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Conversion of even aged forest managed under the system involving coupes to selection forest in Klepačov

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ABSTRACT: The paper evaluates the development of the tree numbers, secondary stand and species composition on eight partial control plots in Klepačov where the conversion of even aged forest managed under the system involving coupes to selection forest has been implemented within the framework of a long-term project. The plots capture various stages of conversion. Plots A, D, and H still possess structures nearing the forest of age classes. The assessment was made of the measurements taken in 1974, 1994, and 2004. Tree numbers on the partial control plots in the diameter degrees 10–70+ decreased in the first inventory period as compared with both the model situation and the initial situation in 1974 due to increased felling volumes in that period. The felling and the subsequent opening of stands resulted in a rapidly developing regeneration, which manifested itself by the increase in the number of trees in diameter degrees 2 and 6 above the values given by the model curve for these diameter degrees. In the second inventory period, tree numbers in these diameter degrees were lower by 11% as compared with the model situation and slightly lower as compared with the initial situation. Moreover, the results of the survey show that the forest stands under the selection system of management are massively invaded by broadleaved species, namely the beech and that danger exists that broadleaves will dominate in the future. This is generally considered undesirable because the quality of broadleaved stems in the stands under the selection system is low.

Keywords: conversion to selection forest; curve of diameter frequencies; secondary stand; tree species composition

Poor stability and disturbed ecosystem of homogeneous and even-aged, mostly coniferous forests in Central Europe that came to existence in the past, largely under the influence of the theory about net yield from the soil, prompted foresters to search new ways of forest management at the end of the 19th and at the beginning of the 20th century. The mathematical aspect of the forest gradually passed to the biological conception (Konšel 1931), which became a foundation for the conception of the near-natural forest management. The near-natural forest management becomes today a topical form of the forest management in Europe and the leading idea of the contemporary ProSilva movement (Tesař 2007).

A primary management group of forest stands in conversion to selection forest was established in the Masaryk Forest Training Forest Enterprise Křtiny, a special-purpose facility at the Mendel University of Agriculture and Forestry in Brno as a demonstration and testing object in 1973. The selection principles have been applied in these forest stands since the 1950s, i.e. nearly 60 years. In this primary management group of forest stands, the object of Klepačov served for testing the possibilities of using the selection system in forests with admixed deciduous species and in zones less favourable for them.

The object and site conditions

The research object of Klepačov is situated ca 5 km southeast of the town of Blansko. Its total area is 80.07 ha. The climatic data recorded by the nearest Meteorological station in Olomučany are as follows: mean annual temperature in the period

Table 1. Sizes and natural conditions of the partial control plots

Partial control plot	Area (ha)	Forest type	Altitude (m a.s.l.)
A	0.2417	4O1 – fresh oak-fir with oxalis on recurrently waterlogged soils	420
B	0.1974	3K3 – acidophilous oak-beech with spiked wood-rush on continental platforms and mild slopes	400
C	0.2063	3K3 – acidophilous oak-beech with spiked wood-rush on continental platforms and mild slopes	395
D	0.2411	3S1 – fresh oak-beech with oxalis on humid mesotrophic Cambisol	420
E	0.1967	3K3 – acidophilous oak-beech with spiked wood-rush on continental platforms and mild slopes	380
F	0.2053	3K3 – acidophilous oak-beech with spiked wood-rush on continental platforms and mild slopes	370
G	0.2011	3K3 – acidophilous oak-beech with spiked wood-rush and *Carex pilosa* on continental platforms and mild slopes	365
H	0.2088	3S7 – fresh oak-beech with spiked wood-rush and *Carex pilosa* on continental platforms	410

1971–2000 amounted to 7.9°C and mean annual precipitation was 596 mm (375 mm in the growing season). Maximum and minimum precipitations were recorded in July and February, respectively. Prevailing is northern and western air flow (Truhlář 1996). Geological basement is the Brno igneous rock, largely amphibolic granodiorites covered by loess loams. Dominant soil types are typical mesotrophic and oligotrophic Cambisols.

The object belongs to the Natural Forest Region 30 – Drahanská vrchovina Upland. The most represented is forest altitudinal vegetation zone (FAVZ) 3 of oak-beech (83%), the rest (17%) being occupied by FAVZ 4 of beech. The most represented of trophic series is the fertile series (46%), which is accompanied by the acid series (36%) (Truhlář 1993). The tree species composition as recorded by the inventory in 2003 is as follows: spruce 32.42%, fir 25.83%, pine 21.83%, beech 15.28%, larch 3.61%, oak 0.31%, hornbeam 0.10%, other broadleaves 0.57%, and other conifers 0.05%. Total shares of conifers and broadleaves are 84% and 16%, respectively.

METHODOLOGY

In 1973, eight permanent partial control plots in total were established in Klepačov. The plots were selected to be typologically uniform and to characterise the typical structure of the stand (Truhlář 1975). The sizes and natural conditions of the control plots are presented in Table 1. The partial control plots represent a mosaic of individual stages of conversion, their complete image characterising the conversion in the studied Klepačov object. Plots A, D, and H have still structures nearing the forest of age classes. The original demarcation of the plots was specified more precisely by digital measurements in 2003. Diameter and height of trees on the partial

Table 2. Model values of tree numbers

Diameter degree	Model tree numbers (pcs/ha)	Model standing volume (m^3/ha)
2	316	–
6	236	–
10	177	8.28
14	132	12.24
18	99	16.59
22	74	20.83
26	55	24.46
30	41	27.10
34	31	28.53
38	23	28.27
42	17	27.91
46	13	26.20
50	10	23.90
54	7	21.20
58	5	18.50
62	4	15.81
66	3	13.28
70	2	11.01
Total 2–70+	1,245	324.61
Total 10–70+	693	324.61

control plots were measured in 1974, 1994 and 2004. The diameter at the breast height was measured on the plots in two mutually perpendicular directions by attaching aluminium calliper with an accuracy of 0.1 cm. The tree height was measured by Suunto hypsometer with an accuracy of 0.5 m. The dendrometric data found were introduced into Microsoft Excel database and processed into tables and graphics by the same software. The values of individual variables were allocated by tree species into diameter degrees at an interval of 4 cm and converted per hectare.

The formulation of ideal selection forest dwells on the diameter stratification expressed in individual diameter degrees. In this work, we used the E-type model curve according to Meyer (Meyer 1933). As Meyer's curve begins from the registration limit of 16 cm (from diameter degree 18) and does not capture tree numbers in lower diameter degrees 2, 6, 10 and 14, we used a converted curve for the concerned range of diameter degrees (Table 2). The curve was modified in cooperation with the Department of Forest Management at the Faculty of Forestry and Wood Technology in Brno. Based on the model curve of frequencies and tariff tables, a model standing volume was calculated, which is the sum of model standing volumes in the respective diameter degrees. Model standing volume in individual diameter degrees is presented in Table 2.

RESULTS

Tree numbers

With respect to sustainability, the division of stems by diameter degrees in the selection forest can be attributed the same informative value as the division into age classes in the even-aged forest (Schütz 1989). The development of the structure of stands in conversion to selection forest and the advanced level of the conversion are in our case assessed by comparing the curves of tree numbers from repeated measurements on the partial control plots in years 1974, 1994, and 2004 (Figs. 1–9).

The development diagrams in Figs. 1–9 show that the distribution of trees in diameter degrees gradually approaches the model curve. The curve of the actual representation of tree numbers by diameter degrees is in the case of conversions of a typical shape of elongated horizontal S, with the representation in lower diameter degrees (10–22) being below the model curve, and in middle diameter degrees (30–46) above the model curve. During the thirty years of development, the deviations have become gradually reduced and the curve has gradually approached the model curve. Although it is not unambiguous on all partial control plots, this development generally brings evidence for the successful conversion. The changes in the tree numbers are reflected in the change of standing volumes too, which gradually approaches the model standing volume.

Most approaching the model curve are today real curves on partial control plots B, C, E, F, and G although the distribution of the tree frequencies in 1974 still corresponds to the Gaussian curve typical of even-aged forest managed under the system involving coupes. The peak of the curve has been successfully lowered during the conversion by phytotechnical measures supporting the forest stand differentiation and natural regeneration. On the other hand, plots A, D, and H markedly deflect from the model condition with plot A showing the greatest difference. This plot was affected at the beginning of conversion by

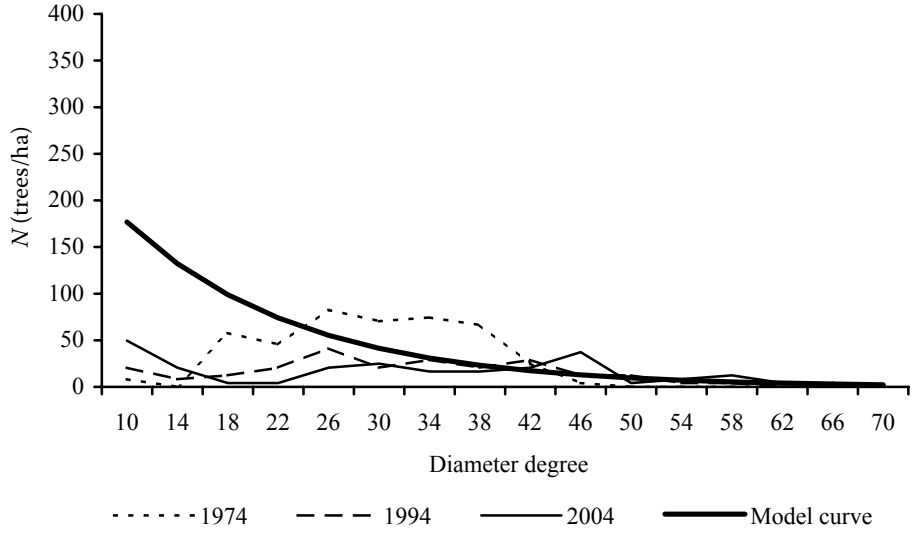

Fig. 1. Development of tree numbers on plot A

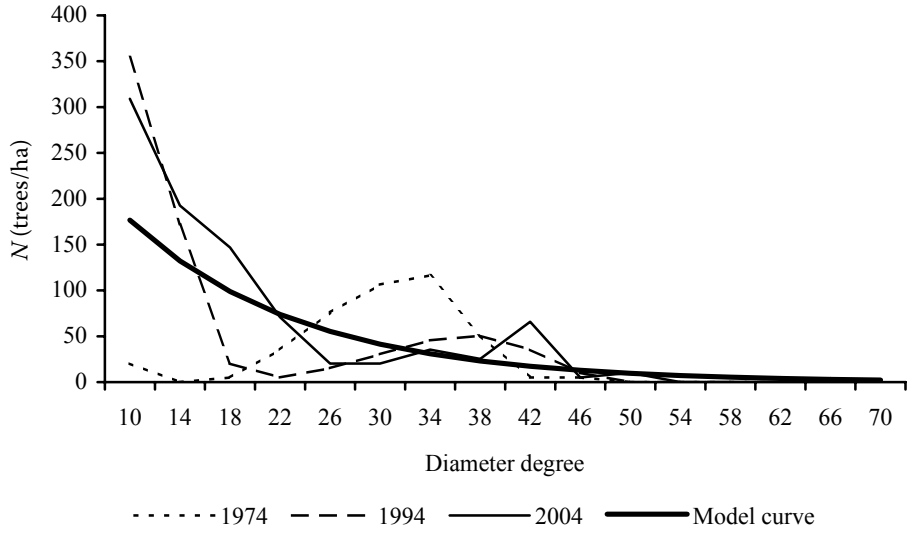

Fig. 2. Development of tree numbers on plot B

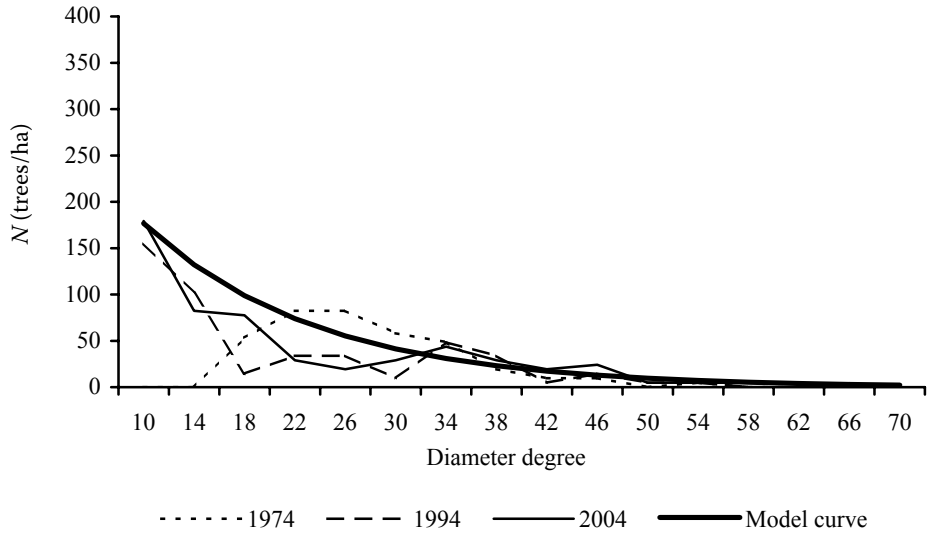

Fig. 3. Development of tree numbers on plot C

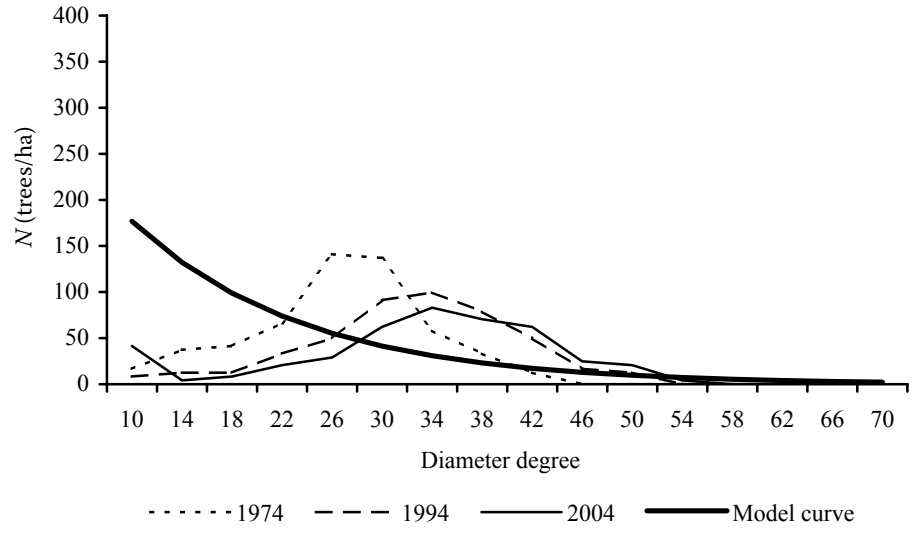

Fig. 4. Development of tree numbers on plot D

incidental fellings, which showed in an extremely low number of trees (236 pcs/ha), as compared with the model condition (693 pcs/ha) as well as in weed infestation, which made natural regeneration impossible. Although the substitution of the tree numbers was resolved by underplantings, these have not yet reached the diameter at breast height and cannot influence the representation of tree numbers in lower diameter

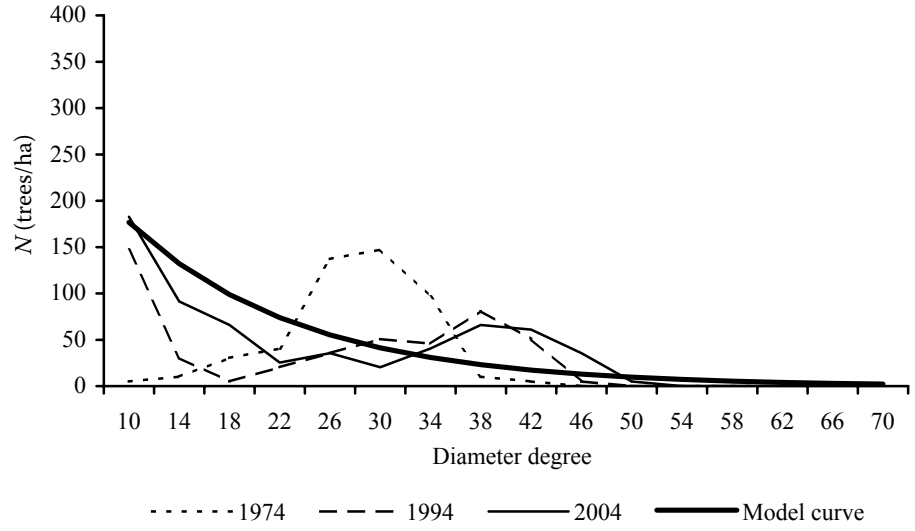

Fig. 5. Development of tree numbers on plot E

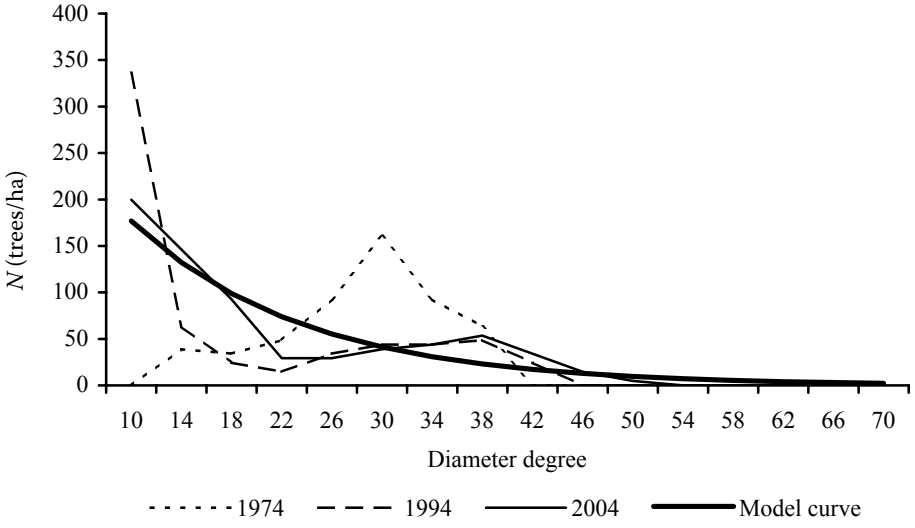

Fig. 6. Development of tree numbers on plot F

degrees. An entirely different situation can be seen in the development of the tree inventory on plots D and H. The curves of the tree representation by diameter degrees answer the Gaussian curve, which brings evidence for a low conversion work in progress. The forest stand on plot D is a two-storeyed stand with a successfully developing lower storey, in which the trees already reach the diameter at breast height and their representation markedly affects the frequency curve. With the proceeding conversion, the peaks of hitherto curves gradually decrease and the curves become elongated and engaging a wider range of diameter degrees. Plot H was established in an even-aged stand adjacent to the converted subcompartments as a control plot, which stigmatised its future development, markedly different from other plots. This plot with a complete subcompartment was allocated to the management group of stands in conversion to selection forest only during the preparation of the Forest Management Plan for 1993–2002.

Secondary stand

For the maintenance of the selection structure, the felled trees must be replaced by trees from lower diameter degrees. A sufficient amount of low diameter trees is ensured by a continual supply of recruits from the natural or artificial regenerations. The total number of trees in diameter degrees 2 and 6 (secondary stand) give a prerequisite for the maintenance of the selection structure in the future. However, it depends on the stand structure. Regeneration processes need be evaluated with respect to the diameter structure and standing volume, which are reflected in the canopy closure of the stand and in the degree of the use of available space (Saniga 1996). An excessive canopy opening by the reduction of the standing volume would induce a mighty onset of regeneration that would act against the target structure. Therefore, the felling should be focused on the maintenance of the continuity of the regeneration

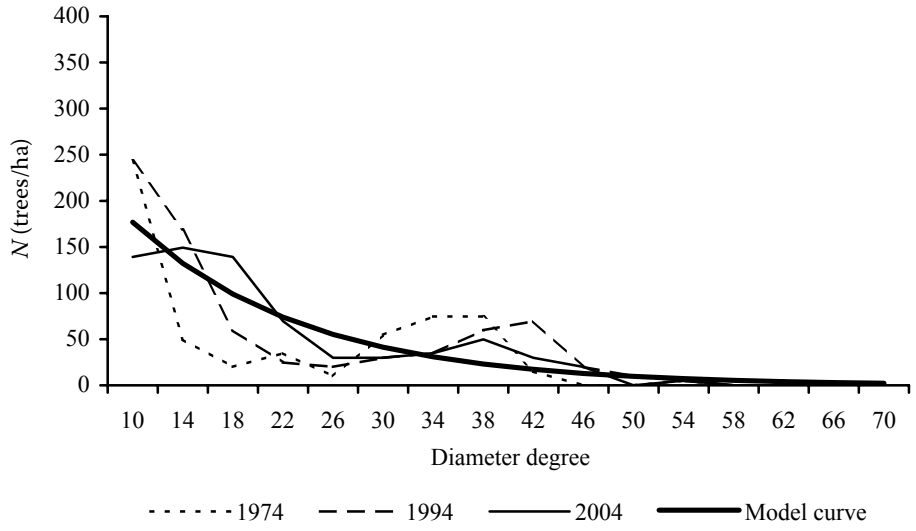

Fig. 7. Development of tree numbers on plot G

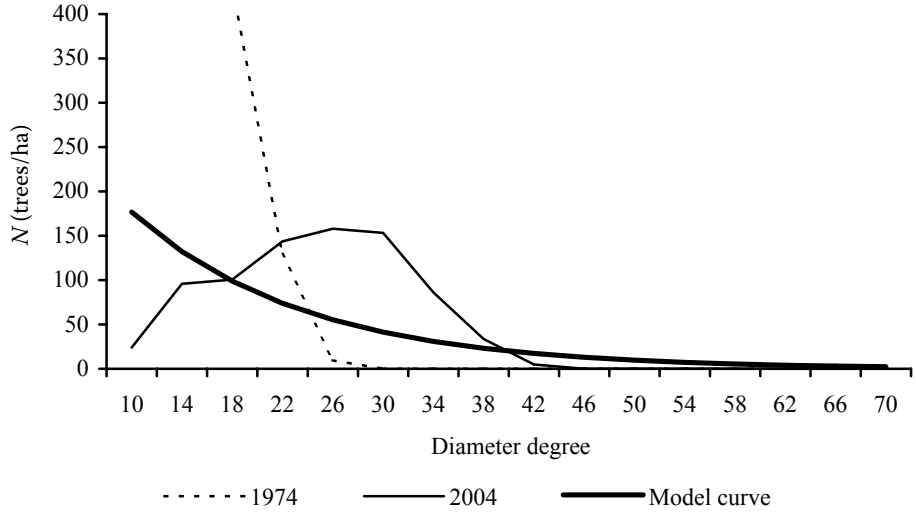

Fig. 8. Development of tree numbers on plot H

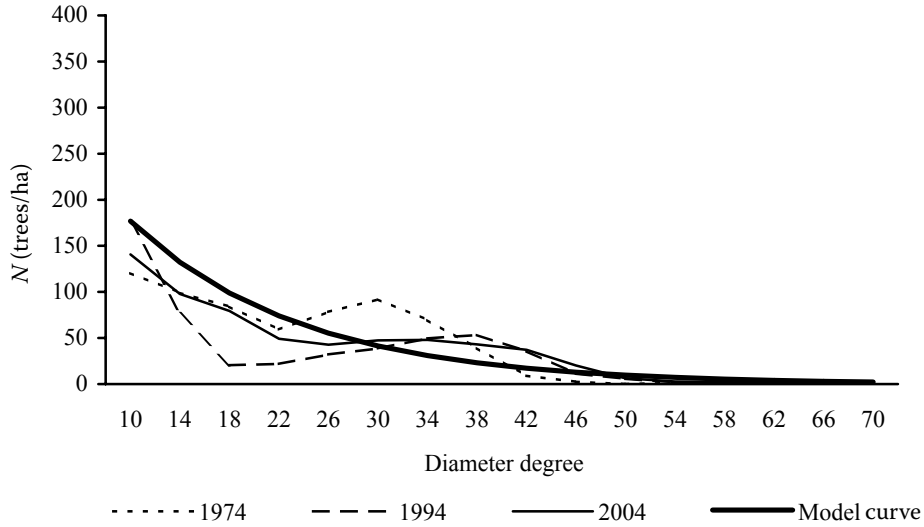

Fig. 9. Development of tree numbers – average of partial control plots

process and on the differentiation of the lower layer of the converted forest stand.

Due to the intensive incidental felling which affected the partial control plot A during the first inventory period, the plot was severely infested by weeds and stagnation occurred of natural regeneration. The number of trees in diameter degrees 2 and 6 is therefore markedly lower as compared with the

model tree numbers. The trend of increasing tree numbers in these diameter degrees is demonstrable, though. Favourable is a high representation of the tree numbers in the secondary stand due to canopy reduction namely on partial control plots B, D, E, F, and G. The measurements in 2004 indicated that the tree numbers on these plots exceeded the model values for diameter degrees 2 and 6 (Table 3). In the partial control plot C, the increased standing volume and hence canopy coverage in the second inventory period resulted in a decreased number of trees in diameter degree 2 below the model value, the tree numbers in diameter degree 6 being only slightly above the model values.

Tree species composition

Table 4 shows that the partial control plots are dominated by coniferous species, namely by the spruce the share of which was growing during the survey. The spruce regenerates and grows readily while the felling volumes are relatively low. The average representations of the fir and pine are nearly equable but their trend is decreasing. In the fir, the decreasing number of trees results from an insufficient secondary stand due to game damage to natural regeneration and new fir growths. The share of the pine was decreasing due to its relatively high felling, especially in the first twenty years of the survey. The fact that the pine does not occur in the secondary stand and hence the lower diameter degrees are not replenished is understandable if we realise the species light demands. The representation of the larch is very low and the species regenerates naturally only rarely. The carriers of the selection structure are the spruce, fir, and beech. The representation of deciduous tree species (almost exclusively the beech) is increasing with the stand development. The expansiveness of the beech as judged namely by the number of trees in diameter degrees 2 and 6 is obvious (Table 3). The fact warns that the dominance of the beech in future stands could result in a failure of the conversion to the selection forest. The pine and larch as light-demanding tree species are not represented in these diameter degrees at all.

DISCUSSION

The number of trees in the selection forest is determined by the shape of the model curve; it is however, generally lower than in the even-aged forest. In the comparison studies, it is necessary to

Table 3. Development of tree numbers (pcs/ha) by species in diameter degress 2 and 6

Partial control plot	Diameter degree	Spruce			Fir			Beech			Total		
		1974	1994	2004	1974	1994	2004	1974	1994	2004	1974	1994	2004
A	2	0	104	46	8	0	12	0	58	21	8	162	79
	6	0	54	70	4	0	0	12	15	12	16	69	82
B	2	395	429	117	5	94	15	173	232	233	573	755	365
	6	39	400	263	5	10	10	30	123	162	74	533	435
C	2	480	221	39	36	0	0	62	779	204	578	1,000	243
	6	222	284	121	10	10	10	10	134	136	242	428	267
D	2	0	1,350	809	0	0	0	4	174	120	4	1,524	929
	6	0	197	382	0	0	0	19	108	29	19	305	411
E	2	39	601	34	10	10	0	5	118	41	54	729	75
	6	15	315	117	10	5	5	0	69	30	25	389	152
F	2	205	318	34	21	31	24	10	205	244	236	554	302
	6	67	287	117	10	5	5	0	190	180	77	482	302
G	2	205	985	900	80	15	20	15	20	94	300	1,020	1,014
	6	67	382	403	392	75	20	5	30	45	464	487	468
H	2	0	–	0	0	–	0	0	–	0	0	–	0
	6	0	–	5	0	–	0	0	–	14	0	–	19
Average		**108**	**423**	**216**	**37**	**18**	**8**	**22**	**161**	**98**	**167**	**603**	**321**
(%)		**65**	**70**	**67**	**22**	**3**	**2**	**13**	**27**	**31**	**100**	**100**	**100**

Table 4. Development of tree numbers (pcs/ha) on partial control plots by species in diameter degrees 10–70+

Partial control plot	Year of measurement	Tree species									Standing volume (m^3/ha)	Felling (m^3/ha)
		spruce	fir	pine	larch	total conifers	beech	other broadleaves	total broadleaves	total		
A	1974	236	178	8	4	426	8	0	8	434	319.22	209.73
	1994	108	91	4	4	207	29	0	29	236	232.55	
	2004	137	74	4	4	219	17	8	25	244	268.88	
B	1974	10	117	279	0	406	14	0	14	420	298.90	197.97
	1994	486	56	142	0	684	56	0	56	740	238.44	
	2004	608	46	137	0	791	106	5	111	902	299.54	
C	1974	29	329	10	0	368	0	0	0	368	234.43	137.52
	1994	257	174	10	0	441	19	0	19	460	212.97	
	2004	334	170	5	0	509	43	0	43	552	292.57	
D	1974	373	91	33	0	497	46	0	46	543	315.18	96.71
	1994	311	54	33	0	398	66	0	66	464	445.60	
	2004	303	54	33	0	390	41	0	41	431	462.31	
E	1974	213	5	267	0	482	0	0	0	482	284.21	135.22
	1994	300	0	162	0	462	10	0	10	472	302.94	
	2004	437	0	147	0	584	41	5	46	630	370.99	
F	1974	102	15	404	0	521	10	0	10	531	327.23	228.85
	1994	380	24	142	0	546	88	0	88	634	209.39	
	2004	443	29	132	0	604	68	15	83	687	288.69	
G	1974	35	313	224	0	572	10	0	10	582	265.55	170.39
	1994	159	358	204	0	721	25	0	25	746	368.64	
	2004	209	343	119	0	671	25	0	25	696	295.05	
H	1974	1,523	86	230	0	1,839	71	0	71	1,910	211.01	87.52
	2004	584	19	134	0	737	63	0	63	800	377.53	
Average	1974	315	142	182	1	640	19	0	19	659	281.98	157.99
	1994	286	108	99	1	494	42	0	42	536	287.22	
	2004	382	92	88	1	563	51	4	55	618	331.95	
(%)	1974	48	21	27	1	97	3	0	3	100		
	1994	53	20	18	1	92	8	0	8	100		
	2004	62	15	13	1	91	8	1	9	100		

take into consideration the lower registration limit, which is normally higher (usually 15 or 16 cm) in the classical control methods. The number of trees depends on the site degree, too, the tree numbers on sites with a lower index being higher even if the standing volume is comparable (Bachhofen 1999). Leibundgut (1968) points out that the number of trees in the middle layer may be reduced on fertile sites, and such stands exhibit seemingly a two-layer structure.

Réh (1978) summarised the research results from the selection forests and conversions in formerly Czechoslovakia and mentions the tree numbers at the lower registration limit of 8 cm ranging from 348 to 882 pcs/ha with an average of 579 pcs/ha. Hladík (1992) had recorded during twenty years of conversion a decreased number of trees from 833 pcs/ha to a half, i.e. 437 pcs/ha. However, the decrease occurred due to the absence of recruits. At the lower registration limit of 8 cm, Saniga and Szanyi (1998) found a number of trees fluctuating from 269 to 725 pcs/ha in the dependence on the site, species composition and target diameter. Flury (1929) mentions an average number of trees in the selection forests at the lower registration limit of 8 cm to be 450–700 pcs/ha. In our case, the real number of trees was 618 pcs/ha. Höher (1994) claims the range of the tree numbers at a lower registration limit of 7 cm to be 350–400 pcs/ha.

References on the forest stand conversion to the selection system in the same or similar natural conditions as those of the Klepačov site are very scarce. The most similar object in Czechia is in Klokočná where Kozel (2006) reported tree counts at the lower registration limit of 7 cm ranging from 776 to 858 pcs/ha and standing volumes ranging from 358–372 m^3/ha.

In an even-aged forest with the same site degree as that of Klepačov partial control plots, the number of trees fluctuated from 621 pcs/ha at 100 years to 499 pcs/ha at 130 years of age (Černý et al. 1996).

The data on the tree numbers greatly differ. They range between 269–725 pcs/ha with a comparable lower registration limit, which points to an endangered selection structure. The higher tree numbers in Czechia and Slovakia are given by the lower inventory limit and by the fact that a majority of stands were at the beginning of the conversion. The number of trees decreased on some plots in the repeated survey while other elements of the selection forest remained preserved.

In our case, the real number of trees was 618 pcs/ha (model 693 pcs/ha). The comparison with the above studies shows that the tree numbers found on the partial control plots in Klepačov range largely at the upper boundary of the mentioned limits, which documents a lower site class index of the Klepačov locality.

The principle of the selection forest consists in the sustained structure, which would guarantee a regular and even production. Its sustainability can be secured if a sufficient secondary stand can compensate for the losses. Thus, the initial stem numbers represent one of the most important variables in controlling the long-term maintenance of the structure and production, being conclusive for the judgement whether or not the selection forest stability is secured for a long time or threatened. The initial stem numbers have to correspond to certain light conditions, which depend on the standing stock.

Inevitable for sustainable stability of the selection forest appears to be a sufficient number of trees with $d_{1.3} < 8$ cm (Bachhofen 1999). Stem numbers required for recruits are mentioned e.g. by Duc (in Schütz 1989) according to whom the required numbers for diameter degrees 2 (0–4.0 cm) and 6 (4.1–8.0 cm) are 250–750 pcs/ha and 160 to 350 pcs/ha, respectively. In another work (Duc 1991), he claims that a proper functioning and stability of the selection forest require 600 pcs/ha of individuals with $d_{1.3}$ ranging from 0.1 to 7.4 cm.

The model tree numbers in Klepačov and hence on the control plots are 316 pcs/ha in diameter degree 2 and 236 pcs/ha in diameter degree 6. Real average tree numbers on the partial control plots are 513 pcs/ha in diameter degree 2 and 269 pcs/ha in diameter degree 6. The model and the actual tree numbers are in good accordance with those mentioned by Duc (in Schütz 1989).

CONCLUSION

The work is focused on the evaluation of the tree numbers, secondary stand, and species composition development on eight partial control plots of the primary management group of stands under conversion to the selection forest in Klepačov. Evaluated are the measurements taken in 1974, 1994 and 2004.

The comparison of the curves of development of the tree numbers and other variables with a selected model curve showed that the hitherto methods of conversion lead to the structure of stands approaching the model condition, and that the used modified curve of Meyer's E-type was chosen appropriately. As compared with the initial situation in 1973, the numbers of trees on the partial control plots in diameter degrees 10–70+ decreased in the first inventory period by 19%, and by 23% as compared with the model condition. This resulted from an increased felling in the period concerned. The felling and re-

lated opening of the stands furthered a rapid growth of regeneration. In the second inventory period, the numbers of trees in diameter degrees 10–70+ decreased by 6% as compared with the initial situation and by 11% as compared with the model condition. Thus, it shows that during the 30 years of monitoring, we have gradually approached the model tree number of 693 pcs/ha.

The abundance of the secondary stand is sufficient and the results of measurements in 2004 indicate that the average tree numbers in diameter degrees 2 and 6 exceed the model value by 40%. Selection felling will be focused on the sustained continuity of regeneration processes and on the differentiation of the lower storey of the forest stands under conversion.

The existing species composition as expressed by the tree numbers is dominated by conifers (91%) with the share of the spruce, fir, and pine being 62%, 15%, and 14%, respectively. Broadleaved species are represented at 9% (beech 8% and other deciduous species 1%). This composition considerably varies from the natural tree species composition, which is entirely dominated by broadleaves, namely the beech. The research results show that deciduous species invade the forest stands managed by the selection system, and danger exists that they will dominate the stands in the future, which is considered generally undesirable with respect to the poor quality of their stems in the even-aged forests managed by the selection system. The spreading of broadleaves – namely those, which suppress coniferous species by their expansion – can be prevented by their adequate reduction in lower storeys. In the case of the predomination of broadleaved species, it is advisable to switch from the hitherto individual selection to the group selection, which facilitates reaching a better quality of broadleaved stems.

The results of our study demonstrated that the application of the selection system of management under natural conditions of oak-beech and beech forest altitudinal vegetation zones, i.e. under conditions less favourable for this management system as proved by the hitherto experience, is possible with the natural species composition altered in favour of coniferous tree species. To maintain the species composition will be difficult due to the penetration of deciduous species under the influence of climatic change. It will be economically demanding, too. Therefore, it does not appear prospective.

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Převod lesa pasečného na výběrný na objektu Klepačov

ABSTRAKT: Práce hodnotí vývoj počtu stromů, podružného porostu a dřevinné skladby na osmi dílčích kontrolních plochách na objektu Klepačov, kde se dlouhodobě realizuje převod na les výběrný. Plochy podchycují různá stadia převodu. Plochy A, D, H mají dosud strukturu blízkou lesu věkových tříd. Jsou hodnocena měření provedená v letech 1974, 1994 a 2004. Počty stromů na dílčích kontrolních plochách v tloušťkových stupních 10–70+ se v prvním inventarizačním období snížily proti vzorovému i výchozímu stavu v roce 1974. Bylo to způsobeno zvýšenými těžbami ve sledovaném období. Těžby a s nimi související proclonění porostů mělo za následek rychlé odrůstání zmlazení. Tím se počet stromů v tloušťkových stupních 2 a 6 zvýšil nad hodnoty dané vzorovou křivkou pro tyto tloušťkové stupně. Počty stromů v tloušťkových stupních ve druhém inventarizačním období jsou nižší o 11 % proti vzorovému stavu a mírně nižší proti stavu výchozímu. Výsledky šetření dále prokazují, že listnaté dřeviny (zejména buk) pronikají do porostů obhospodařovaných výběrným způsobem a vzniká nebezpečí, že do budoucna převládnou. To se obecně považuje za nežádoucí pro špatnou kvalitu kmenů listnáčů ve výběrně obhospodařovaných porostech.

Klíčová slova: převod na výběrný les; křivka tloušťkových četností; podružný porost; druhová skladba

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