

Management of mixed-species forest:  
silviculture and economics

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5.4 Conversion of pure pine and spruce forests into  
mixed forests in eastern Germany: some aspects of  
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### **Abstract**

*Due to their condition which is far from a natural tree species composition and their instability, the forests of eastern Germany urgently need to be converted into stable mixed stands. This study reports on aspects of the silvicultural strategy that might be adopted in order to achieve such a forest conversion and includes descriptions of the natural regeneration processes as well as direct sowing techniques. These processes may provide a low energy and cost-effective means of forest conversion in eastern Germany, while also enhancing the multiple forest functions.*

Key words: pine, spruce, conversion, natural regeneration, reforestation, direct sowing

### **Actual situation and long-term silvicultural aims**

In eastern Germany the forest area accounts for almost 2.8 million hectares. Scots pine (*Pinus sylvestris*) is the most frequent tree species (53%), followed by Norway spruce (*Picea abies*, 20%). Coniferous trees constitute 76% of the overall stocking. Beech (*Fagus sylvatica*) and oak (*Quercus*) are the main broadleaved tree species, and represent only 13% of the woodland area. The forests in eastern Germany are mainly homogenous and scarcely vary in structure with pure coniferous stands comprising 47% of the forests (BFH 1993). Compared with the natural forest associations, mostly composed of beech-mixed forests, the stocking in eastern Germany appears to be far from that of a natural species composition.

In general terms, mixed or close-to-nature stands, ensure a higher degree of the fulfilment of forest functions as compared with pure crops (Hanstein 1967; Thomasius 1980; Altenkirch 1982; Currie 1989; Clough 1991). Thus conversion of pure pine and spruce stands into mixed forests is regarded by the Forest Services of the new Lands of the Federal Republic of Germany as one of their principal long-term silvicultural tasks (Hasselbach 1994).

### **Silvicultural strategies for the conversion of pine and spruce stands**

If the proportion of mixed stands is to be increased in the medium-term and is to be effective on a large scale, the silvicultural strategies for forest conversion must not

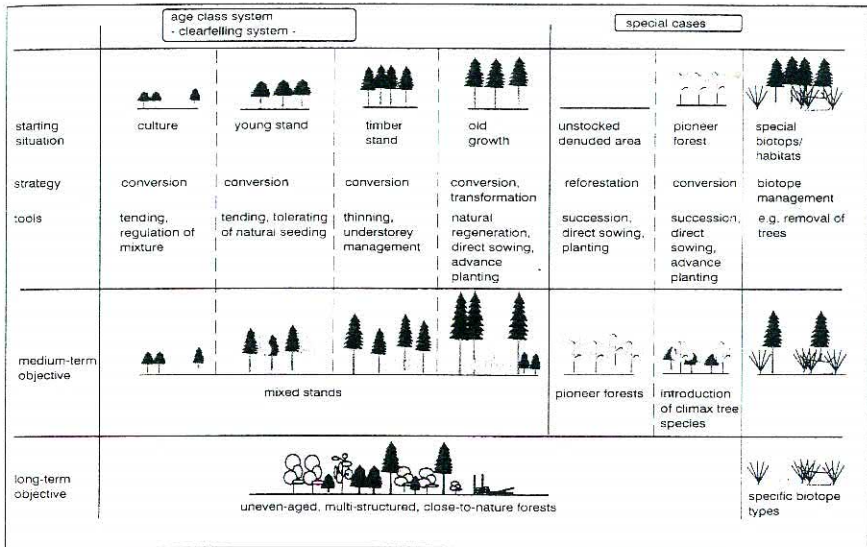


Figure 5.4.1

Silvicultural strategies for conversion of pure pine and spruce stands.

be confined solely to the phase of regeneration in old growth stands. Such a strategy would have only minor effects on the tree species composition due to the actual age class composition of the forests, where young stands or timber stands prevail. Hence, silvicultural strategies to convert pure pine and spruce stands must incorporate all 'starting situations' from newly established to old growth stands (Fig. 5.4.1).

The following four examples present silvicultural conversion and reforestation strategies based upon a number of research studies. The first example (starting situation 'timber stand') shows the role of dispersal of acorns by jays for natural regeneration in pure mature pine stands, which are widespread in the colline zone of eastern Germany. Pure spruce stands are characteristic for submontane and montane zones. The second example deals with toleration of natural seeding in the tending phase of young stands, which effectively supports the forming of mixed stands. The third example (starting situation 'old growth') illustrates the dynamics of natural regeneration processes in pure mature spruce stands and their importance in a forest conversion strategy. The fourth example (starting situation 'denuded areas') investigates direct sowing in the ridge zones of the Erzgebirge, which have been denuded by emissions and shows the possibilities and problems of the reforestation of such unstocked areas. The objective of these four case studies is to contribute to a conversion strategy for the forests of eastern Germany. The results illustrate the possibilities of including natural regeneration processes or silvicultural techniques, like direct sowing, into an ecologically sound forest conversion strategy. Specific details on the research areas are given in Table 5.4.1.

Table 5.4.1

Characteristics of the research areas used as examples of silvicultural options for the conversion of pure pine and spruce stands into mixed stands and the reforestation of denuded areas.

TOPIC	REGENERATION IN PINE STANDS	SELF-SOWN BIRCH IN YOUNG SPRUCE STANDS	REGENERATION IN SPRUCE STANDS	REFORESTATION OF DENUDED AREAS
Forest district	Weisswasser /Saxony	Tharandt/Saxony	Altenberg/Saxony	Altenberg/Saxony
Altitudinal zone	colline	submontane	montane	ridge zone
Annual mean temperature	8.2 °C	7.5 °C	5.8 °C	4.1 °C
Annual mean precipitation	640 mm	800 mm	900 mm	1020 mm
Nutrient status	low / medium	low / medium	low / medium	low / medium
Soil water supply	medium	medium	medium	medium
Natural forest associations	(hornbeam-, beech-) oak forests	(oak-) beech- and (spruce-, silver fir-) beech forests	(spruce-, silver fir-) beech forests	(mountain ash-) spruce forests

### Development of oaks established from bird-dispersed seeds

#### Methods and results

The silvicultural system of pine regeneration used in eastern Germany until recently was very intensive in energy consumption, i.e. mechanised tilling, high stocking density (30000 trees/ha), as well as an intensive removal of other tree species competing with pine. The silvicultural aim of this first case study was to increase the proportion of oaks within those pine areas mostly associated with Pleistocene sands.

Apart from deliberate intervention, an opportunity to utilize natural regeneration processes for the conversion of the stand is provided by 'seeding by jays'. Jays (*Garrulus glandarius*) can transport acorns over large distances. Several studies have investigated the transportation and emergence of acorns deposited by jays (Johnson & Adkisson 1985; McClanahan & Wolfe 1987; Schupke 1928). Few investigations, however, were dedicated to the problem of how oaks develop in competition with other natural regeneration (Mosandl & Kleinert 1998). Of particular importance in relation to the issue of subsequent silvicultural treatment of natural regeneration, is the quality of the resulting oaks.

Six Scots pine stands were investigated in the forest district of Weisswasser, where oak (*Quercus petraea*) regeneration (introduced by jays) could be related to three different development stages: the stage of advance regeneration, the thicket stage and the stage of young timber stand. Each development stage was represented by two separated plots, each of which was 0.09 ha in extent.

Both the oaks in the advance regeneration stage, and the oaks in the thicket stage were developing under the shelter of 64 to 80-year old pines and were competing with pine regeneration. The oaks in the two plots in the young timber stand had no overstorey, as the pine old growth had been removed in 1960. Since that time the oaks had been growing without the shelter of the upper storey and in competition with natural pine regeneration.

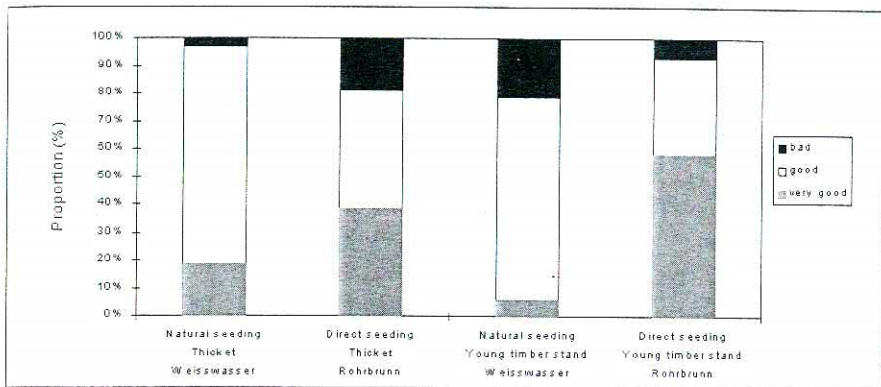


Figure 5.4.2

Quality classes of oaks emerged from jay-dispersed seeds (Weisswasser) in comparison to seeded oaks (Rohrbrunn).

The pine overstorey in the advance regeneration and thicket stages, had a sheltered area (crown projection area to ground area) of 65 to 85%, respectively and a mean height of about 16 m.

In spite of the dense canopy of pine, between 1200 to 3300 oaks per hectare and 1200 to 4800 pine trees per hectare were found in the advance regeneration. In the thicket stage plantations, as many as 2100 to 4300 oaks and 9600 to 15000 pine trees per hectare had regenerated. In the young timber stand, between 800 to 1300 oaks and 500 to 800 pine trees per hectare, were found. In both the advance regeneration and the thicket development stages, oak was older than pine, whereas oak and pine in the young timber stand were of the same age.

The status of competition between oak and pine in the three development stages is characterized by the more frequent occurrence of pine regeneration than oak. On the other hand, the mean height of oak exceeds that of pine beneath the pine overstorey in the first two development stages. Nonetheless, in the young timber stand which has been without the suppressing effect of any shelter in the past 34 years, the pines are taller and larger in diameter than the oaks.

In terms of height increment rates, the more shade-tolerant oaks are growing faster than pines under the shelter of the old pine stand. In the young timber stand, where the upper storey has been removed, the situation is vice versa: the competitive establishment of oak and pine did not provide an advantage in growth for oak. Here, the dominant oaks are smaller than the pines.

The quality of dominant oaks in the thicket and the young timber stand is compared to one of the best quality oak stands in Germany in the forest district of Rohrbrunn (Bavaria), where the stands have been established by sowing. The number of oaks counted in the thicket and in the young timber stand at Rohrbrunn was 43000 and 3000 oaks per hectare, respectively. On the basis of measured quality criteria (e.g. position of the crown and diameter of the thickest green and dry branch), the oaks were classified into three quality classes: oaks of very good, good and bad quality (Mosandl et al. 1988).

Figure 5.4.2 reveals that most of the oaks dispersed by jays in the forest district of Weisswasser were of good quality. Bad dominant oaks were scarce. Only a few oaks in the young timber stands were classified as bad because of forks. The higher proportion of very good oaks at Rohrbrunn is due to the higher position of crowns. Self-pruning has occurred a little faster at Rohrbrunn as a result of the high density of oaks, compared to that at Weisswasser. Some quality characteristics of oaks were even better at Weisswasser than at Rohrbrunn. For example the proportion of oaks with stem bends was less at Weisswasser than at Rohrbrunn.

### Discussion

In competition with pine regeneration, oak dispersed by jay has two advantages: 1) because of its shade tolerance in the young stage, oak regeneration can establish earlier than pine in relatively dense old pine stands and 2) this advantage is enhanced by the reduction in height growth of the light demanding pine under canopy shelter.

The sample size used to determine the quality of the oak trees was very small ( $n=38$  per development stage). So, these results can only illustrate a trend. However, the results of other investigations support the hypothesis that oaks dispersed by jay can exhibit good quality (Eisenhauer 1994; Leder 1993). The question of whether low numbers of oak of good quality are sufficient for economic purposes has often been raised. Leder (1993) emphasises the possibility that other associated tree species (e.g. mountain ash, birch) can enhance the self-pruning processes in oak. Depending on the specific situation, the amount and quality of oaks dispersed by jay can be sufficient to form mixed oak-pine or pine-oak stands.

The number of oaks recorded as regenerating naturally in this study correspond well with some other investigations, as outlined in the literature review of Stimm and Böswald (1994). In addition the quality of the oaks is at least sufficient, suggesting that sowing by jays could be an opportunity to utilise the 'free powers of nature' to facilitate the conversion of pine stands into mixed stands, which are closer to natural forests in their tree species composition (Bergmann 1994; Eisenhauer 1994).

### Self-sown birch in spruce stands

#### Methods and results

Until recently self-sown birch (*Betula pendula*) in spruce plantations and young spruce growth was removed at regular intervals. It is only over the last few years that birch and other softwoods have been encouraged as admixture tree species. Based upon investigations conducted in an 11-year-old thicket stage forest, Lange (1995) concentrated on the question of the influence of birch within a spruce crop. The thicket has been subject to various treatments. Self-sown birches were periodically removed from the dominant and subdominant tree classes in one part of the stand, resulting in a predominance of spruce in the stand ('spruce type'). In the other part, all of the self-sown birches were left in the spruce stand, in which case both spruce and birch were prevalent within the dominant and subdominant tree classes ('spruce-birch type'). Two plots each 10 m x 10 m were selected in each stand type and their composition is discussed.

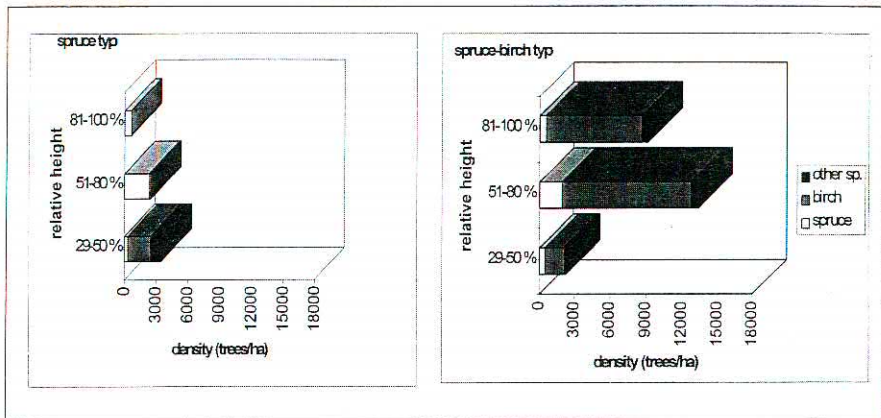


Figure 5.4.3

Vertical stand structure of both stand types (Lange 1995). Relative height: 100% corresponds to the height of the tallest plant per stand type.

Although the density of spruce is nearly the same in the spruce type (3350 spruce/ha) and the spruce-birch type (2900 spruce/ha), the spruce-birch type surpasses the spruce type distinctly in terms of overall tree density on account of the high proportion of birches. The spruce-birch type includes 20650 birches/ha and 1150 other trees/ha. The birches in the spruce type number 2350 stems/ha. The fact that birch has survived among the spruce has caused a marked change in the vertical stand structure of the spruce-birch type compared to the spruce type (Fig. 5.4.3).

It is obvious that birch in the untreated stand type i.e. spruce-birch, significantly outcompetes spruce in height. So, the question is, to what extent does the interspecific competition between birch and spruce affect the growth and development of spruce? A comparison of some average growth parameters of spruce in both forest types shows that there is no significant influence of birch on the height of spruce (Table 5.4.2). The results also give no statistical evidence of reduced diameters.

Table 5.4.2

Growth parameters of spruce and birch in the 11-year-old thicket (Lange 1995).

cv = coefficient of variation (%); same letters occurring after a value indicate no statistical differences between the values for the given parameter.

TREE SPECIES	SPRUCE TYPE		SPRUCE-BIRCH TYPE	
	SPRUCE	SPRUCE	BIRCH	
height (m)	4.67 a	4.42 a	3.84	
cv for height	18	25	24	
d.b.h (cm)	5.0 a	4.4 a	1.6	
cv for d.b.h.	23	31	44	
crown proportion (%)	77	76	31	
height/d.b.h-ratio	96	104	269	

### Discussion

The competition between the even-aged birch and spruce trees has not had a negative effect on the height of spruce in the 11-year-old thicket, neither have the spruce trees (due to strong competition) been compelled to undergo enhanced height growth in order to hold their dominant position in the canopy. It may be possible however, that spruce responds to enhanced competition by exhibiting decreased diameters, so that it does not lag significantly behind in height.

It can be assumed that self-sown birch in spruce stands may be left up to the thicket stage. The high height/diameter values (Table 5.4.2), within both stand types investigated, are indicative of unstable situations in the stand. Thus, an improvement felling will be necessary in either case, which may be combined with correction of the relative species proportions (reduction of inter- and intraspecific competition). In this way mixed stands may be formed by natural processes from initially pure crops.

### Natural regeneration processes in mature spruce stands

#### Methods and results

The question of whether natural regeneration processes may lead to mixed stands with an element of climax tree species found in the natural vegetation is particularly important among the present-day objectives. The natural regeneration processes of the secondary tree layer and of the regeneration in opened-up mature spruce stands were investigated in two trial plots in the eastern parts of the Erzgebirge.

Both mature, pure spruce stands are about 80 years old. In the first experimental plot, at 'Ladenmühle', heavy emissions and summer droughts in recent decades resulted in the stand density index decreasing to 0.6 (stand density index of a fully stocked stand = 1.0). In the immediate vicinity of the research plot there are several older beeches, larches (*Larix decidua*), and pines. The second experimental plot, 'Bobbahn', had an average stand density index of 0.7. No beech trees were in the vicinity of this stand.

In the shelter of the mature spruce stand at 'Ladenmühle' a secondary tree layer (tree heights ranging between 0.5 m and 5 m) has developed through natural regeneration within a short period. The number of trees represented in the secondary tree layer has increased markedly from 4300 trees/ha in 1994 to 7400 trees/ha in 1995. These are mainly composed of birch (70%) and mountain ash (*Sorbus aucuparia*, 19%). In the partial plot with the highest density of regeneration, there were an estimated 22000 trees/ha. Climax tree species such as beech contribute 2% to the tree composition in the secondary tree layer. This relatively large proportion is due to the flowering seed trees in the vicinity.

The natural regeneration (height < 50 cm) dominated by spruces, which germinated in 1993 has reached high densities in both mature spruce stands (Table 5.4.3). In the research plot 'Ladenmühle', the density of spruce decreased distinctly in number within two growing seasons due to mortality. There are relatively high numbers of other climax species, such as beech, due to the presence of seed trees in the vicinity and to the dispersal of beech-nuts by animals. In contrast to the 'Ladenmühle' research plot, the 'Bobbahn' plot is located within a large-scale spruce monoculture area. Thus the regeneration is highly dominated by spruce and as a result only a few broadleaves could regenerate.



Table 5.4.3

Natural regeneration in two research plots in the eastern parts of the Erzgebirge: densities in 1000 trees/ha.

RESEARCH PLOT DATE	LADENMÜHLE				BOBBAHN	
	BEGINNING OF 1994 TREES/ha	%	BEGINNING OF 1996 TREES/ha	%	END OF 1995 TREES/ha	%
spruce	177.9	91	81.5	78	161.3	98
larch	1.9	1	1.7	2	-	-
other conifers	0.2	0	0.2	0	-	-
mountain ash	9.6	5	11.0	11	2.9	2
birch	3.8	2	6.3	6	0.8	0
beech	1.3	1	2.2	2	<0.1	0
other broadleaves	0.6	0	0.8	1	0.1	0
total	195.3	100	103.7	100	165.1	100

### Discussion

The emergence of pioneer tree species in a secondary tree layer beneath the opened canopy of spruce may form multistoreyed mixed stands from previously single-storeyed pure stands. The urgency to reconstruct the disintegrating mature spruce stands is reduced by the multistoreyed stand structures developing via natural regeneration. Thus, while one option is to plan for subsequent advance planting, a second option is to tolerate the continued processes of natural regeneration.

The 1992/93 cone year caused very high stocking densities of spruce seedlings in the natural regeneration. Presupposing a suitable genetic constitution, spruce may be included in the regeneration strategy. Compared with spruce, the proportion of other climax tree species like beech or silver fir, however, is minute, such that an adequate percentage admixture of tree species has to be established by silvicultural measures. In those cases typical of the submontane and montane zones, in which no flowering beech or silver fir trees grow in the immediate environment, processes of natural regeneration will not lead to the desired types of mixed stands. Here, the incorporation of beech or silver fir via artificial regeneration will be necessary.

### Reforestation of unstocked denuded areas in the ridge zones of the Erzgebirge by direct sowing

#### Methods and results

The influence of very high emission rates over recent decades has led to widespread forest dieback in the ridge zones of the Erzgebirge (Liebold & Drechsler 1991). The silvicultural strategy aims to reforest these denuded areas with pioneer tree species, which will later have to be advance planted with climax tree species (Fig. 5.4.1). Direct sowing was tested on a research plot at 'Lugstein' (Table 5.4.1) as a silvicultural tool for reforestation of these unstocked, denuded areas, where grasses (mainly *Calamagrostis villosa*) dominate up to 80% of the ground vegetation (Benabdellah 1995). Since the natural forest association, *Calamagrostio villosae-Piceetum* (Runge 1990), consists of spruce in mixture with mountain ash and birch,

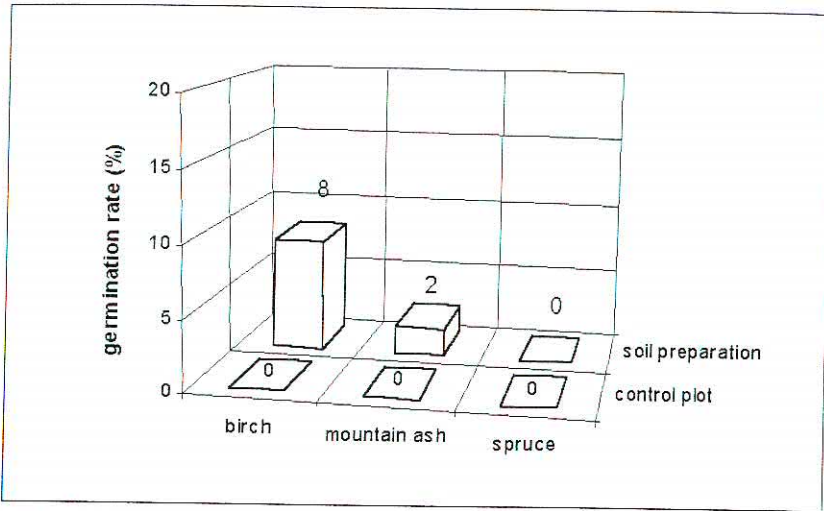


Figure 5.4.4

Results of direct sowing in the denuded, grassy areas of the ridge zone in the Erzgebirge/Saxony (Benabdellah 1995). Germination rates refer to a seed density (100%) of 923 seeds/m<sup>2</sup> for birch, 1632 seeds/m<sup>2</sup> for mountain ash and 102 seeds/m<sup>2</sup> for spruce.

these tree species were directly sown on control plots as well as on soil prepared plots.

Direct sowing succeeded only in combination with soil preparation, where the grass competition was removed and the seeds could germinate on the mineral soil (Fig. 5.4.4). The germination rate was highest for birch, followed by mountain ash. The failure of spruce was due to biotic damage (mice, birds).

#### Discussion

The potential for direct sowing as an appropriate tool for reforestation purposes on denuded, grassy areas in the ridge zones still has to be proved. Survival and growth rates of direct seeded trees are indicators which have to be intensively investigated.

## Conclusions

Strategies on the conversion of pure pine and spruce stands into mixed stands in eastern Germany may include natural processes like; regeneration of oak, emerged from bird-dispersed seeds in pine stands or self-sown birch and mountain ash in young and mature spruce stands. Where conversion strategies aim at the establishment of mixed stands, mainly composed of climax tree species of the natural forest associations, natural regeneration processes normally have to be completed by silvicultural means like advance planting. On climatically extreme

sites in the ridge zones of the Erzgebirge with grass dominated vegetation types, soil preparation measures are necessary for the establishment of pioneer stands of birch and mountain ash by direct sowing. All these natural processes and silvicultural means (like regulation of tree species composition, supplementary planting, soil preparation and direct sowing) may support a low-energy and cost-effective forest conversion in eastern Germany. By utilising these natural processes and by adopting a few controlling silvicultural measures, forests may be managed to satisfy the new objective and fulfil the multiple forest functions to a greater extent.

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