Evaluation of Silvicultural Practices from a Multipurpose Perspective

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Abstract

Appropriate silvicultural practices, based on the objectives of forest owners, should be incorporated into forest management plans to promote sustainability. The main objective of this study was to compare the suitability of different silvicultural practices with respect to the multiple objectives of small-scale forest owners. In addition, a method for evaluating the results of research within the field is presented. A model describing the objectives of private forest owners was used to compare different silvicultural practices. A literature review was conducted and the appropriateness of different practices and objectives was analysed using matrixes. The results indicated that the practices evaluated have the potential to allow the development of forestry with multiple functions: thinning and successive felling appeared to be most suitable. Passive practices were less well adapted to the multiple objectives of private forest owners. It is important to continue collating and reviewing the available data, especially relating to forestry practices not commonly used in Scandinavia.

Key words: Amenities, conservation, economic efficiency, forest management plans, forest owners' objectives, multipurpose forestry, silvicultural practices, utilities

Introduction

Appropriate silvicultural practices, based on the objectives of the forest owners, should be incorporated into forest management plans to promote sustainability. The forest owners´ rights and obligations during forest management are regulated by the Swedish Forestry Act. The first paragraph states: "The forest…. 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" (Handbook of the Forestry Act 1994, p.8). At the same time, the regulations of the Act are not detailed, leaving decisions largely to the forest owner. For example, in the previous Act a forest management plan had to be produced, but in the new Act of 1994 this is no longer a requirement. Forest ownership in Sweden can be divided into four types: private, state, community and company forests. With about 400 000 owners and an average estate size of about 45 hectares, private holdings encompass approximately 50 percent of the total area of forest, or 10.7 million hectares (Enström 1997). Approximately one quarter of forest owners earn at least part of their living through forest-related activities (Lidestav and Nordfjell 2002). The most commonly used management practices are clear cutting, followed by planting, cleaning and thinning (Skogsstyrelsen 1998). The structure of forest ownership is changing in Sweden and the economic importance of the forests is deceasing for the small-scale owners (Hugosson and Ingemarson 2004), sometimes referred to as non-industrial, smallholder or family forestry (Harrison *et al*. 2002). Changes in legislation during the 1990s resulted in deregulation of the property market. Farmers' pre-emptive rights were largely terminated, possibly resulting in a larger proportion of forest owners who belong to a new generation with different values. They are concerned not only with wood production and profit, but also, for example, with conservation and amenity (Hugosson and Ingemarson 2004). The result shows that small-scale forest owners could have many different objectives that affect silvicultural practices in different ways (Ibid). A practice may be well adapted to one objective, but be less suited to another, for example:

- Clear cutting is economically sound, but increases both leaching and soil erosion.
- Leaving an old forest undisturbed may be appropriate for nature conservation, but not if the owner requires a high economic return.

The main objective of the present study was to compare different silvicultural practices and their suitability for fulfilling multiple objectives. In addition, a method for evaluating the results of research within the field is presented. The evaluation is intended to be used as a foundation for decision-making by small-scale forest owners.

Material and methods

A model describing private forest owners' objectives (Hugosson and Ingemarsson 2004) was used to compare the different practices. The objectives from the model are described below. The cluster of objectives entitled 'Conservation' relates to careful management of forest resources for protection and preservation. The objective Nature Conservation refers to the creation of opportunities for a rich and varied plant and animal life, including biodiversity. Cultural Conservation represents the desire to protect and preserve historic and cultural features. Water/Soil Conservation relates to managing water systems in a way that will not adversely affect the water quality, and protecting the soil from leaching and loss of nutrients. The cluster entitled 'Utilities' relates to producing a range of forest products. The objective Game Production represents a desire to improve habitats and increase the amount of forage for game, in this study limited to deer. The objective Berry Production concerns cowberries (*Vaccinium vitis-idaea* L.), bilberries (*Vaccincum myrtillus* L.) and raspberries (*Rubus idaeus* L.). Mushroom Production concerns harvesting mushrooms. The cluster entitled 'Amenities' has a weaker connection to activities than the other motivations and accordingly, is more related to underlying values. Forestry Tradition represents the desire to manage forests for previous and future generations, maintaining continuity of the forest structure. Silvicultural Challenge concerns forest management as a source of intellectual and physical challenges. The objective Aesthetics relates to the visual appearance of the forest. The cluster 'Economic Efficiency' reflects economic objectives for managing forest land. The objective Yield of Capital concerns the creation of opportunities for a high financial return from forestry. If the forest owner regards the forest as a Liquidity Reserve, forestry probably does not provide his/her primary income. For example, the economic output of the forest may be used by a farmer during years with poor crops. Tax Planning determines when and what type of management activities should be carried out, depending on the tax system and the structure of the forest (Hugosson and Ingemarsson 2004).

The relationships between practices and forest owners' objectives were analysed. A literature review was conducted, followed by an analysis of the relationships between silvicultural practices and the objectives of forest owners. The results of the review were summarised in the form of matrixes, with the clusters of objectives on one axis and silviculture practices on the other. One matrix was constructed for each cluster of objectives, i.e. conservation, amenities, utilities and economic efficiency. Each cell was allocated a level of adaptation and the levels were summarized using the following variables: A for adapted (1); P for partly adapted (0); and N for not adapted (-1). Following Gustafsson (1998), a system for reviewing the references was used, allocating asterisks according to their validity:

*** Refereed articles or monographs
** Scientific reports and textbooks
* Inadequate reference

The asterisk system maps documented knowledge for the area under consideration, thus areas lacking research were apparent on the matrixes. In such cases, the evaluations were based upon interpolations and common knowledge. The suitability of each practice was evaluated individually and summarised (Tables 1 to 4). Horizontally, the summation included the scores for each individual practice. Vertically, the summation of practices demonstrated their suitability for each individual objective. Finally, Table 5 shows the level of suitability for the multiple objectives of small-scale forest owners. There are large numbers of forest owners, representing a wide variety of values, and for whom the different objectives assume different levels of importance. This is not taken into account in the summations, but a proposal for how to handle this issue is described under the heading 'Discussion'.

The practices were analysed at forest stand level during a period of twenty years. This period was chosen for several reasons. First, properties tend to change owners during such a period: on average, a Swedish owner possesses the forest for about twenty years (Eriksson 1989). Second, this period is a time suitable for surveying; after twenty years the forest has developed into a new age class and a new silvicultural practice is often necessary. Over a longer period of time it would be difficult to gain an overview. If the period considered were a rotation, the analysis would have been on the level of systems, rather than practices. The latter was not within the scope of this study, but a rough outline, with a comparison between two silvicultural systems is presented in the discussion. The stands referred to were assumed to have a history and pre treatment such that the practices would function without severe risk. The tree species were limited to Scots pine (*Pinus syl-*

vestris L.) and Norway spruce (*Picea abies* Karst.) in their natural habitat: other species could be kept in the stand for biodiversity purposes. Although the emphasis was on the most common practices related to clear cutting and uniform shelterwood systems (Matthews 1989), other practices, related to silvicultural systems in Central Europe that could be adapted to Scandinavia, are also discussed.

Definitions and descriptions

'Silvicultural system' was defined as "the process by which the crops constituting a forest stand are tended, removed, and replaced by new crops, resulting in the production of stands of a distinct form" (Matthews 1989, p. 3). The term 'Silvicultural practices' refers to techniques for managing forest compartments such as felling, tending, regeneration, etc. They are, in general, active Terms for defining practices and stands can be interpreted in various ways, thus following delimitations: (felling, planting and burning), but there are exceptions (no felling, no cleaning).

Clear cut referred the 'original form'; *i.e.* no Green Tree Retention (GTR) after harvesting. Successive felling corresponded to 'uniform felling' (Matthews 1989) and was achieved in two steps, with a reduction of the number of trees to 80-150 stems ha^{-1} followed by a clear cut 10-12 years later. In addition, it was assumed that the first intervention had been preceded by a thinning 20 years previously, thus leading to a relatively storm resistant stand. However, stand density was considered to reach and exceed 1.0 if no intervention (*e.g.* thinning) was conducted during the next 20 years. 'No felling' was a 'non-active practice', mentioned because forest certification rules state that a certain percentage of the forest should be left for free development - without human intervention. This will lead to a 'virgin' forest stand at the end of the period. Scarification was performed mechanically by uncovering the mineral soil in patches or in ranges (disc trenching) or by mounding. Ploughing was excluded from this study. Prescribed burning was used to maintain the natural diversity (Spurr and Barnes 1980), especially concerning habitats for red listed species, and to promote the establishment of young stands of Scots pine (Skinnemoen 1969, Matthews 1989 a.o.). Planting was performed in a 'traditional way', resulting in a young forest with evenly spaced trees growing in ranges. Manual scarification was also included as part of the practice. Sowing was preceded by an efficient mechanical scarification. Natural regeneration under uniform shelter (NUS) referred to a shelterwood (Börset 1986, Matthews 1986, Figure 14, p.119) of 120-150 stems ha^{-1}, created to produce seed, shelter and high quality timber, with removal after 12-15 years. Natural regeneration under irregular shelter (NIS) was comparable to the 'Group System' (Matthews 1989), which involved taking up 'initial gaps'. The practice also included at least one extension of the gap during the 20 year period. The stand was assumed to have been well tended earlier during the rotation. NIS may also include planting to obtain a mixture of species. Natural regeneration at forest edges (NFE) was understood to be the initial steps of the Strip System, which also constitutes a "side shelter" (a shelterwood system) (Matthews 1989, p. 90). Cleaning referred to 'conventional cleaning', consisting of one heavy cleaning, leaving 1500- 3000 stems ha^{-1}, depending on the site index, at a stand height of 2-3 m. Generally, conifer stems were favoured, but deciduous trees are frequently left in the stand. Thinning referred to 'intermediate thinning' (Hibberd 1991), or 'free Danish thinning' (Söderström 1971). Absence of cleaning and of thinning were also evaluated because they are not obligatory under the Swedish Forestry Act, and some forest owners do not tend their forest stands (Skogsstyrelsen 1995, 2002a). 'Stand' is the "basic management unit of a forest" (Hibberd 1991, p.148), while 'compartments' are "permanent management units" (Ibid.)

Results of the evaluation

'Culture conservation' refers to opening up areas, *i.e.* removing vegetation, in order to allow prehistoric graves, old ruins etc. to become visible within the landscape (Andersson 2000, Gustavsson 2000), thus preventing damage by roots and stopping trees from concealing the area. This is the principle when clear cut is used, but this practice may be too rigid and aggressive, since large areas are treated systematically with heavy machinery (Gren 1997). The taller a tree, the greater the risk of windthrow (Burschel and Huss 1997). Successive felling in old stands is therefore inappropriate in an area where culture conservation is the aim, since it can damage prehistoric graves or other remains (Andersson 2000). Virgin forest is never opened up in a controlled way (Buschel and Huss 1997 a.o.), and obscures historic monuments. Scarification of grave sites is not permitted, thus precluding regeneration by sowing (SFS 1988:950). Since the protection of objects of cultural value often involves the removal of vegetation and maintaining open areas, all practices with the objective of regeneration are more or less unsuitable. In such cases, planting is strictly forbidden by Swedish law (SFS 1988:950). NIS and NFE present the same problems as NUS – *i.e.* the risk of windthrow, but to a lesser extent (Matthews 1989, Burschel and Huss 1997). If not removed, young forest compartments should be tended in a way that leads towards stability. It is recommended that thinning should be confined to the early stages of stand development, during the thicket stage (Matthews 1989, Cameron 2002).

Forestry practices that radically change the forest are generally considered inappropriate for nature conservation. Vanha-Majamaa and Jalonen (2001) find that clear cutting caused major understory vegetation changes. Cover and species number of both bryophytes and many vascular plants decrease. However, clear cutting does not always impoverish the flora. Kardell and Lindhagen (1998) find that shade-tolerant species disappear after clear cutting but are replaced by light demanding species. The number of species remains the same, or even increases in a clear-cut area. Different forms of successive felling result in fragmentation, which creates habitats for various plants and leads to increased occupancy of edge habitats (Esseen 1994). Consequently, it is likely that felling to create smaller gaps maintains a larger number of species. Uniform shelterwood is sometimes recommended as it is considered ecologically more valuable than clear felling (Ingelög 1981, Bergquist *et al*. 2001). Shelterwood maintains the number of species at the pre-treatment level, but the cover of shade tolerant plants may decrease (Vanha-Majamaa and Jalonen 2001). Although absence of felling is, in part, beneficial for biodiversity (especially mosses, lichens, fungi and insects) it can be detrimental for some herbaceous plants and tree species. A stand density approaching 1.0 or more is not recommended (Ingelög 1981), unless only shade-tolerant species are required. Forest regeneration using the same species that was present before harvesting supports nature conservation by providing vascular plants with an opportunity to re-establish after a clear cut (Naturvårdsverket 1994), but planting or sowing of a single tree species creates monocultures. However, such practices are often combined with scarification, which although sometimes considered to have a negative impact (Buschel and Huss 1997), is positive for biodiversity. The number of naturally regenerated birch seedlings (*Betula pendula* Roth. *and Betula pubescens* Ehrh.) is considerably higher on scarified than on non-scarified areas (Folkesson and Johansson 1981, Karlsson *et al*. 2002), at least on mesic and moist ground (Fries 1985). Burning is often considered a natural component of boreal ecosystems, since burnt trees provide a variety of substrates used by insect species, indeed some are completely fire-dependent (Ehnström 2001). Burning causes chemical and physical changes in the forest soil. These are important for the germination of forest tree seeds, particularly aspen (*Populus tremula* L.) and sallow (*Salix caprea* L.), two species important for creating biodiversity (Granström *et al.* 1995). NFE creates special light conditions, which permit the regeneration of shade-tolerant species, such as Norway spruce, as well as the survival of light demanding species (Matthews 1989, Buschel and Huss 1997). This is also the case for NIS, but to a less extent (Ibid.).

Tending forests creates opportunities for a rich and varied vascular plants composition, including different tree species (Ingelög 1981). Even though various tending practices can enhance nature conservation, some can be detrimental. If a forest owner favours one particular tree species then diversity is reduced (Ibid.). Cleaning and thinning tend to leave equal distances between the trees and increase the uniformity of the forest, unlike natural virgin forest (Ibid.). Targeted thinning of rotten and hollow trees has a negative impact both on the wildlife (birds and bats) and on the diversity of insects, cryptogams and fungi (Ehnström 2001, Nilsson *et al.* 2001). From this perspective, absence of tending is more suited to nature conservation, especially since it also favours the creation of dead wood. However, absence of tending often results in a high stand density, thus reducing the diversity of tree species (Schütz 1997, Otto 1998) and herbaceous plants (Ingelög 1981, Naturvårdsverket 1994), of which only shade-tolerant species can survive. Skidding roads, created as part of thinning operations, often become refuges for rare or threaten forest plants, such us calypso (*Calypso bulbosa* (L.) Oakes) and hard fern (*Blechnum spicant* (L.)Roth) (Ingelög 1981).

Opening up the canopy on a large scale may cause several problems with respect to water and soil conservation. This can expose the site to erosion, because there is no protection against rapid run-off of rainwater (Matthews 1989, Burschel and Huss 1997). These problems are less severe when shelter trees are left in the area (Burschel and Huss 1997). The absence of felling and tending in a stand may be appropriate for water and soil conservation, but not if this causes forest degeneration (Lanier 1994). Regeneration practices aim at rapid re-colonisation of the harvested area, which has a positive impact on water retention (Savill *et al.* 1997). In Nordic ecosystems, neither burning nor scarification have a negative impact if they are conducted moderately and on appropriate sites (Johansson 1987, Lundmark 1988, Gemmel and Örlander 1989). Burning on sites with a thin humus layer reduces fertility of the soil (Kardell and Laestadius 1987), especially for Norway spruce (Lundmark 1988).

NIS and NFE appeared to be suitable for conservation purposes (Table 1). Absence of tending, clear cutting and successive felling produced low scores. The sum for the column 'culture conservation' was low.

Table 1. Suitability of the various practices to deliver conservation objectives

	Culture conservation	Nature conservation	Water/Soil conservation	Sum:	Numeric sum:
Clear cutting	P **	P ***	N **	2P+N	-1
Successive felling	N **	P ***	P **	2P+N	-1
No felling	N **	P **	P **	2P+N	-1
Scarification	N ***	P **	A **	A+P+N	0
Burning	N *	A **	P **	A+P+N	0
Planting	N ***	P **	A **	A+P+N	0
Sowing	N ***	P **	A **	A+P+N	0
NUS	N **	P **	A **	A+P+N	0
NIS	P **	A **	A **	2A+P	2
NFE	P **	A **	A **	2A+P	2
Cleaning	P **	P **	A **	A+2P	1
No cleaning	N **	P **	P **	2P+N	-1
Thinning	P **	P **	A **	A+2P	1
No thinning	N **	P **	P **	2P+N	-1
Sum:	5P+9N	3A+11P	8A+5P+N	11A+21P+10N	1
Numeric sum:	-9	3	7		1
Inadequately documented (%)	7.1	0.0	0.0	Mean:	2.4

*** High validity, * Low validity, A - adapted (1), P - partly adapted (0), N - not adapted (-1)

Utilities

Clear cut creates space for broadleaf trees, raspberries and herbaceous plants, all important for game production (Ahlén *et al.* 1979, Cederlund *et al.* 1980, Börset 1986). This may be the case for all forms of successive felling and natural regeneration (Ahlén *et al.* 1979). Absence of felling causes excessive competition between the canopy species and species providing fodder for game. A boreal virgin forest may produce little game fodder (Hermansson *et al*. 1974). Therefore, it may be necessary to open up older stands to allow the establishment of appropriate species. Establishing a new crop also means producing food for game (Savill *et al*. 1997, Skogsstyrelsen 1998). Scarification has a positive influence on game food supply, resulting in a high number of broadleaf species (Folkesson and Johansson 1981), but has a negative impact on berry-producing species (Kardell and Eriksson 1983), which are important food sources for the roe deer (*Capreolus capreolus* L.) and moose (*Alces alces* L.) (Ahlén 1977, Börset 1986, Cederlund *et al*. 1980). Deer, in general, respond favourably to fires (Spurr and Barnes 1980). Cleaning in young coniferous stands often removes broadleaf species, but some practices can be game-friendly. Cleaning, by cutting the tops trees such as birch, rowan (*Sorbus aucuparia* L.) and different *Salix*-species, produces fodder and shelter, which are utilised by many kinds of game (Hermansson *et al*. 1974). Opening up a dense stand creates space for the growth of broadleaf tree species and herbs. An absence of cleaning is initially good for game production because existing deciduous trees (and other fodder species) remain in the compartment, and the vegetation provides shelter (Ibid.). Thinning is necessary, however, to maintain the production of game fodder. Absence of thinning restricts the opportunities for wildlife conservation (Cameron 2002).

Clear-cutting influences the production of berries in various ways. Raspberry and cowberry production is positively influenced by clear cutting (Kardell and Eriksson 1990). Bilberry generally supports a lower biomass in a clear-cut area than under a shelterwood (Hannerz and Hånell 1993, Öhman 1997) It is, however, favoured by clear cutting where temperature is a limiting factor, for example in areas of high exposure and in northern Sweden. In southern Sweden, bilberry production is adversely affected by this practice, especially on south-facing slopes (Kardell and Eriksson 1990). However, in terms of annual production (kg ha^{-1}), irrespective of berry species, clear cutting is undoubtedly very efficient (Kardell 1993). Different forms of successive felling lead to fragmentation that creates habitats for a variety of plants (Esseen 1994); opening up old forest stands favours the production of bilberry and cowberry (Kardell and Eriksson 1989). Burning and scarification are beneficial for raspberry production, but not for cowberry and bilberry (Kardell and Eriksson 1990). The influence of different regeneration practices, and the impact that a gradually closing tree canopy might have on berry production is not well documented (Kardell and Eriksson 1983). Production of raspberry and cowberry is initially high in a newly regenerated area (Kardell 1993), but active practices are supposed to increase the competition from the new generation of trees by the end of the 20 year period. Compared to a lack of intervention, thinning appears to have a positive influence on berry production (Kardell and Eriksson 1990). Cleaning was considered to have a similar positive influence.

Five years after clear-cutting the production of edible mushrooms is only 5% of the quantity usually found in an untreated stand (Kardell and Eriksson 1987). If 50-100 seed trees are left per hectare, the production of mushrooms is 30% of the production in an untreated stand (Ibid.) Successive felling, including different forms of natural regeneration, are thus partly suitable. In scarified areas, the production of edible morels (*Gyromitra esculénta* (Pers.) Fr.) is double that of non-scarified areas (Kardell and Eriksson 1987). Low intensity fires seem to have a limited long term effect on mycorrhizal diversity and community composition (Jonsson *et al*. 1999). The presence of tree roots is essential for fulfilling the life cycle of mycorrhizal fungi such as ceps (*Boletus edulis* Fr.) (Otto 1998). It was presumed that a rapid re-colonization by forest trees has a slight positive impact on the production of mushroom. Production of edible mushrooms tends to be the same in thinned and non thinned compartments (Kardell and Eriksson 1987).

Thinning was the only practice appropriate for all three objectives (Table 2). Successive felling and cleaning were also useful, but inactivity was less appropriate.

Table 2. Suitability of the various practices to deliver Utility objectives

	Game production	Berry production	Mushroom production	Sum:	Numeric sum:
Clear cutting	A ***	A **	N **	2A+N	1
Successive felling	A **	A **	P **	2A+P	2
No felling	N **	N **	A **	A+2N	-1
Scarification	P **	P **	A **	A+2P	1
Burning	A **	P **	P ***	A+2P	1
Planting	A **	P *	P *	A+2P	1
Sowing	A **	P *	P *	A+2P	1
NUS	A **	P *	P **	A+2P	1
NIS	A **	P *	P *	A+2P	1
NFE	A **	P *	P *	A+2P	1
Cleaning	P **	A *	A **	2A+P	2
No cleaning	A **	N *	A **	2A+N	1
Thinning	A ***	A **	A **	3A	3
No thinning	N ***	N **	A **	A+2N	-1
Sum:	10A+2P+2N	3A+8P+3N	6A+7P+N	19A+17P+6N	14
Numeric sum:	8	0	5		14
Inadequately documented (%)	0.0	50.5	28.6	Mean:	26.2

Amenities

Clear cutting may be linked to a desire to manage the forest for future generations, but the operation involves drastic changes at the stand level (Burschel and Huss 1997). Successive felling results in gradual changes and is therefore better suited to a continuation of forestry tradition (Nyland 1996 a.o.). There are no radical changes in the absence of felling, but it was not considered beneficial for future generations. The feeling of leaving a well-tended forest to future generations is a very important motivation for the forest owner when regenerating and tending (Sennblad 1990). Burning is an exception as it drastically changes the appearance of an area (Nyland 1996). For the same reason, scarification was also considered an exception. By being passive, the forest owner is not taking care of the legacy of previous and future generations (Sennblad 1990). In Finland, postponement of the first thinning has been seen as one of the most serious threats to sustainable forestry (Hyytiäineen and Tahvonen 2002).

Clear cutting is a reliable way of harvesting a crop (Matthews 1989 a.o.) and it is seldom an activity undertaken personally by the owner, therefore, clear-cutting provides no silvicultural challenges. Creating a shelterwood by successive felling can fulfil this need. It is not necessarily a personal activity, but the practice itself is challenging, as it requires an instinctive feeling for minimising the risk of wind thrown trees and for producing good quality regeneration (Hagner 1962 a.o.). The same principle applies to the regeneration at forest edges and in irregular shelterwoods (Matthews 1989, Schütz 1997, a.o.). Scarification is reliable and does not involve personal activity, whereas burning an area in the forest in a controlled way demands skill (Nyland 1996). Planting and sowing may at least offer the owner opportunities for physical activity and skill (Söderström 1971). Sowing was considered more challenging than planting: its success requires more skill. Tending also requires skill on the part of the forest owner and provides the opportunity for physical activity. Undemanding passive practices present no silvicultural challenges.

Shelterwoods are more aesthetically pleasing than clear–cuts (Bergquist *et al*. 2001); large areas of clear-cut are not aesthetically valuable (Kardell 1990, Kardell and Lindhagen 1998). Old untouched forests are usually valued (Ibid.), but if no felling takes place, the structure of the forest may change in an uncontrolled way. Whether an area of forest is aesthetically pleasing depends on previous management (Ibid.). Virgin forests are still considered unsuitable for recreation by the majority of Swedish people (Lindhagen and Hörnsten 1997). A burned area is, initially, not very attractive, but produces vigorous stands after a few years (Skinnmoen 1969). Scarification, planting and sowing produce regeneration in blocks, often with equal distances between the plants, which tends to be unattractive (Kardell and Lindhagen 1998). However, after a few years plant mortality and natural regeneration will improve the aesthetics. Attitudes towards young stands are often neutral unless it does not obscure the view (Kardell 1990). NIS is generally considered beautiful (Matthews 1989 a. o.), whereas NFE often results in a rigid geometric layout (Ibid.). Young stands, tall enough to obscure views, often have dry ugly twigs. This is unappealing to those walking in the forest, and is a particular problem where the trees are not tended (Kardell and Lindhagen 1998). Newly cleaned or thinned areas are also unattractive because of the presence of logging wastes, however, mature, well-thinned, middle-aged and open stands are appreciated (Ibid.). Kardell (1990) concludes that tending raises the aesthetic value of a forest even if it is delayed. Absence of tending restricts the opportunities for enhancing visual appearance (Cameron 2002).

Successive felling, the main regeneration practices (especially different forms of shelter) and active tending were appropriate in supporting the objectives of the amenities cluster (Table 3). Clear cutting and passive practices were not appropriate.

Table 3. Suitability of the various practices to deliver Amenity objectives

	Forestry tradition	Silvicultural challenges	Aesthetics	Sum:	Numeric sum:
Clear cutting	P **	N **	N ***	P+2N	-2
Successive felling	A **	A **	A ***	3A	3
No felling	P **	N *	P **	2P+N	-1
Scarification	P *	N **	P **	2P+N	-1
Burning	P **	A **	P **	A+2P	1
Planting	A **	P **	P **	A+2P	1
Sowing	A **	A **	P **	2A+P	2
NUS	A **	A **	A **	3A	3
NIS	A **	A **	A **	3A	3
NFE	A **	A **	P **	2A+P	2
Cleaning	A **	A *	P ***	2A+P	2
No cleaning	P **	N *	N ***	P+2N	-2
Thinning	A **	A *	A ***	3A	3
No thinning	P **	N *	N ***	P+2N	-2
Sum:	8A+6P	8A+P+5N	4A+7P+3N	20A+13P+8N	12
Numeric sum	8	3	1		12
Inadequately documented (%)	7.1	35.7	0.0	Mean:	14.3

Economic Efficiency

A high yield of capital is achieved if the stand is clear cut in time to produce the maximum net present value (NPV) with respect to the land value (Streyffert 1965). NIS and NFE were considered only partially suitable, since not all compartments are cut. Creating a shelterwood by successive felling and NUS, makes it possible to concentrate and maintain production on the trees most suited to maximising NPV (Ibid.) and allows the proportion of saw logs to be maximised (Hånell *et al*. 2000). When no felling is undertaken, the increment as well as the yield of capital decreases (Streyffert 1965). Increases in interest rates calculated for costing purposes render regenerative practices, for example planting and sowing, less profitable (Håkansson 2002). An interest rate of 3% makes it hard to maintain a high yield of capital on cultivation costs (Streyffert 1965); only the most productive sites will yield profits from planting and sowing (Håkansson 2002). Scarification, which involves relatively low costs, was considered an exception. Cleaning and thinning produce early harvest revenues and increase the value of the residual trees (Hyytiäineen and Tahvonen 2002, Streyffert 1965). The production of high quality saw logs is restricted if there is no tending (Cameron 2002) and long intervals between thinning can result in a reduction in volume production (Assmann 1970).

Investment in shelter decreases the liquidity reserve, but only temporarily. The remaining trees in a shelter, and trees in stands after commercial thinning, represent reserves as well as production potential (Streyffert 1965). This is of particular interest when maximizing the proportion of saw logs (Hånell *et al.* 2000). In contrast, clear cutting leaves no such reserves (Ibid.). In the absence of unforeseen events, the owner will have some liquidity reserve if there is no final felling, but this was not considered efficient. The costs of regeneration decrease the reserve (Streyffert 1965) and a period of twenty years is too short to convert the associated production into cash. Cleaning is costly, and reduces liquidity, but it has the potential to produce a reserve after twenty years, which is not possible with no cleaning. Thinning was considered beneficial.

Harvesting practices, regeneration under shelters and at forest edges are adapted to tax planning, since the income can be spread over several years (Håkansson 2002). Absence of felling and thinning creates no opportunities for tax planning, except by avoiding income (Ibid.). Swedish fiscal legislation considers planting to be an investment and is therefore an operative expense, which can reduce taxes, especially as the costs for regeneration can be spread over time (Ibid.). Income from business can, under some circumstances, be offset against a loss through forestry management practices, for example investments in regeneration and tending. Absence of cleaning provides no opportunities for tax planning. Another means of reducing taxes results from the fact that income from forestry and other businesses can be jointly taxed. Income from the forest can be considered as income from capital, according to the interest rates; income from capital is taxed at a lower rate business (Håkansson 2002).

Successive felling, regeneration under different shelters, cleaning and thinning were well suited to economic efficiency (Table 4). Not cleaning had no economic efficiency benefits.

Summation of the four clusters

Combining the above results allowed an examination of the suitability of different practices for multipurpose forestry (Table 5). Thinning and NIS produced the highest scores, indicating that they were the most adaptable practices. NUS, NFE, cleaning and successive felling also emerged useful. Clear cut was less appropriate, and the least useful approach was passivity. The sum of the columns indicates the suitability of the practices for each of the clusters. The highest scores were for utilities and amenities; scores were lower for economy and were especially low for conservation.

Table 4. Suitability of the various practices to deliver Economic efficiency objectives

	Yield of Capital	Liquidity reserves	Tax planning	Sum:	Numeric sum:
Clear cutting	A **	N ***	A ***	2A+N	1
Successive felling	A ***	A ***	A ***	3A	3
No felling	N **	P *	P ***	2P+N	-1
Scarification	P *	N **	A ***	A+P+N	0
Burning	N **	N **	A ***	A+2N	-1
Planting	N **	N **	A ***	A+2N	-1
Sowing	N **	N **	A ***	A+2N	-1
NUS	A ***	A ***	A *	3A	3
NIS	P *	A ***	A *	2A+P	2
NFE	P *	A **	A *	2A+P	2
Cleaning	A ***	P *	A ***	2A+P	2
No cleaning	N ***	N *	N *	3N	-3
Thinning	A ***	A *	A ***	3A	3
No thinning	N ***	P *	P ***	2P+N	-1
Sum:	5A+3P+6N	5A+3P+6N	11A+2P+N	21A+8P+13N	8
Numeric sum:	-1	-1	10		8
Inadequately documented (%)	21.4	31.7	28.6	Mean:	28.6

Table 5. A summary of the level of suitability of various practices for the four clusters of objectives

All clusters of objectives	Conservation	Utilities	Amenities	Economic efficiency	Sum:
Clear cutting	-1	1	-2	1	-1
Successive felling	-1	2	3	3	7
No felling	-1	-1	-1	-1	-4
Scarification	0	1	-1	0	0
Burning	0	1	1	-1	1
Planting	0	1	1	-1	1
Sowing	0	1	2	-1	2
NUS	0	1	3	3	7
NIS	2	1	3	2	8
NFE	2	1	2	2	7
Cleaning	1	2	2	2	7
No cleaning	-1	1	-2	-3	-5
Thinning	1	3	3	3	10
No thinning	-1	-1	-2	-1	-5
Sum	1	14	12	8	35
Inadequately documented (%)	2.0	26.2	14.3	28.6	Mean: 17.9

Discussion

The practices examined were suitable for forest owners who valued hunting, picking mushrooms, forestry traditions and aesthetics. Economic efficiency did not achieve a high score within the clusters. This may be because most of the practices considered were regenerative, reducing the liquidity reserves and requiring more than twenty years to produce a yield on investments. Another choice of model for describing the objectives of the forest owners would influence the results, as would a different choice of practices, however those presented here include the most common practices. The poor value for conservation was mainly due to the low scores for 'culture conservation', indicating that forestry is difficult to combine with the protection of areas of high cultural value (Hasselmo 2000). Excluding 'culture conservation' from the cluster makes the practices more useful. The majority were only partly suitable for 'nature conservation'. This is understandable, since all intervention causes changes, which are positive for some organisms, but fatal for others (Naturvårdsverket 1994). In view of this, the score allocated for 'burning' (adapted) is questionable. Under natural conditions, forest fires should affect 1% of the boreal forest area in Sweden annually (Naturvårdsverket 1994), but fires have been rare in Swedish forestry for almost half a century. Thereby burning undoubtedly has a mainly positive impact on biodiversity. Practices' consisting in no interventions in the stand received low scores for nature conservation. The untended 'virgin' forest is often overestimated as a deliverer of biodiversity (Schütz 1997). Amelioration for a relatively small number of species, specialized on dead wood, is often obtained at the expense of the disappearance of a more important number of light demanding species in untended stands (Ibid).

The practice 'no regeneration' was not analysed, since regeneration is a legal obligation under the Swedish Forestry Act. 'No scarification' was examined initially, but few references were found; it is still possible to make interpolations using the material referred to in the text. Green tree retention (GTR) was found to be unimportant for the majority of the objectives, except nature conservation. Modified forms of tending were initially considered, but there was little literature and the results did not differ much from traditional forms of cleaning and thinning.

Tree species could influence the evaluation, but a focus on pine and spruce along with the prerequisites relating to risks resulted in small differences. For example, clear cutting was equally negative for soil and water conservation irrespective of tree species. Pine is preferable when producing game fodder and berries, but the structure and density of the stand has probably a bigger impact (Kardell and Eriksson 1983). Moreover, to make an evaluation for each tree species, four matrixes per species would be required.

The ranking presented here was based on interpretations from available literature based on research within the field. In some cases, such as for forest owners' preferences, there was a lack of adequate information. Available literature covered general opinions and not the specific opinions of forest owners. It was presumed that the forest owner's opinions did not differ from more general views (Mörk 2000). Occasionally the available literature only addressed part of the issue, for example with respect to 'nature conservation', even when a wide range of literature was available. Research about biodiversity in connection to silvicultural practices is still rather 'partial', too much based upon studies of a small number of organisms, *e.g.* one single group (Schütz 1997). There was also a lack of information on practices such as NIS and NFE under Scandinavian conditions. The objectives 'game production' and 'aesthetics' were well covered in the literature, but the remaining objectives require more research. Consequently, the evaluations from the matrixes may be affected by a certain amount of subjectivity, reflecting the cultural background of the authors.

The documented references (more than one star) covered 80% of the evaluations. In the cases where references were missing, the validations were tested. First, all such evaluations were classified as 'adapted' (A). Second, all were classified as 'not adapted' (N). The matrixes were summarized for both classifications individually and the results compared with the evaluations based on interpolations and common knowledge, i.e. the adaptation level presented in the results section. This process demonstrated that there was no appreciable change in the order of precedence for different levels of adaptation. The 'economic efficiency' and 'utilities' clusters contained the most cases with no documented references (29 and 26% respectively), indicating a greater uncertainty associated with their results compared to the 'amenities' and 'conservation' clusters.

Allocating only three levels of suitability limited the possibility for identifying differences between the practices. For example, clear cutting and irregular shelter were both classed as suitable for game production, but to what extent was not indicated by the model. A narrower categorisation would have produced results that were more detailed, but this was not possible using the literature available.

Matrixes tend to be schematic and do not always reflect reality: all variables cannot be represented in a 'square' in which simplifications and generalisations are necessary. For example, no thinning on a very fertile soil may cause self-thinning, which would make that practice unsuitable for creating a liquidity reserve; however, on poor sites with low tree density, creating a liquidity reserve without thinning is possible. To take such variation into account would require several matrixes with various site indexes. In addition, each practice could be conducted in different ways. For example, if all young trees were removed during cleaning or burning, the practice would be well adapted to culture conservation; however, this would require annual cleaning and thus it would deviate from the definition of a forestry practice. Another example, planning of the logging in a suitable way, preceded by an inventory of historical monuments at local level, could make clear cutting more suitable to culture conservation.

Each objective has a different degree of importance for a forest owner; these could not be considered during the summation of objectives within the clusters. The matrixes provided a systematic and theoretical means of describing a problem, for example allocating an index even where there is a lack of information. An alternative method would have been to evaluate the practices by means of case studies of well-defined compartments and categories of forest owners. This would have been advantageous in that there would be precise descriptions for each compartment and of the preferences of each category of owner, but the lack of literature would remain.

A time frame of twenty years for the analysis also influenced the results: this is a short period for changes within the forest. However, analyses over a longer period demand consideration of complete silvicultural systems, which was not the aim of the study. Despite the limitations, it is necessary to begin at the stand level in order to evaluate different systems, *e.g.* clear cutting and selection systems.

The technique might be applied where a forest owner, with a definite profile, requests an evaluation of a complete silvicultural system for a compartment over a whole rotation period. Below is an example where a forest owner with an ecological and nature-oriented profile might leave the compartment free to be influenced by natural processes. This hypothetical owner is interested in studying how the practices affect nature and water/soil conservation, in collecting edible mushrooms, in encouraging game and in tax planning. In Alternative 1 (Table 6), the owner chose to avoid active management during the whole rotation and to employ burning. In Alternative 2, a more active and traditional strategy was chosen.

Alternative 1 appears inferior in all aspects except for the production of edible mushrooms. The first alternative was, perhaps, extreme, but the example demonstrates that it is possible to examine the suitability of a large number of different silvicultural systems with a range of objectives. In practice, a forest owner could find, for example, that 'nature conservation' and 'mushroom production' were twice as important as the other objectives. The relative positions could be taken into consideration by allocating higher scores, perhaps double those for other objectives, to the most important ones. This would make the two alternatives in Table 6 equally valuable. Thus it is possible to adapt the choice of practices to the different relative importance of the objectives.

Table 6. Two examples of interactions between several practices in systems (Scores from Tables 1-2)

Alternative 1.	Nature conservation	Water/Soil conservation	Mushroom production	Game production	Tax planning	Sum
No felling	0	0	1	-1	0	
Burning	1	0	0	1	1	
No cleaning	0	0	1	1	1	
No thinning	0	0	1	-1	0	
Sum:	1	0	3	0	2	6
Alternative 2.						
Clear cutting	0	-1	-1	1	1	
Planting	0	1	0	1	1	
Cleaning	0	1	1	0	1	
Thinning	0	1	1	1	1	
Sum:	0	2	1	3	4	10

An evaluation at stand level may not provide sufficient information for decision-making at the estate level. Clear cutting is certainly not evaluated in the same way at estate level as at compartment level. In some cases, a clear cut could be considered as aesthetically pleasing *e.g.* in front of a lake creating a view. The composition of the stands, their structure and prior tending, all influence the outcome of favourable practices at the estate level. A complete evaluation of the optimal choices of practices for a large number of compartments at estate level would be complex, especially if it is extended to encompass a whole rotation. A computerised system would facilitate the right choice of practice and could be used to consider the relative importance of the objectives to the individual forest owner.

Conclusions

Thinning appears to be the most useful forestry practice for private forest owners. Different forms of natural regeneration and cleaning are also appropriate. Passive practices seem to be unsuitable for the multiple objectives of private forest owners. The silvicultural practices examined here were not well adapted to conservation. The results indicate that the practices evaluated provide opportunities for forest owners to adapt their forestry to multipurpose objectives. The matrix system could be computerized, but for it to function efficiently it is important to continue to add supporting evidence, especially concerning practices different to those commonly used in Scandinavia. Although the results are essentially restricted to Sweden, the method for evaluating the results of research within the field may have broader applications for the forestry sector in general. The relationship between forestry practices and objectives in general requires further study, for example with respect to liquidity reserve, tax planning, silvicultural challenges and berry and mushroom production.

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ОЦЕНКА ЛЕСОВОДСТВЕННОГО ОПЫТА В МНОГОЦЕЛЕВОЙ ПЕРСПЕКТИВЕ

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Резюме

Обеспечение устойчивого развития требует внедрения соответствующей лесохозяйственной практики в управлении лесным хозяйством. Главная цель данного исследования состояла в оценке пригодности различных способов ведения лесного хозяйства для достижения разнообразных целей, стоящих перед владельцами малых лесных хозяйств. В задачи работы входила также разработка метода оценки результатов исследований в данной области. Для сравнения различных способов ведения лесного хозяйства была использована модель, отражающая цели владельцев частных лесных хозяйств. Был проведен обзор литературы и совместимость различных хозяйственных подходов и целей ведения хозяйства. Оценка проведена матричным методом. Результаты показали, что изученный опыт имеет потенциал, позволяющий обеспечить ведение многоцелевого лесного хозяйства, прежде всего – рубки с последующей распилкой древесины. Пассивная практика хуже приспособлена для ведения частного хозяйства в многоцелевой перспективе. Большое значение имеет постоянное отслеживание и обзор доступных данных, в особенности – данных относящихся к практикам ведения лесного хозяйства необычным для Скандинавии.

Ключевые слова: сохранение, экономическая эффективность, планы управления лесным хозяйством, цели и задачи лесовладельцев, многоцелевое лесоводство, лесохозяйственные системы, практическая пригодность