# Conversion of a forest managed under systems involving coupes to a selection forest on an example of the Opuky research area

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**ABSTRACT**: This paper evaluates the development of growing stock, number of trees and diameter distribution of the standing volume in the Opuky locality where conversion to a selection forest has been the aim of management over a long period of time. With respect to species composition, the stand is divided into two plots. The initial condition and development of both plots differed. The favourable initial composition of the stand has gradually deteriorated due to delay in natural regeneration and therefore recruitment of young trees over a long period. The total number of trees on both plots has been low for target diameter of 51 cm. On the other hand, the growing stock has exceeded the model condition. The proportion of broadleaved species in the stand gradually increases, reducing the possibility of conversion to a selection forest in future.

**Keywords**: selection forest; conversion; spruce; species composition; target diameter

At the present time, there is increasing support for a return to close-to-nature and sustainable methods of management within the whole of Europe. One of the possibilities for close-to-nature management is the selection forest system, which can fulfil both wood-producing and non-wood-producing functions of forests and provide long-term stability without serious changes in the forest. The selection system of forest management has been known and generally studied for many years although its expansion outside its original range is minimal. Once the selection system has become the new aim of management, the effects are not instantaneous because the complex structure develops over a long period of time. Acceleration of the process is possible by means of an active approach to converting forests managed under systems involving coupes to selection forests. At present the introduction of selection systems is the subject of much debate, but the discussion is only theoretical because long-term experience with conversions is missing. Stands of a suitable species composition, structure and condition for natural regeneration can be gradually converted to a selection forest. The main condition for attaining the selection forest is that it will require a suitable system of management be adopted in forest stands and be applied consistently over a long time. According to Schütz (1999) conversion is the most difficult stage requiring consistency and the resolution of a forest manager. According to the author, the main reasons for a lack of knowledge about conversion are as follows: it is a long-term task, there are greater risks in transition to a large-scale system of management and the mistake of premature felling of stands.

In former Czechoslovakia Hugo Konias and his successor Vladimír Zakopal were instrumental in researching these problems. Konias carried out conversions of species composition and also conversions to the selection system of management in selected localities of Opočno region from 1933. The main goal was to increase the stability of trees through new management measures and changes in species composition. Only where the species composition was considered suitable were stands converted to selection forest. In the region of Opočno, some of these converted stands remain that are now most interesting as they have been developing for almost 70 years, particularly those areas that have been the subject of long-term research.

This paper evaluates the development of conversions of forest systems involving coupes to the selection forest in the Opuky experimental area where conversion started in 1933. This long-term study makes it possible to evaluate stand development in detail.

## SITE AND STAND CONDITIONS

The Opuky research area was established in 1958 to monitor conversion of a forest managed under systems involving coupes to the selection forest. The stand is situated in Eastern Bohemia (about 5 km from Dobruška) on a very gentle SW slope at an altitude of 380 m. Parent rock of the site consists of green slates, the soil being classified as Luvic Cambisol of medium depth with a medium content of nutrients. The locality is situated in Forest Region No. 26 (foothills of the Orlické hory Mts.), it has a special purpose forest category due to forest research. The original typological classification 3K1 (acid oak-beech stand) was later changed to degradation 3H1 (clay oak-beech stand) under pine. In the management group of stands 421 (spruce management on acid sites), the target species composition should be as follows: Norway spruce 50–70%, beech 20–30%, larch 10%, sycamore 10%, silver fir, grand fir, oak, Douglas fir, lime, hornbeam, ash. Site class is low (spruce 7, pine 4) which corresponds to absolute height classes: spruce 24 m, pine 26 m, larch 30 m, broadleaves 22–24 m. Mean annual temperature of the locality is 7.6°C (in the growing season 13.8°C). Annual precipitation averages 644 mm, 61% of the precipitation occurs in the growing season.

The whole stand has been repeatedly measured since 1930. In 1958, all trees of d.b.h. > 7 cm were numbered and measured. The original stand was divided into two plots according to the prevailing species composition: plot A of 1.1 ha and plot B 1.08 ha. The parent stand originated by combined regeneration: spruce, pine and larch were planted, silver fir and broadleaves regenerated naturally. According to management records, in 1998 the stand age was 145 years, the actual age of dominant and co-dominant trees fluctuated from 131 to 148 years (the mean value of 137 years was determined on the basis of increment bores of 50 co-dominant trees). The age of the original stand trees in the lower layers ranged from 60 to 130 years (autumn 1998). Repeated opening up of the stand by incidental felling since the small pole stage encouraged regeneration of dispersed younger groups.

The considerable height and diameter differences of the stand led Konias to start the conversion as early as in 1933 (KONIAS 1950). In gaps, broadleaves were planted to modify species composition, on favourable sites natural regeneration occurred. Beating up of poor natural regeneration was carried out by planting spruce, silver fir, beech and lime whereas oak regenerated naturally.

## METHODS

Diameters (d.b.h.) were measured with a calliper in two directions to the nearest 0.1 cm, heights of particular trees by a hypsometer to the nearest 0.5 m. Repeated inventories of trees were carried out in 1958, 1966, 1974, 1989, 1994 and 1998. The recruitment was recorded in 1966 and 1974, new recording of the recruitment was carried out in 1994 and 1998. Felling were carried out at the end of the periods under study, total volume of harvested timber was calculated from inventory (special measurements on the fallen trees were not made). Incidental felling reached minimum volumes during the study period. Based on repeated measurements, basic characteristics of trees were calculated (mean tree diameter, basal area, volume, slenderness ratio and particular increments), stand characteristics were determined summarising particular data for the area, all characteristics being converted to 1 ha. Trees were grouped into diameter classes at 4 cm intervals (starting from 6 cm). With respect to site and climatic conditions the target diameter of the stand was set to 51 cm.

## RESULTS

The main stand on plot A was formed by Norway spruce and Scots pine. Spruce was regularly distributed in the stand, pine created smaller groups. Participation of other species was small, lower layers were formed by spruce, silver fir and broadleaves. Species composition was more favourable on plot B. Larch occurred as a dominant tree while the mixture of spruce and pine represented co-dominant trees. Spruce, silver fir and broadleaves occurred as subdominant and intermediate trees. The position of spruce in all stand layers decreased its share in the growing stock as compared with its count (Table 1).

By the time of recording in 1998, after 40 years of management, the number of conifers on both plots decreased, however, on plot A more markedly (Table 1). With the exception of spruce on plot B, the number of conifer species decreased. A marked decrease occurred particularly

Table 1. The proportion of species according to the number and growing stock on plots A and B in 1958 and 1998

| Species | Plot A | | | | Plot B | | | |
|---|---|---|---|---|---|---|---|---|
| | Number (%) | | Volume (%) | | Number (%) | | Volume (%) | |
| | 1958 | 1998 | 1958 | 1998 | 1958 | 1998 | 1958 | 1998 |
| Spruce | 57.0 | 48.2 | 48.0 | 65.0 | 28.7 | 30.8 | 19.6 | 32.4 |
| Fir | 3.2 | 1.2 | 0.8 | 0.2 | 21.1 | 8.1 | 7.1 | 4.9 |
| Pine | 31.2 | 9.6 | 48.7 | 21.0 | 15.1 | 7.1 | 29.8 | 11.8 |
| Larch | 1.1 | 0.4 | 1.9 | 1.1 | 19.8 | 16.8 | 41.5 | 42.1 |
| Beech | 1.1 | 21.7 | 0.1 | 8.2 | 1.0 | 8.1 | 0.1 | 2.2 |
| Oak | 5.8 | 9.4 | 0.5 | 3.3 | 12.8 | 22.5 | 1.8 | 6.1 |
| Other broadleaves | 0.4 | 9.6 | 0.0 | 1.2 | 1.6 | 6.6 | 0.1 | 0.5 |
| Conifers | 92.5 | 60.2 | 99.4 | 87.3 | 84.6 | 62.8 | 98.0 | 91.2 |
| Broadleaves | 7.5 | 40.8 | 0.6 | 12.7 | 15.4 | 37.2 | 2.0 | 8.8 |

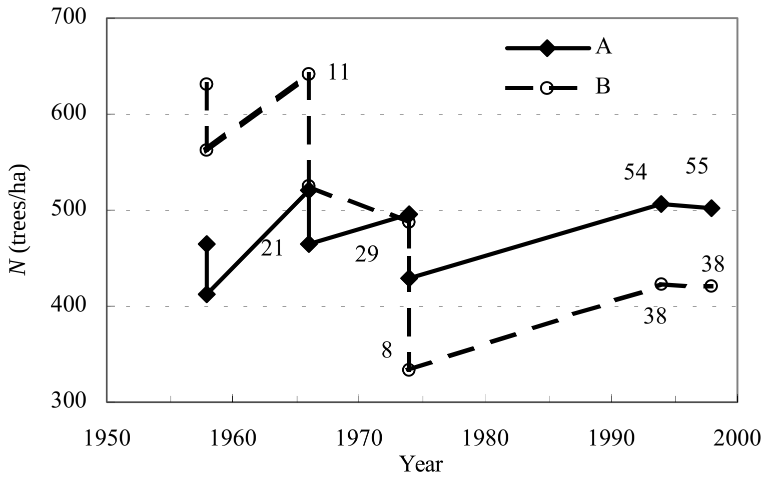


Fig. 1. Tree numbers on plots A and B. Numbers by the lines within the graph give percentage of recruitment from the total tree numbers

in pine and silver fir due to impaired tree health and resulting minimum increment. The proportion of beech and other broadleaves (particularly lime) was affected by planting at the beginning of conversion, the change in oak from natural regeneration was not so marked. Reduction of conifers was markedly demonstrated only in their number. Spruce always dominated in the growing stock. The volume proportion of spruce increased in spite of the decrease in its number, due to its dominant position in the stand. Less marked changes in the volume proportion of broadleaves are given by their predominance in the subdominant layer as they were introduced in 1933.

## NUMBER OF TREES

The initial numbers of trees, as well as species composition, on both plots were different. In 1974, the numbers of trees on both plots became equal (Fig. 1). The total number of trees on plot A changed minimally during forty years, felled trees being gradually replaced by recruits. On plot B, the number of trees decreased at first quickly due to sanitation felling, later on, however, the decrease slowed by the inclusion of the recruitment. The total number of trees on plot B decreased by 210 trees. The proportion of recruitment gradually increased on both plots, amounting to 55% of the number of trees on plot A and 38% on plot B (both in 1998).

The initial curves of tree frequencies show two peaks on both plots (Fig. 2). This fact demonstrates the connection of stand components of various age each with its peak of frequency. The age range of younger components of mature stand on plot B was larger and a more favourable diameter distribution confirms this. The irregular course of the curves shows marked age differences between particular stand parts. On plot A, trees of d.b.h. 30–34 cm made up the most numerous proportion, whereas on plot B, trees of smaller diameter predominated (10–14 cm). The initial curve on plot B approaches better to the model condition of a selection forest.

Frequency curves from 1998 were flattened in medium and large diameters and elongated in large diameters as compared with the initial state (1958). The number of small-sized trees on plot A increased by the inclusion of recruits. A peak formed by medium-sized trees shifted to

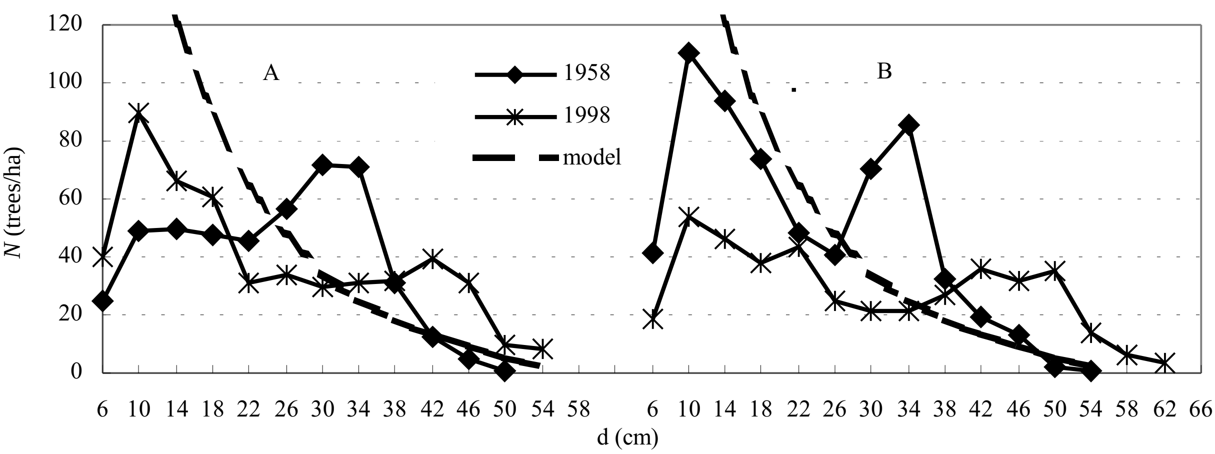


Fig. 2. Tree numbers according to diameter on plots A and B in d.b.h. classes. The model represents the state for target diameter 51 cm (A =163, q = 1.36)

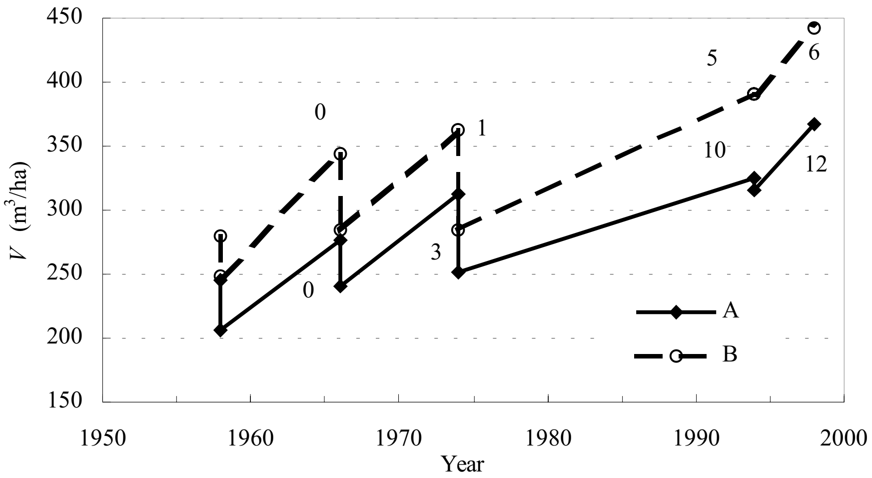


Fig. 3. Development of standing volumes on plots A and B. Numbers by the curves show percentage of recruitment to the total volume

large-sized trees. The surplus of these trees could not be felled because of the risk of windthrow. On plot B, the number of small-diameter and medium-diameter trees decreased in consequence of felling and diameter shifts. A marked peak is missing in the curve (Fig. 2). Scarce recruits did not suffice to replace the gradual decrease of trees by felling. The curve on plot B from 1998 does not show a marked peak of frequency. The final form of the curve on plot A approaches to the model condition in selection forests. The number of small-diameter trees increased as compared with the initial state (1958), however, on plot B recruitment was less successful and numbers did not reach the initial state. On both plots, large-diameter trees > 40 cm are in excess of the model and, on the contrary, small-diameter and medium-diameter trees are missing (lack of management negatively affected natural regeneration).

## GROWING STOCK

The initial growing stock of both plots was different and in the course of recording, growing stocks and their differences on both plots increased (Fig. 3). The growing stocks of both plots were very close after felling in 1966 and 1974. At first, the growing stocks of the stand were influenced by recruits minimally, and subsequently, irrespective of the number of trees, could not markedly affect the volume of the total growing stock. The recruitment on particular plots contributed differently to the number of trees and to the volume of growing stock. On plot A in 1998, the recruitment accounted for 55% of the number of trees but only 12% of the volume. On plot B in 1998, the recruitment accounted for 38% of the number of trees but only 6% of the volume.

The original symmetrical distribution of the growing stock, according to diameter classes, gradually changed to a right-hand asymmetric distribution (Fig. 4). In 1958, both curves culminated in the diameter class of 34 cm. After 40 years the peak of the curve shifted to the diameter class of 42 cm on plot A and to 50 cm on plot B. The more marked shift of the curve peak on plot B was caused by the lower volume of harvested mature trees in the later periods. The sum of the small-diameter tree volume did not markedly change at the beginning and at the end of monitoring on plot A; on plot B the sum moderately decreased.

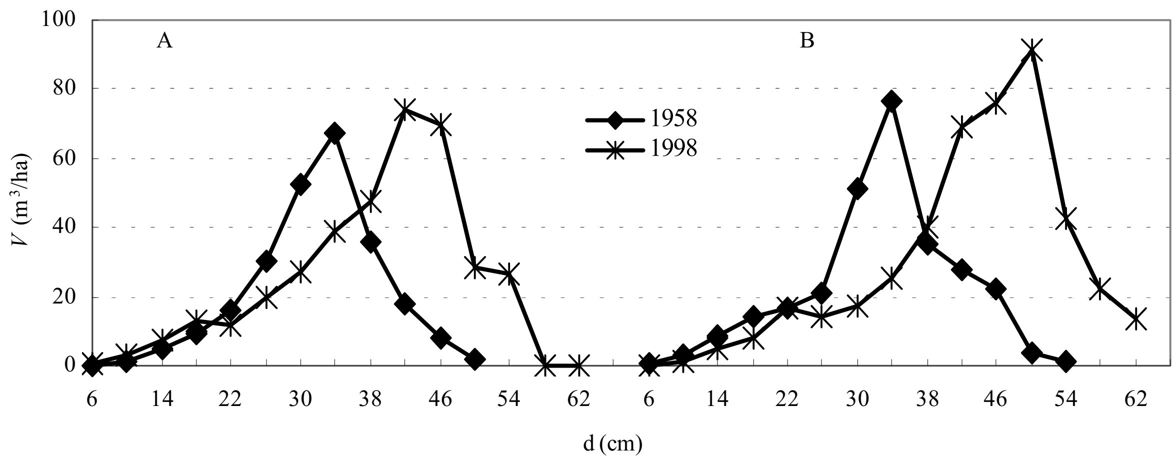


Fig. 4. Curves of standing volume on plots A and B in d.b.h. classes

Table 2. The percentage proportion of diameter classes in the growing stock

| Year | Plot A | | | | | | Plot B | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before felling | | | After felling | | | Before felling | | | After felling | | |
| | SD | MD | LD | SD | MD | LD | SD | MD | LD | SD | MD | LD |
| 1958 | 28.4 | 68.1 | 3.5 | 28.2 | 68.3 | 3.5 | 24.3 | 68.1 | 7.6 | 24.2 | 68.3 | 7.6 |
| 1966 | 21.5 | 71.9 | 6.6 | 22.8 | 73.3 | 4.0 | 18.9 | 69.4 | 11.7 | 19.3 | 72.0 | 8.7 |
| 1974 | 14.9 | 73.9 | 11.2 | 15.8 | 76.4 | 7.7 | 16.1 | 63.1 | 20.8 | 12.6 | 69.2 | 18.2 |
| 1994 | 17.0 | 55.1 | 27.9 | 17.4 | 55.6 | 27.0 | 11.8 | 40.4 | 47.8 | 11.8 | 40.3 | 47.9 |
| 1998 | 14.9 | 51.2 | 33.9 | 14.9 | 51.2 | 33.9 | 10.2 | 34.4 | 55.5 | 10.2 | 34.4 | 55.5 |

Diameter classes: small-diameter (SD) trees 7–28 cm, medium-diameter (MD) trees 28–44 cm, large-diameter (LD) trees > 44 cm (ZAKOPAL 1965)

Optimum distribution of the growing stock is described by particular authors variously in relation to site and stand conditions, target diameter and inventory limit. Usually a ratio of 20:50:30 is used for growing dimensions (small-diameter, medium-diameter and large-diameter trees). A model proportion for this small target diameter (51 cm) can markedly differ. With an increasing target diameter the proportion of small- and medium-diameter trees decreases at the expense of large-diameter trees.

The initial share of large-diameter trees was low on both plots, particularly on plot A. The proportions of diameter classes changed during the period under study. Generally, the proportion of large-diameter trees increased at the expense of small-diameter trees. Recruits did not markedly affect the proportion of small-diameter trees and their share in the stand growing stock gradually decreased.

The distribution of growing stock on plot A gradually approached the optimum distribution, the condition in 1994 being nearest to the model. The initial condition on plot B was more favourable due to the higher proportion of large-sized trees. Their share, however, steadily increased at the expense of trees of smaller diameters in consequence of low fellings. This unfavourable situation was caused not only by the large size of the original growing stock of both plots but also by its old age. Relatively large numbers of big trees cannot be arbitrarily felled due to an increased risk of windthrows.

## DISCUSSION

In Bohemia there has been a persistent long-term study of the conversion of forest managed under systems involving coupes to selection forest. The problems were researched particularly by ZAKOPAL (1958, 1965, 1981) and TRUHLÁŘ (1977, 1995). Foreign publications relating to these problems are relatively rare, partial results being published for example by: MITSCHERLICH (1952), FAVRE (1994), SCHMITT (1994), HLADÍK (1992) and SANIGA and SZANYI (1998).

The species composition of the stand did not correspond to the theoretical ideas on the composition of selection forests formed by a mixture of silver fir, spruce and beech. Some authors admit the admixture of heliophilous trees although they are aware of the difficulty of regenerating the species below the canopy of a parent stand (MITSCHERLICH 1952; TREPP 1974). Also the stand mixture did not fully correspond to site conditions. Over the years the species composition better approached the site conditions, however, the approach caused further deviations from the model of selection forest. The share of broadleaved species in the growing stock will increase due to their growth by volume and of the need to regenerate the original stand. It will be very difficult to include the present rate of broadleaves into the subsequent management. Some modern authors recognise there are problems in increasing the proportion of broadleaved species in selection forests (e.g. FAVRE 1994).

The number of trees in selection forests determines the course of the tree frequency curve. This course also depends on site conditions, diameter range and target diameter. In selection forests of appropriate structure, the number of trees is not markedly changed in the course of time, trees removed by felling are continuously replaced by recruits and diameter shifts (SCHÜTZ 1999). The average number of trees found on long-term research plots in selection forests of the corresponding diameter range fluctuates from 450 to 700 trees per ha (MITSCHERLICH 1952; SCHÜTZ 1999). Similar results were found by SANIGA and SZANYI (1998) during model calculations of the number of trees and growing stock in selection forests in Slovakia. SCHMITT (1994) evaluated a stand of the similar species composition near Munich. The number of trees and the share of recruits corresponded to tree numbers found in the Opuky area. Here the number of trees on plot A fell into the given interval, the final number of trees on plot B was, however, lower. Models for selection forests of the corresponding structure and target diameter give higher numbers of trees (KNOKE 1998). MITSCHERLICH (1952) and HLADÍK (1992) give information on a similar problem of decreasing numbers of trees. Plots studied by the authors gradually lost their selection structure and changed to a single-layer forest. TRUHLÁŘ (1995) reported decreasing tree numbers, 20% reduction of trees over 13 years did not endanger the stand structure.

While the growing stock in selection forests changes according to site and stand conditions, the proportion of large-sized trees is also important because of felling. Felling frequency is important because too low or high volumes of harvested timber can threaten the selection forest structure and stand stability. According to SCHÜTZ (1999), on various sites various types of selection forest can occur in a balanced state with a variable target diameter and thus also a variable growing stock. The standing volume in selection forests of appropriate structure fluctuates between 250 and 750 $m^3$/ha. The growing stock in the Czech Republic conditions should be lower with respect to climatic conditions and smaller target diameter. In Slovakia, SANIGA and SZANYI (1998) found by means of modelling optimum growing stocks ranging from 250 to 520 $m^3$/ha.

ZAKOPAL (1958, 1965, 1981) found that, in surrounding areas with forest conversions, the growing stock of the majority of areas fell into the given intervals, gradually increasing in the course of monitoring. Model studies for selection forests of low target diameter give considerably lower growing stocks which should not exceed 300 $m^3$ for the given diameter (KNOKE 1998; SCHÜTZ 1969). Here the results found on both plots show the gradual increase in growing stocks has exceeded the model state. This has occurred because of the dominant position of the original stand and age distance between the parent stand and the recruitment. FAVRE (1994) found in the course of 100-year monitoring in selection stands situated on northern slopes minimum fluctuations in the growing stock whereas on southern slopes, the growing stock doubled during the same period. The proportion of large-sized trees increased in both variants (FAVRE 1994). SCHÜTZ (1969) found a relationship between the optimum growing stock, volume increment and growing stock distribution under various target diameters. With an increase in the growing stock the increment and proportion of small- and medium-diameter trees decreased.

## CONCLUSION

The results of monitoring in the Opuky research area confirm that regardless of adequate diameter and height differences in the stand conversions require considerable long-term management. To achieve proper conversion, the most important factor is a sufficient age differentiation within the tree population and long-term management according to selection system principles. For the majority of parameters, the studied stands reach model values for selection forests, however, with respect to the determined target diameter of 51 cm the number of trees is insufficient and, on the other hand, the growing stock is too high. In the studied stand, it will not be possible to carry out speedily the necessary growing stock reduction because of the windthrow risk. The recruitment has not yet fully replaced felled trees in spite of sufficient numbers. The proportion of broadleaved species gradually increases on both plots. This will reduce the possibility of achieving and then preserving the selection forest structure for a long time yet. Regular and consistent management is the most important condition for the success of conversion to selection forest.

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# Převod lesa pasečného na les výběrný na příkladu výzkumné plochy Opuky

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**ABSTRAKT**: Práce hodnotí vývoj počtu stromů, porostní zásoby a tloušťkového rozdělení zásoby na lokalitě Opuky, kde se dlouhodobě realizuje převod na les výběrný. Plocha je rozdělena na dvě části s ohledem na rozdílnou dřevinnou skladbu. Výchozí stav a vývoj obou ploch se lišil. Příznivý výchozí stav porostu se vlivem věkového odstupu dorostu do kmenoviny postupně zhoršoval. Pro cílovou tloušťku 51 cm byl počet stromů na obou plochách nízký, porostní zásoba naopak převyšovala modelový stav. Podíl listnatých dřevin v porostu se postupně zvyšuje, to omezuje možnosti převodu v budoucnu.

**Klíčová slova**: les výběrný; převod; smrk; dřevinná skladba; cílová tloušťka

Práce hodnotí vývoj počtu stromů, porostní zásoby a tloušťkového rozdělení zásoby na lokalitě Opuky, kde se realizuje převod na les výběrný již od roku 1933. Sledovaný porost se nachází v nadmořské výšce 380 m na velmi mírném JZ svahu. Geologické podloží tvoří zelené břidlice, na kterých se vytvořila středně hluboká kambizem luvická se středním obsahem živin. Lokalita se nachází v lesní oblasti 26 (Předhoří Orlických hor). Výchozí typologická klasifikace 3 K1 byla nověji upravena jako degradační stadium 3 H1 pod borovicí.

Celý porost byl opakovaně měřen od roku 1930, v roce 1958 byla v centrální části založena pokusná plocha pro sledování převodů. Mateřský porost tvořila směs smrku, borovice a modřínu v úrovni, jedle a listnáče se vyskytovaly v podúrovni. Tabulkový věk mateřského porostu v roce 1998 dosahoval 145 let, skutečný věk zjištěný z vývrtů kolísal v rozmezí 131–148 let. Mateřský porost byl již od stadia tyčkovin opakovaně prořeďován, to umožnilo skupinovitý výskyt následného porostu.

Porost byl v roce 1933 rozpracován skupinovitou sečí, vzniklé mezery byly zalesněny kombinovanou obnovou, listnaté dřeviny se vysazovaly pro úpravu druhové skladby. Při založení výzkumné plochy se očíslovaly a změřily stromy s tloušťkou nad 7 cm ve výčetní výšce, opakované měření proběhlo v letech 1966, 1974, 1989, 1994 a 1998. Ve stejných letech se realizovaly těžby. Dorost do kmenoviny byl podchycen v letech 1966, 1974, 1994 a 1998. Výchozí plocha 2,18 ha byla rozdělena podle dřevinné skladby na dvě části se srovnatelnou výměrou.

Výchozí stav a vývoj obou ploch se lišil. Počet stromů na ploše A zůstal během 40 let zachován, na ploše B poklesl o třetinu. Příznivý výchozí stav porostu se vlivem věkového odstupu dorostu do kmenoviny postupně zhoršoval. Křivky rozdělení tlouštěk se změnily. Nejpočetnější byly dlouhodobě úrovňové stromy, počet slabých stromů na obou plochách nedosahuje modelového stavu. Distribuce tlouštěk na ploše A je po 40 letech příznivější vlivem vyššího podílu dorostu. Pro cílovou tloušťku 51 cm byl počet stromů na obou plochách nízký, porostní zásoba naopak převyšovala modelový stav. Přes značný podíl dorostu na počtu stromů jeho podíl na zásobě byl dlouhodobě nízký. Rozdělení zásoby podle tloušťkových stupňů se na ploše A blíží modelovému stavu pro výběrné lesy, s ohledem na zvolenou cílovou tloušťku je podíl silných sortimentů vysoký. Sledované hodnoty spadají do širšího rozpětí udávaného pro výběrný les, pro danou cílovou tloušťku však neodpovídají. Podíl listnatých dřevin v porostu se postupně zvyšuje, to omezuje možnosti převodu v budoucnu.

Převod na les výběrný je dlouhodobá záležitost, ani dostatečná výšková a tloušťková variabilita na počátku nezaručuje úspěch. Důležitým předpokladem je také pravidelná těžba upravující nejen tloušťkové, ale i prostorové rozdělení stromů.

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