Structure of virgin and managed beech forests in Uholka (Ukraine) and Sihlwald (Switzerland)

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Structures of virgin and managed beech forests in Uholka (Ukraine) and Sihlwald (Switzerland): a comparative study

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Abstract
Based on an inventory of two permanent plots of 10 ha each, the main structural differences between a virgin beech forest in the Uholka-Massiv in Transcarpathia, Ukraine, and the Sihlwald, an – until recently – managed beech forest near Zurich, Switzerland, were analysed. In this paper, first results are presented and discussed. The diameter distribution of the Sihlwald showed the typical structure of a two-layered forest, whereas that of Uholka indicated a very uneven-aged structure with a more-or-less even distribution of trees over a large diameter range. Apart from the top height and the number of trees, which did not differ significantly between the two sites, all measured parameters such as basal area, standing volume and stand density index were higher in Uholka than in the Sihlwald. The volume of deadwood was about 14 times higher in the virgin than in the managed forest. Variability of most of the measured parameters between subplots of 0.25 ha was higher in Uholka than in the Sihlwald. Regeneration density is considered sufficient on both sites. Small-scale regeneration methods, such as progressive felling by small groups and single tree or group selection systems, "imitate" best the natural regeneration processes in undisturbed beech forests. The maintenance of a certain amount of admixed species needs silvicultural interventions as beech is very dominant on its optimum sites.

Keywords: *Fagus sylvatica,* pristine forests, virgin forests, managed forest, forest structures, regeneration, deadwood, Ukraine, Switzerland

1 Introduction

In recent years there has been an increased interest in virgin forests. Due to the tense economic situation, forest enterprises are forced to cut down on the costs for tending and thinning operations and to make full use of the self-regulating processes of the forest. At the same time, ecologists and conservationists are placing increasing demands on a close-to-nature forest management to enhance and maintain biodiversity. One of the questions often discussed is the amount and size of dead trees that should be left as habitat in managed forests. However, there is only little data about the distribution of coarse woody debris in virgin forests. Forest policy also promotes the establishment of forest reserves where timber harvesting is given up completely or where only targeted interventions for the enhancement of biodiversity are allowed. One such reserve is the Sihlwald near Zurich, a beech (*Fagus sylvatica* L.) forest that was intensively managed till 1990. Also more and more forests, especially on steep and low productive sites, are not utilised any more for economic reasons. It is not yet clear what consequences reducing silvicultural treatment will have with regards to the sustainable fulfilment of the various public demands on the forests (including the production of high-quality timber), and what will happen if formerly managed forests are entirely left to develop naturally.

Although detailed descriptions of virgin forests can be found in the European forest literature since the middle of the 19th century (BRANG this issue; COMMARMOT *et al.* 2000), scientifically based studies started mainly after the Second World War, initiated by the silviculture section of the International Union of Forest Research Organisations (IUFRO). Most of these studies were carried out on permanent inventory plots of 0.25–1 ha (sometimes dating back several decades), which were usually laid out subjectively to represent different developmental phases (KORPEL' 1995; LEIBUNDGUT 1959; LEIBUNDGUT 1982; MAYER *et al.* 1987; STOYKO *et al.* 1982). The inventories of the plots were often completed by detailed measurements of a stand profile along a transect and by mapping developmental phases on the whole area. As the definition of developmental phases varies according to authors (e.g. KORPEL' 1995; LEIBUNDGUT 1959; LEIBUNDGUT 1982; MAYER and OTT 1991; MEYER 1999; WEBER 1997) and the transitions (temporal as well as spatial) from one phase to the next are fluid, maps showing the spatial distribution of developmental phases are usually very subjective and not reproducible. In order to analyse the variation and horizontal patterns of stand characteristics, detailed inventories of larger areas are necessary. Such studies, such as the one of TABAKU (2000), are rare.

This comparative study of a 10 ha area in the virgin beech forest Uholka in Transcarpathia, Ukraine, and in the Sihlwald near Zurich, Switzerland, should contribute to answering the following questions:

- What are the main structural differences between an untouched and a managed beech forest?
- What forest structures are most suitable to benefit from self-regulating processes and how can these structures be achieved?
- What are the possible consequences of reducing tending and thinning operations in managed beech forests?
- What will the future development of the Sihlwald be like after all tending and harvesting operations have stopped?

In this paper, our preliminary results are presented and discussed.

2 Material and methods

2.1 Study areas

In 2000, two inventory plots of 10 and 11 ha respectively were established in the Uholka-Shyrokoluzhanskyi reserve in Transcarpathia and in the Sihlwald in Switzerland.

The Uholka-Shyrokoluzhanskyi reserve with an area of 15 974 ha is part of the Carpathian Biosphere Reserve in the western-most region of Ukraine. It is situated on the southern and eastern slopes of the Mentschul (1501 m a.s.l.) and the southern slopes of the Krasna Mountain (400–1400 m a.s.l.). The more or less steep slopes are covered by almost pure beech (*Fagus sylvatica* L.) forests. Almost 9000 ha are considered to be virgin forest. The first forest reserves were founded in Shyrokyi-Luh in the 1920s by the Czechoslovakian

Republic and in Uholka in 1958 by the Ukrainian Soviet Republic. The massif consists of flysch layers with marls and sandstone and of jurassic limestone and cretaceous conglomerates. The climate is temperate with mean annual temperatures of 7° C, –4° C in January and 17° C in July, and annual precipitation of 950 mm (BRÄNDLI and DOWHANYTSCH 2003). The inventory plot is located north of the village Mala Uholka (48°14’ N / 23°36’ E) on a south-east exposed slope of 20 to 40 %, at an altitude of 700 to 800 m a.s.l. The soils are mainly dystric cambisols, in some patches also eutric cambisols. The main forest associations are Fagetum dentariosum and Fagetum asperulosum.

The Sihlwald, one of the largest continuous beech (or mainly beech) forests in the Swiss lowlands, is situated 10 to 15 km south of Zurich, on the north-eastern slope of the Albis ridge (500–915 m a.s.l.) consisting of “obere Süsswassermolasse” (LABHART 2001). The Sihlwald was used already in the 14th century to cover the fuel demands of the citizens of Zurich. First regulations concerning wood cutting in the Sihlwald can be found in the town book of Zurich from 1314; since 1417 a forest ordinance (a sort of management plan) has been in force. Nevertheless, in the 18th century the Sihlwald was heavily over-exploited, although it was never totally clear cut (KREBS 1947; MEISTER 1903). With Ulrich Meister, who managed the town forests of Zurich from 1875 to 1914, an era of nature-oriented silviculture started, which was continued by other forest managers. In the 1990s, under the management of Andreas Speich, it was decided to stop wood cutting in large areas of the Sihlwald, and to leave the forest to natural development. As timber harvesting only stopped about 10 years ago, we still consider the Sihlwald a managed forest. The inventory plot was installed in an approx. 150-year-old beech stand, at an altitude of 600 to 700 m. The Biriboden (47°15’ N / 8°33’30’’ E), as the area is called, is a N-E exposed, gently inclined slope of about 16 %. The soils are eutric cambisols. The vegetation belongs to different sub-associations of the Galium odorati-Fagetum, and in one small area to the Aro-Fagetum. The mean annual temperature in the Sihlwald is 7 to 8° C (–1° C in January, 17° C in July), the annual precipitation reaches 1200 to 1300 mm. As the inventory plot is divided by forest roads, we enlarged the studied area by one ha (11 instead of 10 ha).

2.2 Methods

The inventory plots of 200 × 500 m (Uholka) and 200 × 550 m (Sihlwald) were divided into subplots of 50 by 50 m. Within these subplots, all trees with a minimum diameter ($d_{1.3}$) of 8 cm were numbered and their positions recorded (measurement of coordinates). The $d_{1.3}$ of all trees were measured and several other criteria assessed (species, biological characteristics according to IUFRO Tree Classification (LEIBUNDGUT 1958), special stem forms and “damage” such as cracks, holes, crown-breakage and fungi). The tree heights of five sample trees per subplot were measured (200 in total). The heights of the other trees were estimated according to the equation of MICHAILOFF (1943):

$$h = h_0 + a \times e^{b/d_{1.3}}$$

where h_0 = 1.3 m. In Uholka, four crown radii of all trees were also measured, but in the Sihlwald only those of the sample trees. To estimate the amount of deadwood, the $d_{1.3}$ and height of the standing tree stumps were measured, as well as the length and mid-diameter of lying deadwood more than 2 m in length and 8 cm in diameter.

Regeneration was surveyed on 160 circular sample plots of 20 m^2, distributed in a regular grid of 25 × 25 m (four sample plots each per 0.25 ha subplot). Saplings of 30 to 130 cm were counted within 20 cm height classes. For trees higher than 1.3 m, tree height and $d_{1.3}$ were measured. Seedlings and saplings with a height of 10 to 29.9 cm were counted on 1 m^2 within the 20 m^2 sample plots.

Data were analysed mainly by the 0.25 ha subplots to show the variation and spatial distribution of stand characteristics. The t-test was used for testing the hypothesis that the means of the studied parameters of the two sites are equal. For parameters that were not normally distributed, the Mann-Whitney U-test was used. For the Sihlwald, only 10 of the 11 hectares were included in the analysis.

The height and diameter of the dominant trees h_{dom} and d_{dom} were defined as the mean height/diameter of the 100 thickest trees per ha. For comparison, we calculated these values only for beech. Only the beech belonging to the group of the 100 thickest trees per ha (or 25 trees per subplot) were included in the calculations according to the recommendations of ZINGG (1994) for mixed species forests. Reinekes stand density index (SDI) was calculated according to DANIEL and STERBA (1980) as

$$SDI = N \times (25 / dg)^{-1.605}$$

where N is the number of trees and dg the diameter corresponding to the mean basal area of the stand. The distribution of trees on the area was tested with the aggregation index of CLARK and EVANS (1954), and corrected for edge effects according to DONNELLY (1978). It is the ratio between the observed mean distance to the next neighbour and the expected distance for randomly distributed trees. Test statistics were calculated according to PRETZSCH (1996).

3 Results

Uholka is almost a pure beech forest, and only 3 % of the trees are other species (2.1 % of the trees were *Acer pseudoplatanus* and *A. platanoides,* 0.6% *Fraxinus excelsior,* 0.4 % *Ulmus glabra).* In the Sihlwald only 76.8 % of the trees are beech *(Fagus sylvatica);* 10.2 % were *Abies alba,* 8 % *Picea abies,* 1.9 % *Fraxinus excelsior,* 1.7 % *Acer pseudoplatanus,* 1.2 % *Ulmus glabra* and 0.2% *Larix decidua.*

The beech in Uholka and Sihlwald had a similar relationship between $d_{1.3}$ and tree height within the range of 8–86 cm $d_{1.3}$ (maximum diameter of beech in the Sihlwald), as can be seen by the height curves (Fig. 1). On both sites beech may reach a maximum height of about 50 m. 43 % of the trees (N) in Uholka were in the upper storey (height of more than 2/3 of the top height), 19 % in the middle and 38 % in the lower storey (height of less than 1/3 of the top height). In the Sihlwald only 27 % of the trees belonged to the upper storey, 17 % to the middle and 56 % to the lower storey.

In Uholka, 21 trees per ha had a $d_{1.3}$ of 80 cm or more (the largest beech measured was 132.6 cm thick), but in the Sihlwald only one. Figure 2 shows the diameter distribution (frequency of trees per 4 cm diameter classes) on all the 10 ha plots. Up to 34 cm, the distribution curves of Uholka and Sihlwald are similar, although tree numbers in the Sihlwald are slightly higher, especially in diameter class 18 (16–19.9 cm). Between 30 and 78 cm, the curve of Uholka runs rather flatly and evenly with two small peaks around 56 to 58 and 74 cm, and decreases afterwards slowly to 110 cm. In contrast, the curve of the Sihlwald shows a pronounced peak around 54 cm. Most of the 0.25 ha subplots in Uholka show a similar distribution with a very large range of diameters, although the amount of trees especially in the smallest diameter class varies. In the Sihlwald, not all of the subplots show this peak around 50 to 58 cm in the diameter distribution. Some of the distribution curves look similar to the ones in Uholka; however the maximum diameters are smaller.

The main stand data per ha and their variation between the 40 subplots in Uholka and Sihlwald are given in Table 1. The similar shape of the height curves (Fig. 1) enabled us to use the same volume tariff functions (WSL, unpublished) for the estimation of stand volume on both sites. Apart from the top height and the number of trees all parameters studied differed significantly between the two sites (Table 1).

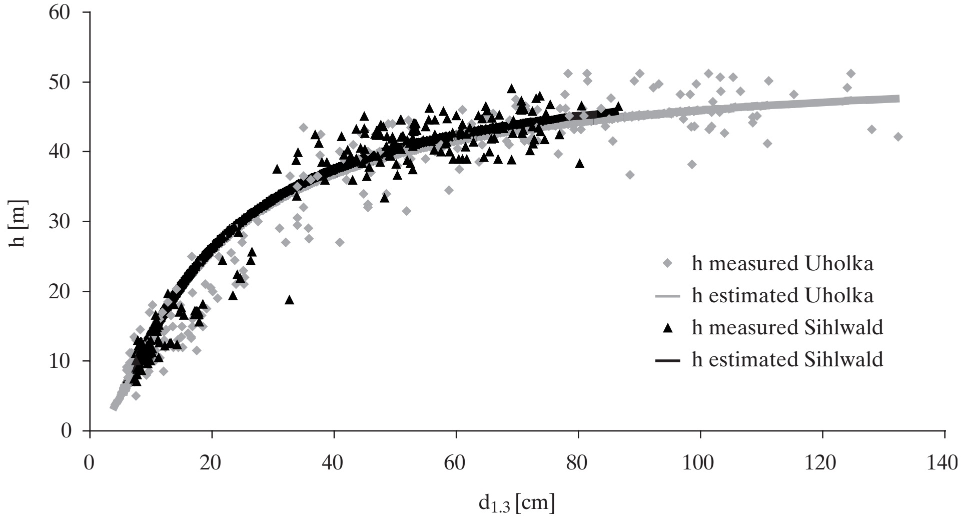

Fig. 1. Height curves of beech in the virgin forest Uholka and the (formerly) managed forest Sihlwald calculated according to the equation of Michailoff (1943).

Table 1. Variation of stand characteristics within an area of 10 ha in the virgin beech forest Uholka and the (formerly) managed forest Sihlwald (40 subplots of 0.25 ha). Abbreviations: N = number of trees, G = basal area, V = stand volume, h_{dom} = top height 100, d_{dom} = mean diameter of 100 thickest trees, d_g = diameter corresponding to mean basal area, SDI = stand density index. * living trees ≥ 8 cm $d_{1.3}$; ** standing and lying deadwood; *** of total volume (living and dead).

	Uholka					t-test / U-test^x	Sihlwald				
	mean	min	max	std dev	c.v.	p	mean	min	max	std dev	c.v.
N*/ha	219	140	336	46.9	0.21	n.s.	259	144	796	143.5	0.55
G*, m^2/ha	38.5	23.0	51.8	7.4	0.19	<0.0001	30.7	18.2	40.5	5.3	0.17
V*, m^3/ha	770	421	1042	155.9	0.20	<0.0001	524	253	705	106.9	0.20
$h_{dom\ (beech)}$*, m	40.3	32.9	42.9	2.33	0.06	n.s.^{x}	40.2	31.6	41.5	1.7	0.04
$d_{dom\ (beech)}$*, cm	63.3	44.4	74.5	7.3	0.11	<0.0001	54.2	34.4	59.4	4.54	0.08
$d_{g\ (all\ species)}$*, cm	48.0	29.5	59.9	6.9	0.14	0.0004	41.6	19.0	52.4	8.3	0.20
SDI*	602	394	750	96.4	0.16	<0.0001	513	393	674	70.1	0.14
V_{dead}**, m^3/ha	111	27	255	61.4	0.55	<0.0001^x	8	0	62	12.4	1.64
V_{dead}, %***	13.0	2.7	32.6	7.8	0.60	<0.0001^x	1.4	0	9.8	2.2	1.54

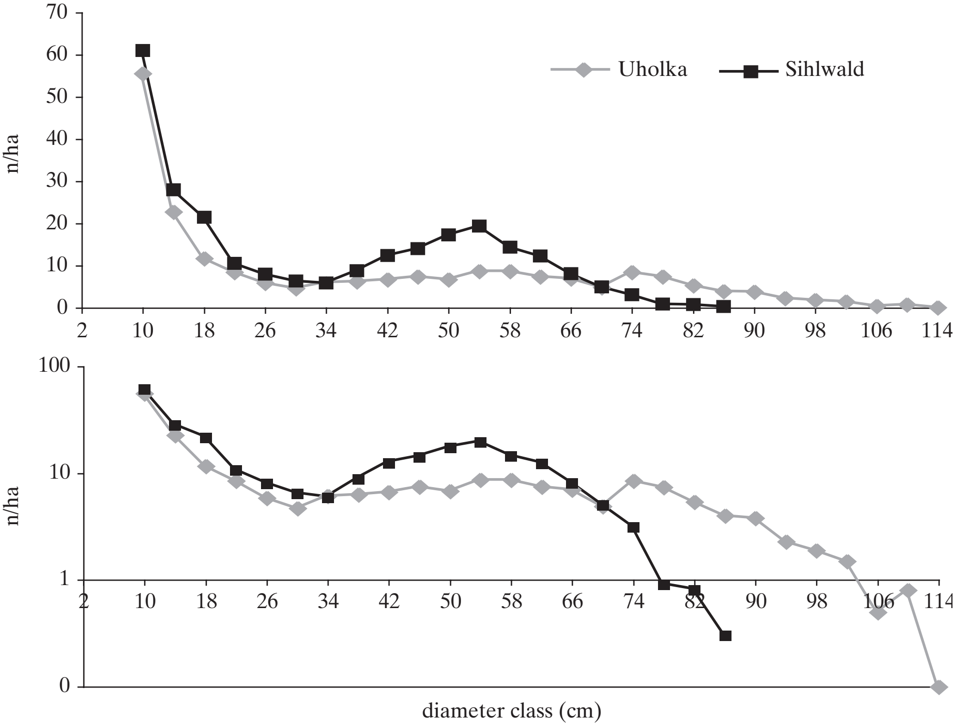

Fig. 2. Diameter distribution (frequency of trees per 4 cm-diameter classes) on the 10 ha plot in Uholka and Sihlwald (in linear and logarithmic scale).

The variation in tree numbers was greater in the Sihlwald than in Uholka. The minimum number of trees per subplot was about the same on both sites, but the maximum number per subplot was much higher in the Sihlwald due to a small area within the plot with obviously younger trees. The higher number of thick trees in Uholka meant that the basal area and stand volume as well as the mean and maximum stand density index (SDI) were higher than in the Sihlwald. The largest stand volume on a 0.25 ha plot in the virgin forest was 1042 m^3/ha, the lowest 421 m^3/ha. In the Sihlwald the stand volume ranged between 253 and 707 m^3/ha. The volume of standing and lying deadwood was about 14 times greater in the virgin than in the managed forest. The average percentage of deadwood in Uholka was 13 % of the total volume; in the Sihlwald it was only 1.4 %. The proportion of standing deadwood in Uholka was 28 %. For most stand data, the standard deviations are higher in Uholka than in the Sihlwald. The coefficients of variation, however, are similar. The volume of deadwood varied most from subplot to subplot.

Figure 3 shows the spatial distribution of the basal area within the 10 ha plots in Uholka and Sihlwald. On both sites, the distribution of subplots with large or small basal area does not show a regular pattern. Differences in basal area diminish, when subplots are merged to areas of 1 ha and more.

The aggregation index of CLARK and EVANS (1954) was used to analyse the horizontal distribution of trees. Table 2 shows the values of the CLARK and EVANS index together with the test parameters according to PRETZSCH (1996), calculated for different groups of living and dead trees.

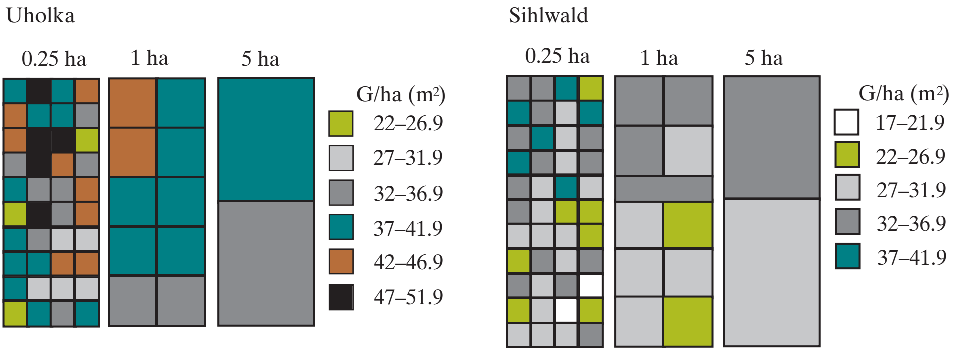

Fig. 2. Diameter distribution (frequency of trees per 4 cm-diameter classes) on the 10 ha plot in Uholka and Sihlwald (in linear and logarithmic scale).

Table 2. Clark and Evans-indices (R_{corr}), corrected for edge effects, and related test parameters (TR_{corr}) for tree distribution in the virgin forest Uholka and the (formerly) managed Sihlwald. R-values of more than 1.0 indicate a tendency to regular distribution (with a value of 2.1491 the distribution is strictly hexagonal), and values below 1.0 a tendency to clustered distribution. Random distribution is given by values of R = 1.0. p is the probability of error for the distribution differing from a random distribution.

	Uholka			Sihlwald		
Attribute	R_{corr}	TR_{corr}	p	R_{corr}	TR_{corr}	p
Living trees with $d_{1.3} \geq 8$ cm	1.0316	3.0917	1%	1.0901	9.182	0.1%
Trees in the upper layer	1.0697	3.7947	0.1%	1.2291	17.1356	0.1%
Trees in the middle layer	0.9327	–2.6412	1%	0.8328	–7.0419	0.1%
Trees in the lower layer	0.8186	–12.9066	0.1%	0.7578	–13.3777	0.1%
Trees with $d_{1.3} \geq 80$ cm	1.0690	1.9060	n.s.	0.4320	–6.7370	0.1%
Trees with 18 $d_{1.3} < 80$ cm	1.0231	1.4376	n.s.	1.2056	16.0432	0.1%
Trees with $8 \leq d_{1.3} < 18$ cm	0.8183	–12.7921	0.1%	0.7796	–14.397	0.1%
Standing dead trees	0.8294	–3.6815	0.1%	0.6572	–5.1011	0.1%
Standing and lying dead trees	0.8799	–5.2528	0.1%	0.6945	–5.1014	0.1%

In Uholka and in the Sihlwald, trees in the upper layer tend to have a regular distribution (this is more pronounced in the Sihlwald), whereas trees in the middle and lower layer are clustered. Large trees with a $d_{1.3}$ of 80 cm and more are randomly distributed in Uholka but clustered in the Sihlwald (in the Sihlwald, these trees are mainly spruce). Dead trees are clustered on both sites.

On both sites, regeneration was present on almost all analysed sample plots. Only on 4 of the 160 sample plots in Uholka and Sihlwald did we not find any saplings 10 cm in height to 7.9 cm $d_{1.3}$. Regeneration density was higher in the Sihlwald (44 506 trees/ha) than in Uholka (25 166 trees/ha), which was mainly due to the height class 10–29.9 cm (Table 3). But there were also more saplings higher than 130 cm. In the height class 30–129.9 cm the regeneration density was higher in Uholka than in the Sihlwald. The species composition of the regeneration varied according to height classes. In Uholka less than 25 % of the saplings smaller than 129.9 cm were beech, 62 % were maple (*A. pseudoplatanus* and *A. platanoides*), 10 % ash and 3 % elm. With increasing height, the percentage of beech increased, and in height classes of 5 m and more, 98 % of the trees were beech. In the Sihlwald only in the height class smaller than 30 cm were tree species other than beech present in noteworthy numbers, with 28 % ash, 3.5 % maple and 1.4 % silver fir. Almost all saplings higher than 50 cm and with less than 8 cm $d_{1.3}$ were beech.

Table 3. Regeneration (of 10 cm height to 8 cm $d_{1.3}$) within an area of 10 ha in the virgin beech forest Uholka and the (formerly) managed forest Sihlwald. 160 sample plots (s.p.) of 1 m^2 (for saplings smaller than 30 cm) and 20 m^2 (for saplings 30 cm and higher).

	Uholka (160 sample plots) height class (cm)				Sihlwald (160 sample plots) height class (cm)			
	10–29.9	30–129.9	≥130	all ≥10	10–29.9	30–129.9	≥130	all ≥10
mean (N/ha)	9375	13466	2325	25166	33313	7669	3525	44506
median (N/ha)	0	7750	1000	19000	10000	3750	2500	16500
min (N/ha)	0	0	0	0	0	0	0	0
max (N/ha)	90000	122500	22500	158000	520000	72500	23500	535000
std dev (N/ha)	14349	17324	3400	26556	76098	11333	3712	80242
s.p. without regen. (%)	51.9	5.6	17.5	2.5	48.1	16.9	11.3	2.5

4 Discussion

The similar height curves of beech in the Sihlwald and Uholka indicate that the growth conditions for beech on both sites are comparable although site conditions differ in some aspects. Both are highly productive sites, as can be seen from the h_{dom} of 40 m and maximum tree heights of 50 m. According to KORPEL’ (1995) beech reaches similar heights in the virgin forest reserve Havešová, which he considers a record in the Western Carpathians. The mean number of trees and volume per ha in Uholka are comparable to the data KORPEL’ gives for the beginning of the disintegration phase in Havešová (monitoring plot 3), whereas the basal area of 38.5 m^2/ha is slightly higher in Uholka than in plot 3 in Havešová. It is, however, lower than the mean basal area (43–45 m^2/ha) in the virgin beech forests Puka and Rajca in Albania (TABAKU 2000). With a mean standing volume of 770 m^3 per ha and maximum volumes of more than 1000 m^3 per ha, Uholka lies in the upper range of the values LEIBUNDGUT (1993) mentioned as typical for virgin beech forests.

The main differences between Uholka and Sihlwald are in the diameter distribution, especially in the number of thick trees, and in the volume of living trees and of deadwood. This is not surprising as timber utilisation in the Sihlwald only stopped about 10 years before the installation and measurement of the plots. However, it is remarkable that the mean standing volume in Uholka is higher than the maximum volume of the approx. 150 year old stand in the Sihlwald. It must be assumed that some of the big trees are already rotten inside or hollow (BÜRGI 2002) but it is impossible to determine the proportion of rotten wood with non-destructive methods.

The diameter distribution (Fig. 2) of the Sihlwald shows the typical structure of a two-layered forest with a more or less even-aged upper layer. This is also confirmed by the height curve (Fig. 1) which shows two distinct layers, an upper layer with crowns between 35 to 45 m and a lower layer with trees between 10 and 20 m. This structure is the result of thinnings concentrating on the upper storey, which allowed the establishment and maintenance of undergrowth. The diameter distribution of Uholka indicates a very uneven-aged structure.

The shape of the curve, showing a more or less even distribution of trees over a large diameter range (from approx. 30–80 cm), seems to be typical for virgin forests of pure *Fagus sylvatica* and *F. orientalis* (GIURGIU *et al.* 2001; KORPEL' 1995; ROTH 1932; SAGHEB-TALEBI and SCHÜTZ 2002; STOYKO *et al.* 1982; TABAKU 2000). The distribution differs though from the model distribution of a selection forest ("Plenterwald") described by SCHÜTZ (2001). It is striking that most diameter distributions of virgin beech forests show a slight dent in the curve around 30 cm, indicating that there are not enough trees in this diameter class for a constant replenishment of the next classes. Without information on tree ages, however, it is difficult to say whether this is due to a stand structure composed by only a few overlapping tree generations with large intervals, as described by KORPEL' (1995), or rather to the fact that beech grows very quickly through this diameter class. As a diameter of 30 cm coincides with the diameter when beech reaches the upper crown layer (Fig. 1), we tend to favour the second explanation. It seems that beech stays in the lower storey and hardly shows any increment when suppressed, but reacts very strongly and grows quickly through the middle layer when the light conditions become more favourable. The middle layer therefore is rather sparse. This also explains why the vertical stand structure is less differentiated than the diameter distribution and why virgin beech forests were sometimes described as being uniform and "hall-like"(e.g. LEIBUNDGUT 1993; SCHÜTZ 2001).

According to STERBA (1991), the stand density index (SDI) for fully stocked beech stands may reach maximum values of 650 to 750. In Uholka the value of 750 is reached on at least one subplot. The mean SDI of 602 also seems rather high for an uneven-aged forest. In the Sihlwald, which was regularly thinned, the SDI in some subplots was also up to 674. This high value is partly due to the percentage of mixed conifers but also to the added basal area of the undergrowth.

The distribution of trees in the Sihlwald plot shows the effect of "high thinnings" that concentrate mainly on the upper crown layer, aiming to give space to the selected final crop trees. Therefore only trees in the upper layer are distributed regularly, whereas trees in the middle and lower layers are clustered. In Uholka, the clustered distribution of trees in the lower layer and, to a lesser degree, also in the middle layer is the result of regeneration growing in gaps created by dead trees. Although in Uholka old trees with a $d_{1.3}$ of 80 cm and more are distributed randomly, dead trees tend to have a clustered distribution. This is probably due to the fact that often two to three neighbouring trees are thrown by the wind. Nevertheless, a simultaneous break-down of trees on larger areas could not be observed, which confirms the view of FRÖHLICH (1954), KORPEL' (1995), ROTH (1932) and others that large-scale disturbances in virgin beech forests are rare.

The maximum percentage of deadwood on an area of 0.25 ha in Uholka was one third of the total volume, and the average 13 %. In none of the 0.25 ha subplots was the standing volume less than 420 m^3/ha. As KORPEL' (1982 and 1995) claims, the stand volume in virgin beech forests in the Western Carpathians never drops below 400 m^3/ha. The volume of deadwood is lowest in the middle of the optimum stage with 30 to 50 m^3/ha and highest at the end of the disintegration stage with maximum values of 200(–300) m^3/ha. These data correspond surprisingly well with our findings in Uholka. Carpathian beech forests seem to have higher deadwood volumes than Albanian ones, where TABAKU (2000) found average deadwood volumes of 4–10 % (32–86 m^3/ha). The relation of standing to lying deadwood in Uholka was 28 : 72. This corresponds to the findings of NILSSON *et al.* (2003), who consider a proportion of standing deadwood of about 30 % as independent of the total volume of deadwood. In the Sihlwald, the percentage of deadwood (1.4 %) was only slightly higher than the average in forests in the Swiss plateau (1.1 % according to BRASSEL and BRÄNDLI 1999). In future, the amount of deadwood will certainly rise and may even surpass the deadwood volumes of virgin forests. Due to the more or less even-aged upper storey, it must be expected that in about 50 to 100 years the whole old stand will disintegrate over a comparatively short period. In the natural forest reserve "Heilige Hallen" in north-eastern Germany, which has not been utilised for more than 150 years and which has been strictly protected since 1938 (BORRMANN 1996), the average deadwood volume on an area of 13.5 ha was in 1999 approx. 200 m^3/ha or 28 % of the total volume (TABAKU 2000). This indicates that in formerly managed forests disintegration may occur faster and more concertedly than in virgin forests.

Due to the former management, the tree species composition in the Sihlwald was more varied than in Uholka. However, this does not continue in the regeneration. Although in Uholka only 3 % of the trees ≥ 8 cm $d_{1.3}$ were other species than beech, they accounted for 75 % of the 10 to 29.9 cm high seedlings. In the Sihlwald with a much higher percentage of admixed species in the old tree generation, they had a proportion of only 33 % in the regeneration smaller than 30 cm, although light conditions were more favourable than in Uholka. The species composition and density of seedlings smaller than 30 cm are strongly influenced by recent seed years of beech. The much greater abundance of beech seedlings in the Sihlwald indicates that seed production within the last ten years has been more frequent and more ample in the Sihlwald than in Uholka. Comparable data, however, are not available. With increasing height, the admixed tree species are increasingly suppressed by beech. In Uholka, this leads to a continuous decrease of maple, ash and elm with increasing tree height; in height classes > 5 m beech makes up almost 100 %. In the Sihlwald the admixed species already drop out when they are 30 to 50 cm high, in spite of the lower stand density and the more favourable light conditions than in Uholka. As deer populations are much higher in Switzerland than in the Ukrainian Carpathians, we suppose that browsing by deer is an important reason for this. In Uholka and in the Sihlwald regeneration can be considered sufficient. On both sites, there is more than one sapling of 30 cm or higher per m^2. The total regeneration density as well as the density of regeneration ≥ 1.3 m fit in the range given by KORPEL' (1995) and TABAKU (2000) for virgin beech forests. If we ignore the seedlings smaller than 30 cm, regeneration densities in Sihlwald and Uholka are similar. However, saplings higher than 1.3 m are more frequent in the Sihlwald and they seem to be more evenly distributed than in Uholka. This might be due to the former thinning operations in the upper storey resulting in better and more even light conditions.

5 Conclusions

Small-scale regeneration methods, such as progressive felling by small groups ("Swiss Femelschlag") and single tree or group selection systems correspond best to the natural regeneration processes in undisturbed beech forests, as far as this can be judged from our results and the published data about virgin beech forests from other areas. Such types of continuous cover forests ("Dauerwald") may also best fulfil the demands being placed on a mutifunctional forest management. Even the overall economic performance of selection forests (also of pure beech) is at least as good as or even better than that of even-aged forests (SCHÜTZ 2001; BIEHL 1991).

The intensity of silvicultural interventions depends on the management goals. Beech is a very dominant tree species, at least under site conditions such as those prevailing in Uholka or Sihlwald. If a certain percentage of admixed tree species is to be maintained, larger regeneration gaps and continued tending operations will be necessary (see also von LÜPKE 2004).

In the Sihlwald, where timber harvesting stopped a few years ago, the standing volume will still increase before the disintegration phase starts, possibly in about 50 to 100 years. Disintegration of the upper storey might happen over a rather short period, due to the similar age of the trees in this layer. The lower storey, however, is well developed and will close resulting gaps very quickly. The percentage of beech will increase in the long term, while other species will drop out.

The preliminary results of this comparative study only allow limited conclusions. With further analysis on a single tree basis more detailed information on the spatial distributions of very large or dead and dying trees and the size of resulting canopy gaps could be gained. A second inventory of the plots will provide a better basis to model and predict stand dynamics and to analyse processes of mortality and regeneration. The increment data will also allow a better comparison of the growth conditions of the two stands.

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