Silvicultural principles, phases and measures in growing valuable broadleaved tree species

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Summary

Valuable broadleaved tree species can play an important role in economic forest management of today and the future. Besides good genetic characteristics and a suitable site, silvicultural treatment plays an important role in getting timber with a high value. In traditional silviculture trees are planted or regenerated and grown with a high stemnumber per hectare. In this way long knotfree boles can be achieved within a rather long rotation time. Approximately the same amount of valuable timber can be achieved in a relatively short rotation period by low tree numbers per hectare and pruning. The same principles can be used for treatment of individual trees in mixed forest stands.

Key words: silviculture, broadleaves, thinning, pruning, quality tree

Introduction

In all European countries, valuable broadleaved tree species are important producers of high-quality wood, used especially in the veneer and furniture industries. They can play an important role in economic forest management of today and the future. To improve the economic outcome of management results the costs have to be reduced, while the quality and therefore the price of timber has to increase. In addition, forest stability has to be enhanced, and ecological services have to be maintained. There is a big price difference between low quality veneer (“D”), which amounts to a price of less than 10 Euro per m^3 and high quality veneer (“A, TF and F”), which amount to a price of between 200 to over 1,000 Euro per m^3. Even though the price of high quality timber from valuable broadleaves varies over time, their prices were always significantly higher than those of medium or low quality timber during the last decades.

The main objective of this article, written in the background of improving the silviculture of valuable broadleaved tree species, is to produce a scheme for describing the necessary silvicultural measures necessary to achieve these goals. It is a general scheme, which provides the principles of silvicultural management of valuable broadleaved tree species. The scheme can be used at the level of individual trees in pure or mixed stands, either planted or naturally regenerated.

Silvicultural principles

For producing high-quality timber valuable broadleaved trees need to have certain genetic characteristics. They should grow straight, the crown should develop monopodially, and forks as well as branches, with acute angles of insertion,should be avoided. Trees should be well adapted to the site and resistant to biological and physical threats. To produce high-value timber site fertility should be high. As in the case of other important broadleaved tree species such as oaks or European beech, the silviculture of valuable broadleaved trees aims at producing as much high-quality and knot-free wood as possible. To achieve this objective two important general principles are targeted in the case of all valuable broadleaved species:

1. *Restrict branchiness;* less branches mean better wood quality and higher market value;
2. *Dimensions*; *large* diameters (“the larger the better”) and *long* butt logs.

Both branchiness and dimensions can be manipulated by silvicultural interventions (planting distance, weeding, cleaning, respacing and thinning) controlling the stand density and available free space around tree crowns. Pruning (high and formative) can play the same effect on branchiness.

High timber quality can be reached by application of the right measures. adequate management. Economically sound activities have to be linked to the value-producing trees. When dealing with fast growing broadleaves the number of final crop trees per ha is relatively small. This is due to the fact that valuable trees need to have large diameters and big crowns. At the end of the rotation, only a low number (for most species 40-80) of large diameter trees can grow per hectare. The management has to concentrate on these value-producing trees. Marking of these trees facilitates efficient management. Valuable broadleaves in natural conditions generally grow in mixed stands. Single-tree oriented management may facilitate growing valuable trees in mixed stands.

Regeneration methods have an important influence in securing the quality of timber production by regulating intensive silvicultural techniques from the young stand phase. Tree quality and stand density are the key parameters for natural regeneration. The number of plants and their spacing design are the vital essentials where planting is the method of establishment. These are the criteria that determine the further development of the stand, the need of silvicultural interventions and their costs. The economic success of the production program depends not only on the value of the wood produced but also on the total costs for the regeneration, tending operations and the period until revenues repay the investment. Therefore, well-defined silvicultural goal(s) are needed to fulfil the requirements of target diameter, species composition and especially the process of natural pruning during the thicket phase.

In order to reduce costs the number of trees to be planted should be much lower than in the past.
In some countries a definitive number of target trees (50-100 per hectare) are planted mixed with other nursery species. Sometimes a limited number of tree groups is planted of which the best trees are selected. The proposed silviculture is more tree-oriented as opposed to the traditional "stand" silviculture. The contrast between these two silvicultures becomes important in cases where the number of future crop trees is low.

A basic question is whether we should grow in the future less crop trees with larger crowns or more crop trees with smaller crowns and smaller d.b.h.'s but reaching a higher crown base? The decision has an impact on the rigor of the selection criteria and on the clean bole timber volume per ha. Less crop trees with larger crowns may produce higher wood quality and dimension; the harvesting costs per volume unit may be reduced and stability may be increased. The decision may have less effect on diversity and aesthetic values. The total volume production of all wood may slightly decrease when the distance between trees increases and the stand density decreases considerably. The percentage of the volume of the clean bole (stem without branches) decreases while the percentage of the wood in the crown increases when the relative crown length increases. Therefore the clean bole timber volume per ha will be smaller. Figure 1 summarizes the outcome (the lines give indications): with decreasing crown base the stem diameter and timber price per m^3 will increase while the volume of clean bole per ha will decrease (Spiecker 2006a). The optimum depends on the economic conditions, especially on the impact of tree diameter on price. The higher the impact of diameter on price the larger should be the diameter and the lower should be the crown base. The price sensitivity to diameter may

vary with species and use of the timber. On more productive sites the bole length can be longer while the same diameter can be reached in a given time. The optimal length of the bole depends on the use of valuable timber. Veneer producers generally ask for minimum 2.5 m length or a multiple of 2.5 m. For some species such as *Sorbus spp* or walnut (*Juglans spp*) the length can be shorter.

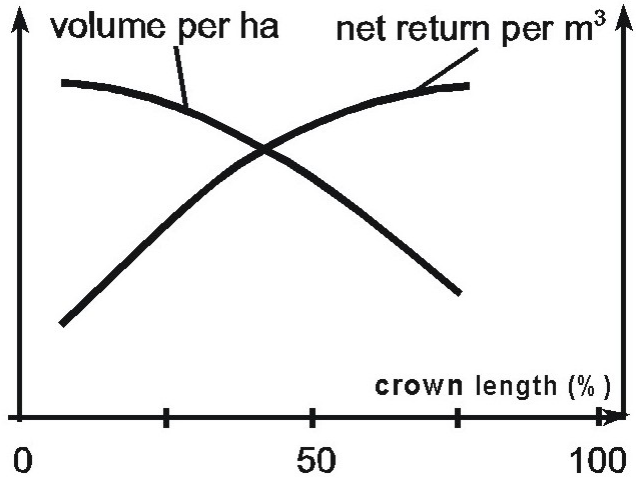

Fig. 1: Where should the crown base be?
With decreasing crown base (increasing crown length) the stem diameter and timber price per m^3 will increase, while the volume of clean bole per ha will decrease (Spiecker 2006b).

To decide the timing and manner of practicing such interventions extra information is needed on different issues such as:

- growth pattern;
- forest owners' needs and behaviour;
- wood buyers' requirements;
- market behaviour;
- possible defects arising at certain ages as well as derived rotation age taking into account the influence of such defects;
- economics of silviculture (including the grant system for silvicultural operations as existing in many European countries).

At present many factors influencing the general principles such as growth pattern, owners' needs, buyers' requirements etc. are not sufficiently known so there is a need for these to be better defined. Such a task will require efforts in modelling and simulating the growth and development of valuable broadleaved species in relation to all other influencing factors of.

Regardless the need for deeper knowledge it is necessary to acknowledge that the silviculture of valuable broadleaved species is costly and requires high-intensity

silvicultural interventions starting in the early stages of development. Without such inputs the objective of producing high-quality wood with important end-uses will be impossible to fulfil.

Silvicultural phases, natural processes and measures

Phases and processes

The evolution of forests can be divided in terms of development stages (Oliver and Larson 1996) as follows:

- *seedling (establishment) stage*: new or renewing tree cover by establishing young trees naturally or artificially until trees reach 1.30 m height. At this stage the young trees begin to compete for light, water and nutrients. When 100 % of the space is occupied with crowns, the lowest leaves and branches begin to die.
- *young stage*: period between the moment when the trees are 1.30 m mean height and the first thinning (dbh about 10 cm). During this stage a great part of height growth takes place and there is a high/severe competition between the young trees. Natural thinning occurs when stand density is high. The lowest branches of the surviving trees die and fall off to a certain extent, depending on the tree species. Stem diameter increases rather slowly because of the competition between the trees.
- *thinning stage*: period between the first thinning (dbh about 10 cm) and the time when the regeneration felling takes place. During this stage trees are given more space and competition is reduced by thinning. Diameter increases more rapidly than with competition. During this stage canopy opens and there will be enough space for the next generation.
- *regeneration stage*: regeneration cutting(s) are carried out and timber is harvested; measures are taken in order to get a satisfactory regeneration (natural or/and artificial).

Translation to measures

During different stages various silvicultural questions play a role. These questions at different stages are connected to each other. Forest managers have to look first for the goals into the future and then have to select the measures to achieve these goals. In table 1 the main silvicultural questions within each stage have been outlined. The next column shows possible silvicultural measures, which can be used to reach these goals.

Table 1. The main silvicultural goals in each development stage and the main silvicultural measures

Development stage	*Silvicultural goals*	*Silvicultural measures*
1 Seedling/ establishment	Sufficient number of young trees with good shape and good growth	Choice of provenance
		Site preparation
		Number of trees per ha
		Tree spacing
		Mixture of species
		Game protection
		Fertilization
		Weed control
		Pest control
		Drainage
2 Young stage	Branch free bole of (potential) future crop trees	Pruning
		Removal of wolf trees
		Pre-commercial thinning
	Healthy stand	Pest control
	Future crop trees	Selecting future crop trees
3 Thinning stage	Optimal diameter growth of future crop trees	Thinning
	No dieback of the lower branches	Thinning
4 Adult/ regeneration stage	Usable diameter	Final harvesting
	Species composition next generation	Remaining seed trees
	silvic goal(s) of next generation	Fertilization
		Site preparation

		Weed control
		Pest control

This table can be used to describe the silviculture of valuable broadleaved species by filling up the silvicultural goals for a tree species of a region. Filling up means that the following questions should be answered:

- What good potential quality and growth is? (timber quality, annual height growth/volume increment)
- What is enough selection potential? (number of trees per ha)
- What branch-free length is achieveable? (meters, % of reachable height))
- Which serious diseases or attacks have to be controlled? (type, species)
- What is the optimal diameter growth? (ring width)
- Which diameters are usable? (min-max)

The answers to these questions provide a guide to the measures which are necessary.
In order to control the most important silvicultural characteristics of valuable trees species (branchiness and dimension), two measures are vitally important: pruning and thinning. Basic conditions can be controlled in the seedling/establishment stage and the young stage. These are described in detail in the next paragraphs.

Seedling/establishment stage

Natural regeneration

Natural regeneration of stands has important advantages as management is less expensive and regenerated species are well adapted to the site in general. This regeneration method is favoured if the mother trees are of genetically highly valuable. Under such conditions an adequate growth performance can be expected combined with a high quality standard of timber.

Artificial regeneration

Artificial regeneration of stands is applied in situations with:

- an unsatisfactory natural regeneration dynamic because of density and/or quality
- a change of targeted tree species and
- afforestation.

The following aspects are highly important for operating artificial forest regeneration:

- Tree species choice

    ++ evaluation of the site conditions (site mapping)

++ tree specific growth performance and/or pattern

++ use of genetically suitable seed sources (provenance)

- Tree number and spacing design

++ plant quality (provenance); the variation of „quality“ and the absolute quality standard determine the planting density (number of trees); the number of trees is influenced by the tree species. Advantages and disadvantages of narrow and wide spacing are given in table 2.

Table 2 Advantages and disadvantages of narrow and wide spacing

	Narrow spacing	*Wide spacing*
Costs	- *)	+
Closing of canopy	+	-
Necessity of thinning	-	+
Necessity of pruning	+	-
Diameter increment	-	+
Vitality/resistance against diseases and pests	-	+
Chances for undergrowth, underplanting	-	+

*) + = advantage, - = disadvantage

- Planned pruning process

++ natural pruning processes need close spacing, independent of the afforestation/reforestation design (total area, partial area); in general wide spacing has to be combined with artificial pruning (formative, high)

++ specific tree growth performance during the young stage phase determines the mixture type.

Young stage

Tending activities of young stage stands are carried out to promote the inclusion of the targeted tree species and tree specific growth pattern in naturally regenerated stands. Tending activities are also aimed at(tree mixture regulation) - especially for rare species and high quality trees. The use of the „treatment cell“ concept combined with a clearly defined tree hierarchy for favouring tree species and/or tree species composition can be helpful in reducing costs.

In artificially regenerated young stands, silvicultural operations are aimed at improving the establishment conditions (cleaning); maintaining the desired tree species composition (tree mixture regulation); improving the tree quality by starting a single tree oriented treatment procedure (formative stem shaping; for close and wide spacing situations); and the start of artificial pruning(for widely spaced stems). In addition, successional development processes

should be integrated into the treatment concept. During the young stage, artificial pruning plays an important role in relation to the transition to single-tree silviculture.

The most important measures: pruning and thinning

Pruning

Pruning should take place at a very early stage, when branches are still young and small. Repeated artificial pruning or alternately natural pruning by higher competition is needed. This leads to the early development of a clean bole, while in the second phase the crown base should be constant. This kind of management leads to an acceleration of pruning in the early phase and to a cessation of pruning in the second phase (see figure 2).

In naturally regenerated stand, care should be taken not to lose the existing potential for species diversity. Many desired species (e.g., wild service, cherry) are not very competitive during the early stages and may rapidly disappear where a high competition level is maintained to enhance natural pruning. A good balance between these two constraints should be maintained.

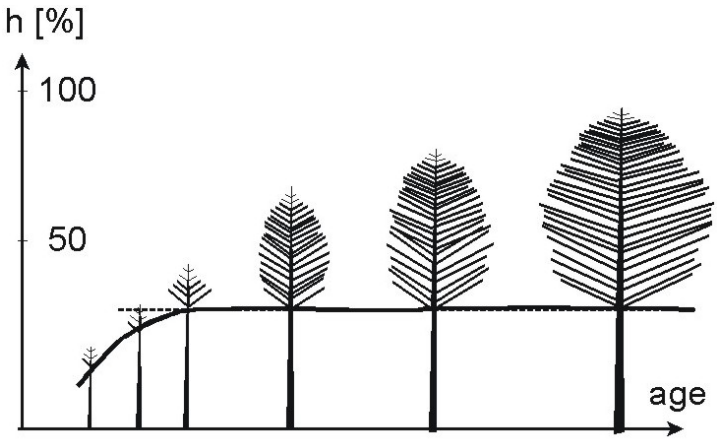

Fig. 2: The two-phase management system

In order to improve the quality a two-phase management system is needed. In the first phase the pruning is stimulated, while in the second phase the diameter growth is stimulated (Spiecker & Spiecker 1988).

Thinning

In the second phase, the diameter growth should be on a high level. This can be achieved by thinning which allow the trees to expand their crowns. Another important aspect is to avoid any dieback of the lower branches of the crown in order to avoid any loss of bole quality. Since there is a close, almost linear relation between crown width and stem diameter, the release of tree crown means that the diameter growth will be accelerated. While the diameter growth may be lowered to some extent at the beginning of pruning phase, the diameter growth is staying on a high level in the second phase (see fig. 3).

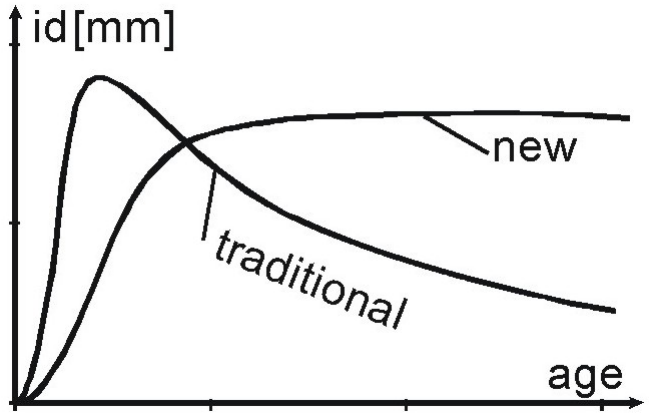

Fig. 3: Comparison of diameter increment (id) within traditional management and new management

While, traditionally, the diameter growth slows down with age, with the new recommended management approach the diameter growth stays on a high level (Spiecker 2003).

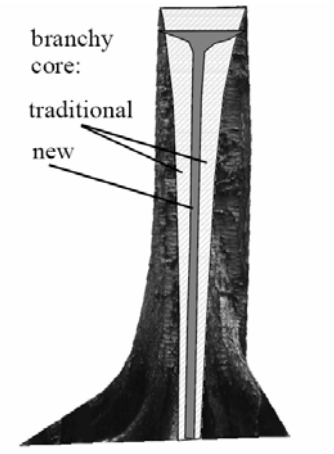

Fig. 4: Proportion of timber without internal defects branches

The two-phase management system increases the volume of clear timber without branches (Spiecker 2006a).

result of this management approach will mean that, within the tree bole, the branchy core will be much smaller, especially in the upper part of the tree (see fig. 4).

The time of harvesting depends on the current and expected net value production of the individual tree, the time preference of the forest owner expressed by the interest rate and other objectives and the expectations of the forest owner. As some defects of timber are age-dependent and vary with tree species, site conditions and markets, no single optimal rotation time can be given.

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