6.3 The effects of thinning regimes on assortment and financial yield in mixed stands

M. Kahn

Abstract

The growth model SILVA 2 is a distance dependent single tree based decision support system. SILVA 2 was used in this study to analyse the effects of thinning on assortment and financial yields in mixed stands. The appropriateness of applying the model to numerical research on mixed forests was investigated. Prognosis runs were based on the forest scenario of a spruce-beech stand in single tree mixture. Two thinning options were compared; a heavy selective thinning promoting spruce and a heavy selective thinning promoting beech. The prognosis runs were conducted over a period of 145 years. Resulting assortments were based on the single tree data of both removed and remaining trees. Evaluation of assortments used prices for both log wood and industrial wood. Thus the gross financial yields for a spruce-beech stand subjected to two different thinning regimes could be assessed. The final stage of the analysis provides a comprehensive view of the net monetary return resulting from the two alternative management regimes by including harvesting costs.

Key words: single tree growth model, growth prognosis, assortment, harvesting costs, financial return, spruce-beech management class

Introduction

Practical problems in the management of mixed forests

Reliable data about the growth development of trees and forest stands are indispensable to successful forest management decision-making. In growth and yield science, the traditional approach of describing the expected development of forest stands, is to summarise extensive empirical information about stand growth in comprehensive yield tables (Assmann & Franz 1963; Bradley et al. 1966). A more powerful approach is to use the modern capabilities in computer technology and modelling methods to develop computer aided prognosis tools (von Gadow 1988; Lemm 1991; Nagel 1996; Pretzsch 1992; Sterba et al. 1995; Wykoff et al. 1984). For example, computer based single tree models can perform numerical analysis of the natural production of a forest and thus can be used to assess the economic and ecological implications of management in mixed forest stands.

Practical management of mixed forests in Germany encounters several problems. There is an increased demand on new forests stands being established to contain a mixture of suitable tree species. These are usually coniferous species for timber production and broad leaved species for ecological purposes. Furthermore, management of existing mixed stands no longer concentrates on one main tree species alone, but rather requires mixtures to be preserved or even extended through the rotation. The successful management of such mixed stands is therefore more suited to a single tree management system than, for example clear cutting. However, the economic implications of such trends in mixed forest management are not well analysed and thus expectations of financial returns from mixed forest management are quite uncertain.

The financial uncertainty of mixed forest management

The insecurity concerning the financial aspects of mixed forest management is based on a number of difficulties that arise, even on a scientific level. The first problem is in giving a reliable prognosis on the development of the natural production capabilities including annual volume, height or diameter increment of a mixed stand. These parameters depend heavily on stand structure, i.e. the mixture of the occurring tree species, which may be a single tree mixture of different shade tolerant species, or a group mixture of shade tolerant and light demanding species. A second reason for the uncertainty concerning the financial yield of mixed forest management is associated with the difficulties in predicting the natural dimension correctly. Because it cannot be expected that single tree dimensions develop in the same manner in mixed stands, as they do in pure species stands, it is difficult to find correct estimations for the assortments. Thus the harvesting costs, sale prices for single trees and consequently the corresponding stand parameters are also difficult to assign. When the effects of different thinning regimes or site conditions are also taken into consideration, the difficulties in analysing the financial dimensions of mixed stand management culminate. Thinning modifies stand structure permanently, and depending on the site conditions, the resultant mixture can develop in different ways imposing direct effects on financial return.

This paper presents the single tree dependent growth model SILVA 2 and its analysis of the effects of different thinning regimes on assortments and financial yield in mixed species stands of spruce and beech. SILVA 2 is an example of an integrated, computer based, site and structure sensitive growth and yield model, with interfaces to traditional yield analysis and single tree analysis, as well as biodiversity and economic analysis. The following shows the extent of SILVA 2's application as an appropriate decision support tool for research on mixed forest stands.

The growth model SILVA 2

A preliminary version of the growth model SILVA was first developed by Pretzsch (1992). The basic idea was to describe and to explain tree growth dependent on site conditions and competitive stress. SILVA 2 has site sensitive growth functions which are initialised by the site module STAOPROD (Pretzsch & Kahn 1996). The model is single tree orientated and dependent on the distance between trees. If tree positions are not known before a prognosis run starts they can be generated by applying the structure generator STRUGEN (Pretzsch 1993). The competitive situation is derived numerically by determining the neighbours of a tree that are competitors and then

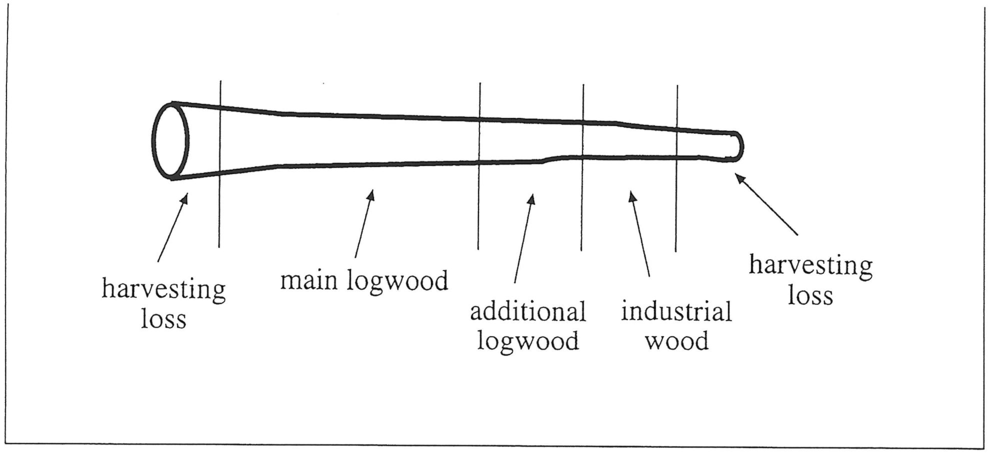

Figure 6.3.1
The assortment is performed on a single tree basis. The most important input parameters for the assortment module are: grading rule, tree species, diameter at breast height, tree height, height of base of crown, transport length restrictions and diameter at the top of the logwood.

quantifying the effect these neighbours have on a certain tree (Pretzsch 1995; Dursky 1997). Thinning regimes are implemented with the fuzzy logic rule based control system STRUMOD (Kahn 1995). Ecological aspects can be characterised by indicative parameters (Pretzsch 1996). The growth model SILVA 2 is parameterised on a large database. Elements of the data come from experimental plots in mixed species stands. Some of these experimental plots have been under surveillance since the 1960's, while others are relatively new, being first surveyed during the 1980's and 1990's.

Economic interface of SILVA 2

The economic unit of SILVA 2 consists of three modules: 1. performs the assortment; 2. includes the harvesting costs and 3. calculates the financial return based on market timber prices.

Assortments

Computer based assortments included in a growth model, transform the traditional growth and yield data of single trees, for example tree diameter at breast height or tree height, into marketable timber assortments. Because harvesting costs and market prices are related to timber assortments the inclusion of these assortment data allows an economic analysis.

The program BDAT was developed in the 1980's to support the German national forest inventory (Kublin & Scharnagl 1988). It performs an assortment based on a number of tree parameters and follows different grading rules (Fig. 6.3.1). The programme module BDAT is incorporated into SILVA 2. The assortment follows a mid diameter grading rule (L-classification: L1 to L6) and a Heilbronn grading rule (H-classification: H1 to H6). For both classifications the index 1 to 6 indicates increasing stem dimensions.

Harvesting costs

Harvesting costs are also calculated on a single trees basis. Two different algorithms are used for determining the harvesting costs, depending on whether the tree is to be processed with a harvesting machine or by a chainsaw operator. In the former case the algorithm follows the approach of van Laar et al. (1992), who describe a regression analysis between the technical productivity of a harvester and the mean diameter of spruce to be removed from the stand. The alternative method of motor-manually processing the trees using a chainsaw and operator is the more usual scenario in German state forests. In such instances and depending on the assortments, the costs are assessed in accordance with official grading rules, as well as a comprehensive system of tables outlining processing times and application rules.

Financial yield

Using single tree assortments the calculation of financial return is now straight forward, being price multiplied by quantity. The prices applied are derived from Bavarian timber market statistics from 1994 (Anonymous 1994). As wood quality is not taken into account by the growth model, the prices applied are an average of those given for various quality classes. The prices are weighted by the traded volume of each quality class (Table 6.3.1).

Table 6.3.1
Average market prices in DM/m^3 for commercial wood from a statistic of the Bavarian timber market in the year 1994.

TREE SPECIES	GRADING RULE	ASSORTMENT	SUB-CLASS	ASSORTMENT CLASS 0	1	2	3	4	5	6
Spruce	Heilbronn H	logwood			77	102	116	124	134	145
	Mid diameter HL	logwood	a		70	90	112	125	128	142
			b		81	103	119	125	128	142
	Mid diameter IL	industrial wood	a		56	53	32	30	33	43
			b	54	61	38	30	30	33	43
Beech	Mid diameter L	logwood	a		52	71	100	158	204	242
			b		66	74	129	158	204	242
		industrial wood					47			

Evaluating thinning effects in spruce-beech stands

Starting conditions for the prognosis runs

The initial stand conditions for the prognosis runs with SILVA 2 are defined as a spruce-beech mixture with the spruce approximately 20 years of age and the beech 25 years. It is assumed that 30% of the stems are beech. The spruce are planted in a regular planting pattern while the beech are a result of natural regeneration and as such are mixed randomly between the spruces. The site conditions are characterised as a medium supply of soil nutrients and soil moisture, with temperature and precipitation during the growing season adapted in line with average values for southern Germany. The selective thinning to be applied is controlled by stem number over top height curves. Thinning impacts are defined and occur in the model at every time step (i.e. every 5 years).

In total three scenarios are compared. Scenario 1 promotes spruce, but maintains the spruce-beech mixture ratio of 70:30 throughout the prognosis period. The harvesting costs are assessed on the basis of a motor-manual tree processing. Hereafter, this scenario will be referred to as 'Scenario Promoting Spruce'. Scenario 2 promotes beech and inverts the spruce-beech mixture ratio of 70:30 at the beginning of the prognosis run to 30:70 by the end of the prognosis period. Hereafter, scenario 2 will be called 'Scenario Promoting Beech'. Scenario 3 is identical to 'Scenario Promoting Spruce', with the exception that the tree processing is performed by a harvesting machine. Thus the cost structure follows van Laar et al. (1992). Hereafter, scenario 3 will be referred to as 'Harvester Scenario'. The timeframe of each prognosis run is 145 years and within this timeframe there are 30 periods each of five years. Every scenario except the 'Harvester Scenario' is repeated ten times. From the repetitions, mean values and standard errors are calculated for each of the output parameters.

Growth and yield of the natural production

The traditional results of the natural production i.e. the development of growth and yield, shall be considered only briefly. Growth and yield results differ only between 'Scenario Promoting Spruce' and 'Scenario Promoting Beech' because the 'Harvester Scenario' differs from the first in harvesting costs only. The current annual increment of usable timber for the stand is maximised in the 'Scenario Promoting Spruce' at a stand age of approximately 50 years and 22 m^3/ha (Fig. 6.3.2). This is a result of maximum mean annual increment occurring at approximately 45 years of age for spruce and 60 years for beech. Because of the strong reduction of spruce in the 'Scenario Promoting Beech', this scenario exhibits considerable losses in total volume increment. Obviously such losses are evident in older stands only.

Assortment, harvesting costs and financial yield of material removed

The log wood assortments of the remaining stand gives insight into the hidden reserves of the forest owner and the potential for the owner to participate in the timber market in the future. On the other hand, the assortment of the material

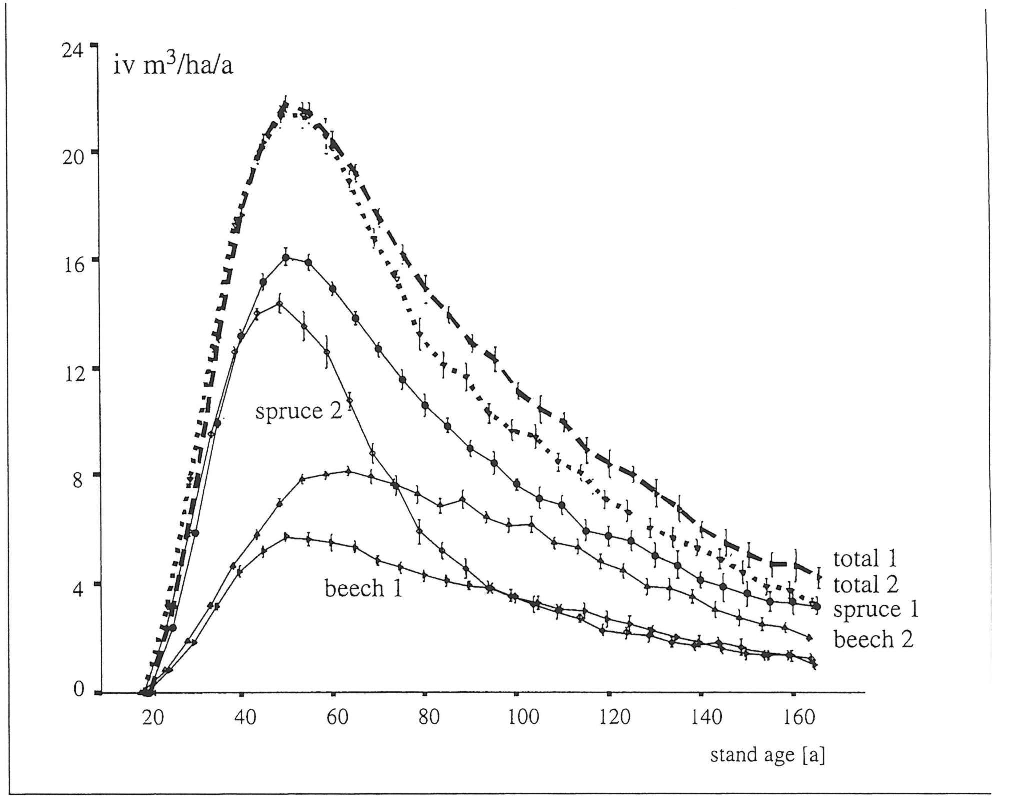

Figure 6.3.2
Current volume increment per ha and year (iv) for spruce, beech and total stand over stand age. 1 = scenario 1 (promoting spruce), 2 = scenario 2 (promoting beech). Presented are mean value +/-2*standard error.

removed from the forest provides the necessary information to allow the forest owner compete in a commercial timber market. In this respect, the most interesting scenario is the 'Scenario Promoting Beech'. It is characterised by a heavy spruce thinning in which a considerable volume of logwood is removed. The greatest volume of tradable spruce logwood is removed in the periods 8 to 12 (Fig. 6.3.3). This leads to processing costs of up to 2,200 DM per ha in one period for spruce alone and results in a maximum net financial yield of more than 5,000 DM per ha. When the prognosis periods are considered as management classes, the same volume in assortment classes, the same costs and the same net financial yields occur in each of the age classes. Remarkably there is a negative net financial return from thinnings during the first 30 years of the prognosis runs and in the youngest age classes of the management classes. It should be possible to prevent this phase of negative financial return by imposing different management strategies. For example a higher degree of mechanisation might be applied during these age classes, stem numbers in the plantation may be reduced, or an early and heavy thinning might be applied in the initial years.

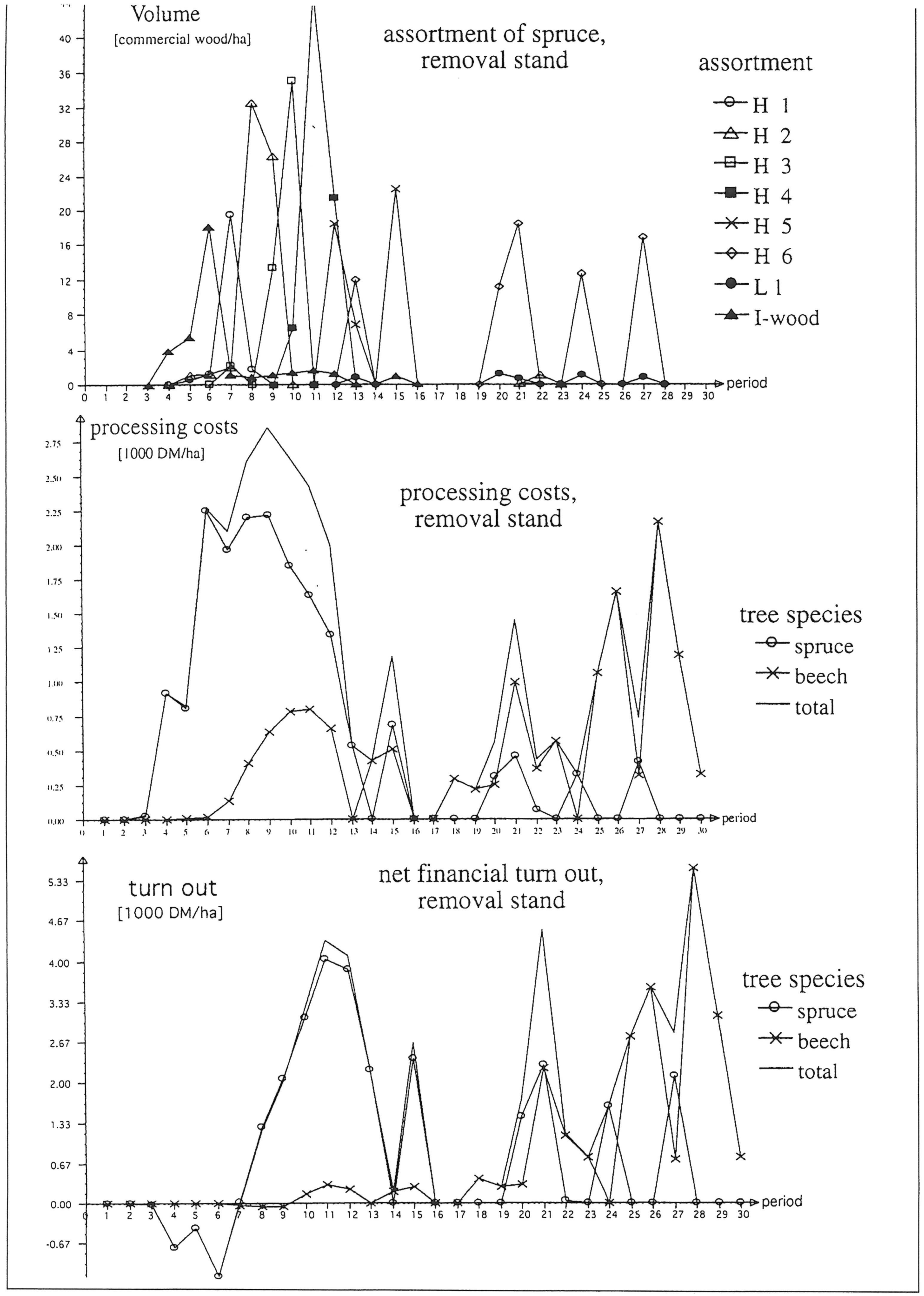

Figure 6.3.3
Assortment, harvesting costs and net financial turn out of removal. At the top: assortment of removal stand, spruce, of scenario 2 (promoting beech), Mid: removal stand for spruce, beech and total.

Financial yield of the management class

The question now is how to comprehensively present the financial yield over the total prognosis period and so, for example, facilitate comparisons between different thinning regimes, or under a given thinning regime determine the optimum rotation length. Having considered the prognosis runs as management classes it must be emphasised that no interest rates are taken into account.

In the 'Scenario Promoting Spruce' a maximum current net value increment of 1,600 DM/ha/annum, occurs at a stand age of approximately 60 years, some 10 years after the maximum current volume increment (Fig. 6.3.2). It is interesting to note the very sharp increase that occurs in the current net value increment between stand ages 30 to 60 years. Although this is then followed by a slow decline, nonetheless the increment remains on a relatively high level for the remainder of the prognosis run. The current net value increment is an important factor, but it should not be used as the deciding factor on the rotation length of a spruce-beech management class. Rather, the mean net value increment is a more comprehensive criterion on which such decisions may be based. Mean net value increment is calculated by dividing the total net value of the remaining stand by stand age. The net value of the remaining stand is calculated by estimating future income from assortments (valued using market prices) minus harvesting costs. The total net value on the other hand, includes all the net values of the material removed since the beginning of the prognosis run. The optimum rotation length will coincide with the maximum mean net value increment. For example, in the 'Scenario Promoting Beech', maximum mean net value increment occurs at approximately 120 years. This assumes a spruce-beech stand, with permanent stem number proportions of 70% spruce and 30% beech of given site and silvicultural conditions (Fig. 6.3.4b). A very slow decrease in mean net value increment occurs after the point of culmination. Without considering risk or interest rates it is thus more critical to harvest a spruce stand before it reaches 100 years than after.

Comparison of the scenarios in respect of financial yield

To determine which of the three thinning scenarios (Promoting Spruce; Promoting Beech; Harvester) is financially superior, the mean net value increment of all three scenarios was compared. 'Harvester Scenario' was found to be superior to 'Scenario Promoting Spruce', but only at younger stand ages. This is a result of the high degree of mechanisation possible during the early thinnings (Fig. 6.3.5).The implication is that harvesters are not as expensive in young stands as motor-manual chainsaw processing. However, the differences between these two scenarios at the older stand ages are not as great as those between 'Scenario Promoting Spruce' and 'Scenario Promoting Beech'. This difference is largely due to the heavy removal of spruce in the latter scenario. The opportunity cost therefore of promoting beech, is a loss in mean net value increment of approximately 200 DM/ha/annum until a stand age of 120 years.

It must be emphasised that the mean net value increment as presented in Ffigure 6.3.5, is the sustainable net financial yield that can be earned per hectare per

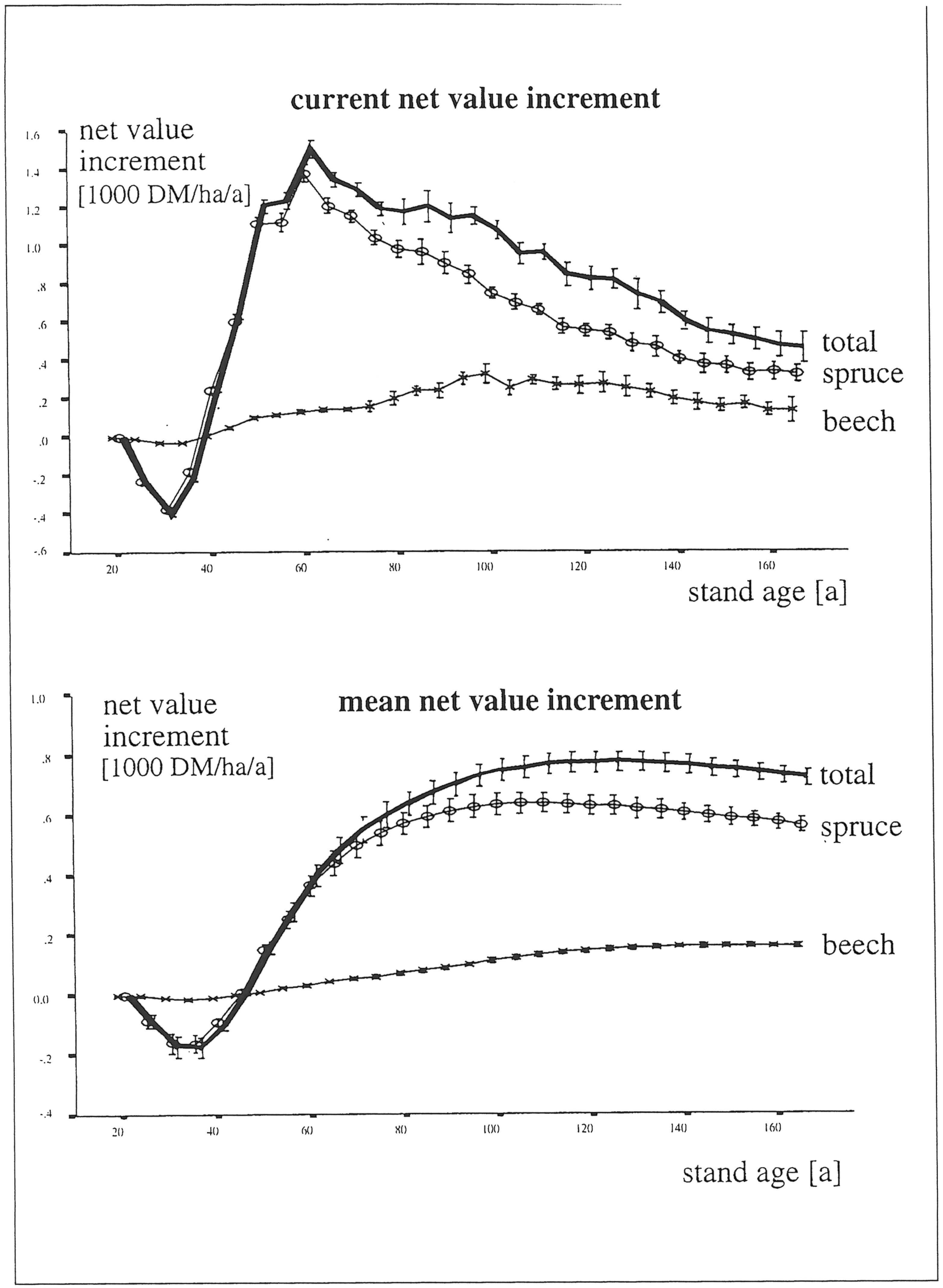

Figure 6.3.4
Net value increment per ha and year for spruce, beech and total stand over stand age scenario 1 (promoting spruce). At the top: current net value increment. At the bottom: mean net value increment. Presented are mean value +/- 2*standard error.

annum for the spruce-beech management class described. The determining variable in Figure 6.3.5 is the stand age. The rotation length of each of the management classes may be determined by comparing mean net value increments per hectare per annum. Having determined this it would be costly to deviate from the optimum rotation length if the net financial yield of a management class is to be maximised.

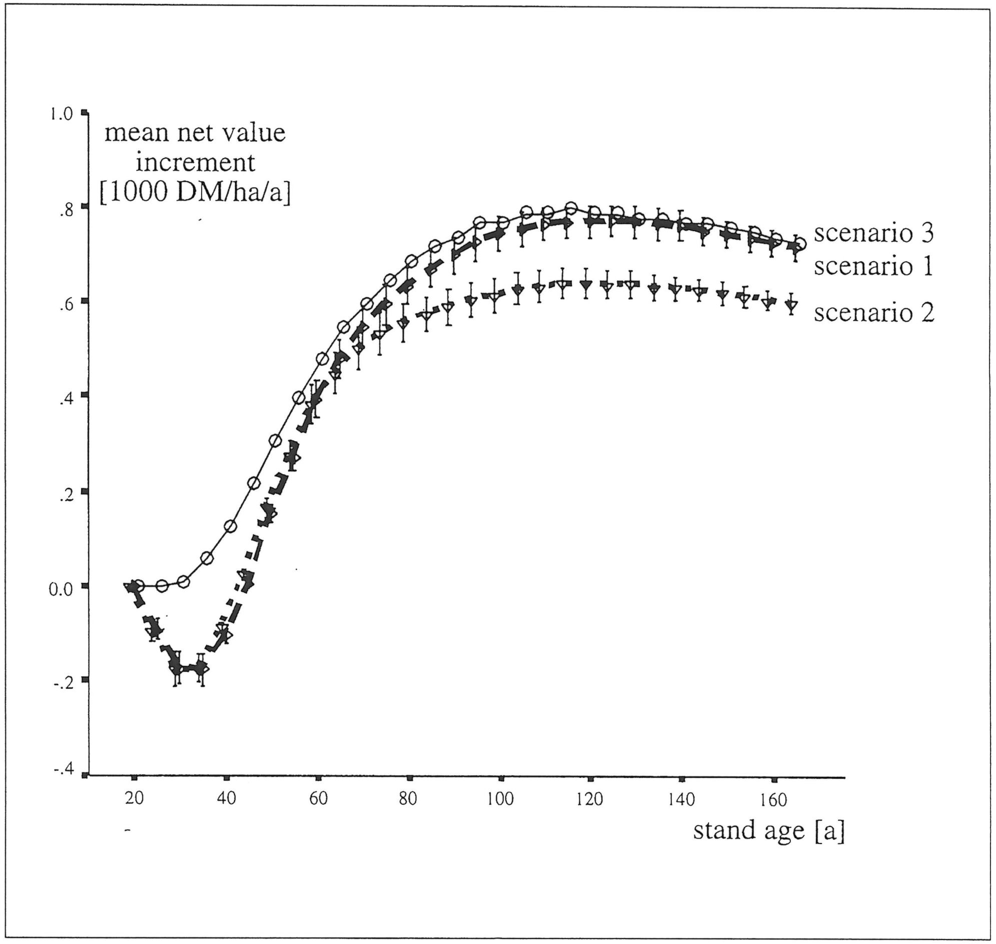

Figure 6.3.5
Mean net value increment of the total stand in dependence on stand age for all scenarios. Scenario 1 = promoting spruce (motor manual processing), scenario 2 = promoting beech (motor manual processing), scenario 3 = promoting spruce (harvest processing). Presented are mean value +/-2*standard error.

Discussion and conclusion

The following discussion will focus on the model SILVA 2 and its capability to provide the necessary information for analysing the effects of different thinning regimes on the financial yield of mixed species stands. The validity of the financial analysis presented in this paper is dependent on the reliability of the natural production data. The validation of the natural production data and the model parameters are not of major interest here.

Main problems solved

The growth model SILVA 2 is a distance dependent, single tree based prognosis tool. The output from each prognosis run provides information far in excess of that provided by traditional yield tables. In addition it provides information on the three dimensional stand structure, diversity and financial yields. The economic interface of SILVA 2 is based on an elaborate assortment module which assorts each tree as a function of tree dimensions, processing restrictions and grading rules. The results of the assortment procedure, outline to the forest owner, the potential of the forest to supply the timber market with particular products from a spruce-beech mixture of a given management class. In addition the results reveal the sustainability of product supply, as well as, if and how rotation length may need to be altered in order to achieve such sustainability. Using the assortments the cost of harvesting can be assessed. Two different harvesting procedures; one highly mechanised, the other motor-manual, can be compared using the same natural production data. This capacity for comparisons is of great importance when considering different processing strategies at different stand ages. In this particular case, results indicate that motor-manual thinnings during the first 20 to 40 years of the rotation lead to highly negative financial yields.

In order to attain net financial yields, timber market prices can be incorporated into the equation. Thus, a considerable amount of data can be presented as an all-inclusive net value. This reduction to monetary values provides the forest manager with decisive data for stand management. The scenario analysis reveals that for the site conditions and restrictions outlined, the higher the proportion of spruce in a spruce-beech management class, the higher the mean net value increment. In the spruce-beech scenarios analysed the mean net value increment culminates at a stand age of approximately 120 years. Remarkably, the mean net value increment increases sharply before reaching its maximum. After this point however, it decrease slowly. The standard errors of the mean net value increments are considerably small despite carrying out only ten repetitions of each prognosis run for 'Scenario Promoting Spruce' and 'Scenario Promoting Beech'.

Model restrictions

The main restrictions to the model output presented here are lack of data concerning timber quality, risk aspects and natural regeneration. These modules are still under development. Timber quality is of considerable importance for beech products as it is with other tree species also. Stand structural characteristics like single tree or group mixture have a decisive impact on the structure of a stem. In even aged and pure species stands of beech, the stem quality is more homogenous and can be more easily estimated than in the more variable stand conditions that may be encountered in mixed and uneven aged stands. The first successful step in this area will most likely be to develop a more sophisticated crown model that considers asymmetrical development of the crown, as well as the arrangement and dimensions of the branches along the stem.

The next step will be to include a risk assessment. This would probably be on a single tree basis employing a height:diameter ratio and crown parameters. Without a risk assessment it is not feasible to decide, for example whether the 'Scenario Promoting Spruce' or the 'Scenario Promoting Beech' will lead to a higher financial yield. Referring to Figure 6.3.5, although the former scenario appears to be superior there is always the risk that such a management class never reaches the optimum rotation length of 120 years because of storm and wind damage. On the other hand it may be more likely that the latter scenario can be carried through to its optimum rotation because of a lower risk of such damage. Thus risk assessment is essential to the successful use of growth models like SILVA 2 and requires hasty resolution.

As mentioned in the introduction, the problems involved in the management of mixed species stands on a single tree silvicultural basis are becoming increasingly important. Single tree silviculture undoubtedly leads to higher proportions of natural regeneration in mixed stands, than in even aged pure species stands. In the long run therefore, a holistic analysis of the financial yield of different thinning regimes will have to consider the effects of such regimes on the occurrence of natural regeneration. The implementation of a regeneration model is straightforward.

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forests: an ecological and economic valuation

H. Utschig

Abstract

The establishment and expansion of mixed stands and their silvicultural treatment are basic aims of the public forest administrations in Germany. In most areas, the existing old growth of spruce will be converted into mixed stands during the process of regeneration. In this investigation two sample plots of a mixed stand, in an advanced stage of conversion (more than 40 years of a 'treatment close to nature') are compared with the development of a long-term experimental plot of pure spruce at the same site.

The results of the ecological analysis show high diversity in the mixed stands. From an economic point of view, the pure spruce stand is prominent because of its high productivity and its higher mean annual value increment. At the same time there is a lot of capital stored in the remaining stand. The converted stands have a lower value, less stored capital and more capital gain from the removed stand. The marginal interest rate during the conversion stage is higher than in the pure stand where stored capital is high. The stands to be converted yield a continuous return and show a remarkably high ecological standard.

Key words: single tree, growth model, assortment, financial return, management system, valuation, silvicultural treatment

Introduction

Snowbreak and wind damage during the eighties and nineties highlighted the benefit of mixed stands. As a result, the public forest administrations in Germany decided to establish mixed stands and to improve already existing timber stands with silvicultural methods more 'close to nature' (Bauer 1991; Bergmann 1992; Bentrup 1992; Eckardt 1994; Köhler 1992; Ott 1992; Otto 1992). Typical methods are to harvest only those trees with a defined target diameter at breast height (dbh) of 60 cm, to allow selective thinning only and to initiate artificial or natural regeneration under the shelter of the old stand.

Early in the eighties, the chair of forest yield science in Munich focused its main research activities on mixed stands. A large number of long-term experimental plots in mixed stands were established. Two long-term experimental plots were established that represent an advanced stage of converting a spruce-dominated forest into a mixed forest. The objective was to assess the structural diversity of the stand, to examine the growth rates of the single trees in the old and young stands and to describe the influence of crown cover and competition on growth (Schmitt 1994). At the same time, the single-tree growth model SILVA (Pretzsch 1992) was developed.

MISSION

Believing that the ecological value of an area is influenced by agriculture, urbanisation, recreation, infrastructure, traffic and other human activities, and that both ecological value and sustainability are enhanced if these activities take account of ecological principles, the DLO Institute for Forestry and Nature Research (IBN-DLO) aims to provide the scientific basis for public debate on how best to achieve nature conservation. By helping to solve problems arising from the conservation, restoration and development of nature in this way, IBN-DLO aims to contribute constructively to a high quality environment in The Netherlands and abroad.

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Management of mixed-species forest: silviculture and economics

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Preface

In June 1993, foresters and researchers interested in the management of mixec species forests and small-scale forestry met in Besançon in France, for th International ProSilva Congress. During the meeting, it became apparent that th level of expertise on the management of mixed forests in Europe was varyin significantly, with some countries demonstrating already a long history of researcl while others were only beginning to address this topic. It thus seemed appropriat to form a group of scientists, from both advanced and less advanced countries in thi respect, to discuss the current state of the art, exchange experiences, identify gap and define research priorities for the near future.

To reach these objectives, the concerted action 'Management of Mixed-specie Forests: Silviculture and Economics' was proposed to and eventually funded by th European Commission's AIR specified RTD programme (AIR CT94 2149). Since i start in December 1994, the concerted action provided the means for the organisatio of three workshops, where 22 researchers from 13 EU countries presented the work, reflected on ideas and identified research priorities for the future. A numbe of selected invited speakers have contributed significantly to the success of th project by sharing their experience and thought with the participants of this actior

The present volume summarises all contributions made throughout the action lifetime and is meant to provide useful 'food for thought' to the European forestr community concerning the prospects and orientations of the silviculture, economic and ultimately, the multifunctional management aspects of mixed-species forests i Europe.

I want to thank all participants and invited speakers for their enthusiasm i the meetings and their contributions towards the realisation of this volum Especially, I want to thank Dr.Ir. H.H. Bartelink (Forestry Section of the Waginge Agricultural University) for his great efforts to edit and compile this book, and Jac Gardiner and Sara Wall (Department of Crop Science, Horticulture and Rur Development, University College Dublin) for the technical and linguistic editing. D A. Arabatzis has been our counterpart with DG XII, the European Commission Directorate for Science, Research and Development. Finally I want to thank Drs. T.A.V van Rossum and M. Pijfers who took care of the final book production.

I hope this book shows many persons the way to mixed forests. In mos European countries, there is a desire for further expansion of the area of mixed fore with a multifunctional goal. This book shows that management of mixed forest is challenging task, and that sound research is needed to provide guidelines for sustainable silviculture.

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