# Comparative economic investigations of even-aged and uneven-aged silvicultural systems: a critical analysis of different methods

MARC HANEWINKEL

Institute of Forestry Economics, University of Freiburg, Tennenbacherstrasse 4, D-79104 Freiburg, Germany

*Summary*

This study is based on a literature review of comparative economic analyses of even-aged and uneven-aged forests, mainly in the European context. An initial hypothesis is formulated that silver fir/Norway spruce 'Plenterwald'-type of uneven-aged forests yield higher financial outputs (net revenues) than similar even-aged forests under similar site conditions. A model study is described which avoids the weaknesses in the investigations reviewed in the literature. The results of the model study show that the initial hypothesis cannot be upheld. Assuming the same timber quality, the most favourable variants of the even-aged and uneven-aged systems yielded almost the same net revenues. The calculation of capital charges on the growing stock alters these results. The most important influence on the results in the even-aged model is the level of risk. The main difficulties in comparing the economics of even-aged and uneven-aged forests are discussed.

## Introduction and study objective

For many years, a problem for forest managers and scientists has been how to compare, in an objective way, the economics of even-aged and uneven-aged silvicultural systems. The question is again being raised in Germany because of the movement towards 'close-to-nature' forestry, and similar trends are emerging elsewhere throughout Europe (Duchiron, 2000). The uneven-aged forest is considered to be an attractive goal for many different reasons. The type of uneven-aged forest used in this study is the single-tree selection system referred to in German and Swiss literature as 'Plenterwald'. It is the most renowned form of uneven-aged forest in Europe and is usually dominated by European silver fir (*Abies alba*, Mill.) and Norway spruce (*Picea abies*).

The objective of the present study was to compare the market economics of uneven-aged and even-aged silvicultural systems. Two possible ways to investigate such a problem seemed to be appropriate:

1 An empirical investigation that compares the output of a forest unit managed with an uneven-aged system with one that is managed using an even-aged system. Both should be comparable in terms of species and site conditions, and the area surveyed should be large

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20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 474



enough and the duration of the management period should be long enough to yield adequate results.

2 A study using modelling to compare each of the management systems using a known set of parameters and assumptions.

The economic performance of uneven-aged forests has often been subjected to an analysis in the Anglo-American literature (e.g. Hall, 1983; Nautiyal, 1983; Haight, 1985; Bare and Oppalach, 1988; Buongiorno *et al*., 1994; Chang, 1981). However, the comparison of the two management systems, even-aged and uneven-aged, usually leads to controversial discussion. Chang (1981), for example, shows that a lower interest rate favours even-aged management.

The European literature comparing economic productivity of uneven-aged to even-aged forests is so extensive that this type of comparative study can almost be allocated a separate subdiscipline of applied forest economics. The results of these studies are unambiguous. As far as economic productivity is concerned, the superiority of uneven-aged forests, represented by the Norway spruce/silver fir-dominated 'Plenterwald'-type seems to be definite. Almost every study in the period from the beginning of the 20th century until very recently – regardless of whether an empirical or a model-oriented approach was chosen – shows that uneven-aged forests yield higher net revenues than comparable even-aged forests (Balsiger, 1925; Flury, 1927; Ammon, 1951; Mitscherlich, 1952; Mayer, 1968; Roches, 1970; Siegmund, 1973; Schütz, 1981; Leibundgut, 1983; Schulz, 1993; Knoke, 1998; Mohr and Schori, 1999; Hanewinkel, 2001). The reasons for this superiority in the studies are:

- a higher percentage of stemwood (all cited authors);
- a higher percentage of large timber (all cited authors);
- a higher timber quality (Knoke, 1998; Hanewinkel, 2001);
- lower risk (Mayer, 1968; Hanewinkel, 2001);
- lower costs for harvesting (Roches, 1970; Leibundgut, 1983);
- lower costs for planting (Mayer, 1968; Siegmund, 1973; Leibundgut, 1975, 1983; Mohr and Schori, 1999);
- lower costs for young growth tending (Leibundgut, 1975, 1983; Mohr and Schori, 1999).

Very few of these studies were explicitly designed with an economic focus and they were often performed by growth and yield scientists or silviculturists and not by economists. An overview of some of these studies is presented by Duchiron (2000) and Schütz (1997). The economic advantage of the uneven-aged forest differs depending on the management system with which it is compared. A small difference was detected when the uneven-aged system ('Plenterwald') was compared with a 'femel' system, a silvicultural strategy with long regeneration periods and elements of shelterwood and group selection system that has, at least temporarily, uneven-aged phases (Mohr and Schori, 1999). However, the operating profit (defined as revenues minus expenses) of the uneven-aged forest was 200 per cent higher when compared with that of a short rotation even-aged system (Mayer, 1968). The most significant difference was found in a study where two selection forests with high proportions of valuable timber were compared with neighbouring (even-aged) forests and the operating profit of the former was 500 per cent higher (Hanewinkel, 2001).

Based on the results of the reviewed studies, the following initial hypothesis seems to be justified: that under similar site conditions uneven-aged forests of a silver fir/Norway spruce 'Plenterwald' type yield higher financial results (net revenues) than comparable even-aged forests. The following study was carried out to investigate whether this hypothesis could be upheld.

## Methods and results

The literature review reveals that there is no reliable way to test the initial hypothesis exclusively with an empirical study. It is unlikely that two forest enterprises are so similar that differences in economic indices detectable by a scientific investigation can realistically be assigned to the different management systems. Therefore, a modelling approach was used to test the hypothesis, based on the results of an empirical investigation of uneven-aged forests, including the main factors influencing economic results (such as risk

20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 475



and timber price) and using the latest growth and yield models for both types of management (Hanewinkel and Pretzsch, 2000). The objective of the modelling was to examine the economic potential of working circles of even-aged forests and uneven-aged forests under a very broad range of conditions.

The primary economic target variable for the investigation was the operating profit of working circles of an uneven-aged forest model and an even-aged model in a steady state. Two variants for each management system were investigated: a favourable one that could be used as an upper benchmark (known as the *upper variant* for the uneven-aged system and *normal forest* for the even-aged system), and an unfavourable one as a lower benchmark (known as the *lower variant* for the uneven-aged system and *risk variant* for the even-aged system). This was done using the marginal or contribution costing technique (see Möhring, 1986). Thereby the revenue for timber net of: (1) harvesting costs, (2) variable administration costs (planting, young growth tending and pruning) and (3) fixed administration costs for road maintenance, forest protection and personnel, was calculated stepwise and defined as the contribution margin. Contribution margin I (CM I) is defined as the gross revenue for timber net of harvesting costs. Contribution margin II (CM II) is defined as CM I minus the variable administration costs (for planting and young growth tending). Contribution margin III (CM III) is CM II minus the fixed administration costs (forest protection, road maintenance, personnel, etc.). In this investigation CM III is the operating profit. The calculation was based on actual costs and local data for labour productivity. In addition to that, capital charges (interest cost) on the value of the average growing stock at an interest rate of 2 per cent were calculated and subtracted from the calculated operating profit. This final result of the calculation was defined as contribution margin IV (CM IV). Based on the results of this model study, the principal possibilities and limitations of comparing even-aged and uneven-aged management systems from an economic point of view were discussed.

### *The uneven-aged forest model*

The basis for the construction of the uneven-aged forest model was an empirical investigation of forest enterprises dominated by uneven-aged silver fir/Norway spruce 'Plenterwald' type forest in the central Black Forest (Hanewinkel, 1998, 2001; Hanewinkel and Oesten, 1998). The combined results of this study, shown in Table 1, cover a wide range of economically important

*Table 1*: Calculation basis for the uneven-aged forest models (after Hanewinkel, 2001, modified)

| | Variants | |
|---|---|---|
| Indices | Upper | Lower |
| % of risk-induced harvesting | 10 | 30 |
| % of stem-wood | 92 | 85 |
| %-of A/B/C/D – Quality† | 20/70/10/– | –/75/20/5 |
| dmid of quality class A/B/C/D‡ | 58/45/45/– | –/38/35/45 |
| Standing volume $m^3$/ha | 400 | 340 |
| % of plantation* | 0.1 | 0.7 |
| Plants per ha* | 1 | 7 |
| % preparation of plantation* | – | 4 |
| % young growth tending* | 1.25 | 2.5 |
| % of pruning* | 1 | – |
| Trees per ha pruned | 4 | – |
| % forest protection* | – | 10 |

* Refers to the total forested area (per year).
† Quality classes for stem-wood: A = excellent quality without defects; B = normal quality with small defects; C = with defects but fully utilizable; D = heavy defects.
‡ $d_{mid}$ = mid-diameter (diameter in the middle of the stem section) for quality classes A–D (cm).

20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 476



indices in uneven-aged forests on sites of medium productivity. The two variants in Table 1 represent the range of these economic indices. The upper variant is characterized by a low percentage of risk-induced harvesting, a high percentage of stem-wood, very high timber quality, a high proportion of large timber and small areas for planting and young growth tending. To achieve the high timber quality, 1 per cent of the total forested area has to be pruned each year. The lower variant shows less favourable indices than the upper one.

In order to generalize these results, a steady state model after Prodan (1949) modified after Schütz (1975) was constructed. This model is similar to a matrix model and its output produces results as close as possible to those of the empirical investigation shown in Table 1. The first input parameter for the model is the diameter increment per diameter class determined by Prodan (1949) for uneven-aged forests of medium site productivity (site index III, Prodan 1949). The lower variant is characterized by a rather low percentage of large timber (>50 cm d.b.h.). For the upper variant, where the percentage of large timber is distinctly higher, the diameter increment was reduced to depict the higher competition according to the results of Mitscherlich (1952) and Spiecker (1986). The second input parameter for the model is the harvesting rate. The harvesting rate $e_i$ (percentage of trees harvested in each diameter class $i$ within the cutting cycle) was fixed according to the prescriptions of the two variants in Table 1 with a cutting cycle of 10 years.

The diameter increment was converted into an outgrowth rate $p_i$ (percentage of trees of the diameter class $i$ that grow to another diameter class within the cutting cycle) by dividing it by the width of the diameter classes (4 cm). Starting with an initial value for the number of stems ($n_i$) of the smallest diameter class (8–12 cm, average 10 cm), the diameter distribution of both variants was constructed following equation (1) after Schütz (1975):

$$n_{i+1} = n_i \times \frac{p_i}{p_{i+1} + e_{i+1}} \qquad (1)$$

The volume increment was calculated based on the sum of harvested volume and was controlled with the third steady state condition after Schütz (1975) depicted in equation (2):

$$\Sigma e_i \times n_i \times t_i = \Sigma p_i \times n_i \times \Delta t_i \qquad (2)$$

where: $t_i$ = tariff value of diameter class $i$ (selection forest tariff III after Prodan, 1949) and $\Delta t_i$ = difference of tariff of two consecutive diameter classes.

Thus, the sum of the harvested volume (left side of equation (2)) was adapted to the volume increment (right side of equation (2)). According to this steady state model, the upper variant has a higher growing stock (400 $m^3$ $ha^{-1}$ compared with 340 $m^3$ $ha^{-1}$, see Table 1), a higher percentage of large timber (more than 50 per cent of the growing stock in diameter classes larger than 50 cm), but a lower volume increment (8.4 $m^3$ $ha^{-1}$ $a^{-1}$ compared with 9.4 $m^3$ ha $a^{-1}$, see Table 2) than the lower variant. The maximum diameter of the upper variant is 86 cm and for the lower variant it is 74 cm. For the selection forest model, motormanual harvesting was assumed. The variable administration costs (see Table 2) were calculated based on the indices for planting, young growth tending and pruning in Table 1.

### *The even-aged forest model*

A working circle of an even-aged forest is usually depicted using a model of a 'normal forest' (totally regulated forest). In order to integrate a risk scenario into the calculation, this standard model was modified to a 'target forest' model after Suzuki (1971). This model is characterized by a right-skewed age class distribution and a decreasing degree of density with higher age classes. Decreasing degree of density and modified age class distribution are due to the influence of risk. Specific transition probabilities lead to a loss of age class area with increasing age of the forest stands.

The growth and yield basis of both of the even-aged forest variants were simulation runs for a pure stand of Norway spruce with the distance-dependent growth simulator SILVA 2.1 (Hanewinkel and Pretzsch, 2000). The simulations were executed for a site comparable with that used for the selection forest model, i.e. sandy-loamy plain sites of the northwest Black Forest with medium soil humidity and a medium site index. It started at age 30 and ended after 22 periods of 5 years at age 140. The silvicultural

20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 477



*Table 2*: Contribution margins and operating profits of uneven-aged and even-aged forest variants based on a model study (after Hanewinkel 1998, modified)

| Management system | Uneven-aged forest | | | | Even-aged forest | | | |
|---|---|---|---|---|---|---|---|---|
| Variant | Upper | | Lower | | Normal forest | | Risk variant | |
| Annual cut ($m^3$/ha) | 8.4 | | 9.4 | | 9.3 | | 6.5 | |
| | €/ha | €/$m^3$ | €/ha | €/$m^3$ | €/ha | €/$m^3$ | €/ha | €/$m^3$ |
| Gross revenue | 800.7 | 94.9 | 591.6 | 63.8 | 798.6 | 85.9 | 398.3 | 61.3 |
| Harvesting costs | 162.6 | 19.2 | 199.4 | 21.5 | 175.4 | 18.9 | 130.4 | 20.0 |
| **Contribution margin I** | **638.1** | **75.7** | **392.2** | **42.4** | **623.3** | **67.0** | **267.9** | **41.4** |
| Variable administration costs | | | | | | | | |
| Planting | 0.9 | 0.1 | 16.8 | 1.8 | 8.9 | 1.0 | 16.8 | 2.6 |
| Young growth tending/pruning | 23.6 | 2.8 | 12.9 | 1.4 | 16.6 | 1.8 | 8.8 | 1.4 |
| Sum | 24.5 | 2.9 | 29.7 | 3.2 | 25.6 | 2.8 | 25.6 | 4.0 |
| **Contribution margin II** | **613.6** | **72.6** | **362.5** | **39.4** | **597.7** | **64.4** | **242.4** | **37.3** |
| Fixed administration costs | | | | | | | | |
| Forest protection, roads, etc. | 189.2 | 22.5 | 189.2 | 19.9 | 189.2 | 20.5 | 189.2 | 29.1 |
| **Contribution margin III** | | | | | | | | |
| (= operating profit) | **424.4** | **50.1** | **173.3** | **19.4** | **408.5** | **44.0** | **53.2** | **8.2** |
| Capital charges (i = 2%) | 376.9 | 44.9 | 206.5 | 22.0 | 388.3 | 41.8 | 193.2 | 29.7 |
| **Contribution margin IV** | **47.5** | **5.2** | **−33.2** | **−2.6** | **20.2** | **2.2** | **−140** | **−21.5** |

i = interest rate.

treatment previewed selective thinning at the beginning and target diameter harvest at the end of the simulation (elements of a modern treatment of conifers in central Europe). The guideline for the thinning prescriptions was basal area (for a more detailed description of such a thinning regime, see Hanewinkel and Pretzsch, 2000). If the results of the simulation runs that are produced by the simulator as a time series are interpreted as a spatial side-by-side of stands of different ages, a normal forest model can be constructed. This normal forest is the basis of a 'risk variant' that was developed in the following way. In order to match the risk percentage of the 'lower variant' of the selection forest model, a linear decline in the basal area from the beginning of the simulation run at age 30 until the end of the thinning period at age 65 was assumed, which leads to a decrease in the degree of density of around 30 per cent at the beginning of the regeneration period (at age 95).

In addition, the influence of risk leads to a shift of the age class distribution in favour of the young age classes and at the expense of the old age classes. Taking into account the results of Riedl (1978), who investigated the transition behaviour of coniferous working circles in the Black Forest area, the even-age class distribution of the normal forest was modified to a risk variant using transition probabilities for the different age classes. This was done by iteratively calculating the 'eigenvalue' $a_0$ of a transition matrix $p$ according to equations (3) and (4).

$$a = (a1; a2 \ldots, a7); p = \begin{pmatrix} p1.1 & p1.2 & 0 & 0 & 0 & 0 & 0 \\ p2.1 & 0 & p2.3 & 0 & 0 & 0 & 0 \\ p3.1 & 0 & 0 & p3.4 & 0 & 0 & 0 \\ p4.1 & 0 & 0 & 0 & p4.5 & 0 & 0 \\ p5.1 & 0 & 0 & 0 & 0 & p5.6 & 0 \\ p6.1 & 0 & 0 & 0 & 0 & 0 & p6.7 \\ p7.1 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \quad (3); \quad (4)$$

where: $\sum a = 140$ and

$p1.2 = 0.99$, $p2.3 = 0.97$, $p3.4 = 0.93$, $p4.5 = 0.92$, $p5.6 = 0.85$, $p6.7 = 0.7$, $p7.1 = 1.0$

The iteration was calculated with a starting value $a_i = 20$ for the age classes 1 to 7 and repeated insertion of the results into the matrix, while the sum of the squared deviations was minimized. The eigenvalue of the transition matrix that gives us the steady state age class distribution

20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 478



of the 'risk variant' encompasses the following values for $a_i$:

$$a_0 = (23.92, 23.68, 22.97, 21.36, 19.66, 16.71, 11.69)$$

These values yield the areas of the age classes of the risk-variant model leading to a right-skewed age class distribution of the risk variant. The age classes I to IV (0 to 80 years) have larger areas than the normal forest while the age classes V to VII (80 to 140 years) have less area than the basic model of the normal forest, which assumes a constant area of 20 ha for each age class.

According to the uneven-aged forest model, timber quality varies from the normal forest (high quality as in the upper variant of the uneven-aged forest model shown in Table 1) to the risk variant (timber quality is equal to the lower variant). Planting activities in the even-aged model were restricted due to the long regeneration period (beginning at age 95) that allows natural regeneration. It was assumed that only the area of the final cutting at the end of the simulation at age 140, which fixes the rotation time, had to be replanted. For the risk variant, the areas that are lost due to risk have to be replanted additionally. Young growth tending takes place twice, at the age of 10 and 20 years. Pruning is only done in the normal-forest model. Fully mechanized harvesting was assumed until simulation period 6 (age 60). Costs and labour productivities for planting and young growth tending are equal to those in the uneven-aged models.

Results of the comparison of both of the variants for each management system (Table 2) showed that the operating profit (CM III) per hectare was very similar for the two systems. Thus, the initial hypothesis that under similar site conditions uneven-aged forests yield higher financial results (net revenues) than comparable even-aged forests could not be entirely upheld. The small difference of less than 5 per cent of the operating profit between the two favourable variants indicated that the management system was obviously not the decisive factor for the financial output of the models. Timber quality and influence of risk seemed to be far more important. The different financial results of the two uneven-aged and even-aged forest variants were – besides the difference in timber quality – mainly due to the different assumed percentages of risk-induced harvesting which led to a higher harvesting rate in the small- and medium-sized timber classes in the risk variants (in both systems). In the 'risk variant' of the even-aged forest model, a distinct decrease in volume productivity was detected, which led to a much lower annual cut. Due to the risk-induced shift in the age class distribution, the forest areas with the highest volume and the highest economic productivity were systematically diminished in favour of areas with no or very low volume and low productivity. Comparing the harvesting costs per cubic metre it was apparent that all the models operated within a very narrow range. The higher diameter of the harvested volume in the uneven-aged forests (one of the main arguments for the superiority of selection forests compared with even-aged forests in the literature) was negated by the effects of mechanization of the harvesting in the even-aged systems. However, taking into account the substantial capital charges (interest cost) on the standing volume, due to the long rotation in the even-aged forest models (140 years) and the high standing volume in uneven-aged forests (340–400 $m^3$ $ha^{-1}$), the relative difference between the management regimes increased. The capital fixed in the even-aged model was higher than that in the uneven-aged system and thus produced higher interest costs. The absolute difference between the variants of the different regimes was reduced due to the lower timber quality of the unfavourable variants. These variants (the 'lower' variant of the uneven-aged model and the 'risk variant' of the even-aged model) produced negative results for the CM IV (operating profit minus capital charges), as the capital charges at an interest of 2 per cent cancelled out the operating profits (CM III).

## Discussion

### *Limitations of the reviewed literature*

The general conditions for empirical investigations comparing uneven-aged forests with even-aged forests from an economic point of view are not favourable. The actual amount of empirical data available for such studies, particularly long-term information at the regional level, is small. For the Federal Republic of Germany, one

20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 479



explanation could be that there are almost no forest regions operating the uneven-aged silvicultural system on a large enough scale. Even in Switzerland where uneven-aged silviculture has a very long tradition, the area of the classical 'Plenterwald' does not exceed 8 per cent (Schütz, 1997).

The problems with empirical studies reflect this situation; either forests that are completely different are compared (Flury, 1927) or trial plots that are too small to deliver reliable economic indices (Mitscherlich, 1952) are analysed. Another flawed approach is to compare well-known sites of uneven-aged forestry with extremely high proportions of valuable timber to average even-aged forests (Hanewinkel, 2001). In some studies only cost units of less importance, such as young growth tending or planting, are investigated (Leibundgut, 1975, 1983). Due to problems of site variation, it is usually extremely difficult to find two forest units that are comparable in such a way that the differences in operational results can be attributed to the management system.

The model studies in the literature show similar weaknesses. Most of them do not include any notion of risk (e.g. Siegmund, 1973). In some, assumptions are made that are not empirically based and which partly discriminate against one of the systems investigated (Mayer, 1968). A very common type of comparative model study compares a locally based uneven-aged forest model (sometimes directly based on empirical results) with a yield table of an even-aged system (Ammon, 1951; Roches, 1970; Siegmund, 1973; Schütz, 1981). Using a growth and yield model as a basis for an economic modelling implies that both the uneven-aged model and the even-aged yield table represent the economic goals of a potential decision-maker. This might be the case for the model based on an uneven-aged forest that is managed following a control method which includes economic goals such as 'maximum value increment ' (Biolley, 1920); however, the even-aged yield table, generally used in combination with the 'normal forest' model to estimate sustainable timber production on a forest unit level, is originally an explanatory model that illustrates the coherence between growth and yield and growing stock for a specific tree species under given site conditions and treatments. Such an explanatory model cannot automatically be transferred into an economic decision model merely by including prices and costs without adapting the underlying treatment to actual ideas of sound economic management.

Another disadvantage of such a model approach is that usually only one uneven-aged forest model, typically that of a 'Plenterwald', is compared with one even-aged forest model (Ammon, 1951; Schütz, 1981). The two models are usually chosen in such a way that they yield the same volume productivity. On a given site, an almost infinite number of possible steady states for uneven-aged forests is just as possible as a large number of treatments of an even-aged forest. Picking out only one of each without stating the economic arguments for their choice is an arbitrary approach. A true economic investigation would imply that an economic rationale is chosen first, which is the subject of the comparison. Then the two models should be optimized for the chosen rationale and the results compared. The framework conditions for the analysis and the assumptions that have to be made (e.g. concerning timber quality, risk, etc.) should be configured in such a way that none of the systems to be compared has an unfair advantage. This usually requires a *ceteris paribus* approach (Johansson and Löfgren, 1985). For the present study, this means that a variable (e.g. timber quality or risk) for which a difference between the two systems cannot empirically be proved is assumed to be identical for both models in the comparison. A sensitivity analysis can help to determine which of the systems reacts most when the important influencing factors are varied.

### *Limitations of model studies: the problem of optimization*

Ample research has been done on the optimization of different aspects of even-aged and uneven-aged management. Important parameters for uneven-aged stands are the desired target distribution (Schulte and Buongiorno, 1998), the optimal equilibrium stand structure (Haight *et al.*, 1985), the cutting cycle and the residual stock (Buongiorno and Lu, 1990), and the species composition (Bare and Oppalach, 1988). For the even-aged model, the importance of the optimal thinning regime and rotation time is well known

20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 480



(e.g. Kao and Brodie, 1980). However, when comparing two different management systems, optimization may be problematic. Looking at the results of this model study, it can be seen that the 'upper' uneven-aged forest variant has a lower annual cut than the even-aged 'normal forest' model. For the present investigation this may be acceptable, as the difference between the two models amounts to 10 per cent, which could be within a tolerance margin. As this difference grows, e.g. if other economic arguments are chosen, care is required not to include hidden assumptions in the analysis which discriminate against one management system in favour of the other. For example, such an assumption could be that one of the systems has a higher volume productivity than the other, an assumption that cannot be empirically proved (Kern, 1966).

## Conclusion

Based on the findings of the present study, which reveal fundamental difficulties in comparing even-aged and uneven-aged management systems from an economic point of view, it seems most unlikely that even technical improvements of model studies or new empirical studies with a broader database can lead to critical improvements in such comparative economic studies. A suggestion on how the results of economic studies – either empirical or model-based – can be used to contribute to the evaluation of different management systems is made by Hanewinkel (2001). Here, a benchmarking approach is proposed instead of using arbitrary comparisons. Benchmarking is a process used to reveal best practices in business operations. Applying it to the problem of finding the best management system in forestry would require that we have to look for typical forest enterprises practising even-aged or uneven-aged management that deliver the maximum economic output of all forest enterprises that have been investigated so far. The absolute amount of the maximum under given production conditions (site index, species composition and so on) is then an indication of the economic productivity of the management system. This approach would partly avoid the main disadvantages of the empirical investigations (flawed comparability) as well as of the model studies (unfair assumptions).

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20 Hanewinkel (jr/d) 8/30/02 8:55 AM Page 481



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