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6.4 Reconversion of pure spruce stands into mixed 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

SILVA represents a powerful prognosis and valuation instrument that can be used for both pure and mixed stands.

Details of the investigation in the mixed stand 'Munich 145' follow. They demonstrate the connection of a first assessment of a long-term experimental plot with a growth model, in order to arrive at an evaluation of ecological and economic aspects of the stands and their development. The results are compared with the assessments of a long-term experimental plot in a pure spruce stand, at the same site.

Material and methods

The experimental plot Munich 145

The first experimental plot is located 15 km south-east of Munich in a watershed protection forest belonging to the municipal forest administration of Munich. The typical luvisols developed from fluvioglacial gravel containing about 70% carbonate. The gravel was sedimented at the end of the last glaciation and has a thin cover of loess. The humidity is described as medium wet. The altitude is about 550 m above sea level. The average annual temperature is 7.2 °C, and during the growing season, 14.4 °C. The annual precipitation reaches 1130 mm, 58% of which occurs during the growing season. The natural climax forest is a sub-mountainous beech (*Fagus sylvatica*) forest with oak (*Quercus robur*), Norway spruce (*Picea abies*) and a small portion of Scots pine (*Pinus sylvestris*) and silver fir (*Abies alba*).

The research plot Munich 145 was treated by thinning from below until the age of 80 (in the year 1955). After this, the silvicultural treatment intended to convert the spruce-dominated stand into a mixed stand, with the character of a continuous forest. During the last 35 years, 3500 beech and silver fir trees per hectare have been planted and natural regeneration has been established as volunteer growth under the shelter of the old stand. The influence of game animals was prevented, by fencing the entire watershed protection area. Since 1955, a single-tree management system has been in place. A target dbh (60 cm for spruce and 55 cm for pine) was defined. Only single-tree cutting was carried out and the advanced planting or natural regeneration under the shelter of the old growth was initiated. During this conversion period, the dense, spruce-dominated, old stand with some pine trees, has developed to a spruce and pine stand with open crown cover. Now the whole area is covered with regeneration in both the understorey and the secondary crop. The silvicultural target is to convert the spruce-dominated into a beech-dominated stand, with rich admixture. In 1991, the mixed stands were established as experimental plots. Since then extended measurements and data assessments have been conducted.

The experimental plot Eglharting 73/2

The long-term experimental plot Eglharting 73/2 is a pure spruce stand which was selected as a control stand. The site is very similar to Munich 145, but the topsoil is more acidic. The temperature can be compared to that of the 'stands to be converted', but the precipitation is lower at 940 mm per annum (450 mm during the growing season). The experimental plot Eglharting 73 was planted in 1864 at 1.2 x 2.0 m spacing. Assessment first began in 1906. The silvicultural treatment imposed on the selected plot 2 was a light thinning from below. During the winter 1983/1984, at the age of 119 years and after 77 years of survey, the stand was clear cut. In total 12 assessments took place.

The growth model SILVA 2

The growth model SILVA is single-tree-oriented and distance-dependent. The working principles of the model and the output levels are described by Pretzsch and Kahn (1996). The growth model has site sensitive growth functions, and next to that growth prognosis it performs an ecological and economic analysis of the stand development. The ecological analysis calculates comprehensive indices to describe stand structure and stand development over time (Pretzsch 1998). The programme module for the economic valuation (Kahn 1998) provides for single-tree based assortment, the calculation of harvesting costs and the net financial return.

For the intended ecological and economic comparison of the pure spruce stand, the long-term development of both Eglharting 73/2 and the mixed stand in Munich has to be known. But, since only one assessment has been carried out on the experimental plot Munich 145, the growth model SILVA 2 is applied to calculate the stand development over 40 years, using the real data from 1991 to describe starting conditions. SILVA 2 is used to perform the ecological and economic evaluation of both the real time series data from the pure spruce plot (Eglharting 73/2) and the real world starting conditions and predicted stand development of the experimental plots (Munich 145).

A 'stand to be converted' in comparison with a pure spruce stand

The first assessments of the long-term experimental plots Munich 145/1 and 145/2 are used to define the starting conditions for predicting the development of these 'stands to be converted'. The silvicultural treatment is single-tree cutting and the target dbh is 60 cm for spruce and 55 cm dbh for pine. Only trees in the regeneration with a minimum dbh of 6.5 cm were used in the growth model. This database can be used to reflect the real situation for the starting point of the prognosis run and to predict the stand development for the next 40 years. The results are then compared with the real stand development of the plot Eglharting 73/2. The already existing 12 assessments form the database for calculating the yield, as well as the ecological and economic effects.

Development of growth and yield

Figure 6.4.1 shows the structure of the stand Munich 145/1 at the time of the first assessment in spring 1991, and of the stand Eglharting 73/2, at the age of 119 years in 1983, before it was clear cut. The 'converted stand' is composed of 165 spruce and 76 pine trees in the old stand and 930 trees (spruce, silver fir, beech, dbh > 6.5 cm) in the understorey and the secondary crop. The old stand of Munich 145/2 has a

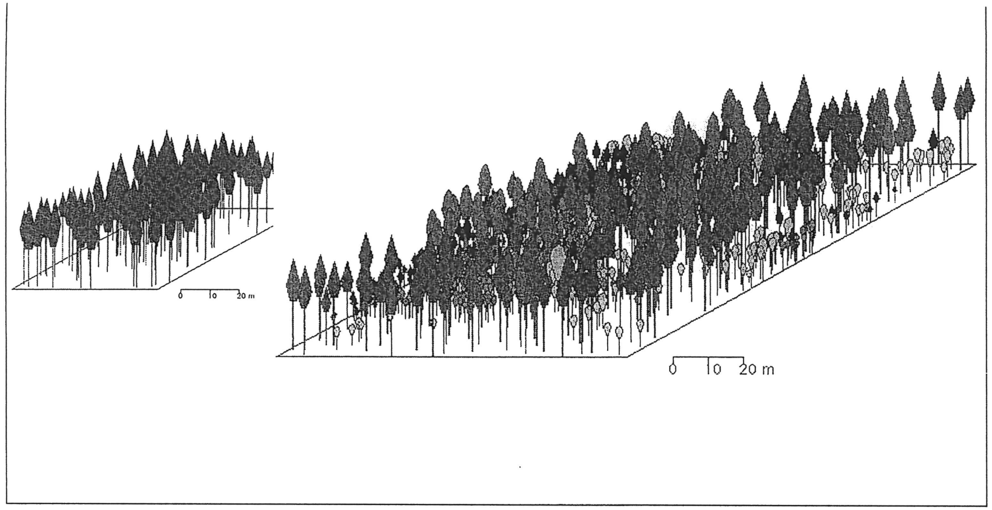

Figure 6.4.1
Structure of the long-term experimental plot Munich 145/1 and the pure spruce plot Eglharting 73/2.

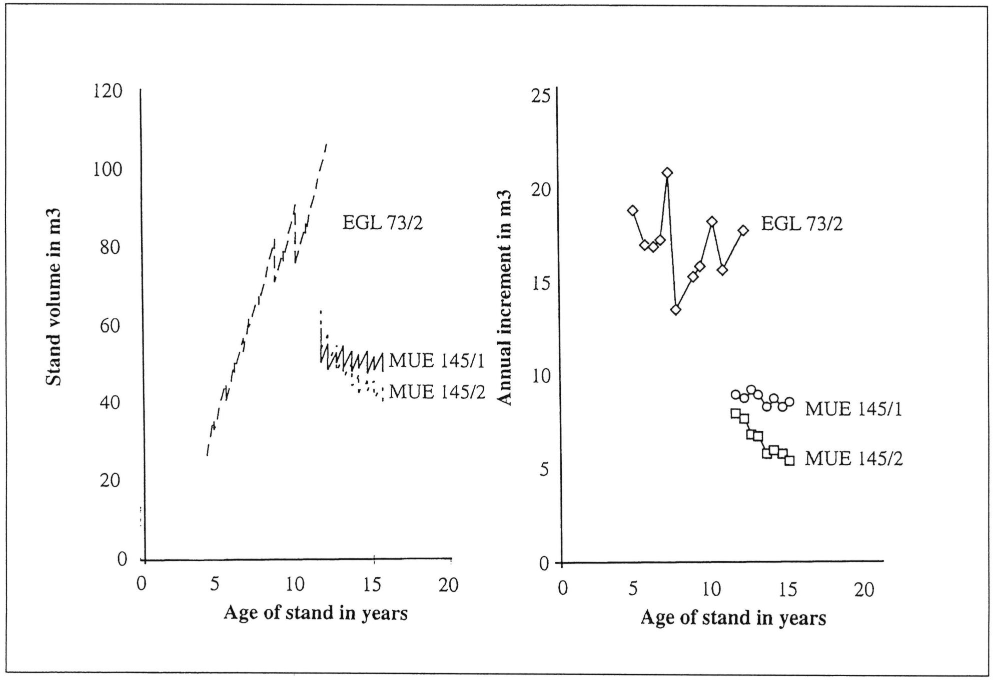

Figure 6.4.2
Left: Volume of the remaining stand for the 'stands to be converted' Munich 145/1 and 145/2 and the pure spruce stand Eglharting 73/2. Right: development of the annual increment rates for the 'stands to be converted' Munich 145/1 and 145/2 and the pure spruce stand Eglharting 73/2.

similar dispersion of spruce and pine, but in the young wood only 292 trees are above the minimum dbh of 6.5 cm.

Figure 6.4.2 depicts the volume development of the remaining stand during the course of the prognosis period. The pure spruce stand has a site index of 33 (Assmann & Franz 1963) i.e. 33 m top height at the age of 100 years which represents a medium yield class for Bavarian growth conditions. The remaining volume reaches a level of 1064 m^3 at the age of 119. In comparison the remaining volume of the 'stands to be converted' is relatively low: 589 m^3 (Munich 145/1) and 636 m^3 (Munich 145/2). The regeneration is high in number, but only a small proportion has reached compact wood dimensions (dbh > 6.5 cm). The annual volume increment reflects the difference in the standing volume. The pure spruce stand has an annual increment between 15 and 20 m^3 per hectare and year, while the 'stands to be converted' have an annual increment below the level of 10 m^3 per hectare for the duration of the prognosis period. These low increment values are mainly a result of the reduced stem number and the fact that 30% of the stand volume is represented by pines, which have lower increment rates than spruce. During the growth prognosis, the plot Munich 145/1 displays a constant annual increment. The increment rates of old trees slow down because of the thinnings but are augmented by the increment rates of trees in the young stand or formerly overtopped trees of the old stand. On the plot Munich 145/2, the annual increment slows down just after the prognosis run starts. This is due to the insufficient number of trees in the young stand with a dbh > 6.5 cm (only 296 stems), that can grow during the prognosis run to greater tree dimensions.

Ecological aspects

Traditional reference numbers used by forest yield science describe the mass productivity of a stand. These reference numbers include little information about spatial diversity, ecological stability, species diversity and the suitability as a species habitat, for recreation or for water protection. Pretzsch (1998) highlights that an increasing horizontal and vertical structure of a forest generally indicates a multifarious population of flora and fauna. The various intraspecific associations increase, and so does the ecological stability of the system. For the definition of the indices used see Pretzsch (1998).

The spatial diversity of a stand can be described using the modified SHANNON index A for the species profile (Pretzsch 1998). There is a clear distinction between the species profile for the 'stands to be converted' Munich 145 and the species profile for the pure spruce stand Eglharting 73/2 (Fig. 6.4.3). The high values (between 1.6 and 2.1) indicate a very heterogeneous stand structure in the 'stands to be converted', whereas the index A of the pure spruce stand decreases after the stage of differentiation (index A = 0.6). At the age of 99, the value of the index A reaches 0 and by the end of the rotation the stand has become a one-storied stand.

In the 'stands to be converted' the aggregation index R by Clark and Evans (1954) points to a random distribution that is typical for 'selection forest stands'. The spruce trees of the old stand are more or less dispersed, the young stand of beech and silver fir covers the whole plot area, and the index R indicates a random distribution for the whole stand. The pure spruce stand was planted in a regular pattern; the

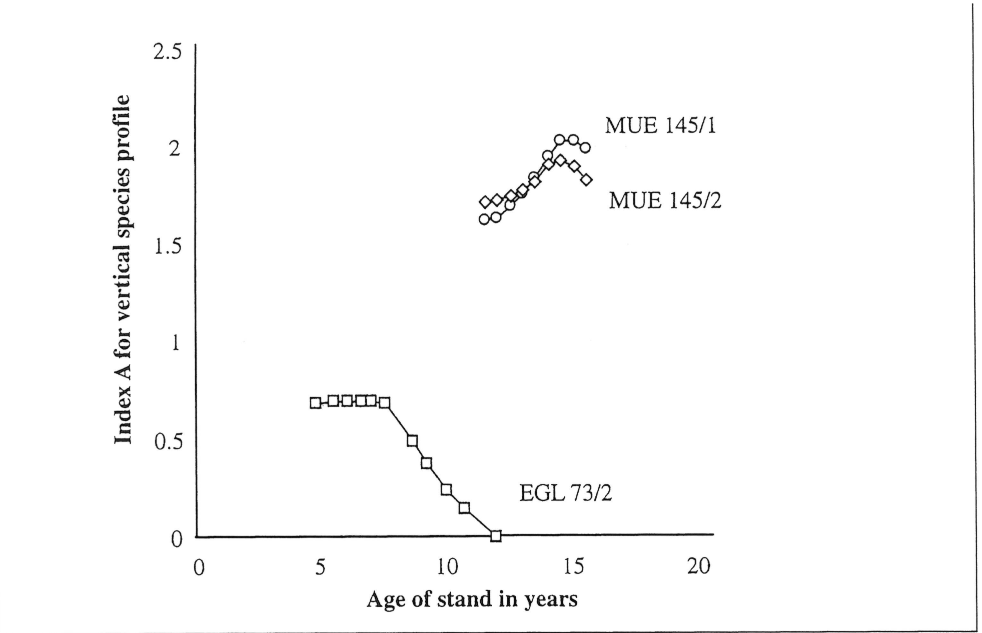

Figure 6.4.3
The modified SHANNON index A for the species profile of the 'stands to be converted' Munich 145/1 and 145/2 and the pure spruce stand Eglharting 73/2.

index R=0.984 at the age of 99 also shows a random distribution of the trees.

Pielou's segregation index S (Pielou 1977) describes the admixture of the species. The plot Munich 145/1 (S=-0.58) tends to an association of the species, whereas the plot Munich 145/2 (S=-0.30) shows a tendency to a more independent distribution. In the pure spruce stand the index of segregation S equals 1, because there is only one species.

As a result of the ecological analysis, it was easy to recognise that two quite different silvicultural treatments were applied. In particular the index A for the vertical species profile highlights the high diversity in the 'stands to be converted' versus the one-storied character of the pure spruce stand. The segregation index S is at a maximum in the pure spruce stand. Use of the indices allows the ecological value of the 'stands to be converted' to be expressed.

Differences in the assortment yield

The main motivation for intensive silvicultural treatments is to increase the potential for greater financial yield from the forest. The two stand types compared in this exercise are quite different in their silvicultural treatment. The economic effects of such treatments are considered. The assortment is calculated for the remaining stands at the end of each prognosis cycle of five years. Assessing the assortment structure of both types of stands (Fig. 6.4.4) throughout their chronological development, some important differences can be noticed. The pure spruce stand has

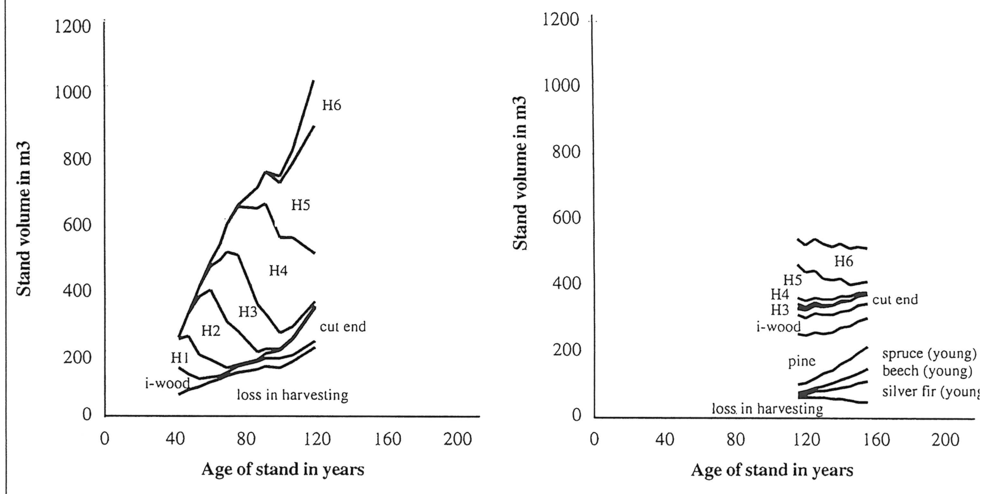

Figure 6.4.4
Assortments for the 'stands to be converted' Munich 145/1 and 145/2 (left) and the pure spruce stand Eglharting 73/2 (right) during the survey periods. The assortments follow the Heilbronn grading rule (H1 to H6, which assort by minimum length and minimum top diameter respectively, H1: 8 m and 10 cm; H6: 18 m and 30 cm) for spruce, the other species are assorted with the mid diameter grading rule; i-wood = industrial wood, loss in harvesting is the unusable timber volume.

completely changed its assortment structure. In the first decades only light timbe assortments exist. However, after the age of 70 the medium-sized timber assortment increase and after the age of 90 a high rate of heavy timber assortment is obvious. A the end of the rotation period heavy timber assortments dominate the structure wit a subsequent large share of the profits and low harvesting costs.

Analysis of the 'conversion stand' shows a lower volume in the remainin stand and a nearly constant distribution of the assortment (Fig. 6.4.4). The stand i managed as a continuous forest system. A target diameter (60 cm dbh for spruce an 55 cm dbh for pine) is defined and only selective thinning is allowed. In particula assortments of heavy timber can be maintained throughout the period of predictio (40 years). Despite harvest cuts of 50-100 m^3 per hectare per decade by selectiv thinning the distribution of assortments remains constant during the prognosi period. The increasing volume of the young stand of beech, spruce and silver fi indicates the high productivity of the young stand under the crown cover of the ol stand. The number of stems in the young stand is comparably low and thus th production of light timber with high harvesting costs is minimised. The stand volum of the pine trees (156 m^3 at the age of 115 and 95 m^3 at 155) supports the heavy timbe assortment. For the whole stand, 50% of the stand volume is stored in heavy timber

Monetary value production

Having determined the assortments it is possible to calculate the harvesting costs and consequently the profits from selling the timber. As a result, both the profit from each thinning and the actual value of the remaining stand can be determined. By adding the accumulated profit of thinnings to the actual value of the stand, the total value of the timber production can be calculated.

In Figure 6.4.5, the steep and nearly linear gradient of the total value for the pure spruce stand is particularly noticeable. After the age of 50 the point of positive total value is reached, while by the end of the rotation period a remarkable total value of 95,200 DM is obtained. The total value of thinnings amounts to 17,800 DM. During the first 80 years, the financial yield of thinnings is close to zero (based on 1994 costs). As 82% of the total value is stored in the remaining stand, one economic target for this stand may be to maximise the value in the remaining stand.

The situation in the 'stands to be converted' is quite different. Thinning value is very high but may be even higher in reality, because the value of the thinning was estimated very cautiously. For the 'stands to be converted' the cumulative values of thinning prior to assessment had to be calculated up to the point at which the assessment started. The value was fixed at 17,800 DM, which corresponds to the value of thinnings obtained at Eglharting 73/2 in former times because the stand was also treated by thinning from below. The value of the remaining stand (37% of the total stand value, 29,000 DM) is constant over the prognosis period of 40 years.

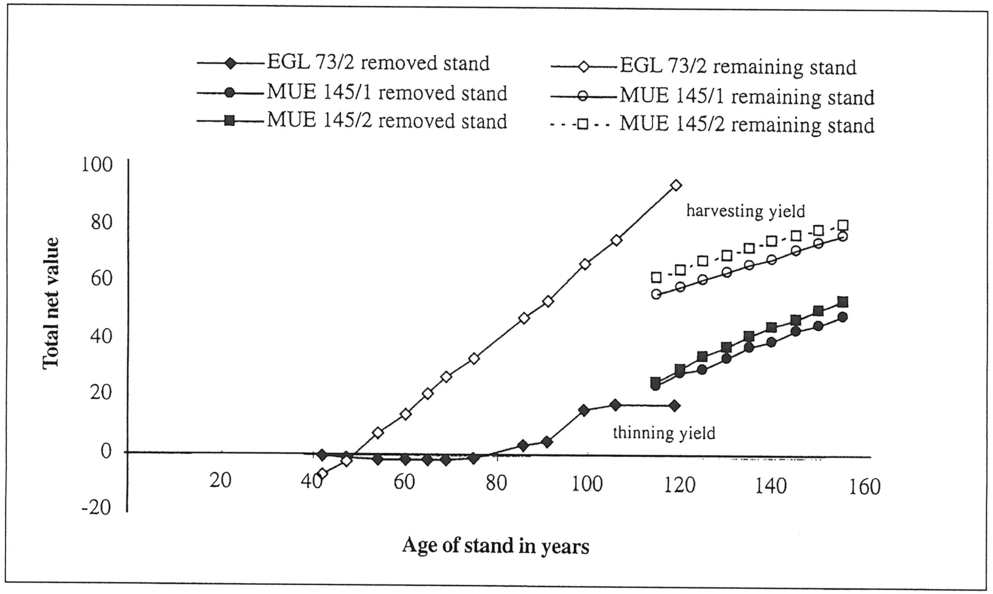

Figure 6.4.5
Total value productivity for the 'stands to be converted' Munich 145/1 and 145/2 and the pure spruce stand Eglharting 73/2. The accumulated value partitioned over the value of the removal stand (black filled signature) and of the remaining stand is described.

However, it should be noted that the economic target is quite different to that of th pure stand, using the principle of nursing the growing stock and siphoning off th annual value increment with a low stored capital in the remaining stand.

Evaluation of the economic effects

How is it possible to compare the economic effects of the two very differen silvicultural treatments? One way is to compare the total value productivity in specific period. In this case a period of 155 years (Fig. 6.4.5) was allowed for th 'stands to be converted'. The total productivity value for the 'stands to be convertec amounts to 77,400 DM (Munich 145/1) and 81,800 DM (Munich 145/2). The pur stand has a total value of 94,800 DM at the age of 119 years. For these rotatio periods the average value increments per hectare per year are 499 DM (Munic 145/1), 528 DM (Munich 145/2), and 800 DM per hectare per annum for the pur spruce stand.

A second approach is to calculate the marginal interest rate for ever prognosis cycle of five years. The value of the remaining stand at the beginning o the prognosis cycle is the base value, while the interest rate is the annual valu increment in the following period. The result is shown in Figure 6.4.6. The pur spruce stand has a high volume and value increment, and the total value of th remaining stand is very high. Due to this high stored capital the interest rate is muc lower with the pure spruce stand yielding a marginal interest of 0.5% to 1.5% (average 1.2%). A general change in the assortment to large timber takes place at th age of 99 and for one period the marginal interest rate reaches 2.5%. In the 'stand

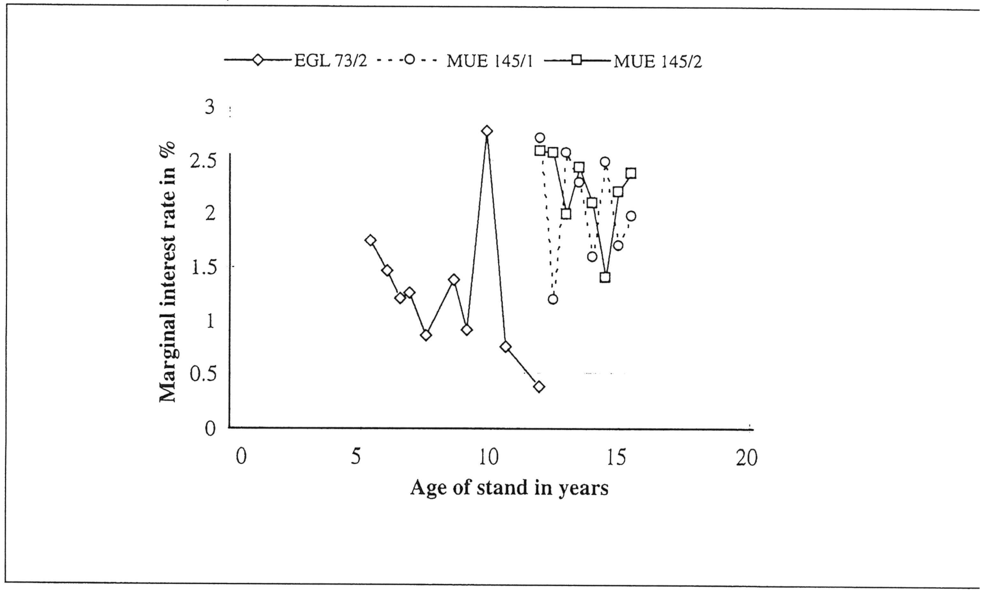

Figure 6.4.6
Marginal interest rate of the 'stands to be converted', Munich 145/1 and 145/2, and the pure spruce stand Eglharting 73/2.

to be converted' relatively low stored capital and a high light increment of the old stand lead to a high value increment and to a high marginal interest rate of more than 2%.

The selected criteria; assortment, mean annual value increment and the marginal interest rate characterise the economic potential of the stands examined. Both strategies have their advantages and disadvantages, which are influenced by the actual size of the forest estate, the personnel staff, the market disposition and the local risks for stand stability.

Conclusions

Over the years, stand valuations have employed a variety of methods including the traditional ones of soil rent and forest rent theories. However, with the help of SILVA 2, this study compares different silvicultural treatments in a simple manner and also estimates stand development over a relatively long period of time. Complex calculations and decisions can be made quickly while very detailed information about the structural dynamics and the financial aspects of long-term experimental plots can also be obtained.

Figure 6.4.7 attempts to summarise the results of the ecological and economic analyses. The different aspects are brought together in a spin-diagram. The scales of the criteria are standardised such that increasing positive values are combined with an increasing value scale. Moreover the value range of each criterion is in the same scale. The high ecological value of the 'stands to be converted' is indicated by the high value of the ecological indices.

The mean annual increment acts as an indicator for stand productivity, while the height/diameter (h/d) ratio acts as a scale for the stability of the stand and the mean annual value increment of the stand acts as an indicator of value productivity. The spin of the spruce stand is very eccentric and it displays a tendency towards positive values in economic aspects only. The spin for the 'stands to be converted', on the other hand, is almost circular, with a balance between economic and ecological aspects indicated.

Different economic targets of the silvicultural treatments are noted. In the 'stands to be converted' the value accumulated in the remaining stand is much lower than in the pure spruce stand. Furthermore, the total value of the pure spruce stand increases by a steep gradient. The mean annual value increment during a period of 155 years is lower by 34-38% in the 'stands to be converted' than it is in the pure spruce stand. This difference seems to be great, but is due in part to the 'stands to be converted' having an admixture of pine trees (30% in volume) with very low growth rates. In addition the increment rate of the young stand would be higher if the trees with dbh <6.5 cm were also included in the prognosis. Unexpectedly, the marginal interest rate is higher in the 'stands to be converted' than it is in the pure spruce stand. Buongiorno et al. (1994) also found real internal rates of return of 2 to 4% in stands with a high diversity.

The conversion of pure stands to mixed stands causes an early reduction of the value in the remaining stand, thus improving liquidity for the forest owner. The opened crown cover leads to a light increment resulting in a high interest rate for the

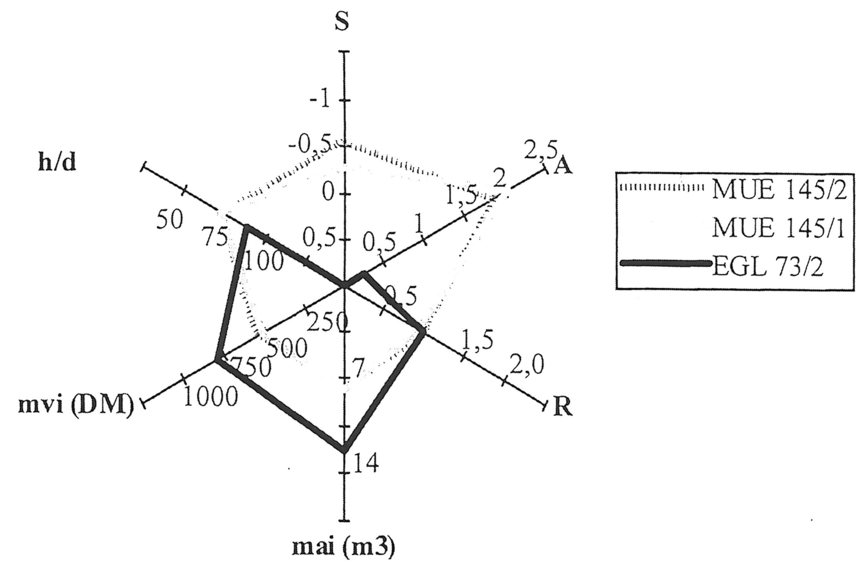

Figure 6.4.7
Spin-diagram for the 'stands to be converted' Munich 145/1 and 145/2 and the pure spruce stand Eglharting 73/2. The aggregation index R (Clark & Evans 1954), the segregation index S (Pielou 1977) and the modified index A of Shannon (Pretzsch 1998) indicate the ecological value of the analysed stands. The height and diameter ratio (h/d), the mean annual increment (mai) and the mean annual value increment (mvi) show the economic power of the stands.

remaining value. At the same time the categories of the assortments that run at a loss, i.e. small timber, are minimized, because the young stand is small in extent. Thus there is a continuity in financial yield. This effect is very positive for people with small forest estates. Knoke (1997) asserts that the calculated net income per cubic meter for big logs is 34% higher in uneven-aged stands than in even-aged stands. In addition, the uneven-aged forest structure has important ecological advantages. The financial value of special functions of multiple-purpose forests like water protection and recreation could until now only be quantified for larger areas by different methods (van Kooten 1995). Solving this problem, the net value of these stand types would rise up. Another important aspect is the higher storm risk in the first decades of opening the crown cover in more or less old and pure stands (Spellmann & Nagel 1996). As a consequence, it is necessary to improve the stability and mixture of the stands during the earlier thinning.

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6.5 Costs, revenues and function fulfilment of nature conservation and recreation values of mixed, uneven-aged forests in The Netherlands

H.J. Hekhuis & E.A.P. Wieman

Abstract

Forestry in The Netherlands is changing rapidly. Recreation and nature conservation are becoming more important and forests have to fulfil a multiplicity of demands. The Dutch government therefore is initiating and stimulating small-scale close-to-nature forest management systems. However, without a clear insight into the consequences for financial costs and revenues and function fulfilment, good strategic decision-making on forest management is not possible.

The scientific challenge in this problem lies in the operationalisation of forest functions, the definition of the different management systems and the determination of costs and revenues. This article describes a research methodology for the evaluation of forest management systems. In a Dutch study, this methodology has been used to evaluate close-to-nature forest management which is based on small-scale felling, natural regeneration and specific attention to nature. Small-scale, close-to-nature forest management can be seen as an alternative to traditional Dutch forest management, which is based on large-scale clear cutting and planting, with no specific attention to other functions of the forest.

The methodology is divided into four steps, consisting of a systems analysis, model calculations in combination with case-studies, an evaluation of forest functions, and a sensitivity analysis. Apart from the large-scale, clear cutting system, three small-scale, close-to-nature forest management alternatives have been defined according to management and forest characteristics and evaluated on forest functions, financial costs and revenues. Forest characteristics are considered as the key to relations between forest functions and between forest functions and costs and revenues.

The evaluation shows that small-scale, close-to-nature forest management leads to better function fulfilment for nature. It appears that the recreational function of forests is also fulfilled better by small-scale, close-to-nature forest management. However, the relationships between forest characteristics and the recreational function of forests is informally understood and more research is necessary in this area.

The usefulness of productivity, as a measure to evaluate the timber production function, depends on the emphasis on nature or timber production and less upon large or small-scale forest management. Timber quality, as another measure with which to evaluate the timber production function, is evaluated by elaborating the relations between forest characteristics and timber quality variables (size, branchness, straightness etc.). The conclusion

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.

IBN-DLO's research has a firm basis in ecology, but is embedded in a social context, because the Institute can draw on extensive expertise in ecology and in the social sciences. The research aims to be innovative, inducing changes at the interface between ecology and society. It is carried out in close consultation with clients. The results are intended to be applied in sustainable land use planning.

IBN-DLO's fundamental strategic research aims to generate expertise to answer tomorrow's questions as well as today's. In this, the Institute is guided by the need to safeguard and steward the various functions of the natural environment for future generations

Management of mixed-species forest: silviculture and economics

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Preface

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

To reach these objectives, the concerted action 'Management of Mixed-spec Forests: Silviculture and Economics' was proposed to and eventually funded by t European Commission's AIR specified RTD programme (AIR CT94 2149). Since start in December 1994, the concerted action provided the means for the organisati of three workshops, where 22 researchers from 13 EU countries presented th work, reflected on ideas and identified research priorities for the future. A numb of selected invited speakers have contributed significantly to the success of t project by sharing their experience and thought with the participants of this actic

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

I want to thank all participants and invited speakers for their enthusiasm the meetings and their contributions towards the realisation of this volun Especially, I want to thank Dr.Ir. H.H. Bartelink (Forestry Section of the Wagening Agricultural University) for his great efforts to edit and compile this book, and Ja Gardiner and Sara Wall (Department of Crop Science, Horticulture and Ru Development, University College Dublin) for the technical and linguistic editing. A. Arabatzis has been our counterpart with DG XII, the European Commissio Directorate for Science, Research and Development. Finally I want to thank Drs. T.A. 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 m European countries, there is a desire for further expansion of the area of mixed for with a multifunctional goal. This book shows that management of mixed forest i challenging task, and that sound research is needed to provide guidelines fo sustainable silviculture.

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