Quantifying the area of edge zones in Swedish forest to assess the impact of nature conservation on timber yields

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Arbetsrapport 38 1998

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ISSN 1401-1204
ISRN SLU-SRG-AR--38--SE

TABLE OF CONTENTS

ABSTRACT	2
1. INTRODUCTION	3
2. MATERIALS AND METHODS	4
2.1 Input data	4
2.2 The HUGIN system	5
2.3 Restrictions of management	6
2.4 Management in edge zones	7
3. RESULTS	8
4. DISCUSSION	12
REFERENCES	14
APPENDIX	

ABSTRACT

The new Swedish Forestry Act states that the forests should be sustainably managed in a profitable way and, at the same time, the current levels of biodiversity should be maintained. This and the pressure from consumers for forest products to be produced in a way that protects biodiversity have changed forestry towards a more nature oriented management. An estimation of the effects of this nature conservation on timber yields and potential cut must be included in forest scenario modelling to assess the long term impacts.

An important component of preserving biodiversity in forests in this nature oriented management is to adjust management measures in edge zones adjacent to mires, riparian zones, non-productive hills, etc. Examples of management measures in edge zones are no cutting, modified thinning, single tree selection or leaving behind large trees. These spatial considerations can now be dealt with in long-term forecasts using HUGIN, a system based on sample plot data from the Swedish National Forest Inventory (NFI). This is because of the improved description of the context of the NFI sample plots in the landscape. Furthermore, geographical positions are determined using the Global Positioning System (GPS), which facilitates the combination of NFI data with other data sources.

A schedule of how to select sample plots located in forest habitats that are valuable for biodiversity is shown.

Analyses of the new NFI data show that approximately 11 % of the productive forest land is located within 25 meters of mires and non-productive hills and 3 % is located in riparian zones. Forest scenario modelling using the HUGIN system will now be able to estimate the reductions in the long-term potential cut due to nature conservation in edge zones.

1. INTRODUCTION

Section 1 of the 1993 Swedish Forestry Act (Anon. 1994) states that, "The forest is a national resource. It shall be managed in such a way as to provide a valuable yield and, at the same time, preserve biodiversity. Forest management shall also take into account other public interests." This statement reflects the current debate concerning Swedish forestry. This debate has largely concentrated on nature conservation management measures, or the lack of them, how to preserve biodiversity and the protection of nature reserves. This is reinforced by consumer demands for forest products to be produced with little effect on the forest environment. The debate and pressure from the public has led to the need for new logging forms, regeneration methods, restrictions regarding ditching, fertilising.

The National Board of Forestry outlines guidelines for achieving sustainably managed forestry that, at the same time, maintains current levels of biodiversity (Wallin et al. 1995). The Swedish strategy for the conservation of biological diversity is based on a combination of multiple-use forestry and protection of sensitive areas, e.g. nature reserves.

This new forestry increases the demands on forest scenario models. In the 1970s and 1980s, scenario models normally dealt with timber production with no or little consideration given to nature, spatial matters or biodiversity. These factors must now be included in forest scenario modelling when reliable estimations of the sustainable level of potential cuttings are to be obtained. Otherwise, there is a risk that the cutting levels will be overestimated and cause problems when strategic planning is linked with operational planning.

There are many systems for forest scenario modelling, which can, to a greater or lesser extent, include spatial relationships. In Päivinen et al. (1996) several forest scenario models are described which are able, to varying degrees, to include spatial relationships. A combination of spatial analysis and heuristic optimisation in short-term forest planning was presented by Nuutinen (1994). An approach for incorporating biological diversity into strategic forest management planning is done by Kangas and Kuusipalo (1993). In one study (Holland et al. 1994) three indices of forest stand structural and compositional diversity were incorporated into linear programming timber harvest scheduling model to examine the trade-offs between managing stands for timber production and biodiversity objectives.

In Sweden a forest scenario model, the HUGIN system, aims at producing regional long-term forecasts of timber yields and potential cut. These can be used to analyse different forest management strategies or for strategic planning for large companies. Lundström & Söderberg (1995) provide an outline of the HUGIN system which has been used for long term forecasts of timber yields for the whole country in 1985 and 1992, (Bengtsson, G. et al. 1989; SOU 1992).

HUGIN already gives some consideration to nature values, spatial issues and biodiversity (Wilhelmsson 1989; SOU 1992), but it must be further developed in order to simulate the forestry of today. It has also been used to analyse how adjustments in the forest landscape resulting from environmental demands affect the costs and revenues to forestry (Holgen and Lind, 1995).

As stated before, an important way of preserving biodiversity in forests is to modify the management measures in edge zones around streams (Nilsson 1992), mires and non-productive hills. But what possibilities are there to include environmental considerations in order to obtain more realistic calculations? The areas affected by these restrictions can be assessed by a plot's spatial context. The spatial restrictions are in this context crucial. However, this increases the requirements on input data. One way to deal with this is to combine different data sources in forest scenario models (Naesset 1997), e.g. remote sensing or digital maps showing roads, mires, built-up areas, streams etc. with field data.

The objective of this paper is to present an outline of how to include nature conservation measures in the HUGIN system. The focus is on forests located in edge zones that are important for biodiversity.

2. MATERIALS AND METHODS

2.1 Input Data

Forecasts made by the HUGIN system are based on the data from the Swedish National Forest Inventory (NFI). The inventory is conducted annually, and uses a cluster design of circular plots randomly located over the whole country (Ranneby et al. 1987). Much information is collected on these sample plots, describing in detail the forest and the particular site (Söderberg 1997). Since 1996, the NFI has improved the description of the context of the sample plots in the landscape. Geographical positions are determined using the Global Positioning System (GPS), which facilitates the combination of NFI data with other data sources. Appendix 1 includes definitions of variables useful in the selection of sample plots located in edge zones. The minimum area of adjacent land use class is 0.02 hectare. Figure 1 shows the division of Sweden into regions, which is used in this paper.

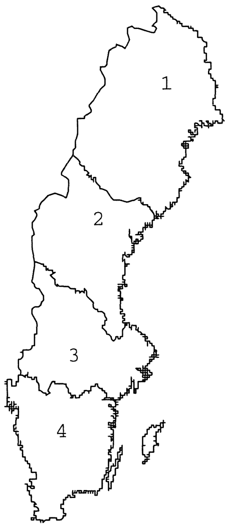

Figure 1. Regions of Sweden.

2.2 The HUGIN system

The basic feature of the HUGIN system is a deterministic simulation model with some stochastic components built in. This implies that the system describes the probable development of the forests under specified assumptions regarding future silviculture and cutting (Figure 2).

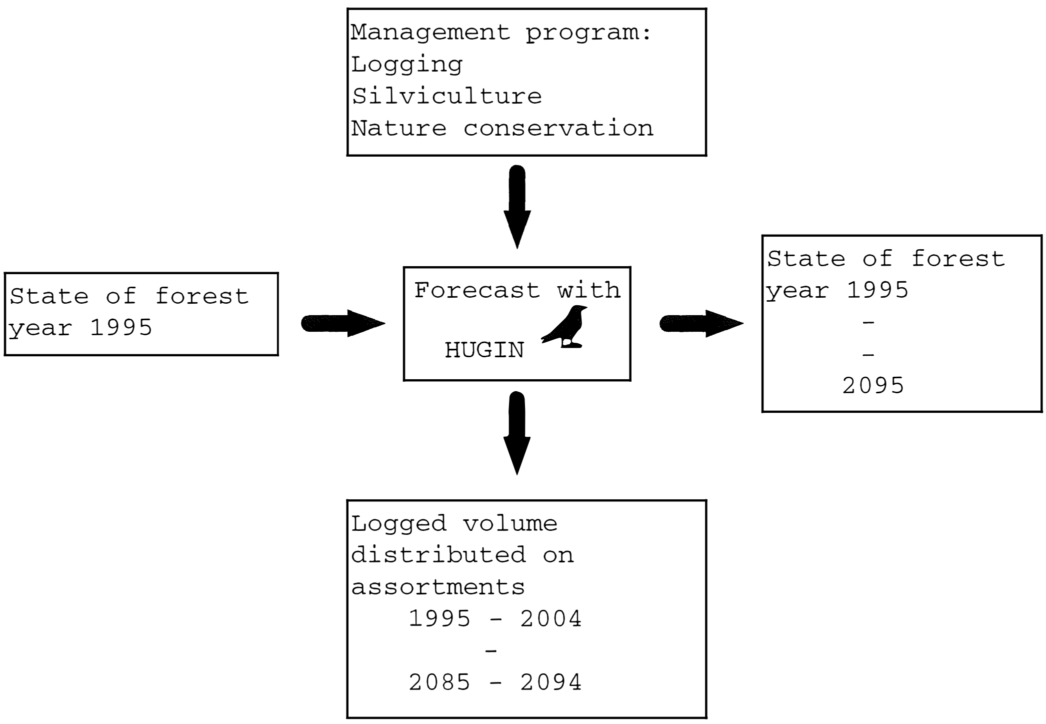

Figure 2. A general outline of the HUGIN system.

The forecasts are based on the data from NFI sample plots on forest land. Forest land is defined as land suitable for timber production which is, in the main, not used for other purposes. The productivity of the land should be a minimum of 1 m^3 ha^{-1} yr^{-1} over bark but excluding stump.

The individual sample plots from the NFI are used as the unit for making decisions about different measures that can be applied. Individual trees on each plot are used as units for the growth prognosis (Söderberg 1986). To make the forecasts more realistic, it is important to take into consideration the various restrictions on timber production, such as economic and technical conditions, recreation and nature conservation. This can be done, for plots affected by any such restrictions, by changing the way they are managed in order to simulate the effects of restrictions.

2.3 Restrictions of management

In order to deal with any restrictions of management in edge zones, a description of the context of the sample plots in the landscape in relation to other land use classes can be used, see appendix 1.

Forest lands, which are important for biodiversity, must be managed with care. However, this raises the question of which plots should be managed with greater care than normal practice? The selection of such sample plots can, in principle, be made according to three criteria:

1. By taking into account the context of the sample plots.
   Alternatives here include:
   a. combining digital maps showing e.g. roads, streams, reserves, and urban land with NFI field data; and

   b. combining satellite images with NFI field data; and

   c. including the context of the NFI sample plots.

2. By combining plot characteristics.

3. By combining alternatives 1 and 2.

Alternative 1a will, most likely, be used in the future, but because of problems relating to, for example, differences in land use class definitions; maps covering the whole of Sweden, and/or are expensive, this method has not yet been used. Research which uses satellite images for contextual classification (alternative 1b) is currently being undertaken and can also be useful in a future (Flygare 1995; Nilsson 1996). Alternatives 1c and 2 have to some extent already been used in HUGIN to select different forest types as swamp forests, forests suitable for single tree selection, and old growth. In this paper, the use of the context description of NFI sample plots (alternative 1c) is analysed.

2.4 Management in edge zones

The silvicultural management of forests in edge zones, which are defined as forest closer than 25 meters to a mire, lake, stream, etc. must be modified compared to normal management. The choice of silvicultural management depends on the characteristics of the forest in the edge zone and on the adjacent land use class. In HUGIN it is possible to change the management of selected plots in many different ways. A number of conceivable management alternatives are listed below;

- No cutting
- Single tree selection system
- Modified thinning instead of clear-cutting, e.g. leaving a lot of broad-leaved trees in thinning
- Leaving behind large trees - nest trees, large broad-leaved trees, old trees, etc.

In order to illustrate the management of an edge zone, assume that a sample plot is located within 25 meters of mire. This implies that some type of alternative management measures is necessary. Figure 3 shows an example of a conceivable management schedule. If none of the selection criteria 1-4 are met, the probabilities ($p(x_i)$) are set to simulate appropriate management measures and mismanagement.

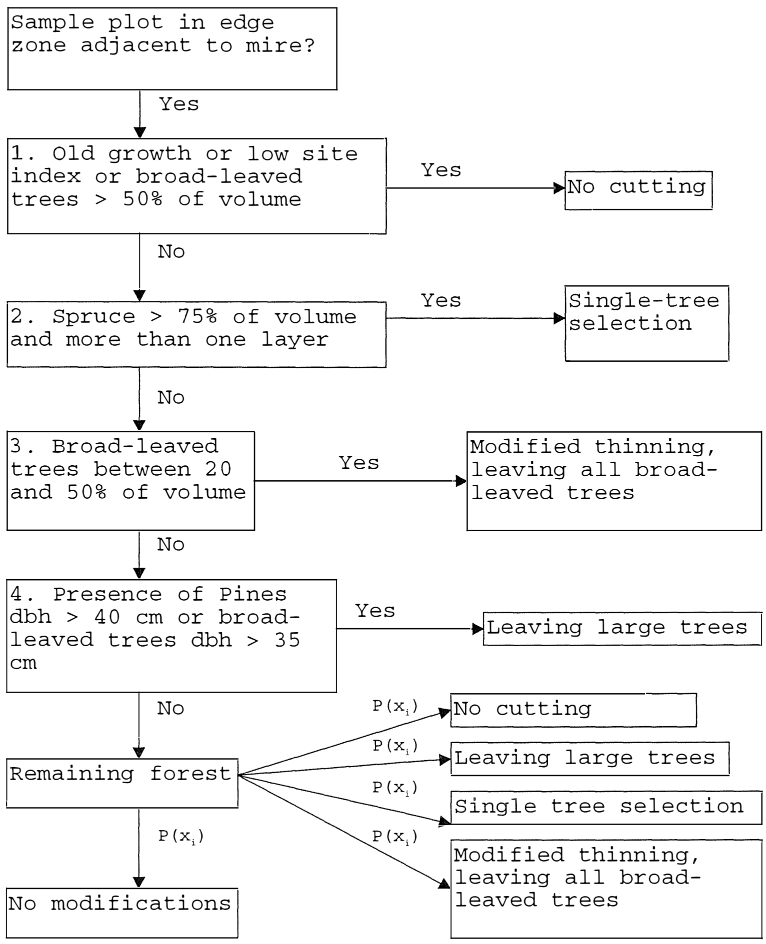

Figure 3. Example of management schedule in edge zone adjacent to mire.

3. RESULTS

Analyses of the 1996 NFI data on 25 meters wide edge zones are reported in Tables 2 to 7. The data include the area, percentage and characteristics of land uses. The results are based on 7683 sample plots. It should be noted that a sample plot can be adjacent to more than one land use class, see Appendix 1. This means that the summation, made in Table 2, of areas inside and outside edge zones gives a larger area of forest land than the total area of forest land. Of the total forest area, 816 000 ha, or 3.6 %, are located in edge zones adjacent to more than one other adjoining land use class. In Tables 2 to 7, other adjacent land use class include the sea, pasture land, mountain conifer forests, mountains, non-productive land (climatic reasons), power lines within forest land, preserved land, land reserved for military manoeuvres and other land. These tables present variables like average tree height and volume in the edge zones. These are required to assess the full impact of nature conservation or long-term potential cut. As will be discussed later, merely an assessment of the forest area of edge zones in not sufficient.

Table 1. Land area distributed according to land use classes, %, (Skogsdata, 1994)

	Region				
Land use class	1	2	3	4	1-4
Forest land	43.0	65.4	65.5	57.5	55.3
Pasture	0.0	0.2	1.1	4.4	1.2
Field	0.8	2.0	11.2	21.4	7.5
Mire	16.4	13.6	8.8	3.8	11.6
Hills	1.1	2.2	2.9	4.5	2.4
Urban land	0.7	1.3	4.6	5.5	2.6
Remaining[1]	38.0	15.4	5.8	3.0	19.4
All	100.0	100.0	100.0	100.0	100.0

[1] Mountain conifer forests, mountains, power lines, protected land, military manoeuvres area and other land

Table 2. Area of forest land distributed in edge zones, 1000-ha and % of total forest land

	Region									
Land use class	1		2		3		4		1-4	
No edge zone	5536	83.0	4862	83.8	4286	81.8	4043	80.0	18727	82.3
Urban land	32	0.5	25	0.4	56	1.1	63	1.2	176	0.8
Roads	180	2.7	230	4.0	139	2.7	253	5.0	802	3.5
Large streams/lakes	54	0.8	86	1.5	49	0.9	72	1.4	261	1.1
Small streams/lakes	68	1.0	123	2.1	160	3.1	87	1.7	438	1.9
Other	33	0.5	71	1.2	98	1.9	220	4.4	422	1.9
Field	24	0.4	53	0.9	71	1.4	190	3.8	338	1.5
Mire	834	12.5	497	8.6	397	7.6	171	3.4	1899	8.3
Non-productive hills	80	1.2	46	0.8	168	3.2	223	4.4	517	2.3

Table 3. Average tree height in edge zones, dm

	Region				
Adjacent land use class	1	2	3	4	1-4
No edge zone	95	109	117	141	119
Urban land	164	108	137	151	143
Roads	108	90	136	142	125
Large streams/lakes	104	124	149	151	137
Small streams/lakes	127	130	109	165	132
Other	94	105	159	142	138
Field	104	124	121	144	136
Mire	85	102	107	115	101
Non-productive hills	111	96	117	119	116
All forest land	95	108	118	139	119

Table 4. Forest area older than 100 years in edge zones, %

Adjacent land use class	> 100 years
No edge zone	19
Urban land	3
Roads	17
Large streams/lakes	31
Small streams/lakes	22
Other	9
Field	6
Mire	28
Non-productive hills	22
All forest land	19

Table 5. Volume in edge zones, m³/ha

	Region				
Adjacent land use class	1	2	3	4	1-4
No edge zone	83	128	133	168	134
Urban land	194	124	178	181	175
Roads	93	101	213	191	163
Large streams/lakes	111	114	194	199	164
Small streams/lakes	115	124	96	216	139
Other	78	125	168	199	179
Field	99	132	191	189	180
Mire	63	97	95	113	89
Non-productive hills	111	123	137	145	139
All forest land	82	124	132	169	134

Table 6. Tree species composition in edges zones (weighted by basal area if mean height > 7 m or number of stems if mean height < 7 m), %

Adjacent land use class	Scots Pine	Norway Spruce	Broad-leaved trees
No edge zone	44	40	16
Urban land	25	35	40
Roads	42	39	19
Large streams/lakes	47	26	27
Small streams/lakes	34	42	24
Other	28	39	33
Field	22	40	38
Mire	57	28	15
Non-productive hills	49	34	17
All forest land	44	39	17

Table 7. Average site index (H100) in edge zones, m

	Region				
Adjacent land use class	1	2	3	4	1-4
No edge zone	17.1	20.6	24.0	28.2	23.4
Urban land	20.1	24.2	27.3	30.4	27.9
Roads	17.0	20.7	23.6	29.0	24.7
Large streams/lakes	18.3	16.7	26.0	26.8	23.1
Small streams/lakes	16.8	19.3	23.0	28.8	23.1
Other	18.3	21.4	26.2	30.2	27.8
Field	20.3	25.2	28.3	29.7	28.6
Mire	15.2	16.7	19.2	23.6	18.2
Non-productive hills	15.5	18.3	23.4	25.0	23.6
All forest land	16.9	20.2	23.7	28.1	23.2

4. DISCUSSION

What are the impacts of nature conservation in edge zones? Unfortunately, it has not yet been possible to use the HUGIN system to make any forecasts of these effects. This is because the NFI data from 1996 will not be completely ready until the beginning of the autumn 1997. However, as a first step, the NFI data has been analysed and an outline of how to include nature conservation in the management of edge zones has been suggested. The next step is to carry out forecasts using the HUGIN system to analyse the effects of modified management in edge zones. A further aim has been to use the potential of a GIS in order to improve the quality of the input data to the HUGIN system.

The effects on the cutting levels depend on the type and percentage of the different land-uses and on changes in the management measures used in the edge zones. They also depend on the growth, site index, volume and tree species composition in the edge zones. Table 2 shows that edge zones, 25 metres in width, around mires, streams, lakes, non-productive hills and urban land constitute approximately 14% of total forest land. Tables 4-7 indicates that forest in edge zones, with the exception of those around mires, are older, higher, denser and grow on more productive land than forests not adjacent to other land use classes. Zones around mires constitute almost half of the total edge zone area (Table 2). These zones around mires have lower average tree height, volume, and productivity, (Tables 3,5 and 7) and a higher share of older forest and broad-leaved trees, (Table 5 and 6). Because of this, the effects on cutting levels of applying conservation measures in edge zones will be lower than might otherwise be expected.

A weakness with the NFI data is that the size of the adjacent land use class is not known. Sometimes it is not meaningful, in terms of preserving biodiversity, to leave an edge zone around very small areas. This must be taken into consideration by not making any modifications to the management measures for some proportion of the edge zones.

However, with the assessment of the characteristics of edge zones, we still do not know what the long-term impacts of nature oriented forest management may be, because within edge zones different types of suitable silvicultural management are possible. There are different opinions with regard to suitable silvicultural management for edge zones. No cutting is the most extreme alternative, nevertheless it is applicable in some edge zones. Other zones demand less drastic changes, such as modified thinning. The effects of these measures on the potential cut will, of course, depend on the extent to which they are applied in the edge zones. If the type of silviculture applied on both private and company forest land follows the new guidelines provided by the National Board of Forestry and by large companies, then we would guess that the potential cut will be reduced by less than ten percent.

The National Board of Forestry is currently undertaking an inventory, the Greenery project, of the regard paid to environmental considerations, when cuttings are made (Sandström, 1991). Findings from this study can be used as a basis for designing management schedules, such as the one presented in Figure 3, to simulate the forestry of today. In a press release (National Board of Forestry, 1996), the results from the Greenery project were presented. These showed that, in 1995, about 5% of clear cutting areas were reserved for nature conservation purposes.

In addition, other nature conservation measures not mentioned in this paper will have effect on sustainable cuttings. For example, no cuttings in wetland forests, key habitats, or old growth, leaving trees when clear cutting, etc. Together these measures will have a considerable effect on sustainable cutting levels. Therefore, the above described likely impact of edge zones does not assess the full impact of nature conservation measures until the edge zone assessment can be further improved.

Until recently, the HUGIN system, with a few exceptions, uses only NFI field data. The NFI measurements are, of course, changing all the time to meet new demands. However, when spatial considerations are included, other sources such as digital maps and data from remote sensing must also be used. Hopefully, digital maps showing streams, roads, urban land etc. will be available in the near future. This should make it possible to vary the width of edge zones around land use classes that are valuable for biodiversity. A GIS can be used because the geographical positions of the NFI sample plots are determined by GPS. It will also be possible to alter the management measures for various intervals in the edge zones.

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APPENDIX

Table A.1. NFI variables describing plot context, year 1996

Variable	Definition of variable
Position in landscape	0 No one of below positions 1 Less than 100 m to urban land or permanent construction for outdoor life. 2 Less than 100 m to larger road. 3 Less than 100 m to Sea. 4 Less than 100 m to lake > 5 ha or stream > 5 m wide 5 Less than 25 m to lake < 5 ha or stream < 5 m wide 6 Less than 25 m to adjacent land use class Three categories on a sample plot can be assessed. Distance assessed from plot centre to adjacent land use class larger than 0.02 ha.
Distance (if position in landscape code 1-4)	25 < 25 m 50 26-50 m 75 51-75 m 100 75-100 m
If position in landscape = 6	Possible adjacent land use classes; Forest land, Pasture, Field, Mire, Non-productive hills, Mountain conifer forests, Mountain, Road and railroad, Other non-productive land because of climate, Power line within forest land, Preserved land, Military land or Other land.

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