

Liberich

An economic principle used to maximize the net present value of tree-groups

Mats Hagner

*Department of Forest Economics, SLU, SE-901 83 Umeå, Sweden; E-mail
mats.hagner@telia.com.*

2007-12-08



UBICON

ISSN 1654-4455

Report 13, 2007

UBICON, Blåbärsvägen 19, 903 39 Umeå, Sweden. Tel 090-141620, 070-64 222 44
Epost mats.hagner@telia.com. Org.nr: 340827-8210. <http://www-sekon.slu.se/~mats>

Abstract

Manual tree-marking according to the Liberich principle is a method to:

- **Adapt silviculture to goals associated with multiple uses, biodiversity and preservation of historic relicts.
- **Adapt silviculture to the land-owner's financial circumstances
- **Utilise the variation between neighbouring trees with respect to size and quality
- ** Utilise the competition between neighbouring trees to concentrate growth resources in a few dominating trees
- ** Utilise the competition from large trees to enhance the wood quality of small trees
- ** Utilise the large numbers of naturally regenerated seedlings and saplings that are present in a mature forest
- ** Utilise the natural dynamics of the ecosystem

The positive results will be that:

- **Silviculture will be adapted at each point in the forest to all values present at that point
- **Long-term productivity of all values will be optimized
- **Fewer areas of natural reserves will be needed
- **Clear-cut, gap-forming areas in the forest will be rare
- **Soil disturbance by scarification will not be used, reducing the negative effects on historic relicts and reindeer husbandry
- **Harvested logs will increase in size
- ** Harvested logs will have better wood quality
- **The forest will become more open, favouring recreation and hunting
- **The forest will have a multi-storied structure, similar to that of a natural forest
- **Damage by wind will be reduced
- **Silviculture will be based on the features of local tree-groups, instead of stand-features
- ** Regeneration costs will be reduced
- **Net revenue from wood will increase

The negative results will be that:

- **The operators of harvesting machinery must perform careful logging
- **Harvesting machinery of present types can be used, but in the future the machinery should be able to remove large trees without felling and without causing soil compaction.
- **Mapping and planning procedures must change from those used in age-class forestry
- **Text-books on silviculture will have to be re-written
- **Ten thousand tree-markers will have to be certified in Sweden
- **Forest staff must be re-educated
- **Forest research scientists must be re-educated

Introduction

In age-class silviculture (AC) a certain area in the forest is used to grow trees of the same age. The goal of AC is to cut down large trees of equal size in a final harvest. An area with trees of the same age is named a "stand".

The competition between trees of the same age-class results in size differences between neighbouring trees. This natural process has to be countered by removing small trees in "thinnings".

After clear cutting, large numbers of seedlings have to be planted, since the openness and lack of competition between trees otherwise make the bottom logs branchy. In Sweden about 75 % of the planted trees are removed in pre-commercial and commercial thinnings. The rotation age varies from 60 to 120 years.

For half a century age-class silviculture has been the only method officially permitted in Sweden. Up to 1994 there was an obligatory rule that the tallest trees should be left after thinning. At present, enforcement of the Forest Act (FA) is based on AC since the rules used by governmental officials are written with only AC in mind.

However, in Scandinavia there is growing interest in alternatives to AC among private forest owners and naturalists. The reasons for this are concerns about biodiversity, climate change, aesthetics and recreation. Furthermore, the price of forest estates is growing rapidly, partly because rich people want to have their own forests for hunting and recreation.

Forest science and technical development have been focused on AC during the last half-century. However, some of the hypotheses underpinning AC have been tested and found to be false. Notably:

- ** A multi-storied forest was considered to be less productive than a single-storied stand.
- ** A small tree of high age was considered unable to grow to full size
- ** Small trees in a multi-storied forest were considered to have less good genotypes than the large trees.
- ** Costs of harvesting large trees without damaging the remaining trees were considered to be very high.
- ** To enable survival of small planted seedlings, radical soil scarification was thought to be necessary.
- ** To restore soil fertility it was necessary to clear cut.

Following the falsification of these hypotheses, forest scientists in Scandinavia have been slowly proposing and developing possible alternatives to AC. Further important factors prompting these developments have been repeated storm catastrophes, which have been very financially damaging for AC-forests, and scientists have long known that multi-storied forests are less vulnerable to storm injuries than single-storied forests.

In Sweden a small group of scientists have been considering alternatives to AC for several decades. We have recognized the importance of meeting economic and technical goals, and found it surprisingly easy to satisfy them in addition to the other goals mentioned above. The natural dynamics of forest ecosystems result in mixtures of trees of diverse sizes within small areas, which can be treated as a valuable feature in silviculture, since competition among neighbouring trees of different sizes focuses volume increments in a few dominant trees. Simultaneously, the competition leads to the development of high quality wood, with respect to structure and strength, in the small and half-grown trees (Eikenes et al. 1995).

We found the most complex element of the new silviculture to be the selection of trees that should be released. It is easy to find big mature trees, or badly injured small trees, that have to be removed, but which ones should be released? Issues that need to be addressed in this context include defining a suitable density, and a suitable structure.

Our research has resulted in awareness that trees must be chosen by a highly educated person. In addition, this person must have a computer model to use whenever he/she is in doubt. We

discovered that the choice of tree should not be based on some mean values of stand parameters, such as the number of trees of a certain diameter, or reduction of basal area to a certain level. Whatever such stand-features may be, the important issues to consider are the economic consequences of removing specific trees, and the effects of its removal on the trees around it. Accordingly, we decided to construct a computer model that would answer the question, “Shall I remove this tree, given that the group of trees around it has these features, the forest owner has such financial requirements, such a harvesting system, such customers buying his logs, and such desire to promote multiple uses and biodiversity. Today we have such a computer model, and a handful of certified persons who are willing to help forest owners who are interested in an alternative to AC.

The name “Liberich” is a portmanteau word, based on a combination of “liberation thinning” and “enrichment planting”. Liberich is defined as an economic principle:

**** maximization of the net present value of the tree-group.**

The “value” includes not only the long-term monetary result of tree-harvesting, but all other values of the forest. Hence, a certified tree-marker has to thoroughly interview the land-owner before he or she enters the forest.

Liberich is unique with respect to the goals considered and the computer-aided choice of trees (Figures 1 and 2) (Hagner 1999, 2000, 2003, Hagner et al. 2001). The principle can be used at any point in any forest around the world, since the silviculture is adjusted to all important local variables: site, ecosystem, biodiversity, local economy, multiple use, etc.

Figure 1. “Tree” is one of two computer models used with the Liberich principle. It gives the net value at roadside of a single tree growing with a certain annual ring width over 120 years. It also shows the present net value and the interest rate on the tree’s value.

Tree is combined with a second computer model “Group”, which gives net present value over some hundred years for a group of trees sharing the same growth resources. It indicates which trees in the group should be removed.

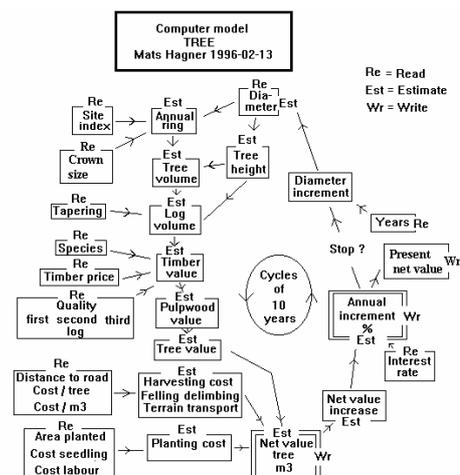


Figure 2. An example of results obtained using “Tree”, including: income (SEK/m³ fub) from single trees; value of wood of standing stems; and costs of felling, delimiting, terrain transport (Harvesting), and for artificial regeneration by planting (Planting). Tree data include values for pine with quality classes for first, second and third log (Pine 132) and for spruce. Price list, Norrskog 2006-7. (Hagner 2004).

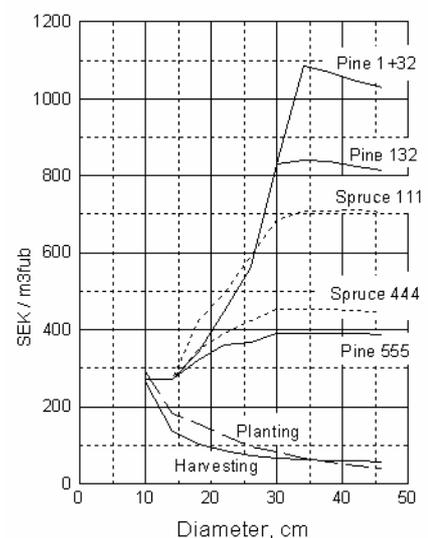
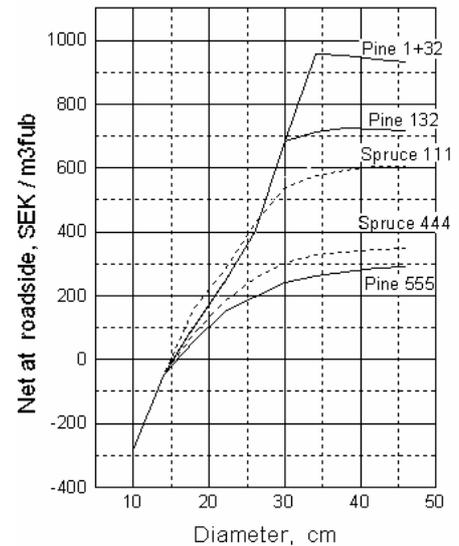


Figure 3. Net income from single trees at roadside, estimated from curves in figure 2, by subtracting “Harvesting” and “Planting” values from stem values.

Note that trees have to reach 16 cm in diameter before they give positive net revenue. In addition, a tree with high quality gives double net revenue if it is harvested at diameter 26 cm instead of 21 cm (Hagner 2004).



In the following section Liberich is described as it has been streamlined for Sweden.

Liberation thinning in practice

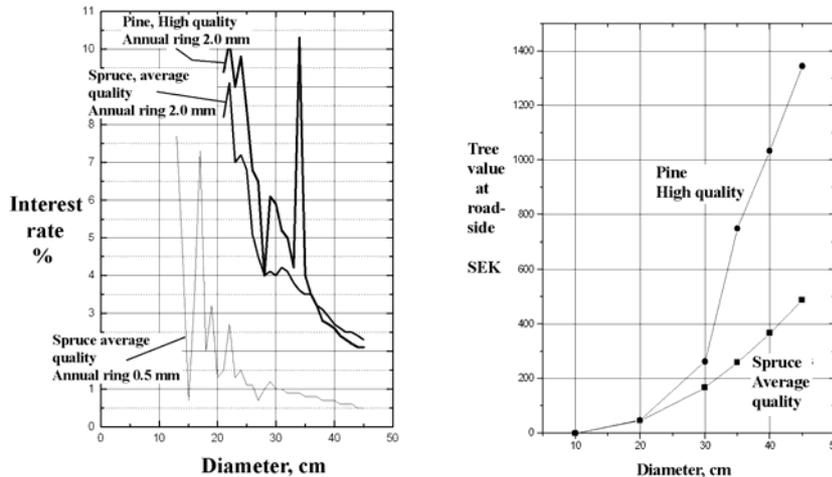
Initial tree-marking process

Tree marking has to be done by a skilled person with great knowledge, since it involves the most intricate silvicultural considerations ever applied in practical forestry. Following a random choice of trees the forest will produce a lot of trees with low value, while an intelligent choice of trees can greatly increase the revenue. Before any marking can start, the tree marker has to ask the forest owner a lot of questions. Without the answers, the tree marker cannot use the computer model and he/she will not be able to adjust his/her tree-marking to the right circumstances. Consideration must be paid to the current and long-term financial situation of the forest owner, and to diverse factors including (*inter alia*) storm risks, biodiversity, hunting, berry picking potential, view-points, historic relicts, etc. At a certain point this can result in anything from preservation of all trees to total clearing.

When the tree marker has arrived **at** the forest he must estimate UDia, LDia, ant TGr.

Upper diameter limit (UDia).

This is the diameter over which the trees do not give an acceptable interest rate on their own net value, assuming they grow at anticipated annual increments after thinning (Figure 4).



Figur 4. The diagram to the left shows the interest rate plotted against diameter at breast height for three types of trees. The upper curve is for a pine with very high quality timber and an annual ring-width of 2 mm. The second curve is for a spruce with fairly good quality timber (class 2, 2, 3 in the first, second and third logs, respectively) and an annual ring-width of 2 mm. The lowest curve is for a spruce with fairly good quality timber, but an annual ring-width of only 0.5 mm.

The diagram to the right shows the net value at road-side of the three trees. Estimates obtained using the computer model "Tree", which can be downloaded from the webpage: www-sekon.slu.se/~mats.

Discussions between the tree-marker and the forest owner will have provided an interest rate, based on his/her possible alternative uses of money. If that level is 3 % it means, according to figure 4, that a well-growing spruce or pine, with an annual ring-width of 2 mm, is economically mature at a diameter of 37 cm, and that a slow-growing spruce is mature at 18 cm. Indications of the time until the next thinning will also have been acquired during the discussions.

In addition, estimates of annual ring-widths will have been obtained from cores drilled into large trees situated in open forest areas similar to those left after thinning. With these inputs, the computer is used to estimate the UDia, which is the maturation diameter that will be reached in the middle of the period until next thinning.

Lower diameter limit (LDia)

The computer is used to estimate a diameter indicating zero net revenue from a tree. This is where harvesting costs are equal to the revenue from the wood. Trees smaller than this threshold should not be marked, since their removal will result in negative revenue.

If the forest has large groups of trees with diameters smaller than LDia, a separate cleaning operation should be carried out. Such an operation might also be necessary if the drivers of the harvesting machinery have destroyed or injured a large portion of the residual trees.

Tree-group radius (TGr)

From many scientific studies on competition between trees, and many practical studies of tree marking, we have concluded that the radius of a tree group should be 0.4 x dominant tree height on moderately productive sites, larger on poor sites, and shorter on fertile sites. However, as yet we cannot quantify such adjustments.

Tree group (TG)

The scientific basis of TGr is that the dominant tree in the group will be able to use most of the growth resources in the area covered by the group. The economic consequence of this is that it is best to focus the resources on just one tree, by removing co-dominants. Hence, the dominant tree will grow rapidly, and give high interest rate on its own value. This means it will be harvested as a taller tree, with greater net revenue per cubic meter, than if several dominants were left within the group.

Continued tree-marking process

After estimating UDia and LDia the tree marker spots mature trees with diameters larger than UDia. After that he/she removes trees with sufficiently severe injuries or defects to give them very low values. Smaller trees than LDia are not marked.

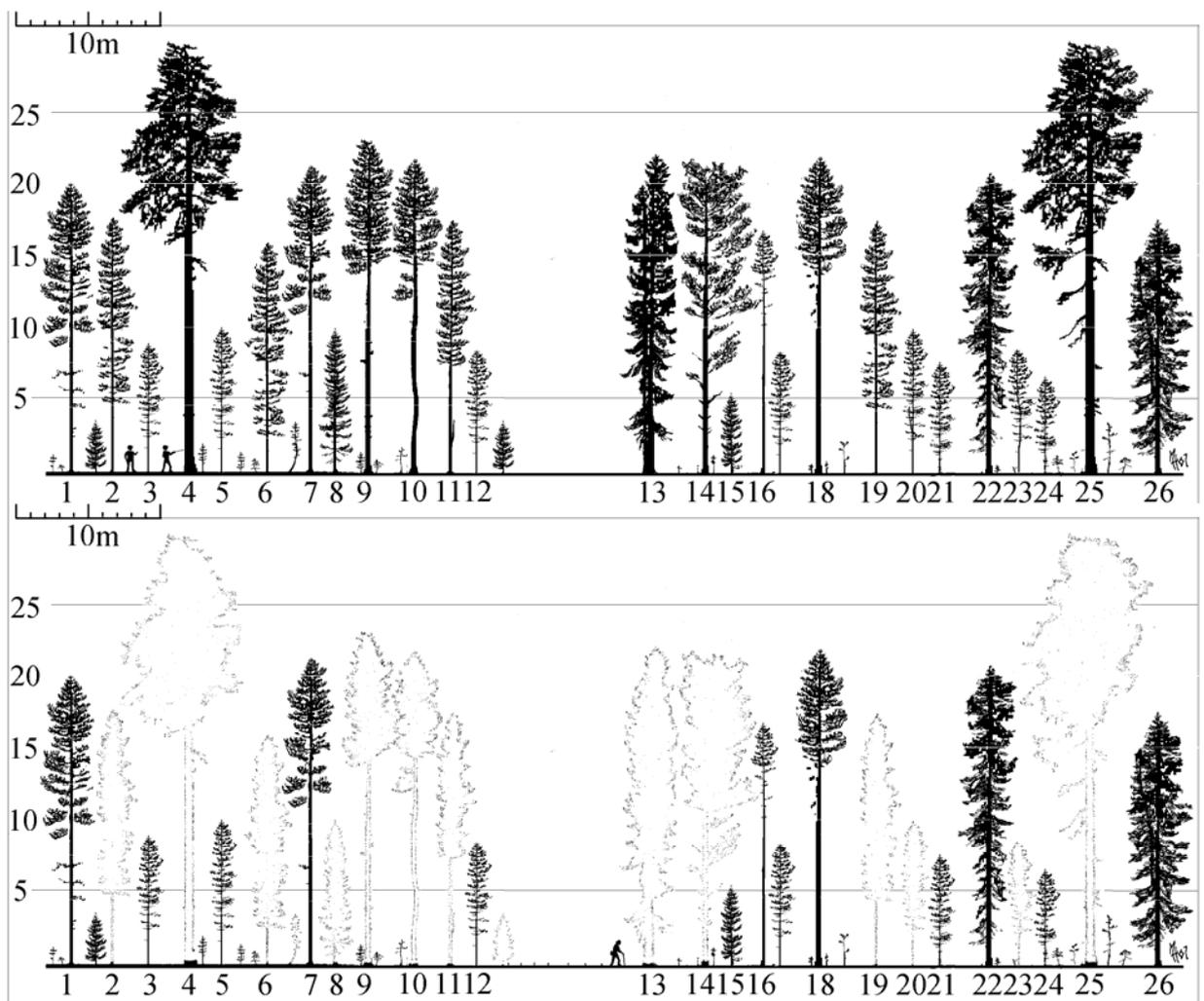


Figure 5.

Above. A hypothetical, typical, central Swedish forest (Latitude 62°). The site is suitable for pine, which has the potential to produce very valuable timber. A lack of intensive care has resulted in a high percentage of trees that have to be removed, because they are over-mature, low quality, or of the wrong species (spruce) (nos. 4, 8, 9, 10, 11, 13, 14, 15, 16, 20, 22, 25, 26).

Below. The residual stand after removal of trees with the following features, economically mature trees, trees with low quality, some trees of unwanted species, and some co-dominating trees that would compete too strongly with “next crop trees”. Some un-numbered small trees, less than five meters tall, were removed in an un-commercial thinning. After thinning a man is carrying out enrichment planting in the central gap.

The tree marker then studies the released trees and finds a dominant tree with favourable features. This enables him/her to remove co-dominants inside the TG. This process is repeated until the whole area has been treated (Figure 5).

It must be stressed that the removal of trees illustrated in figure 5 has not been influenced by consideration of diverse important variables including (*inter alia*): risk for storm felling and snow breakage, multiple uses and biodiversity.

Using the computer program Tree (Hagner 1999), the parameters listed in Table 1 for the case illustrated in figure 5 were estimated.

Table 1. Estimates for trees taller than 5 m. “Net revenue at first harvest” is the income from trees at roadside harvested now (first harvest). “Present net revenue later harvest” is the discounted net value of liberated trees, if they are harvested at the culmination of their present net value. “Total net revenue” is the sum of the first two columns. The “Income per tree Final harv.” is the average net value of the trees harvested in a clear cut now, or the non-discounted road-side value of liberated trees, harvested at the culmination of their present net value.

	Net revenue at first harvest	Present net revenue later harvest	Total net revenue	Income per tree Final harv.
Clear cutting	4166	0	4166	160
Liberich	3848	2182	6030	736

The results show that the total present net value of the illustrated forest can be dramatically increased (by 145 %) by liberating trees with high potential value and by removal of trees with low potential value. Without considering time, the net revenue per tree might be increased more than four-fold (460 %). This is in agreement with a long-term economic comparison of several private estates in central Germany, at which either age-class forestry or Liberich principles were being applied (Hanewinkel 2001), and with the results of a full-scale Swedish test (Hagner 2007).

Theory versus reality

The residual forest created by selective harvest illustrated in figure 5 (lower panel), might seem very open. However, the illustration is two-dimensional and of course the view would be very different if it was presented in three dimensions. This is why this photo is added. It shows a pine forest in the first year after a thinning, carried out in the same manner as described above.



Enrichment planting

Since natural regeneration of desired species does not occur everywhere, it is very important to combine liberation thinning with enrichment planting. Otherwise, liberation thinning will be restricted to areas with abundant natural regeneration.

Figure 6. If natural regeneration from acceptable species is absent in a gap, enrichment planting is carried out with insect-protected seedlings placed directly into the moss-layer.



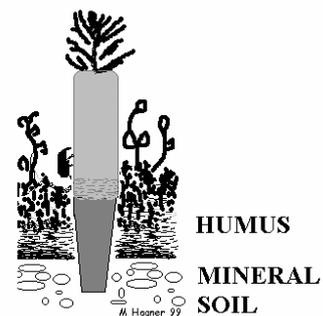
Gaps are formed where mature trees are aggregated and these gaps must not be left unproductive. The cost of artificial regeneration is small in comparison to the revenue from mature trees. This is also one of the basic assumptions in the conventional AC-system.

What is the minimum size of gap in which enrichment planting is economic (MinGap)? To answer this question, huge research areas were created in 1990 throughout Sweden. 300 000 seedlings were planted in residual forests of various densities, irrespective of where trees were left. These areas have not yet been used to estimate MinGap. However, another method, based on the “Freedom figure”, was developed for local estimation of MinGap (see below).

Enrichment planting is carried out in the first summer after harvest. In Sweden large numbers of natural seedlings of desired species are generally present in a mature forest, and practical experience gained from several practical tests in the provinces Jämtland and Norrbotten at latitudes 63-65° has shown that about 100 seedlings per hectare are needed to fill the gaps. In harsher areas further north there is probably a need for more seedlings, and in southern forests fewer seedlings may be needed.

In a forest with scattered small gaps to be planted, it is not feasible to carry out any mechanical soil scarification using large, heavy tractors, so we recommend a different method: placing seedlings directly in the humus layer (Figure 7)

Figure 7. Nursery-produced pine seedling in a “Bema” physical insect shelter. Since the most harmful insect, *Hylobius abietis*, prefers to be sheltered by vegetation, a seedling placed in the moss layer is highly likely to be destroyed if unprotected. However, acceptable survival and growth rates were obtained in our large-scale tests throughout Sweden, in which several hundred thousand seedlings in protective Bema-shelters were placed in the humus in the illustrated manner.



Insects usually browse the bark on the stem of seedlings placed like that, so their survival and growth rates are reduced. Fortunately the presence of trees adjacent to the seedlings lessens insect attacks, since the insects also browse the bark on roots of living trees (Wallertz 2005, Wallertz et al. 2005). In addition we recommend that each seedling should be provided with a chemical or physical insect-resistant shelter. The results of a huge scientific test series carried out throughout Sweden in 1990 clearly showed that this planting system gives satisfactory results (Hagner et al. 2001).

If planting is not carried out in the first summer, we recommend that gaps should be planted the following summer in the same manner, but with twice as many seedlings per unit area.

Structure

We have developed a new indicator to describe the local structure in a multi-storied forest, called the Dissimilarity coefficient (Disco for short). It is very simple to use, since it is based on diameter readings of pairs of trees, standing beside one another (Figure 8).

$$\text{Disco} = (d1 - d2) / (d1 + d2)$$

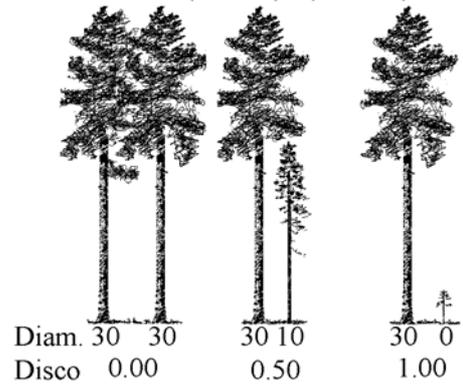


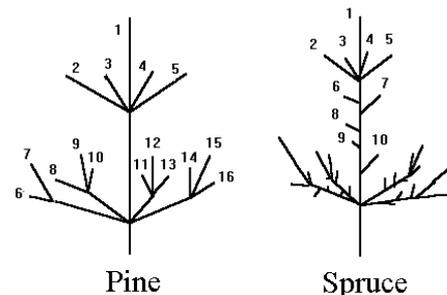
Figure 8. The dissimilarity coefficient (Disco) is estimated from pairs of adjacent trees. A typical value for a natural forest is 0.5.

To obtain an average that is significant for the forest, several pairs have to be chosen randomly (Hagner and Nyqvist 1998). Disco values vary between 0 and 1, and in a natural, unmanaged forest, a typical value is 0.5 (Hagner 1998, 2001). Such values have been found in forests in both Sweden and Malaysia.

Freedom figure

To estimate MinGap we have designed a method named Freedom figure (Ff). The number of new shoots in the tops of pine and spruce saplings is strongly influenced by the competition from large trees (Figure 9). In an open clear-cut pine reaches a Ff over 50 and spruce a Ff over 30, but inside a dense forest pine may have a Ff of just one and spruce a Ff of two. Our experience to date suggests that the probability for survival of planted pine seedlings is too low if the competition from big trees gives the seedlings a Ff of 10 or less. Spruce survives well in a dense forest, even when it has a Ff of 5, but its growth is so slow that investment in a planted seedling is worthless.

Figure 9. The “Freedom figure” (Ff) is the number of new shoots formed in the preceding year. In pine these shoots are formed from the top bud two years ago. In spruce these shoots are formed on the terminal shoot formed in the preceding year.



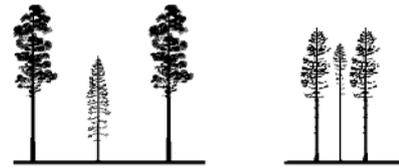
In an open clear cut pine can have a Ff over 50 and spruce can have a Ff over 30, while in a dense forest pine may have a Ff of just one and spruce a Ff of two.

The person who carries out the enrichment planting has to study a forest in the vicinity of the area that is going to be planted. By estimating Ff in different gaps, he/she will soon learn the approximate size of MinGap, which is a gap in which a sapling of pine has Ff = 10 or a sapling of spruce has Ff = 5.

High-quality timber

In most tree species high-quality timber is formed in small trees that are growing under competition from big trees. The small trees are trying to reach light in the upper canopy, and hence form few branches, a straight stem and thin annual rings. Thus, bottom logs are formed with desired structure and strength (Eikenes et al. 1995) (Figure 10).

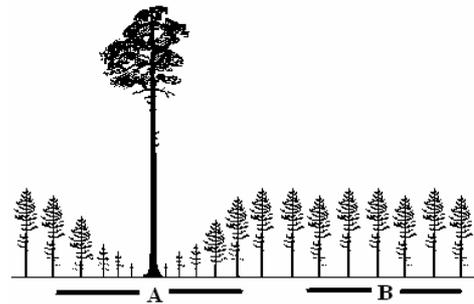
Figure 10. “High-shadow” (left) and “Low-shadow” (right). For a small pine to become a high-quality timber-tree, it has to grow in a fairly open environment between much taller trees. Grown in low-shadow it forms a small crown at the top of a slender stem. If released such a pine is likely to be broken by the weight of snow.



Stem volume increment and financial considerations

The volume increment in a forest is roughly the same for multi-storied and single-storied forests growing at similar sites (Jakobsson and Elfving 2004). However, from an economic perspective, it is better to focus the growth resources into a few big stems instead of many small stems. One reason for this is that the price of timber increases with diameter. Another is that harvesting costs decrease with diameter, and a third is that focusing growth resources in one stem instead of many stems reduces the time to maturity and harvest.

Figure 11. Jakobsson and Elfving (2004) found that the long-term stem increment was somewhat higher in areas like A than in areas like B, both of which support 88-year-old pine forests, but the forest in A includes scattered, dominant, 250-year-old pines. Elfving (1990) found the same trends in spruce stands.



Accordingly, the present net value of stem-wood grown in A is larger than in B. This could be generalized for every situation in the following way. Whenever possible, *** the difference in tree size between neighbouring trees should be maximized.* However this is only valid if the difference between trees is a single function of diameter, and maximising monetary revenue is the single goal of silviculture.

Economic comparison, AC-forestry vs Liberich

Scientific tests, as well as practical tests, in Sweden and Norway, have shown that the net revenue per cubic meter in the first harvest, carried out in a “mature” multi-storied forest, is equal to that from a clear cut, because the higher harvesting cost for thinning instead of clear cutting, is compensated by the higher income from taller trees.

In a practical test trees in a multi-storied forest were marked and harvested with conventional machinery. The forest was a mixture of pine, spruce and birch, situated in Sweden at latitude 63°, 300 m above sea level. The stumps and released trees were measured in several test plots. The following variables were estimated: volumes of all and of harvested trees, net values of harvested trees and of released trees, costs of artificial regeneration and un-commercial thinning on the clear cut, costs of enrichment planting and of un-commercial thinning, net present value of the young stand on the clear cut area, and net present value of the residual forest, enriched by planting. Finally, the total value per hectare was estimated from the income accruing from the harvest, the value of the residual forest and the cost of regeneration (Figure 12).

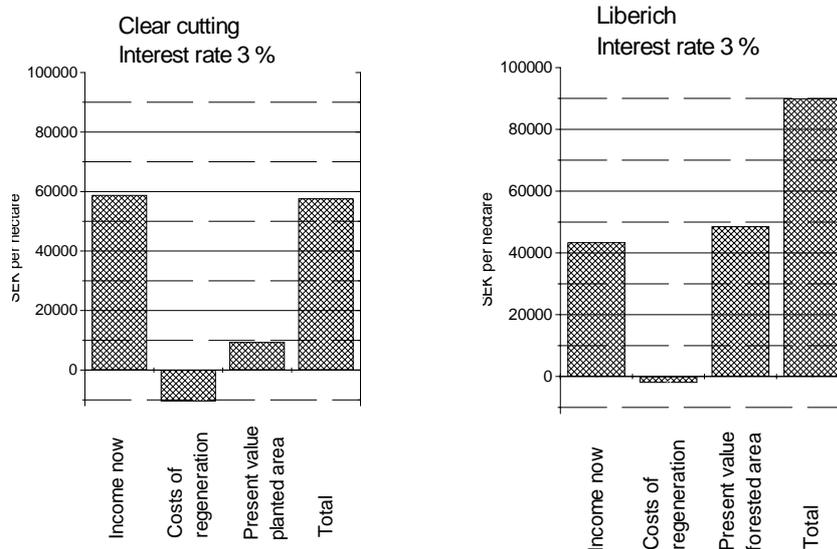


Figure 12. Economic comparison of two silvicultural systems applied to one hectare, showing the income accruing from harvests, costs of regeneration and of un-commercial thinning, present values of the new forest and the residual forest, and the total net revenue after accounting for all silvicultural measures applied.

The results greatly favoured Liberich. Furthermore, a multi-storied forest has equal long-term volume productivity to that of a single-storied forest at a similar site. Thus, the annual harvest in terms of cubic meters should be the same whether AC-forestry or Liberich is applied. Accordingly, a true comparison should not be based on costs and benefits for a single hectare, but per cubic metre harvested. This favours Liberich even more.

Un-commercial thinning

Since large numbers of small and half-grown trees are injured at harvest, it might be economic to remove such trees, if superior neighbours are present. Among smaller trees the density might be so high that self-thinning occurs. However, for Swedish forests it seems reasonable to restrict un-commercial thinning to trees with diameters >5 cm. The net present value of smaller trees does not warrant any such investment.

Storm

It has long been known by scientists, that a multi-storied forest is more resistant to storm-felling than single-storied forest. This is one reason why clear-cutting is prohibited in the state-owned forests of Denmark and Germany. We investigated the destruction caused by storm and snow in a large research area in central Sweden, Latitude 63°, and 100 m above sea level. The results are illustrated in Figure 13.

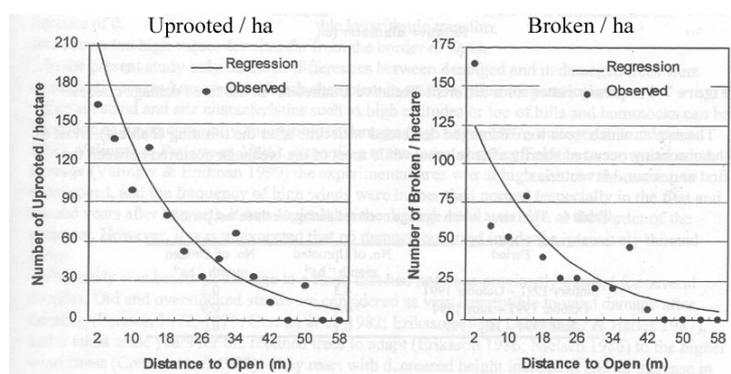


Figure 13. Trees uprooted by wind and broken by snow in a Swedish scientific test at Latitude 63°, 100 m above sea level (Ekelund 1998). In the area thinning from above was carried out by removing 50 % of the standing volume. Injuries were recorded four years after thinning. Distance to open shows the distance to the nearest clear cut area.

The main conclusion was:

**** Injuries from wind and snow were very minor in the recently thinned forest, although the thinning was intensive and there were high winds shortly after it.**

The effect of thinning decreased to zero about two tree-lengths from the edge of a clear cut. Limitation of storm-damage to zones two tree-lengths wide around the edges of clear cuts is in full agreement with the results of earlier large-scale investigations (Laiho 1987).

Suitable density

Only about 10 % of carbon fixed by photosynthesis is used for stem-growth. Unlike full-size trees, half-size trees growing inside a forest do not allocate resources to cones and pollen.

This is one reason put forward to explain why greater proportions of carbon fixed by photosynthesis is allocated to stem growth in half-size trees than in full-size trees.

Accordingly, in single-storied forests it has been shown that stem volume productivity culminates in stands with half-size trees.

To maintain the maximum possible volume productivity in a multi-storied forest, the tallest trees should be continuously removed, and the residual stand should be kept sufficiently open to make half-size trees maintain a large leaf-area. We have suggested that these requirements could be expressed in the following rule:

**** Lower the density of a multi-storied forest until the half-size trees have an annual ring as wide as that of the dominant trees.**

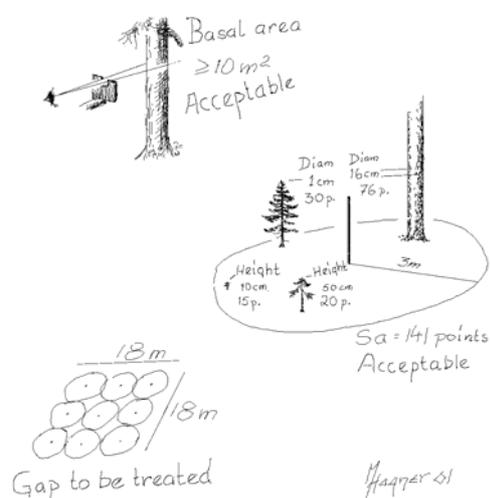
Misuse of Liberich

It would be possible to increase monetary income even more than described in the above chapter. In the short term, monetary income is maximised when all trees that give net revenue are harvested. However, this would be “over-exploitation of a forest”, because it would have adverse consequences. Of course, this would not worry ruthless forest owners, so a new Forest Act should be written, to prevent such over-exploitation.’

Forest Act

The Swedish forest law states that “The forest shall be handled so that the long-term revenue is high and so that biodiversity is maintained” As outlined above, it is likely that some forest owners will state they are following Liberich principles, when what they are really doing is over-exploiting their forests. Therefore, we suggest that the government introduces the rules described below, and illustrated in Figure 14.

Figure 14 If the basal area is not acceptable, a circular plot is examined. Points are given to trees, saplings and seedlings in accordance with their size, so that an acceptable sum for the circular plot is 100. If the sum of points is not acceptable in the first plot, nine plots close to one another are examined. If none of them has an acceptable number of points, the forest owner is obliged to make the gap productive. Enrichment planting will be the logical action, and the forest owner can easily calculate how many seedlings are needed to remedy the situation.



References

- Eikenes, B., Kucera, B., Fjaertoft, E., Storheim, O., N, Vestøl, G., I. (1995) Virkeskvalitet i fleraldret skog. Rapport fra Skogforsk.24, 1-30.
- Ekelund, M. (1999) Wind- and snow damage in an uneven-sized conifer forest in Sweden thinned from above. Sveriges Lantbruksuniversitet, Skogsskötsel, Examensarbete.2, 1-19.
- Elfving, B. (1990) Granplantering under gles högskärm i fjällskog. Sveriges Skogsvårdsförbunds Tidskrift.5, 1-8.
- Hagner, M. (1998) Stand structure before and after a selective harvest. Swedish University of Agricultural Sciences, Dept of Silviculture, Working papers.132, 1-6.
- Hagner, M. (1999) TREE01. A description of a computer model for choice of tree. En beskrivning av en datormodell för val av träd. Available on internet: <http://www-sekon.slu.se/~mats>. Sveriges Lantbruksuniversitet, Institutionen skogsskötsel, Arbetsrapport.144, 1-4.
- Hagner, M. (2000) Group02. Present value of a group of trees. Description of a computer model. The Swedish University of Agricultural Sciences, Department of Silviculture, Working paper.155, 1-4.
- Hagner, M. (2001) Differences in dimensional structure of a virgin and a selectively logged tropical rain forest. Swedish University of Agricultural Sciences, Dept of Silviculture, Working Paper.163, 1-17.
- Hagner, M. (2003) Manual för datormodellen Group. Ubicon, Rapport.3, 1-7.
- Hagner, M. (2004) Naturkultur, Ekonomiskt skogsbruk kännetecknat av befriande gallring och berikande plantering. Mats Hagners bokförlag, Umeå, ISBN 91-631-5010-7.124 sidor.
- Hagner, M. (2007) Tillväxtreaktion och ekonomi efter gallring enligt principen Naturkultur. UBICON Rapport.8, 1-26.
- Hagner, M., Nyqvist, H. (1998) A coefficient for describing size variation among neighbouring trees. JABES.1, 1-21.
- Hagner, M., Lohmander, P., Lundgren, M. (2001) Computer-aided choice of trees for felling. Forest Ecology and Management.151, 151-161.
- Hanewinkel, M. (2001) Financial results of selection forest enterprises with high proportions of valuable timber. Results of an empirical study and their application. Schweizerische Zeitung für Forstwesen.8, 343-349.
- Jakobsson, R., Elfving, B. (2004) Development of an 80-year-old mixed stand with retained *Pinus sylvestris* in Northern Sweden. Forest Ecology and Management.194, 249-258.
- Laiho, O. (1987) Susceptibility of forest stand to windthrow in southern Finland. Folia Forestalia ISBN 951-40-0801-4.706, 1-24.
- Wallertz, K. (2005) Pine weevil *Hylobius abietis* feeding in shelterwood systems. Lic thesis Southern Swedish Forest Research Centre, SLU.
- Wallertz, K., Örlander, G., Luoranen, J. (2005) Damage by pine weevil *Hylobius abietis* to conifer seedlings after shelterwood removal. Scandinavian Journal of Forest research.20, 412-420.