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On the effect of volatile stumpage prices on the economic attractiveness of a silvicultural transformation strategy

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Abstract

This paper evaluates the economic attractiveness of a silvicultural transformation strategy, focussing on risk, as a result of the volatility of stumpage prices.

Based on a situation of a 58-year-old spruce stand (Picea abies (L.) Karst.), which actually can be found near Freising (Upper Bavaria, Germany), a growth model (SILVA 2.2) was used to project the stand development. Growth simulations were conducted for a specific transformation strategy, from regular to irregular age structure on the one hand and for a conservative silvicultural strategy (thinning, clear-cut, reforestation), on the other hand.

The transformation strategy was aimed at achieving an uneven-aged stand structure. It was based on early initiation, small-scale regeneration cuts carried out frequently and periodically. The harvests were, therefore, more evenly distributed over the analysed time period. Unlike transformation, even-aged silviculture consisted of relatively strong thinning up to age 68, followed by weak or no interventions up to age 98, the rotation age, aiming to maximise mean value increment. Both strategies were modelled over a time period of 198 years.

Based on the growth data, a Monte Carlo Model was used to estimate the financial results of both strategies. The stumpage price was assumed as a random variable with a probability density which follows a normal distribution. From the results of 1000 simulations for each strategy, distributions of the net present value (NPV) were calculated. Due to the complexity of the growth model SILVA, the calculations, being valid not for a forest enterprise but for one single stand, were restricted so that the time for every intervention was fixed, regardless of the stumpage price.

Since the revenues produced by transformation were more evenly distributed over time than those achieved by the conservative even-aged strategy, the latter was far more influenced by very low or very high prices at the time of the clear-cuts. This fact caused a much smaller variation of NPV of the transformation. Parallel to this result, the probability to produce a deficit (that is to achieve a negative NPV) was lower for the transformation.

The financial effect shown in this study in favour of transformation certainly compensates for a potentially higher risk of storm damage during the transformation treatment.

Keywords: volatility, deficit**,** uneven-aged silviculture, economics, continuous cover

1 Introduction

When different silvicultural management options are compared, unequal risks should be taken into account (Valsta 1998). The majority of comparative economic studies on silvicultural treatments in Central Europe ignore the uncertainty of future revenues. In decision-making this can only be justified, if compared alternatives are subject to more or less the same risk (Pflaumer 1992). However, the risks of different silvicultural treatments are presumably not identical and poor decisions might be derived from comparisons, which ignore risk.

While the possible variation in future stumpage price has traditionally not been considered in Central Europe (Sagl 1995), the implications of the wind-blow-risk have been investigated by several economic studies (Deegen, 1994, Dieter 1997, 1999, Bräunig and Dieter, 1999). Studies made for other countries admittedly showed the variation of future stumpage prices as an important source of risk. Brazee and Mendelsohn (1988), for example, adapted an asset sale model to forestry and derived a flexible price harvest policy, which increased the net present value (NPV) of expected returns. In line with Brazee and Mendelsohn, Haight (1990) developed optimal feedback thinning policies with volatile prices that resulted in significantly higher NPV. Teeter and Caulfield (1991) derived recommendations for thinning decisions by applying a stochastic price model, based on a first-order Markov process, which were different from those obtained with a deterministic price equivalent. Reed and Haight (1996) used a lognormal diffusion process to model the changes in stumpage price and computed extremely long right-hand tailed distributions of present value. In addition to the aspect of volatile future stumpage price Gong (1998) incorporated risk preferences into calculations.

These studies all aim at optimising one basic silviculture system, either even-aged (e-a) (Brazee and Mendelsohn, 1988, Teeter and Caulfield, 1991, Reed and Haight, 1996, Gong, 1998) or uneven-aged (u-a) (Haight 1990). The probably different effect of volatile stumpage price on the risk of unequal silvicultural strategies is not considered.

As the profitability of u-a silviculture is a frequently discussed topic in Central Europe (e.g., Ammon 1951, Mitscherlich 1952, 1961, 1963, Mayer 1968, Siegmund 1973, Leibundgut 1983, Schütz 1985, 1989, Schulz 1993, Hanewinkel 1998, Hanewinkel and Oesten 1998, Knoke 1999, Mohr and Schori 1999), this study compares the risk caused by volatile stumpage prices during a transformation treatment (an e-a stand is transformed into an u-a stand) with an e-a treatment.

Concretely, the following research question was investigated:

<u>Do distributions of NPV and probabilities of deficits differ between transformation and e-a treatment?</u>

2 Silvicultural treatment

Plusczyk (2000) as well as Knoke and Plusczyk (2000) described the considered silvicultural treatments. Both treatments, transformation and e-a silviculture, were applied to a spruce (<u>Picea abies</u> (L.) Karst.) dominated e-a stand and are considered for a time period of 198 years.

The stand being investigated by Knoke and Plusczyk (2000) belonged to the forest area of Bavarian State Forest Service in Freising (Upper Bavaria, Germany), where highly productive sites dominated (brown earths and loess soils). The stand was located within the growing area 12.8 (Oberbayerisches Tertiärhügelland) in which the natural forest cover should consist of oak (<u>Quercus robur</u> L.) and beech (<u>Fagus sylvatica</u> L.) (Foerst and Kreutzer 1978). However, the current forest cover was dominated by spruce. The mean annual precipitation of 814 mm and the mean annual temperature of 7.7 ^{o}C were representative for Bavaria. Assmann and

Franz's yield table (BMFAF 1990) predicted mean annual increment (age 100 years) of about 12 m^3 ha^{-1} yr^{-1} for the stand under investigation.

According to a concept developed by Abetz (1975), the e-a treatment (rotation 98 years) was based on relatively strong interventions up to age 58 and only light interventions in stands age 68 and above. This treatment is assumed to maximise the mean value increment within a certain period and it is seen as optimal in the production of valuable spruce timber in Germany (Strütt 1991). It generated more total revenue than the transformation, and 88 % of the whole revenue was earned at the end of rotation but not earlier (Knoke and Plusczyk 2000).

The transformation treatment started in a 41-year-old stand and it was based on continuous heavy interventions, which utilised virtually the whole current volume increment. Based on findings of Schütz (1999), who pointed out that a transformation process requires 60 to 80 years, the transformation period was limited to 77 years. As the applied growth model SILVA (Kahn and Pretzsch 1997), which comprises no regeneration model, is not able to project growth in u-a stands for long periods of time reliably, a steady state was assumed after the transformation period of 77 years. Revenues produced by this steady state were estimated basing on the study of Knoke (1998 a) (for details see Knoke and Plusczyk 2000).

3 Assessment of economic returns and risk

In order to quantify the profitability of both silvicultural treatments the NPV, which is the total of all anticipated future revenues and costs, discounted by an interest rate, was computed for the time of 198 years (equation 1).

$$J = \left(\sum_{t=41}^{198} R[v(t)] \frac{1}{(1+i)^n} \right) - PVoh \qquad (1)$$

where

J is the net present value

t is the stand age when a specific intervention takes place

$R[v(t)]$ is the net-revenue earned by a specific intervention, depending on species, volume harvested, log size and quality structure of timber cut at time t (regeneration costs are incorporated as negative net revenues) *i* is the real decimal interest rate

PVoh is the present value of overhead costs (explained in chapter 3.2)

Data for revenues and costs for every intervention (tab. 1) were used taken the study by Knoke and Plusczyk (2000).

3.1 Incorporation of volatility of stumpage prices

To obtain information on the distribution of NPV under uncertain future stumpage prices, the Monte Carlo Method was utilised. This means the distribution of NPV was determined through simulations and the expected NPV and its standard deviation were estimated by means of descriptive statistical methods (Pflaumer 1992).

To model stochastic price processes, information on the distribution of the stumpage prices in the past were needed. In order to obtain such information, data published by the Bavarian Ministry for Food, Agriculture and Forests (BMFAF 1954-1998) was analysed. The average stumpage prices per year, which were adjusted by price indices (with 1980-index as 100 %), for the most common spruce timber assorted log H4, ranged from a minimum of 74 to a maximum of 245 DM m^{-3} (1953 to 1998). According to a Shapiro-Wilk test (Schlotzhauer and Littell 1991) the stumpage prices (fig. 1) with mean 154.7 DM m^{-3} and standard deviation ± 41.8 DM m^{-3} were normally distributed. Consequently, the stochastic price process was modelled based on a normal distribution. Knoke and Plusczyk (2000) computed the revenue data used for the present study on the basis of a stumpage price of 160 DM m^{-3} for spruce timber (assorted log H4). Therefore, the mean of the applied normal distribution was fixed at this level. In line with the minimum and maximum stumpage price observed in the past the extremes of the distribution were fixed at 80 DM m^{-3} and 240 DM m^{-3}.

To simulate a stochastic price process, a random stumpage price for every intervention was drawn from the described normal distribution. The simulations were repeated 1000 times. Figure 2 exemplarily depicts the simulated price process for 5 simulations. To compute the revenues for every intervention an index (equation 2) was used, which was multiplied with the revenue printed in table 1:

$$i_{stump} = \frac{price_{sim}}{price_{\exp}} \qquad (2)$$

where

i_{stump}	is the index
$price_{sim}$	is the simulated stumpage price
$price_{exp}$	is the expected stumpage price (160 DM m^{-3})

The problem of correlation between stumpage prices of different years, which, for example, Valsta (1994) solved by using a first-order autoregressive model, was ignored in this study. As the time between two interventions in the study by Knoke and Plusczyk (2000) comprised normally 10 years (tab. 1), this proceeding can be justified. While a correlation between the timber prices of one year and the year before is obvious, the same cannot be said for the prices from that same year with those 10 years before. An analysis of the relation between the stumpage price and that stumpage price 10 years earlier, based on empirical data formed by 36 pairs of stumpage prices, yielded no significance and a measure of determination (R-square) of only 0.09.

The above-described procedure allowed the calculation of simulated distributions of NPV for both treatments. Those distributions were conceived as quasi-empirical probability density functions of NPV, which were used to compute probability distributions for the NPV.

3.2 Incorporation of overhead costs

To obtain realistic NPV for both treatments, costs other than logging-, skidding- and regeneration-costs should be integrated in the calculation. Those costs were assumed constant over time. Administrative (staff salaries, taxes, building costs, forest office costs) and forest-road costs were considered. The overhead costs observed within the Bavarian State Forest Administration varied between 286 DM ha^{-1} and 359 DM ha^{-1} in the years from 1990 to 1997 (BMFAF 1991-1998). However, efforts to reduce these costs are made by the Forest Administration. Sagl (1995) estimated about 200 DM ha^{-1} for overhead costs in Austria. Although past overhead costs (*oh*) in the Bavarian State Forest Administration were higher, those costs were optimistically assumed to amount to 240 DM ha^{-1} for the present study.

The present value (*PVoh*) for the overhead costs was computed according to equation 3:

$$PVoh = \frac{oh}{i}((1+i)^{198} - 1)\frac{1}{(1+i)^{198}} \qquad (3)$$

4 Results

4.1 The Variation in NPV due to volatility of stumpage prices

Basically, the analysis of variation in NPV proved that volatile timber prices are an important source of risk. As table 2 shows for e-a silviculture, with 3.5 % interest rate the standard deviation can amount to 243 % of the NPV particularly when small NPV were achieved.

By assuming an interest rate of only 1 %, figure 3 exemplarily shows the different simulated distributions of NPV for both treatments. E-a silviculture yielded values between 25,044 DM ha^{-1} and 93,594 DM ha^{-1}. The mean was 58,480 DM ha^{-1} with a standard deviation of ± 11,448 DM ha^{-1}. As the mean NPV of transformation amounted to 51,754 DM ha^{-1} (tab. 2), this treatment produced only 88 % of the NPV of e-a silviculture. The standard deviation of NPV produced by transformation admittedly amounted only to ± 4,571 DM ha^{-1}, which was just 40 % of that value computed for e-a silviculture.

By analysing the relative variation of NPV for transformation through setting the values computed for e-a silviculture to 100 %, figure 4 shows a lower variation of NPV for transformation with interest rates between 1 and 3.5 %. Due to this fact, the risk of transformation induced by volatile stumpage prices was generally lower than that of e-a silviculture.

As pointed out by Knoke and Plusczyk (2000), the relation of NPV between both treatments changed in favour of transformation when interest rate increased. Given an interest rate of 3.5 %, the NPV of transformation was more than three times as large as that of e-a silviculture (fig. 4). Even if the NPV for e-a silviculture exceeded that of transformation for interest rates smaller than 2 %, the lower variation of NPV compensate for this.

4.2 The probability of deficits

For interest rates smaller than 3 % the simulations resulted no negative NPV for either treatments.

Given an interest rate of 3 %, figure 5 depicts an example of curves, which describe the relative frequency sum for all NPV computed during 1000 simulation runs with volatile stumpage price. While all NPV for transformation were positive, e-a silviculture produced deficits (negative NPV) in about 5 % of the simulations. By viewing curves of relative frequency sums as probability distributions for possible NPV, a 5 % probability of deficit can be expected from e-a silviculture.

As an interest rate of just above 3.5 % was identified as the internal rate of return for e-a silviculture, the relative frequency of deficits increased to 35 % when an interest rate of 3.5 % was chosen (fig. 6). For this case, transformation also yielded deficits, but only in 6 % of the simulations, which is minor in comparison to the 35 % probability of deficit expected for e-a silviculture.

By increasing the interest rate to 4 %, the relative frequency sum for deficits in both treatments exceeded 50 % (fig. 7). While it is almost certain to obtain a deficit with e-a silviculture, for which the relative frequency sum of deficits amounted to 94 %, there is still a small chance to be profitable in transformation. In the latter case, a 64 % frequency of deficits was observed.

With regards to the aforementioned results, the question raised at the beginning of this paper

"Do distributions of NPV and probabilities of deficits differ between transformation and e-a treatment?"

can clearly be answered.

The simulated distributions of NPV differed not only by the arithmetic mean but, primarily, by the variation. While the mean NPV of transformation was exceeded by that of e-a silviculture for interest rates smaller than 2 %, the standard deviations of NPV were significantly smaller for the transformation in every case. Consequently, risk caused by volatile stumpage prices was considerably lower for transformation. Smaller variation within the distribution of transformation-NPV, and higher NPV of this treatment with interest rates above 2 %, yielded significantly lower probabilities for deficits.

5 Discussion and conclusions

By proving volatile stumpage prices as an important source of risk, the results of this paper coincide with those of other studies (for an overview see Brazee and Bulte 2000). Nonetheless, analyses of different silvicultural treatments, which consider the robustness of different management options under volatile stumpage prices, are scarce. Although volatile stumpage prices are an important source of risk, one should bear in mind that other important sources of risk do exist, for example, storm damage (e.g., König 1995, Dieter 1999), fire hazards (e.g. Reed and Apaloo 1991), or insect attacks. However, the financial effect shown in this study in favour of transformation certainly compensates for a potentially higher risk of storm damage during the transformation treatment.

The findings that lower risk and considerably lower probabilities of deficits occur in transformation require an explanation. By conducting a transformation, the total revenue is distributed continuously over time. Consequently, extremely low or high stumpage prices at the time of a certain intervention affect only this portion of the entire revenue. It is unlikely to experience either constantly low or constantly high stumpage prices at every intervention within the analysed time period. Therefore, during the whole time period, very high stumpage prices will compensate for very low stumpage prices. In contrast, when 88 % of the revenue is earned all at once, as occurs in e-a management, extreme stumpage prices will significantly affect NPV. It is because of this that it is concluded that continuity of revenues is effective in reducing risk of stand management.

The present study is, however, affected by two restrictions:

1) The times of interventions were fixed, regardless of the current stumpage price.
2) The results are valid only for stands or small-scale properties, not for a forest enterprise.

There is a technical reason for the first restriction. The growth model SILVA is able to project stand development for a minimum period of five years. Consequently, it was not possible to decide whether to harvest or not, depending on the stumpage price, individually for every year of the considered period. As it is common in forest practice in Germany, interventions were carried out every ten years during the simulated period, regardless of the stumpage price. Moreover, the complex transformation interventions could not be automated. They needed to be carried out manually, based on information of the spatial distribution and dbh relations between trees depicted in the plot, showing the local positions of the trees (Knoke and Plusczyk 2000). Every single tree, which was selected for harvesting, had to be labelled in a tree list. Furthermore, random components incorporated in the growth model SILVA, resulting in different stand development for every simulation, complicated the handling of the model (replications were necessary to obtain stable results). Due to both complex intervention and random stand development, even if it would have been possible to decide yearly whether to harvest or not, an enormous number of interventions had to be marked manually. Therefore, it was hardly possible to take into consideration a flexible stumpage price dependent harvest strategy.

Admittedly, a flexible harvest policy may change the results in favour of e-a silviculture, as long as this treatment itself is not subject to wind-blow damage or bark beetle attacks. In forest practice often, however, the time of intervention is determined for silvicultural purposes and, therefore, the restriction of a fixed time for every intervention, maybe, not too unrealistic.

The second restriction, which is that the results are valid for single stands or small-scale forest properties but not necessarily for big forest enterprises, reduces their importance only for few forest owners. In Germany 98 % of the forest enterprises manage on average only 4.2 hectares (AID 1995). However, additional studies focussing on risk and showing validity for whole forest enterprises should be carried out.

Commercial thinning will often improve NPV by yielding earlier revenue. This effect is intensively utilised when conducting a transformation. Periodic heavy crown thinning in even-aged single species stands (Knoke 1998 b) may yield similar effects as transformation with regards to volatile stumpage price. However, in e-a silviculture, once the stand has been clear-cut the continuity of revenues is interrupted. In contrast, transformation ensures perfect continuity of revenues. Consequently, this silvicultural strategy may be seen as well suited to reduce risk for a single stand induced by volatile timber prices.

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Table 1: Basic financial data used for calculations (DM ha^{-1}) obtained from Knoke and Plusczyk (2000)

	transformation				even-aged silviculture			
stand age (yrs)	**revenues**	**logging costs**	**net-reven.**	**regen. costs**	**revenues**	**logging costs**	**net reven.**	**regen. costs**
41	12,709	4,221	8,488	800	7,900	2,618	5,282	0
58	11,838	3,346	8,492	0	12,341	3,252	9,089	0
68	20,512	4,007	16,435	0	1,599	540	1,059	0
78	18,675	4,704	13,971	800	6,057	4,018	2,039	0
88	16,876	3,662	13,214	0	0	0	0	0
98	25,564	4,025	21,539	800	161,521	32,363	129,158	5,000
108	22,147	3,388	18,759	0	0	0	0	0
118	25,132	3,781	21,351	0	0	0	0	0
128	17,603	4,103	13,500	0	0	0	0	0
138	17,603	4,103	13,500	0	7,478	2,478	5,000	0
148	17,603	4,103	13,500	0	8,974	2,974	6,000	0
158	17,603	4,103	13,500	0	9,505	2,505	7,000	0
168	17,603	4,103	13,500	0	1,600	540	1,060	0
178	17,603	4,103	13,500	0	6,060	4,020	2,040	0
188	17,603	4,103	13,500	0	0	0	0	0
196	0	0	0	0	161,521	32,363	129,158	5,000
198	17,603	4,103	13,500	0	0	0	0	0

Table 2: Mean NPV and standard deviations for different interest rates (DM ha^{-1})

	transformation		even-aged silviculture	
interest rate (%)	**mean NPV**	**standard deviation**	**mean NPV**	**standard deviation**
1	51,754	± 4,571	58,480	± 11,448
1.5	28,539	± 2,995	30,292	± 6,809
2	15,673	± 2,065	15,595	± 4,184
2.5	8,303	± 1,479	7,573	± 2,619
3	3,965	± 1,091	3,046	± 1,663

3.5	1,358	± 822	442	± 1,074
4	-230	± 631	-1,064	± 709

Figure captions:

Fig. 1 Distribution of stumpage prices for the time period of 1953 until 1998 (adjusted prices, price index 1980=100%).

Fig. 2 Stochastic price processes for five simulation runs.

Fig. 3 Simulated distributions of NPV for an interest rate of 1 %.

Fig. 4 Mean NPV and standard deviations of transformation relative to the values computed for e-a silviculture (e-a silviculture=100 %) for different interest rates.

Fig. 5 Sum of relative frequencies of NPV formed by 1000 simulations based on stochastic prices for an interest rate of 3 %.

Fig. 6 Sum of relative frequencies of NPV formed by 1000 simulations based on stochastic prices for an interest rate of 3.5 %.

Fig. 7 Sum of relative frequencies of NPV formed by 1000 simulations based on stochastic prices for an interest rate of 4 %.

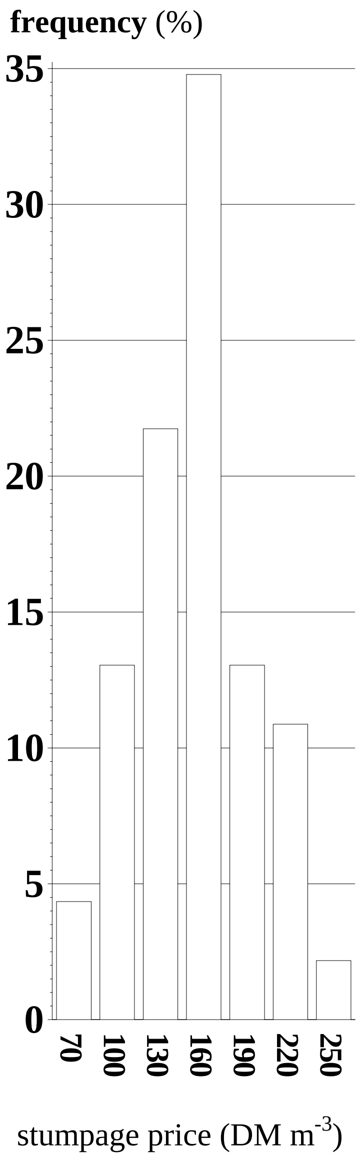


Fig. 1. Distribution of stumpage prices for the time period of 1953 until 1998 (adjusted prices, price index 1980=100%).

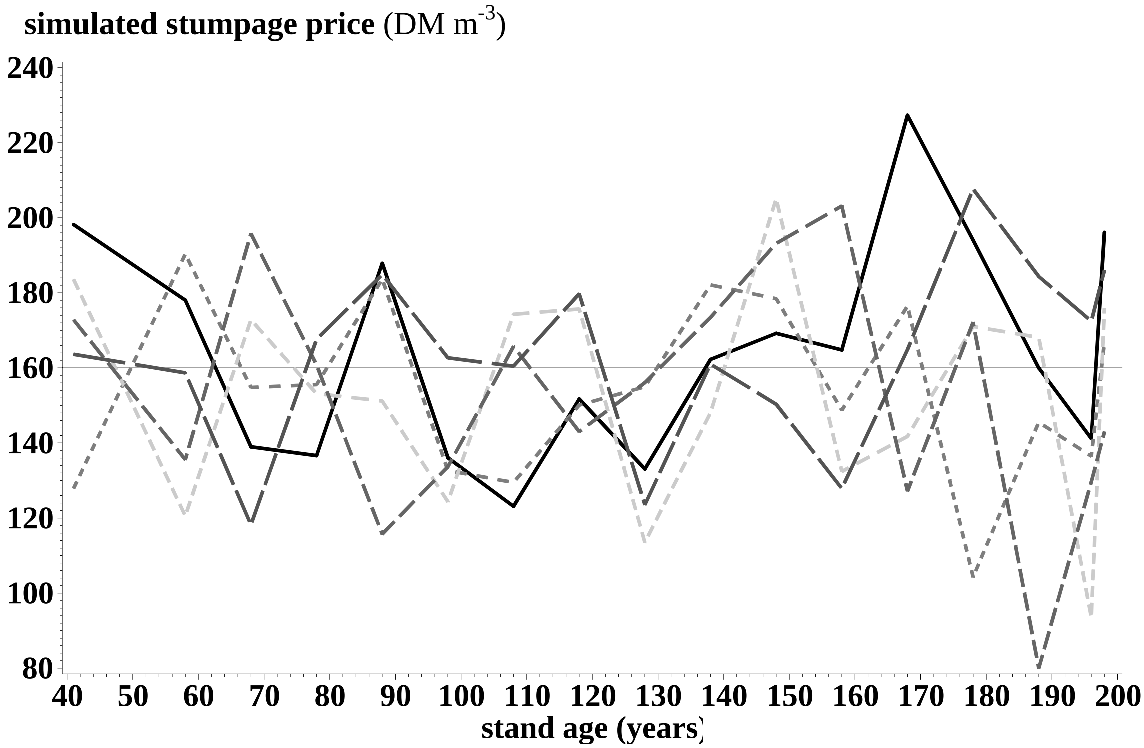
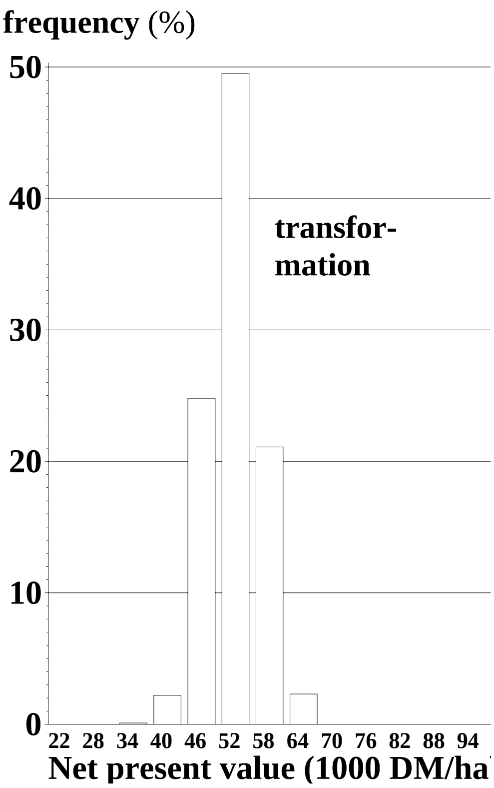


Fig. 2. Stochastic price processes for five simulation runs.


frequency (%)
50
40
30
20
10
0
transfor-
mation
22 28 34 40 46 52 58 64 70 76 82 88 94
Net present value (1000 DM/ha

frequency (%)

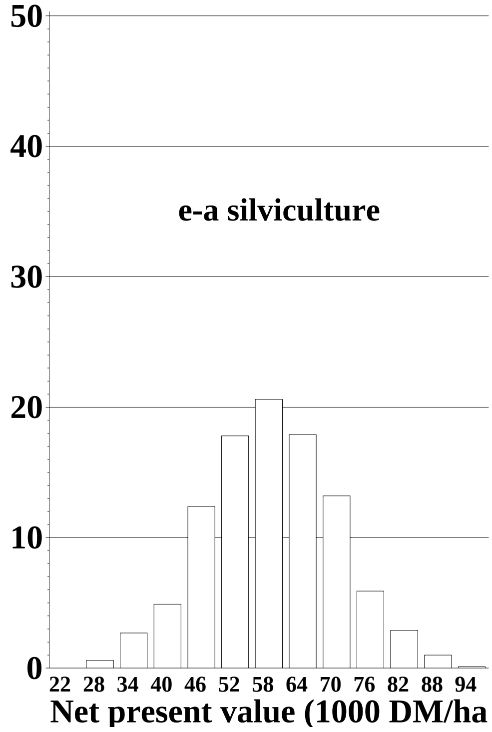


Fig. 3 Simulated distributions of NPV for an interest rate of 1 %.

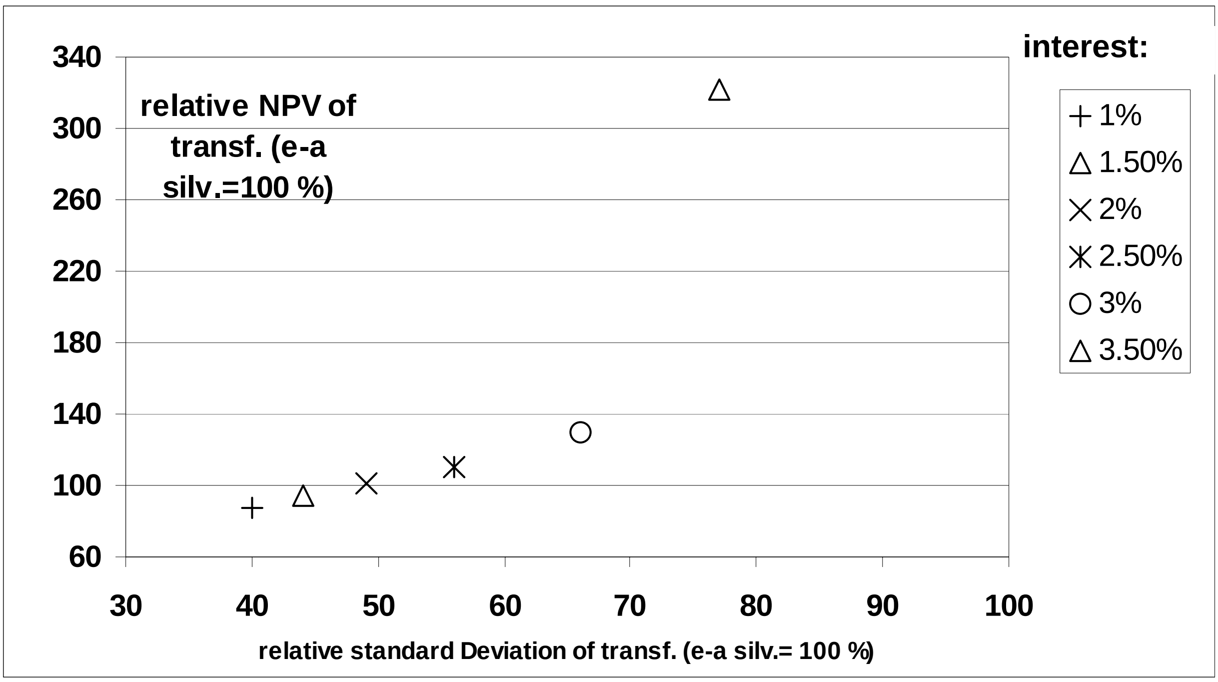


Fig. 4 Mean NPV and standard deviations of transformation relative to the values computed for e-a silviculture (e-a silviculture=100 %) for different interest rates.

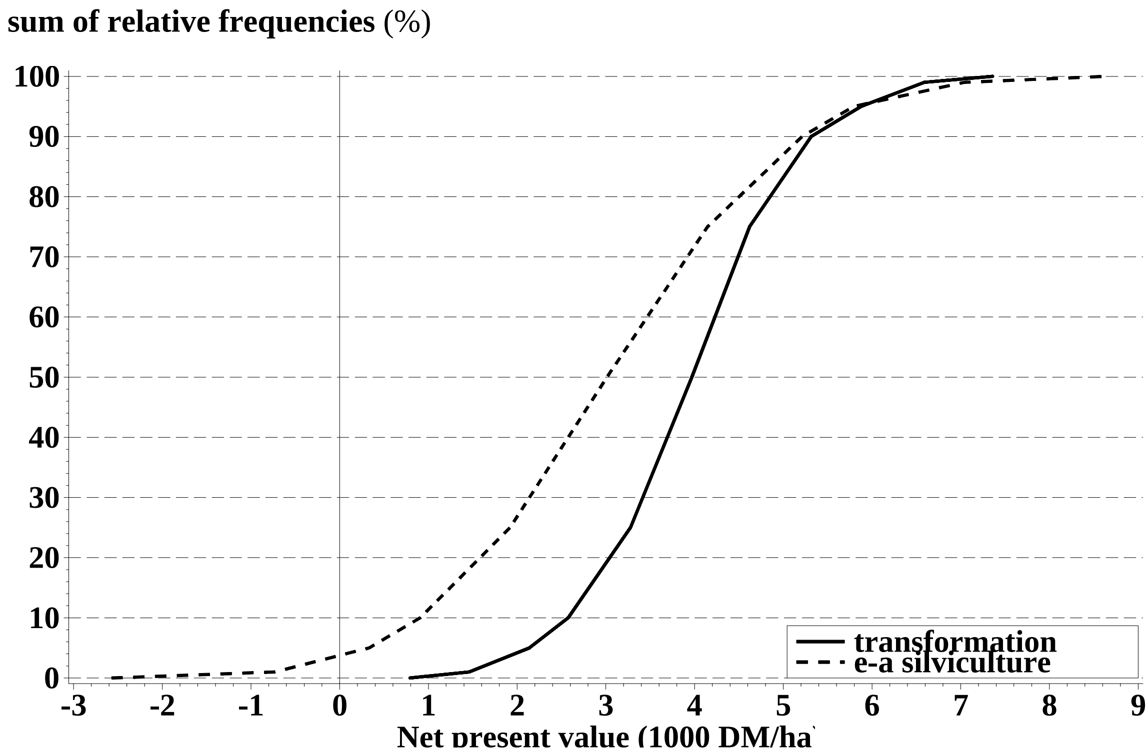


Fig. 5 Sum of relative frequencies of NPV formed by 1000 simulations based on stochastic prices for an interest rate of 3 %.

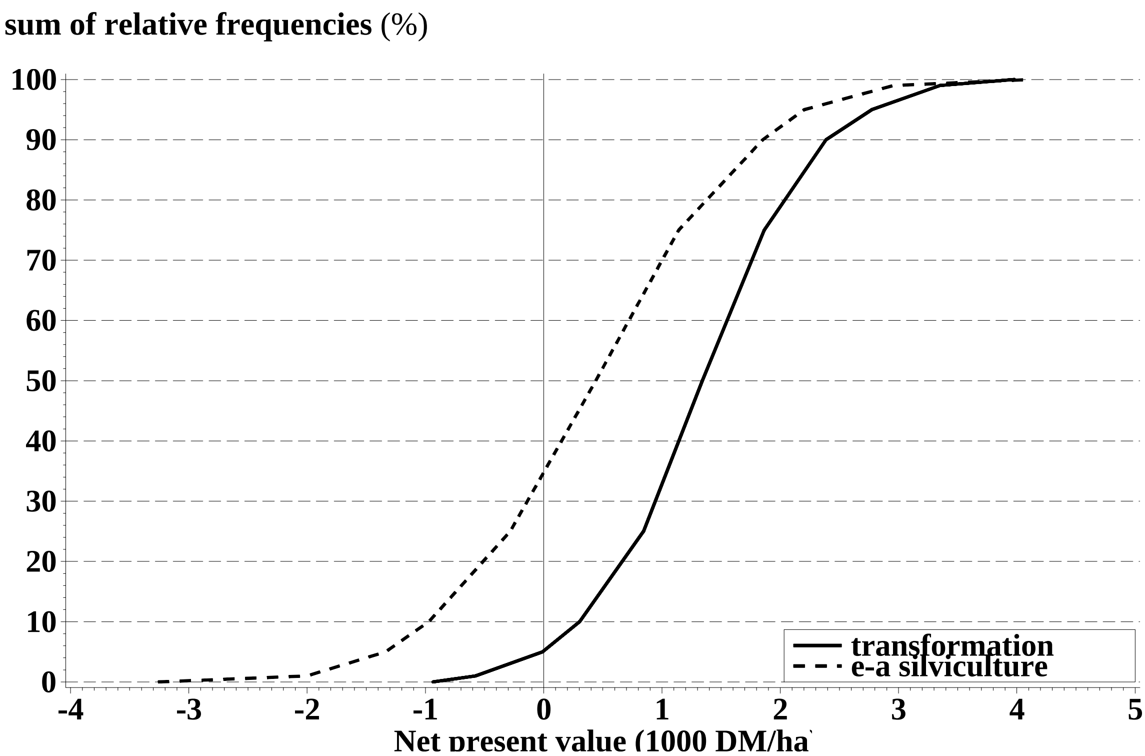


Fig. 6 Sum of relative frequencies of NPV formed by 1000 simulations based on stochastic prices for an interest rate of 3.5 %.

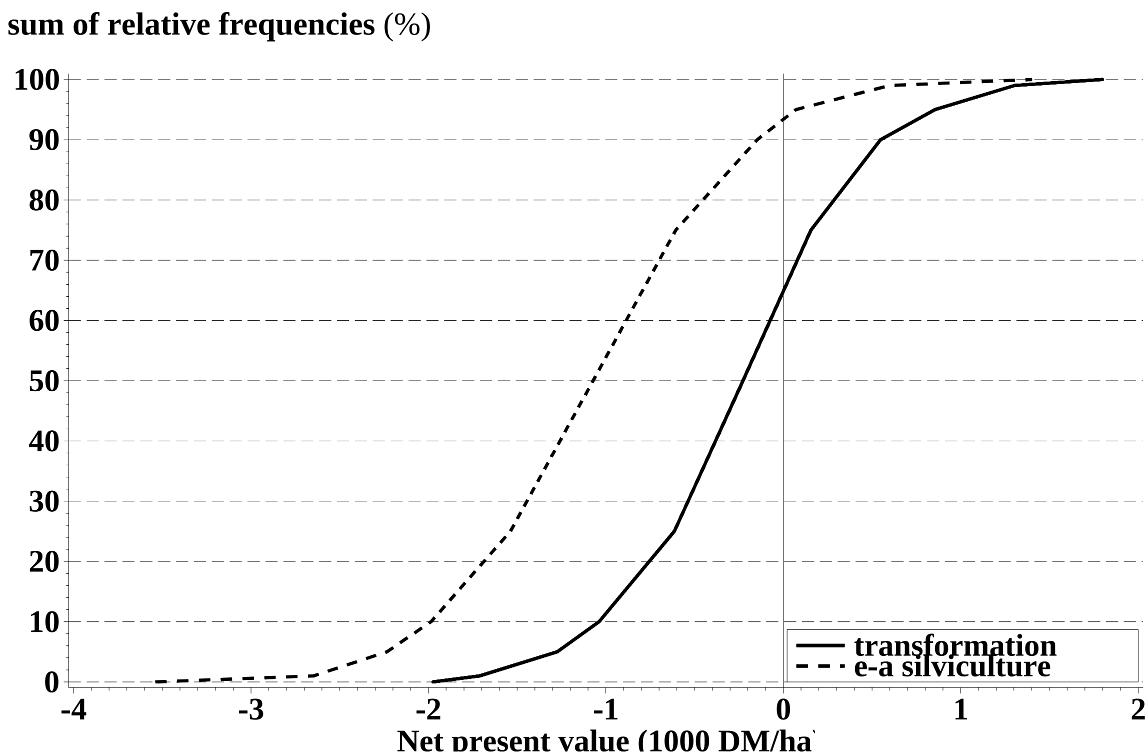


Fig. 7 Sum of relative frequencies of NPV formed by 1000 simulations based on stochastic prices for an interest rate of 4 %.