 species from all multicellular organism groups, 2100 of which are found in forests (Gärdenfors 2000). Insects, fungi and lichens constitute the major part of the forest species involved. Earlier investigations have shown the majority of the red-listed forest species in Sweden to be found in the southern part of the country (Berg et al. 1994).

During the period of 1993–1998 a nationwide inventory of so called "key habitats" was performed in the whole of Sweden by the regional boards of forestry (Nitare & Norén 1992, Anon 1995a). A key habitat is defined as a forest area in which red-listed species can be found, or conditions are favourable for them. About one percent of the total forest area in southern Sweden was classified in that inventory as being a key habitat, the southern deciduous trees being very much over-represented there (Anon 1999a). This is consistent with other investigations that also have shown the majority of the red-listed forest species in Sweden to be associated with southern deciduous trees (Berg et al. 1994, Gustafsson et al. 1999). Although the results of the key-habitat inventory have been questioned (Hultgren 2001), at the moment it is the best source of information on forest biodiversity that is available for forestry planning.

The Swedish emphasis on red-listed species is also reflected in the term *biodiversity value* which is used in the thesis. There are several possible interpretations of the term: For some people a forest of high biodiversity value is one that has as many species as possible. For others it can mean a forest with beautiful ground flora. In the thesis, biodiversity value is defined as *the potential to harbour red-listed forest species*. In southern Sweden this potential is mainly dependent on the structure and composition of the tree cover, since most of the red-listed forest species live in close association with trees. Old trees, especially of the southern deciduous species, usually have a high potential for harbouring such species whereas young trees, planted spruce and pine in particular, have a low potential. The potential to harbour red-listed species can be difficult to measure. Thus, different types of indicators are often used to describe it. Certain species of epiphytic lichens, for example, some of which were considered in paper III, are regarded as being good indicators of an environment being suitable for red-listed organisms (Nilsson et al. 1995, Nitare 2000) and have thus been used in biodiversity inventories in southern Sweden (Anon 1999a).

Landscape management

Large parts of southern Sweden are covered by forest, and together with agriculture forestry dominates the rural-based economy there. It is also one of the major human activities performed in the landscape and has a strong impact on forest ecosystems. Forest management has traditionally been carried out at two different levels: the stand level and the enterprise level. Management at the stand level involves the application of different silvicultural treatments, whereas the enterprise level involves short- and long-term planning of forestry activities within a given company or estate. In areas dominated by NIPF owners, landscape management today largely consists of the sum of the management at the different estates. One can speak of a "bottom-up" perspective. On the other hand, there are regulations concerning forest management and demands placed on it by the authorities and by society. This affects the management of the estates, and perhaps drives it in directions that are desirable for society. One can speak of a "top-down" perspective.

Today when other considerations than those of timber production are regarded as important, the landscape perspective has added new dimensions to forestry planning. It represents a level above that of the enterprise or the estate, but methods and tools to incorporate it into the planning process have not yet been developed. Both a top-down and a bottom-up perspective can be used in implementing a landscape perspective. A top-down approach can serve as a tool for society in implementing its intentions, just as a bottom-up approach can be used by different forest owners to coordinate their management efforts to the benefit of the landscape. One of the aims of the thesis is to achieve a better understanding of the potential of a landscape perspective, with the intention of suggesting ways of incorporating it into the forestry planning process.

There are of course other matters for which a landscape perspective can be useful, many of them having to do with activities other than forestry. In the thesis, however, the forest landscape is of primary interest and the management there is closely linked with the presence (or absence) of forestry activities.

Objectives of the thesis

The major objectives of the work presented in the thesis concern achieving better knowledge and understanding of the problems and possibilities of forest landscape management in southern Sweden. Two different research areas are involved, the objectives being as follows:

1. Exploring the potential of a landscape perspective and possible ways of introducing it in areas dominated by NIPF owners.

2. Finding cost-effective methods for mapping biodiversity in deciduous forests, as well as investigating the consequences of an increase in the proportion of deciduous trees in the southern Swedish forest landscape.

Case study areas

The thesis is based primarily on a number of different case studies performed in landscapes in southern Sweden. The case study method has played a central role in the research field of landscape studies. One reason for this is that here is a constant lack of high quality data covering large geographical areas. This often restricts scientists from using as many areas or as large ones as they would like, and can also force them to use only areas that have already been surveyed. Although specially designed surveys of landscapes can be performed for research purposes, this is often expensive and time consuming, which also restricts the number of cases that can be dealt with. In addition, since every landscape is unique there is no average or typical landscape one can find, upon which more general conclusions can be based. An advantage of case studies is that they represent research that is close to reality and which provides practical insights into problems connected with the research field (Flyvbjerg 1991).

Use has been made in the thesis of five different case study areas in southern Sweden (fig 2). A short description of each area is provided below:

Äspered

The landscape of Äspered is situated about 80 km east of Gothenburg on the western side of the southern Swedish highland (57° 45' N, 13° 12' E). It is located within the hemiboreal zone (Ahti et al. 1968) and covers an area of about 2600 ha. Forests make up about 69% of the land area. Most of the forest area on the hills consists of homogeneous stands of planted Norway spruce, whereas deciduous forests of birch, aspen (*Populus tremula*), oak and beach are found in the valleys closer to settlements and to agricultural land. The latter are also those parts of the landscape in which areas of high biodiversity value are located. Deciduous trees make up 19% of the standing volume altogether. The forest land is owned by a large number of different NIPF owners; 74 of the estates have a forest area larger than 5 ha in size. For a more detailed description see Carlsson et al. (1996) and Dahlin et al. (1997).

Use was made of the landscape of Äspered in two of the papers, in paper of I about one fifth of the area (10 forest estates) and in paper II of virtually the entire area (only the smallest forest estates being excluded).

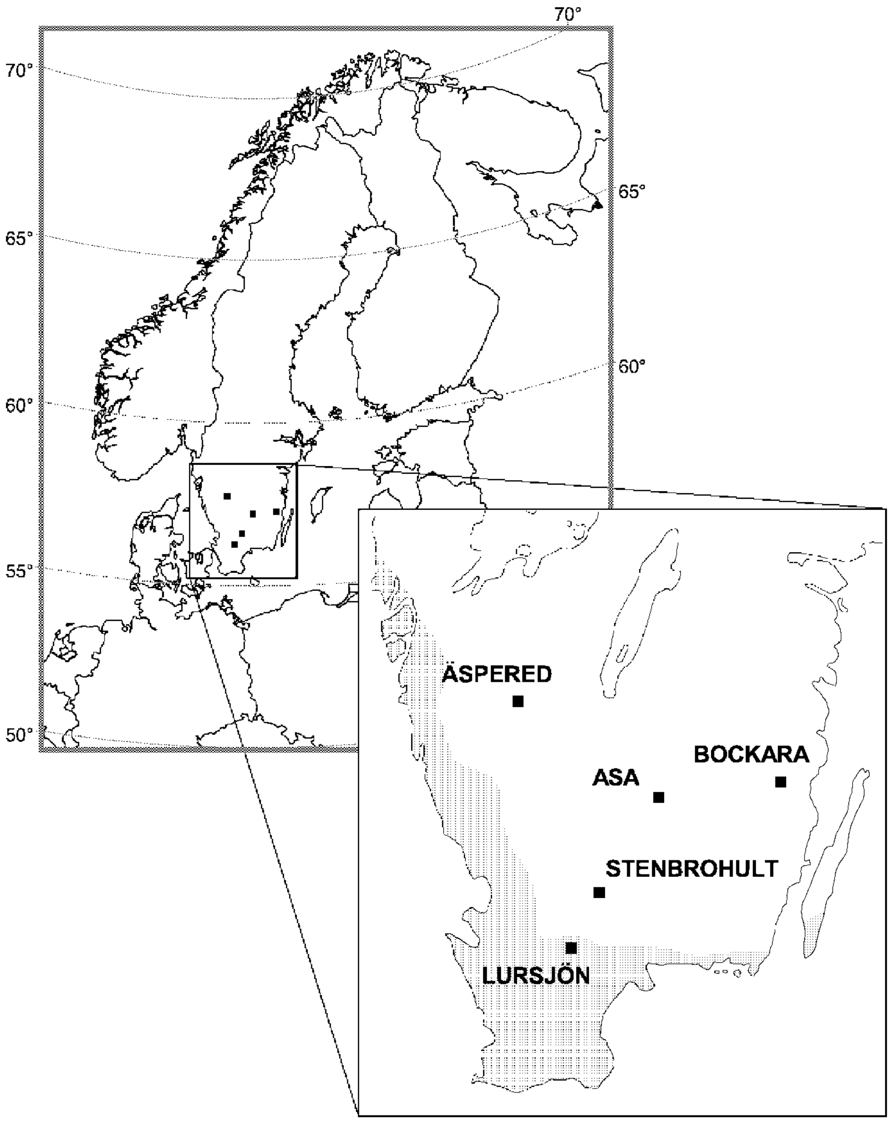

Figure 2. The location of the five study areas involved in the thesis. The temperate zone is shaded on the detailed map, the hemiboreal zone being left blank.

Asa

The landscape of Asa is situated about 30 km north of Växjö in the southern part of the southern Swedish highland (57° 10' N, 14° 47' E). It covers an area of 3300 ha, 87 percent of which is forest land. During the last 40 years forestry in Asa has been concentrated on achieving a high production of coniferous timber. As a result young and middle-aged homogenous stands of planted spruce are dominant in the forests there, deciduous trees making up only some 5% of the total standing volume. The biodiversity value is largely associated with the few old deciduous trees that are left in the landscape. All forest land in Asa is owned by the state the forest company Sveaskog being the proprietor. Parts of the area are an experimental forest used by the Swedish University of Agricultural Sciences. For a more detailed description of Asa see Agestam et al. (2002).

Use was made of the landscape of Asa in paper IV.

Bockara

The landscape of Bockara is situated in the eastern part of southern Sweden close to the Baltic Sea (57° 15' N 16° 10' E). It comprises a total area of about 4200 ha 80% of which is forest land. This part of Sweden is characterised by a rather flat landscape with shallow soil and rocky outcrops. The forest is dominated by pine and spruce, deciduous forests (mostly birch and oak) being found close to settlements and to agricultural land. Most of the biodiversity values are associated with deciduous trees, that make up 11% of the standing volume. Of the 52 forest estates there, two are owned by a sawmill company and the rest by NIPF owners. For a more detailed description see Andersson (1996) and Dahlin et al. (1997).

Use was made of the landscape of Bockara in paper I, about one fifth of the area there being involved (10 forest estates).

Stenbrohult

The landscape of Stenbrohult is situated in the southern part of the hemiboreal zone (Ahti et al. 1968) at the eastern side of the lake Möckeln (56° 37' N, 14° 11' E). It consists of a total land area of 5200 ha, 73% of which is forest land. In the western part of the area close to the lake, deciduous forests of beech and oak are a substantial element whereas the eastern part is dominated more by spruce and pine. Deciduous trees make up about 20% of the standing volume in the area as a whole. There is a high biodiversity associated with the deciduous trees, and key habitats make up a comparatively large area of the landscape. Most of the forest estates in Stenbrohult are owned by NIPF owners, although some are owned by the church, by private companies or by the separate communities. For a general description of the area see Nilsson & Rundlöf (1996).

Use was made of the landscape of Stenbrohult in three of the papers; in paper II the entire landscape except for the smallest forest estates that were excluded, in paper III only the western half of the area, and in paper IV the entire area including the smallest estates.

Lursjön

The landscape of Lursjön is situated in the temperate zone (Ahti et al. 1968) close to the border to the hemiboreal zone (56° 15' N 13° 50' E). Although this is an area outside the natural range of spruce (Hesselman & Scotte 1906), much spruce forest was planted there during last century, spruce now being the most common tree species in the area. Deciduous species make up about 40% of the standing volume, beech being the most common of these. The total land area there is one of about 2000 ha, forest being located in 73% of it. The forest land is divided into 34 different forest estates owned by NIPF owners. A more detailed description of the area is published by Ask (1996).

Use is made of the landscape of Lursjön in paper I , about half of the area there being involved (10 forest estates).

Case studies as a method

Case studies have been criticised for its not being possible to draw general conclusions from only a few cases (Lee 1989). Flyvbjerg (1991) discusses the possibilities for generalising from single cases, arguing that the chances for this increase if a "critical case" is selected, a critical case being defined as a case that is of strategic significance in relation to the problem of major interest. If a particular phenomenon can be detected in such a case, it can be regarded as likely that the same phenomenon can also be found in other cases. Another approach to increasing the amount of information to be obtained from case studies is to choose cases with maximum variation. Such cases define the outer boundaries of what can occur and illustrate the range within which the results that are possible can be expected to lie.

The thesis is based on investigations conducted in five case study areas. The papers are based on one, two or three cases each. Of the many different landscapes it would have been possible to delineate in southern Sweden, these five were chosen due in large part to the existence of digitised forest data there. They are also chosen to some extent so as to reflect the differing conditions present in the western, the eastern and the southern parts of this region. The possibilities of obtaining data of various types (papers III and IV) and the properties of the landscapes (papers I and II) restricted the choice further. Critical cases appear to be difficult to identify in landscape research, and perhaps none of the cases in the thesis can be regarded as representing true critical cases. Paper IV can be regarded as an attempt to use maximum variation between cases where in one of the cases (Stenbrohult) the amount of deciduous trees initially was above the average for southern Sweden, whereas in the other case (Asa) it was far below the average level. There was also a large variation between cases in paper II, the two areas involved (Äspered and Stenbrohult) being different in terms of biodiversity values and the distribution of it within the landscape.

In one sense, it is often possible to draw general conclusions from single case studies. This is when the verification or falsification of theories is involved (Flyvbjerg 1991). If one finds, for example, that a certain phenomenon occurs in at least one case, the general conclusion can be drawn that the phenomenon exists, although it is not certain how widespread the phenomenon is. Such reasoning can be applied to all of the case studies in the thesis. This leads to another interesting possibility regarding case studies; that they can give rise to new theories and new ways of thinking. The theories can then be tested on other cases or with methods other than those of case studies.

Preserving biodiversity in a managed landscape

Background

As was taken up in the introduction, the landscape perspective has come to play an important role in efforts to achieve sustainable forestry. Landscape analysis and landscape ecology have been introduced in forestry planning, and ecological landscape planning has become a popular concept in forest research and in practical forestry (Franklin & Forman 1987, Franklin 1993, Freemark et al. 1995, Angelstam 1997). During the last ten years several ecological landscape planning models for forest management have been developed (Angelstam & Pettersson 1997, Fries et al. 1998). The majority of these models were developed originally in areas characterised by few and large landowners. In Sweden models were typically applied initially to industrial forest land owned by a single landowner (Fries et al. 1998). In areas of primarily NIPF ownership, that is where the landscape is divided into a number of private forest estates with different owners, these models are often difficult to use. A diversity of landowners usually means a variety of different views of how forestry should be conducted, and differing preferences regarding forest utilities. In such areas the planning unit tends to be limited to the individual forest estate, a landscape perspective only being incorporated into the planning process to a very limited degree (Alstad 2002).

In practical forest management, introducing a landscape perspective on biodiversity issues in an area dominated by NIPF owners would require coordinating the efforts made for preserving biodiversity on the different forest estates. Such efforts are best directed at those structures and elements in a landscape that are most important for biodiversity. One way of getting a landscape perspective accepted by forest owners would be to base it on the owners' ideas and preferences concerning forest management and preservation of biodiversity. If the NIPF owners in a landscape had a common view regarding which areas of forest were of greatest importance for forest production, biodiversity and the like, this could be the basis for a planning process pertaining to the landscape as a whole.

Do NIPF owners have a common view of the landscape?

As earlier investigations indicate, some private forest owners set aside areas on their estates voluntarily (Anon 1996). The aim of paper I was to investigate more thoroughly the extent of which such areas exist, to characterise them and to determine whether they could form the basis for a landscape strategy. In each of the three landscapes, those of Äspered, Bockara and Lursjön, ten adjacent forest estates were selected, their owners being interviewed. Questions concerning the requirements for timber yield on different parts of their estate, and of how key habitats and forests close to agricultural land and to residential buildings were managed were asked. The forests were divided into three categories: normal forests, in which requirements for timber yield was high, forest in which it was low, and those in which no particular requirements for timber yield existed. The two latter categories could be regarded as areas that in some respect were set aside.

It was found that 90% of the forest owners who participated in the investigation had some forest stands on their estates in which only a small harvest or no harvest at all was aimed at. On average, 7% of the forest area on these estates was dealt with in this way. An analysis of the stands in question showed that they were generally older and had a higher proportion of deciduous trees than the average stand. These stands that were set aside were not located randomly in the landscape but were mostly found in areas close to key-habitats and to agricultural land (figure 3). They were also forming as large patches as other stands, or larger than these. As a result, they were estimated to be of higher biodiversity value than the average stand, concerning both their structure and composition and their location in the landscape. In Äspered and Bockara the areas set aside generally followed such a pattern, whereas those in Lursjön gave a more fragmented impression.

It was concluded in paper I that most of the forest owners in the parts of Äspered and Bockara that were examined in the study had a common view of which stands should be set aside. Independently of each other they set aside similar broadleaf dominated stands associated with agricultural land and with key habitats. These parts of the landscape encompassed structures that were high in biodiversity value, and were of the type referred to earlier as representing supportive features in landscape planning (Andersson 1996, Fries et al. 1998). Although it is difficult to generalise from a sample of only 30 forest estates, paper I does suggest it to be likely that a common view regarding the landscape could be widespread among forest owners. In areas with fragmented ownership, therefore, such a common view may play an important role in introducing a landscape perspective, and could be a basis for further development of ecological landscape planning.

Western area

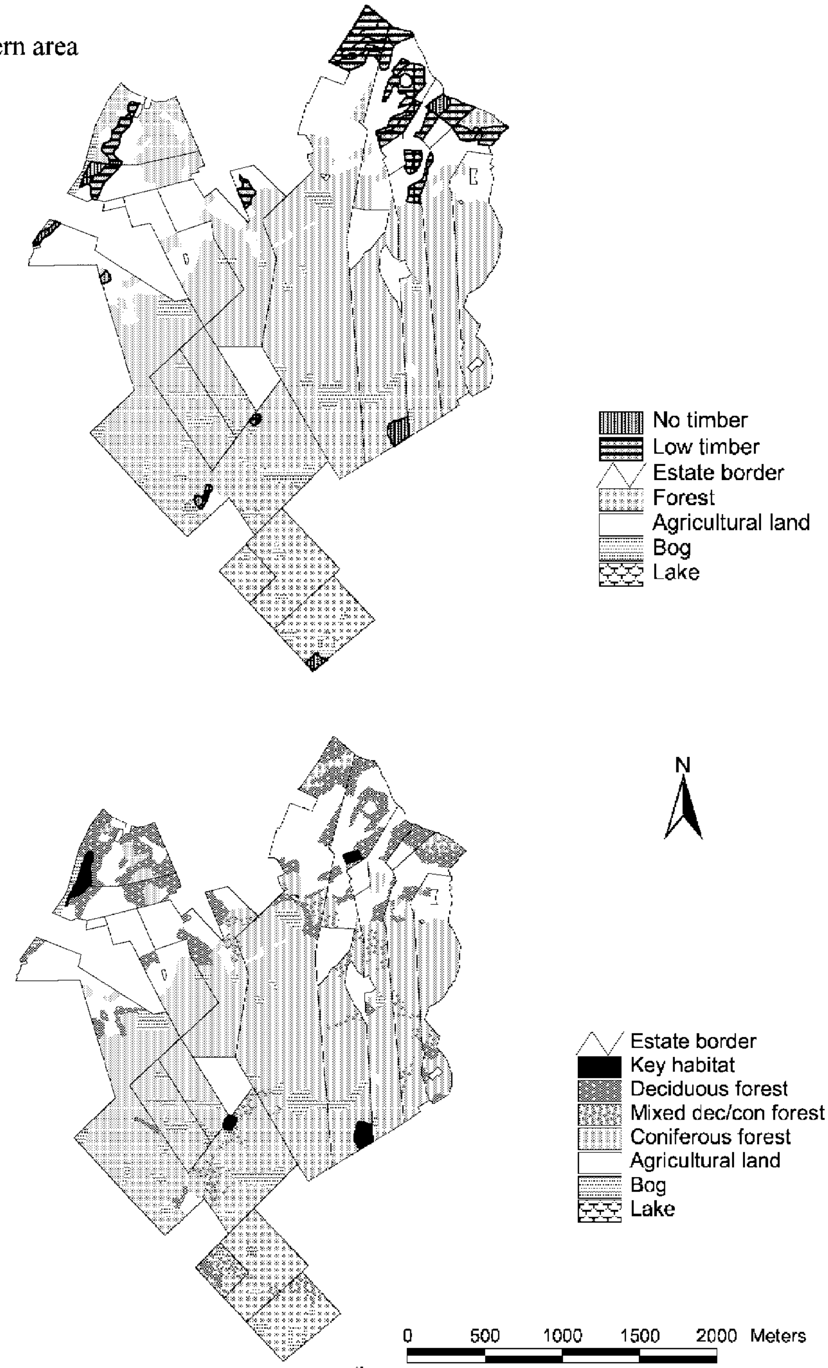

Figure 3. Results for the ten estates in Äspered. At the top the location of the areas set aside, forest land in general and agricultural land is shown. No timber means no requirements for timber yield, low timber means low requirements for timber yield according to the forest owners. At the bottom the different forest types in the area are shown.

Although it would be highly valuable to have the NIPF owners themselves involved in such a planning process, the initiative probably needs to be taken by someone else. In Sweden the Local Board of Forestry in communities generally has a good reputation among private forest owners and may be the most suitable organisations to coordinate projects of this type. They also have considerable experience in launching educational programs, which is a possible way of informing private forest owners about the benefit of a landscape approach to biodiversity and to timber production. The local boards of forestry are engaged too in working out forest management plans for private estates, which could provide them the opportunity to incorporate a landscape view into planning at the estate level.

The results of paper I indicate there to be a connection between deciduous forests and the areas voluntarily set aside. The forest owners in the three landscapes that were studied placed lower requirements on timber yield in stands dominated by deciduous trees, especially if they were located close to agricultural land or to residential buildings. Although the investigation was not designed to provide an explicit answer to the question of why these areas were set aside, both the interview material and the results of other investigations provide some clues: A number of respondents stated that the forests they liked best were mature stands of deciduous tree species or stands of mixed tree species composition. This is in accordance with the results of other Scandinavian studies and follows a pattern found earlier regarding what types of forest are appreciated for their aesthetic and recreational value (Hultman 1983, Pukkala et al. 1988, Savolainen & Kellomäki 1994, Lindhagen 1996). Locations close to open areas and to residential buildings made the areas set aside particularly accessible to the forest owners. This is probably an important reason for the owners' exposing these areas less to commercial forestry. Other reasons mentioned were nature conservation values, low growth rates and bad timber quality.

Is the process of setting aside areas efficient?

The investigation in paper I about areas set aside was performed in 1996-97, before the process of forest certification really started in Sweden. Now, five years later, the certification of forests and of forestry is a big issue in Sweden throughout Europe, the matter of the setting aside of certain areas for purposes of biodiversity being a more burning issue than ever before. There are two major systems involved in the certification process: FSC (Forest Stewardship Council) and PEFC (Pan European Forest Certification). Both of these standards stipulate for southern Sweden that at least five percent of the productive forest land should be set aside for biodiversity purposes (FSC 2000, PEFC 2001). Although the certification process is voluntary, if the forest owner wants to become certified he or she cannot choose freely what areas to set aside. Both of the standards just referred to state that the areas of highest biodiversity value should be given priority when areas are set aside for reasons of biodiversity. This is usually accomplished by establishing a forest management plan for an estate such that at least five percent of the forest land is set aside. In practice, the proportion set aside on NIPF estates is often between five and ten percent of the forest area (Alstad 2002, Andersson 2002).

If the setting aside is to be done in an effective way, it is necessary to obtain information about the biodiversity values for the different parts of an estate. This is usually accomplished by an inventory of biodiversity values prior to a management plan's being worked out. Andersson (2002) investigating several forest management plans developed during the certification process, concluded that in practice the areas of highest biodiversity values on an estate are not always those set aside. Her results also indicate that the individual preferences of the forest owners influence the selection of areas set aside.

A problem concerning the areas set aside is that areas of high biodiversity value tend to be unequally distributed between different estates (Carlsson et al. 1998). Setting aside the same proportion of the area on every estate would probably lead to some of the most valuable areas remaining unprotected, and other areas of low biodiversity value being protected. This implies there to be a potential loss in efficiency when the protection of forests is carried out at an estate level rather than the planning process being concerned with the entire landscape.

In paper II a theoretical framework is applied to a hypothetical landscape divided into 12 different forest estates. The biodiversity values are simplified to the case of there being only one area of high biodiversity in the landscape, all the other land being of low biodiversity value. In simulating the certification process, 1/16 of each estate was set aside. If the location of the area of high biodiversity value is unknown, the forest owners set aside an area at random on each estate. The chance that this area will coincide with the actual areas of high biodiversity values is very small. If the forest owners have information about where the valuable areas are situated (for example after an inventory of the biodiversity values) they can locate the areas they set aside on these parts of their estates. However, this is only possible for estates on which a part of the area with high biodiversity value is located within the estate. On estates without any area of high biodiversity value the areas set aside will consist only of areas of low biodiversity value. If a system for cooperation and monetary compensation over the borders of estates were introduced, this would allow landowners without areas of high biodiversity value to finance the protection of areas of high value on other estates. Through such cooperation it would be possible to locate the protected areas on the parts of the landscape of highest biodiversity value, each forest owner nevertheless contributing to protection of this sort.

The approach just described was applied to the landscapes of Äspered and Stenbrohult, which consisted of 74 and 90 different forest estates, respectively. The biodiversity value for each stand was estimated by use of a biodiversity index ranging from 1 to 8, with 8 being the highest. Ten percent of the forest area in each landscape was set aside in three different ways:

Case A: 10% of the forest area on each estate was set aside randomly.
Case B: 10% of the forest area on each estate was set aside, the areas of highest biodiversity value being given priority.
Case C: The 10% of the area that was highest in biodiversity value in the landscape as a whole was set aside.

The proportion of the total area that was set aside which belonged to index class 7 or 8 was used as an indicator of the efficiency this resulted in. The result for case A was that only 10% of the area belonging to either of these two highest index classes was set aside (table 1). In contrast, for case C all of the forest land belonging to either of these two classes was set aside. Case B showed an intermediate pattern. In Äspered 90% of the areas of highest biodiversity were set aside, whereas in Stenbrohult only 54% were.

Table 1. The proportion of the total area in index class 7 and 8 that is set aside in the different cases.

Case	Äspered	Stenbrohult
Case A	10%	10%
Case B	90%	54%
Case C	100%	100%

This difference lead to a more thorough investigation of case B. It was done by use not only of the 10% level of the areas set aside, but of the entire array of levels from 0 up to 60% of the forest area on each estate. Figure 4 presents the results obtained here.

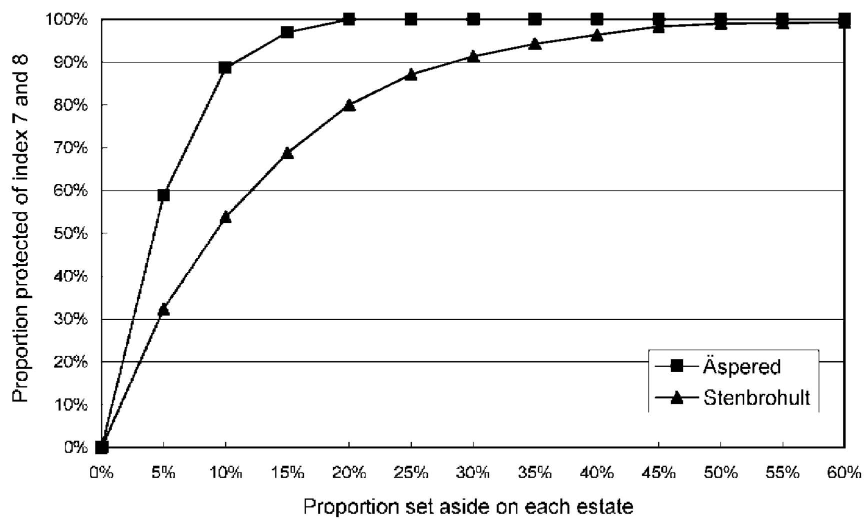

Figure 4. The proportion of the total area belonging to index class 7 or 8 that is protected as a function of the proportion of forest that is set aside on each estate.

In Äspered full protection of the most valuable areas was achieved when 20% of the forest land on each estate was set aside. In contrast, in Stenbrohult one can set aside as much as 60% of the forest land on each estate without having protected all of the forests of highest biodiversity value. This can be compared with case C, in which full protection was achieved in both the two landscapes involved when 10% of the forest land was set aside. These results show that there is a great potential in setting aside areas in a more efficient way than is done today, i. e. than when approximately the same proportion of the area is set aside on each estate. With cooperation between the estates the areas set aside could be located in those areas of the landscape of highest biodiversity value, allowing these areas to be fully protected with much lesser effort.

Figure 4 shows there to be a substantial difference between the two different landscapes included in the study. This difference could be explained by the fact that the areas of high biodiversity value cover a larger area and are more unevenly distributed in Stenbrohult than in Äspered. In such a landscape as that found in Stenbrohult there is a greater potential for selecting areas in an efficient way to set aside.

Deciduous forests

Background

During the last 2000 years there has been a widespread and dramatic change in forest composition in southern Sweden. Around the time of the birth of Christ, forests there were dominated by different species of deciduous trees, although there were substantial amounts of pine in the eastern part (Björse & Bradshaw 1998, Lindbladh & Bradshaw 1998). Spruce was only found in the northern and central parts of Sweden. During the following two millennia, the spruce spread southwards rapidly and is now the dominant forest species in most of southern Sweden. This process has been explained as being based on a combination of climatic changes and of anthropogenic influences such as grazing by domestic animals, selective cuttings, pollarding, and burning, which has been unfavourable for deciduous tree species (Nilsson 1997a, Lindbladh et al. 2000). The border between the temperate (nemoral) zone in which the deciduous trees dominate, and the hemiboreal (boreonemoral) zone, in which the coniferous trees dominate is usually drawn where the southern and western limits of spruce were located at the beginning of last century (Hesselman & Scotte 1906, Lindquist 1959, Sjörs 1965, Ahti et al. 1968). Since then, spruce has been planted extensively through use of modern methods of forestry, also outside what is considered to be its natural range (Emanuelsson et al. 1985, Nilsson 1997a).

Today the total proportion of deciduous trees in southern Sweden is 18 % of the standing volume (Anon 2000). In the southern and western parts that belong to the temperate zone (the counties of Skåne, Halland and Blekinge) the proportion is 30%, whereas in the central part (the counties of Jönköping and Kronoberg) the proportion is only 13%.

An increasing interest

The last decade has seen an increase of interest in deciduous tree species among forest owners, as well as in society generally. There are several reasons for this:

Hardwood timber prices in northern Europe have been on the increase during the last 30 years, whereas in real terms the softwood timber prices have remained unchanged or have even fallen (Lohmander 1992, Spiecker 2000). New technology in paper production has made the short fibers of deciduous trees more attractive, the demand for pulpwood from deciduous trees now being greater than the supply in many parts of Sweden. Many people have also realised that there may be considerable financial risk in relying on only one product, such as spruce wood, in a changing timber market (Lohmander 1992). Coniferous trees affect the soil differently than most deciduous trees do, and the higher level of production that takes place in coniferous stands leads to a greater uptake of nutrients (Thelin 2000). Soil scientists have questioned weather a high production of spruce is sustainable in southern Sweden in the long run (Sverdrup & Rosén 1998). Most species of deciduous trees are more resistant than spruce to such calamities as windthrow (Persson 1975, Peltola et al. 2000, Jørgensen & Nielsen 2001) and root rot (Bendz-Hellgren et al. 1998, Korhonen & Stenlid 1998). Forests of deciduous trees usually have a higher recreational value than dense spruce forests do (Hultman 1983, Lindhagen & Hörnsten 2000). This is a factor worth considering in southern Sweden, where the pressure of visiting by the public is relatively high.

Although all these factors contribute to the increasing interest in deciduous trees and forests, what is perhaps the most important factor has to do with the biodiversity of forests. The majority of the red-listed forest species in different organism groups in Sweden are associated with deciduous trees, especially the southern deciduous trees (Berg et al. 1994). This is particularly evident in southern Sweden, where spruce forests have a short history (Nilsson 1997b). Data from the largest biodiversity inventory conducted in Sweden thus far, the Forest Key Habitat Inventory, indicates the same thing. Deciduous forests, especially southern deciduous forests, are highly over-represented in the key habitats in southern Sweden (Anon 1999a).

Assessment of biodiversity in deciduous forest

The assessment of biodiversity has been mainly accomplished thus far by data being collected in field inventories, which is a time-consuming and expensive approach. It is desirable to find other methods that can cover large areas at lower cost. In this context different types of remote sensing techniques seems appealing. Skånes (1996) reviewed different remote sensing methods, concluding that visual interpretation of colour-infrared (CIR) aerial photographs is the best tool available for collecting detailed landscape information. This is due to the superior spatial resolution and the stereographic properties of aerial photographs. In the key habitat inventory CIR aerial photographs were used as a complement to field inventories (Anon 1999a). Results reported by Ringblom (1994) indicate it to be possible to detect forest stands in which conditions are favourable to red-listed species by using visual interpretation of CIR aerial photographs. In paper III this method was used in the landscape of Stenbrohult to investigate to what extent information from visually interpreted CIR aerial photographs can be used as indicators of the presence of epiphytic lichens that are red-listed or other species that indicate high biodiversity value ("signal species").

On 2000 ha of the Stenbrohult study area an inventory of epiphytic lichens was performed in 1992 -1993, a complementary survey being carried out in 1998. All the lichen surveys were made by experienced lichenologists, who searched for lichens on trees they deemed suitable as substrates. In the same area a survey of deciduous forest on the basis of CIR aerial photographs was performed. Photographs from 1995-1996 were studied in a stereoscope, and a set of forest stand characteristics was obtained for each stand through interpretation of the photograps. Logistic regression was used to determine the correlation between the interpreted variables and the occurrence of one or more species of lichens in each stand.

In the field inventory 20 different red-listed species and 23 different signal species of epiphytic lichens were found, all of them on deciduous trees. Twenty-six out of a total of 675 stands in the area were found to contain red-listed species, and 43 stands to contain signal species. Three of the interpreted stand variables - area times tree height, percentage of southern deciduous trees and crown structure class - were found to be significantly correlated with the occurrence of red-listed species. For the signal species, the variables area times tree height and percentage of southern deciduous trees were significantly correlated with the occurrence of these species.

The results reported in paper III indicates that it may be possible to use information from visually interpreted CIR aerial photographs to predict the presence of epiphytic lichens that are red-listed or in other terms indicate a high biodiversity value. The results also show the importance of deciduous forests for biodiversity, especially the southern deciduous trees. The variable percentage of southern deciduous trees in a forest stand was able to explain to a significant degree the occurrence of the lichens used in the study. This is consistent with what is known about the ecology of epiphytic lichens in southern Sweden (Fritz & Larsson 1996; Arup et al. 1997). The variables tree height and crown structure class can be considered as indicators of tree age, since the height of the trees increases with age and the crown structures are more pronounced in old stands. High tree age is known to be favourable for many of the lichen species included in the study (Thorén 1997; Fahlvik 1999; Hedenås & Ericson 2000; Uliczka & Angelstam 2000). Thus, these species can be expected to be more frequent in older stands.

An interesting result of the study is the role which the size of the stands plays. Hedenås and Ericson (2000) found there to be a similar tendency for various lichen species in northern Sweden. One explanation may be that it is more likely on the basis of chance to find many species of lichens in a large stand than in a small one. Another explanation may be that historically a larger stand has contained larger populations of different lichens, which has given these lichens a better opportunity to survive. Whatever the explanation is, the fact that the presence of large patches of deciduous trees seems to have positive for the survival of some red-listed species can have implications for the future management of deciduous forests. If one wishes to increase the deciduous forests in southern Sweden, a concentration to certain areas may be more favourable for forest biodiversity than an increase that is dispersed over the landscape as a whole.

The epiphytic lichens that are considered in paper III constitute only a small fraction of the total forest biodiversity in southern Sweden. However, many of the species in the study are considered to be "indicator species" the occurrence of which indicates the environment to be suitable for other red-listed organisms or for high biodiversity generally (Nilsson et al. 1995, Nilsson et al. 2001). Such species were also used as indicators of this sort in the nation-wide inventory of key habitats (Anon 1995, Nitare 2000). It is thus likely that the results of the present study can be used in a broader perspective of biodiversity generally, and that CIR aerial photographs can be an effective tool for collecting data on forest biodiversity.

More deciduous forests in the future?

Many policy documents concerning forestry in Sweden express the desire to increase the proportion of deciduous trees in the forest landscape. For example, the Forestry Act states that deciduous trees in forests dominated by coniferous trees should be retained if the soil is suitable for deciduous trees (Anon 1994). In "Action plan for biodiversity" (Anon 1995b) the Swedish Board of Forestry recommends that the proportion of deciduous trees in most Swedish forests be increased as a means for preserving forest biodiversity. The same recommendation has been made by the Swedish Environmental Protection Agency (cf. Anon 1999b). The Regional Board of Forestry in the western part of southern Sweden (*Skogsvårdsstyrelsen västra Götaland*) aims at an increase in the proportion of deciduous trees in their region from 18% today to at least 20% within the next 25 years (Henrikson 2000).

In a recent study the Swedish Board of Forestry presented simulations of different management scenarios for Swedish forests over a 300-year period (Gustafsson 2001). These simulations show that the proportion of deciduous trees in southern Sweden will increase substantially if the forest management that was carried out during the 1990s is continued. This is mainly an effect of deciduous trees being allowed to a large extent to regenerate naturally in coniferous plantations (Nilsson & Gustafsson 1999). This will probably result in there being a high proportion of mixed forests, in which the deciduous trees are spread over the landscape. The major part of the deciduous trees involved will be pioneer species such as birch and aspen that are easily spread. Without actively choosing a strategy for the increase in deciduous trees, we obviously are currently implementing forest management that will result in an increase that is dispersed over the landscape. Are there alternative strategies for such an increase, and if so, what consequences will they have?

In paper IV ten different strategies for increasing the proportion of deciduous trees were applied to the landscapes of Asa and Stenbrohult. These can be divided into two main landscape strategies, dispersed and concentrated. In the dispersed strategy the increase in deciduous trees was accomplished in every stand by increasing the proportion of deciduous trees. In the concentrated strategy the increase is accomplished by converting coniferous and mixed stands into pure deciduous stands. In addition, the stands that were to be converted were concentrated around the five spots in the landscape where today the highest concentration of deciduous trees is found. Each landscape strategy was combined with five different retention tree strategies, where 0 to 15 retention trees per hectare were set aside, either in all the stands or only in those stands with deciduous trees.

The consequences of the different strategies were analysed by simulating the forest development over a period of 155 years using a projection model described by Agestam et al. (2002). All ten strategies were tested against two different goal levels: 25 and 50% deciduous trees of the entire standing timber volume of the landscape. For deciduous trees only natural regeneration was used. On the fertile soils oak was given priority, whereas on the poorer soils birch was the tree species given priority. In designing the different management programs only measures that in our opinion were realistic alternatives in today's forestry were included. Thus, use was not made for example of the final felling of premature coniferous stands or of extended rotation periods for entire deciduous stands.

The results reported in paper IV show it to take a long time to achieve a substantial increase in the proportion of deciduous trees in a forest landscape (figure 5). A forest is a slow ecosystem, changes taking considerable time. Since the strategies were implemented gradually, it took about one rotation period (90 to 115 years) to reach the levels aimed at, regardless of the goal level involved. Although it would be possible to achieve a high proportion of deciduous trees in a shorter period of time, for example by use of deciduous trees alone in all regenerations undertaken during a period of 20 years, this would result in an uneven age distribution, all of the deciduous forests thus being of about the same age. In the long run, this would lead to great difficulties in the proportion of deciduous trees being maintained at a stable level.

Another main result obtained was that it seems to be necessary to use drastic management measures in order to achieve a high proportion of deciduous trees, especially in a landscape such as Asa, where the initial proportion is very low (5%). When using the concentrated strategy in Asa up to 77% of the total forest area had to be converted into deciduous forest in order for the goal level of 50% of the volume to be achieved. The corresponding figure for Stenbrohult was 58%. The reason for such large areas are being needed is that since in terms of the model the management of deciduous forests generally involves a much lower density than in a coniferous or mixed forest, a larger area is needed to obtain the same volume of wood. This also result in the standing volume in the landscape as a whole being less in strategies which involve there being a high proportion of deciduous trees. In such strategies the average annual increment is also less. In Asa the increment is reduced in the case of some strategies to little more than half of what it is today.

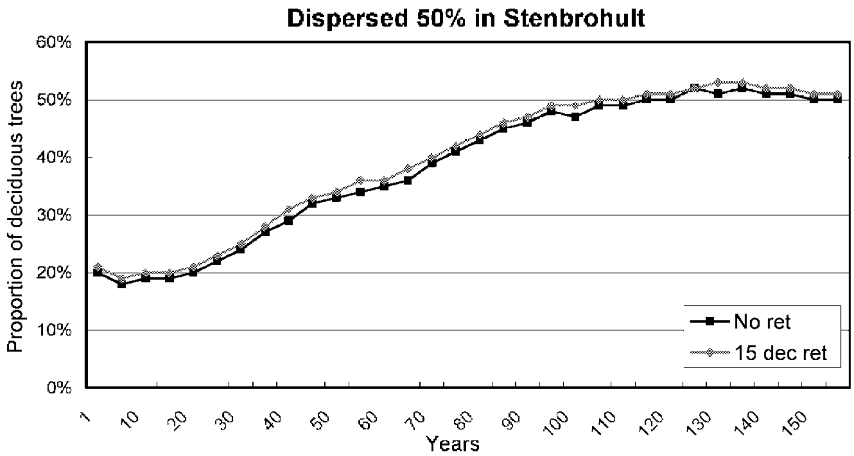

Figure 5. An example of a simulated increase in deciduous trees in Stenbrohult, where a stable proportion over 50% is the goal. By setting aside 15 deciduous retention trees per hectare, the goal is reached 10 years earlier than by a management alternative without retention trees.

Through retention trees being set aside the goal levels were achieved somewhat earlier, especially when the retention trees were located in stands of deciduous trees (that is, when only deciduous retention trees were set aside). Setting retention trees aside can be regarded as a way of extending the rotation period for these trees. This appears to be an effective way of increasing the proportion of deciduous trees. It is also known that since retention trees can grow to be very large and old, they can be of great importance for forest biodiversity (Nilsson 1997a, Hazell & Gustafsson 1999, Nilsson et al. 2001). However, since they are not meant to be harvested they tend to reduce growth and thus the volume that can be harvested (Agestam et al. 2002).

It is concluded in paper IV that the differences between the two main landscape strategies, dispersed and concentrated, are fairly small in terms of the time needed to reach the goals, regarding annual increment and standing volume. Achieving a concentration of deciduous trees could have a positive effect on biodiversity, for example by expanding the habitats of organisms dependent on deciduous trees. On the other hand, it might also contribute to the creation of a more fragmented landscape in which conifers still dominate in the rest of the forest. Previous studies of biodiversity in connection with deciduous forests (cf. Anon 1997, Agestam et al. 2002) have not been able either to clearly recommend any of the strategies. All together, this indicates the need of further research in this area.

Discussion

The landscape perspective in areas dominated by NIPF

The results reported in paper I suggests that in at least some areas dominated by NIPF owners there is a common view regarding problems concerning the landscape. Such a common view provides a strong potential for the introduction of a landscape perspective in such areas. Use of such a common view would be an example of a bottom-up process, one in which landscape management is developed on the basis of the preferences of the different forest owners. The advantages this provides as compared to a top-down perspective in which planning conducted "over the heads" of forest owners are obvious. A disadvantage this would have is that a common view of forest owners might not always coincide with the objectives of society. Nevertheless, one also knows that people's preferences are not constant, that they change over time. Since knowledge and information regarding forest biodiversity has increased over the last few years, it is also possible that this potential has become even greater than the paper implies. The increase in forest certification, which is a voluntary process, suggests a higher proportion of forests to be set aside than that which was reported in paper I. However, whether the areas on certified forest estates that are set aside conform with the pattern shown in the paper remains to be investigated.

The process of forest certification would probably result in a greater improvement in efficiency if the landscape perspective was more widely used. This would allow matters of landscape ecology to be taken into consideration to a greater extent, and also for forest protection measures to be carried out in a more efficient way. If a system for cooperation and monetary compensation over estate borders were introduced, as suggested in paper II, the protection of forest habitats could be directed at areas of the landscape of highest biodiversity value. Such an increase in efficiency would be beneficial to forest owners and also to society in general. However, further investigation of the design of such a system for promoting cooperation is needed.

Deciduous forests of the future

There is a tendency among some foresters and scientists to believe that the establishing of deciduous forests (as opposed to coniferous forest) of any kind will help solve all problems concerning biodiversity, sustainable production, recreation and the like. Efforts to solving such problems will tend to lead, however, to very different demands being placed on forests of the future. A deciduous forest does not automatically have a high value in terms of forest biodiversity, sustainable production, recreational value etc. In fact the conflict between differing goals of forest management is as strong in connection with deciduous forests as in connection with any other type of forest.

If we are to achieve all our goals of landscape management we need to consider what types of deciduous forest we want to have in the future. In paper IV quantitative aspects of deciduous forests were focused on, yet it is equally important to look at quality. The easiest way to obtain larger numbers of deciduous trees is by means of natural regeneration of easily spread species such as birch. This method was applied to most of the forest land in paper IV. Although birch is a tree species that is important for forest biodiversity, the majority of the red-listed species are dependent on other trees, especially the southern deciduous trees as was taken up in paper III. These tree species are more difficult to regenerate, however, and on most forest soils yield a lower annual increment (Almgren 1984). For these reasons they are not very popular in forestry. However, if one seriously wants to protect forest biodiversity, one probably needs to increase the number of trees of these species as well.

The demands on forests placed by its owners and by the rest of society have changed over time, and are likely to change again in the future. At the moment we tend to focus on the production of wood and on the preservation of biodiversity. In the future there may be other demands placed on forests, ones we cannot predict today. An increase in the proportion of deciduous trees is in itself a way of spreading the risks and make forests more diverse. Having different species of deciduous trees and employing different management regimes in deciduous stands may increase our flexibility still further in the future.

Further research

In the thesis, the potential of a landscape perspective was investigated and the attempt was made to develop conceptions of landscape management further. Although the landscape perspective appears to be here to stay, much is yet to be learned regarding its application to forestry planning. Participatory planning and cooperation over the borders of estates seem particularly promising in this connection.

A common view concerning a given landscape among forest owners there could be shown in paper I, but how widespread such agreement is and how views of this sort change over time are matters that could be investigated further. Continuing research is called for too regarding the setting aside of forest areas that are not to be harvested and how this can be done most effectively, matters discussed in paper II. In this context one can ask as well whether the landscape level is always the most appropriate unit of planning when areas are to be set aside for purposes of biodiversity. The distribution of areas of high biodiversity value can be expected to be uneven, both between different landscapes in a given region and from one region to another. This is important to take into account in efforts to maintain forest biodiversity generally.

An obstacle that scientists face is the lack of landscape-covering data. In areas of Sweden dominated by NIPF owners, scientists have been highly dependent upon data from forest inventories conducted by the regional boards of forestry in the 1990s (*ÖSI-data*). Unfortunately, such inventories are no longer conducted and the existing data is becoming out-of-date. In paper III the aim was to develop faster and cheaper methods for collecting landscape data. Although the results appear promising, the approach explored would preferably be tested in other geographical areas so as to establish if the statistical models developed are generally applicable.

Sammanfattning

Det senaste decenniet har vi bevittnat en av de största förändringarna någonsin inom skogsbruket när det gäller synen på skogen. Från att ha betraktat skogen enbart som en virkesproducerande råvarukälla, har vi nu rört oss mot en ståndpunkt där vi i lika hög grad väger in etiska och moraliska aspekter i vår syn på skogen. Den kanske tydligaste manifestationen av denna omsvängning är den nu gällande skogsvårdslagen som jämställer värdet av virkesproduktion och bevarande av biologisk mångfald. Det nu gällande idealet är ett skogsbruk som är uthålligt i alla avseenden, även när det gäller biodiversitet, markförhållanden, rekreationsvärden etc.

Landskapsperspektivet har kommit att spela en väsentlig roll i strävan mot ett uthålligt skogsbruk, inte minst när det gäller bevarandet av biologisk mångfald. En rad olika modeller för landskapsplanering har presenterats, men de flesta av dessa är svåra att använda i Sydsverige där skogslandskapet ofta är uppdelat i ett stort antal privata fastigheter. I avhandlingen behandlas problematiken kring att införa ett landskapsperspektiv i områden som domineras av enskilda privata skogsägare. I två av de tre undersökta landskapen finns någon form av samsyn mellan skogsägarna när det gäller vilka områden som frivilligt undantagits från produktionsskogsbruk. Slutsatsen är att en sådan samsyn skulle kunna utgöra basen för ett helhetsperspektiv på landskapet i områden med många privata markägare.

Avsättning av skog för naturvårdsändamål är ett av de viktigaste åtgärderna för att bevara biologisk mångfald. Idag avsätts betydande arealer frivilligt enligt reglerna för certifiering av skogsfastigheter. Denna process medför att ungefär samma andel av varje fastighet avsätts för naturvårdsändamål. Då de högsta naturvärdena i ett landskap ofta är ojämnt fördelade mellan fastigheterna, kommer en sådan modell för avsättning förmodligen att medföra att stora arealer med låga naturvärden skyddas, medan en del områden med höga naturvärden förblir utan skydd. I avhandlingen föreslås ett system för samarbete och ekonomisk kompensation mellan fastigheter, vilket skulle leda till att avsättningarna kan styras till de områden i landskapet som har de högsta naturvärdena. Potentialen för en effektivtivisering av avsättningarna enligt denna modell undersöks också i två olika skogslandskap i Sydsverige.

För att på ett effektivt sätt kunna bevara den biologiska mångfalden krävs betydande kunskap om olika arter och deras utbredning. Tyvärr är fältinventeringar av naturvärden både dyra och tidsödande, varför billigare och snabbare metoder är önskvärda. En metod att korrelera förekomsten av rödlistade lavar med ett antal beståndsvariabler tolkade i IR-flygbilder testades därför. Resultaten visar att variablerna andel ädellövträd, beståndsarea gånger trädhöjd samt förekomsten av tydliga kronstrukturer hos lövträden är signifikant korrelerade med förekomsten av rödlistade lavar. Detta indikerar att tolkning av IR-flygbilder kan vara ett användbart sätt att i framtiden skaffa information om naturvärdena i ett landskap.

Intresset för lövskog och lövträd har ökat på senare år, inte minst på grund av att huvuddelen av naturvärdena i de sydsvenska skogarna är knutna till lövträd. Från skogsägare så väl som från samhället finns ett intresse av att öka lövandelen i Sydsveriges skogar. Olika strategier för att för att öka lövandelen har därför testats i två olika landskap i Sydsverige. Skogens utveckling simulerades under en period av 155 år med hjälp av en framskrivningsmodell där målet var att uppnå en stabil lövandel på 25 eller 50% av virkesvolymen. Resultaten visar på små skillnader mellan de olika strategierna. Huvudslutsatsen är att det tar ungefär en omloppstid att uppnå och behålla en högre andel lövträd i ett landskap, oavsett om man siktar mot den höga eller den låga målnivån. Tiden kan dock kortas något om man avsätter lövträd som evighetsträd.

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