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Analyses of stand structure as a tool for silvicultural decisions - a case study in a Quercus petraea - Sorbus torminalis stand

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Abstract

The study applies structural indices using the example of an oak (*Quercus petraea* (Matt.) Liebl.) - chequer tree (*Sorbus torminalis* (L.) Crantz) stand in order to derive recommendations for the silvicultural treatment of Chequer trees. The investigated stand, located in the northern part of Bavaria, comprises eight tree species and four shrub species. Various indices were used to analyse the stand structure and the crown coverage frequency. It was shown that chequer trees, which are presently of high economic interest, are strongly oppressed in the upper layer and almost completely missing in the lower layers of the stand. The possible reasons for this finding and alternatives for the further management of the stand are discussed. Persistent and repeated thinnings in order to ensure a sufficient crown development of the chequer trees seem to be essential for their survival.

Key word: Sorbus torminalis, stand structure analyses, species diversity, mixed-species stand, silvicultural treatments

Zusammenfassung

Die vorliegende Untersuchung wurde in einem nahe Bamberg gelegenen, aus insgesamt acht Baum- und vier Straucharten bestehenden Eichen (*Quercus petraea* (Matt.) Liebl.) - Elsbeeren (*Sorbus torminalis* (L.) Crantz) - Bestand durchgeführt. Sie hatte das Ziel mittels einer detaillierten

Strukturanalyse Empfehlungen für die weitere waldbauliche Behandlung des Bestandes zu erarbeiten und daraus in Verbindung mit Literaturangaben allgemeine Hinweise zur waldbaulichen Behandlung der Elsbeere abzuleiten. Zur Charakterisierung des Bestandes dienten zahlreiche Indizes (Aggregationsindex nach CLARK und EVANS, Durchmischungs- und Durchmesserdifferenzierungswert nach FÜLDNER, SHANNON-index), dreidimensionale Kronenkarten und ertragskundliche Bestandeskennwerte. Die Oberschicht des Bestandes, der nur 4 % der Individuen angehören, die jedoch 37 % der Grundfläche bildet, wird zu 76 % von Eichen gebildet, die teilweise noch aus der ehemaligen Mittelwaldbewirtschaftung stammen. Elsbeeren finden sich hauptsächlich in der zweiten der vier Höhenklassen. Sie nehmen dort sowohl stammzahl- als auch grundflächenbezogen einen Anteil von rund 40 % ein, darunter fehlen sie jedoch fast vollständig. Die Elsbeeren sind in der Regel von Individuen anderer Baumarten umgeben und werden von diesen in den meisten Fällen stark bedrängt. In Übereinstimmung mit den Ergebnissen anderer Autoren wird empfohlen Elsbeeren durch wiederholte Eingriffe dauerhaft von der Konkurrenz anderer Baumarten im Kronenraum zu befreien und qualitativ befriedigende Individuen bereits frühzeitig zu begünstigen.

1 Introduction

The distribution and the use of chequer trees (*Sorbus torminalis* (L.) Crantz) has decreased drastically since the conversion of coppices with standards to high forests and the substitution of wood by other materials (RÖHRIG 1972, KAUSCH-BLECKEN VON SCHMELING 1994, KLEINSCHMIT 1998). Chequer tree therefore is an almost forgotten tree species which has been "rediscovered" only recently for economic and nature conservation reasons (EWALD et al. 1994). Only in France it has also been of economic interest for a long time (WILHELM 1993). However, stands including chequer trees of a remarkable portion are rare. As a result there are considerable uncertainties regarding the silvicultural treatment of this species (SCHÜTE and BECK 1996). In contrast to the traditional proceeding - deducting silvicultural recommendations by analysing data originated from long termed investigations - the present study tries to derive silvicultural advices for the handling of stands where chequer trees are concerned by interpreting the structural status of a particular stand combined with literature comparisons. The tools for the description of the stand structure are numerous structural indices. Structure is understood here in the sense of OLIVER and LARSON (1996) as "the physical and temporal distribution of trees and other plants in a stand".

2 Materials and methods

2.1 Study site

The stand investigated is located approximately 55 km distance Bamberg in Bavaria, Germany (10° 21' 41'' E, 50° 17' 11'' N) at an altitude of 320 m above sea level. The area is slightly (5°) inclined to the east. The annual precipitation amounts to a long-year average of approximately 600 mm, 200 mm of which fall in the vegetation period. The annual average temperature amounts to 9°C. The type of soil is Terra fusca, which has been formed from shell limestone disintegration. The substrate is well ventilated due to a high proportion of fragments beneath the surface, the nutrient content is very good. This also results from the fact that the shell limestone is partially covered by loess. In the whole area the ground vegetation is abundant in species. It is dominated by calciphilous species. The humus type is mull.

2.2 Measurements and tree species

The stand is part of a 3 hectare area and has developed from a former coppice with standards. A 0.6125 hectare section abundant in chequer trees was selected from this area. The diameter at breast height, the total height of the tree, the height at the point where the crown commences (lowest living branch), 8 crown radii (by way of looking up tangentially starting in the north and continuing in 45° steps) and the root collar coordinates were determined or measured in decimeter precision of all trees taller than 1,3 m on this area. The stand (between 90 and 140 years old) consists of *Quercus petraea* (Matt.) Liebl., *Sorbus torminalis* (L.) Crantz, *Fagus sylvatica* L., *Carpinus betulus* L., *Pinus sylvestris* L., *Acer pseudoplatanus* L. and *Acer campestre* L. The brushwood present almost throughout the whole area comprises the following species: *Corylus avellana* L., *Crataegus monogyna* Jacq., *Sambucus nigra* L., *Lonicera xylosteum* L. and *Cornus sanguinea* L.

2.3 Stand structure characteristics

The following measures were carried out to describe the stand structure:

1. Stem numbers and basal areas of the stand in different strata. The largest height measured (= 100%) formed the basis of the strata, which were classified as follows: height class 1 (76% to 100%) = 24.2 to 31.8 m, height class 2 (51% to 75%) = 16.5 to 24.1 m, height class 3 (26% to 50%) = 8.8 to 16.4 m, height class 4 (0% to 25%) = 1.3 to 8.7 m.

2. Crown coverage frequency and crown maps. The crown coverage frequency was determined on the basis of a grid in a 10 cm layout (100 points per square meter forest floor). For each grid point calculations were carried out on the basis of the stem positions measured and the crown radii determined in order to ascertain whether a perpendicular drawn on that point crossed one or more tree crowns. Each crown shape was adjusted between 10 measuring points (tree height and height of the point where the crown commences as well as 8 crown radii) by means of cubic paraboloids in order to prepare spatial crown maps. The crown bodies could be reproduced in the three-dimensional space using the positions of

the corresponding root collar coordinates. A detailed description of the method is given by NÜßLEIN (1995). The resulting crown maps show only the crown parts visible from above. This form of representation is particularly suitable for highly structured forest stands because the vertical strata as well as the horizontal entanglement of the tree crowns are easily recognisable. The position of a tree or a tree species in the stand structure becomes visible.

3. Shannon-Index. The formula is (see MÜHLENBERG, 1989):

H'= $-\sum_{i=1}^{S} p_i * \ln p_i$

where H'=Shannon-Index, S=number of species, $p_i=n_i/N$ (n_i=number of individuals or basal area of species i, N=total number of individuals or total basal area). A t-distributed test statistic for testing differences between different clusters (e.g. stand strata) is given by MÜHLENBERG (1989). As an index of equitability the eveness (E=H'/lnS) was calculated additionally. In accordance with PRETZSCH (1996) the Shannon index was not only calculated for the complete stand, but furthermore for each stratum separately, in order to characterize the vertical species structure.

4. Aggregation index by CLARK and EVANS (1954), extended by DONNELLY (1978, cited according to PRETZSCH, 1996)):

$$R = \frac{\bar{r}_{ob}}{\bar{r}_{exp}}$$

where R=Index of aggregation, $\bar{r}_{ob} = \frac{1}{N}\sum_{i=1}^{N} r_i$, N=total number of trees, r_i=distance of tree i to its next neighbour, $\bar{r}_{exp} = 0.5\sqrt{A/N} + 0.0514P/N + 0.041P/N^{3/2}$, A=area of the experimental plot (m^2), P = circumference of the experimental plot (m). A t-distributed test statistic for testing deviations from a random distribution is given by PRETZSCH (1996).

5. Admixture by FÜLDNER (1995 a and b):

$$DM3 = \frac{1}{3}\sum_{j=1}^{3} v_{ij}$$

where DM3=index of admixture, j refers to the three nearest neighbours of tree i, v_{ij}=0 if neighbour j belongs to the same species as tree i, v_{ij}=1 if tree i and neighbour j belong to different species. The DM3-value can be one of the following: 0 = all trees of a group of four belong to the same species, 0.33 = one neighbour of the tree in question belongs to a different species, 0.67 = two of the three neighbours of the tree in question belong to a different species, 1 = all neighbours belong to a different species.

6. Diameter differentiation by FÜLDNER (1995 a and b):

$$TD_i = 1 - d_{ij}$$

where Td_i=index of diameter differentation, j refers to the nearest neighbour of tree i, d_{ij}=quotient of dbh's (numerator: thinner tree, denominator: thicker tree)

3 Results

3.1 Stem numbers and basal areas

The stem number of the stand is very high and the number of individuals is distributed very unevenly throughout the different strata (table I). Only 4 % (41 in 1042 individuals) of the trees are found in the overstory. However, these few individuals represent 37 % of the stand basal area. The individuals of the second height class make up a further 51%, while the two lower height classes include a very large number of thin trees. The dominating individuals are mainly oaks. The co-dominating layer is basically formed by oaks and chequer trees. However, the two species represent only a small proportion of the basal area and the stem number of the strata below. There the dominating species are mainly beeches and hazelnuts (table I). Only the hornbeam is distributed relatively evenly throughout the different strata.

3.2 Vertical structure - crown coverage frequency and crown maps

91.9 % of the stand surface is sheltered by tree crowns. Frequently multiple coverages occur in the broadleaved forest stand abundant in species. While 20.4 % of the area is covered by only one tree crown, 29.9 % is sheltered by two and 41.6 % even by three or more crowns (table II). If height classes are differentiated, it can be seen that height class 1, which forms the upper layer, covers about one third of the stand area and height class 2 covers less than two thirds. The latter exhibits many horizontal crown entanglements, as shown by the fact that the proportion of multiple coverages amounts to 18.8 % in this height class alone. Height classes 3 and 4 account for 40.3 % and 44.2 % of the area, respectively. Such an intricate horizontal and vertical structure of the strata finally results in the intense use of the complete crown space.

The crown map in Figure 1 shows a relatively densely covered section of the stand. Usually the oaks exhibit the largest crowns. At the same time the oaks often overtop their neighbours. Figure 1 also gives an imagination of the amount of competition to which the Chequer trees are exposed. They are mostly found in the second height class, jammed at the sides and even partially sheltered.

3.3 Species diversity

In the overstory the species diversity, expressed by the Shannon index is the lowest (table III), irrespective of the basis of calculation (stem number or basal area). In spite of almost identical numbers of species height classes 2 and 3 exhibit higher values. This is due to the comparatively even distribution of the species with regard to the stem number and basal area of the respective height class (higher evenness). The highest diversity values with regard to stem number are found in the lowest stratum. The reason is that there the species number is one third higher. The values calculated on the basis of basal area are distinctly below those based on stem numbers because the additional species are shrubs, whose contribution to the basal area is very low in this stratum. This finding also applies to the stand as a whole.

3.4 Horizontal structure and admixture

The horizontal distribution of the trees deviates from the random distribution, when the stand is considered as a whole and also when the overstory formed by trees of height classes 1 and 2 is considered exclusively (table IV). Viewing the four most frequent species altogether, the trees are distributed in both cases with a highly significant tendency towards regularity. Viewing the individual tree species, most of them except the oaks, rather occur in clumps (table IV). In any case the tendency of one species towards an aggregate in the overstory of the stand is higher than when all individuals of this species are considered.

The admixture value DM3 according to Füldner (1995 a) allows a differentiated study of individual growing conditions. Considering all stand members, the three nearest neighbours of the oaks and particularly those of the chequer trees, in many cases belong to a different species (figure 2). In the case of beeches, however, all possible constellations occur in similar frequency (figure 2). A different result is obtained when only the trees of height classes 1 and 2, which at that time determine the stand, are considered. Thus, in 40 % of the cases at least two of the three nearest neighbours of the oaks of the dominating stratum are also oaks (figure 3). The situation is completely different in the case of chequer trees. Groups of four with more than two chequer trees are found in less than 20 % of the cases even when understory and middlestory are neglected. However, beeches form groups of four much more frequently than oaks or chequer trees even in the dominating stratum (figure 3).

3.5 Diameter differentiation

The calculation of the parameter TD developed by Füldner (1995 a) is applicable to answer the question whether the valuable stand members are surrounded by an understory which is able to shade their stem, thus preventing the formation of water sprouts. The values calculated for each tree theoretically can range between 0 (the diameter of the nearest neighbour is identical to that of the tree in question) and 1 (the difference between the diameters is infinitely large). Figure 4 shows the frequency distribution of the TD values for all oaks and chequer trees with a dbh ≥ 35 cm. It is shown that in the vast majority of cases the nearest neighbours of these most valuable stand members are trees with a distinctly smaller diameter (figure 4).

4 Discussion

The position of the chequer trees in the stand presented here, i.e. a high proportion of stem number and basal area in height class 2, confirms the results of a study carried out by SEVRIN and KELLER (1993). These authors analysed numerous chequer tree stands and classified 74 % of the individuals investigated as co-dominating and therefore refered to chequer trees as trees of the second story. So it is likely, that first of all not stand history determined the position of the chequer trees in the stand investigated here. Their position in the stand bears the danger of being sheltered, or at least of being jammed at the sides. In some cases this can already be observed in the analysed stand (figure 1). While it is true that the nearest neighbours of the thicker chequer trees are basically distinctly smaller trees (figure 4), in the future considerable competition will grow, mainly from the beeches of height class 3. RÖHRIG (1972) and DRAPIER (1993 b) also mentioned the danger of losing the chequer trees as a result of a strong competition from beeches. In this context the finding that more than 80% of the chequer trees of the overstory (height classes 1 and 2) are surrounded by at least two neighbours of a different tree species (figure 3) is of importance. Chequer trees of high quality which have not yet reached their exploitable diameter, must therefore be freed quickly from competitors which are present in the crown space of the chequer trees or on the verge of growing into it. NAMVAR and SPETHMANN (1985), DRAPIER (1993 a) and WILHELM and DUCOS (1996) also recommend persistently and repeatedly freeing viable chequer trees as a necessary silvicultural measure. According to Wilhelm and Ducos (1996) treatments of this kind, with the aim of effectively setting free the crown, imitate the composite forest system. This method has proved to be particularly beneficial to the growth and the conservation of chequer trees, since competition is already periodically reduced (DRESCHER and MAJER, 1984; DRAPIER, 1993 b). If only little or no treatment is carried out, or if only the mature trees are harvested - as has been the case up to now - over the medium term as a result of a slow, natural demixing process only isolated specimens of chequer trees will remain.

The overstory of the stand studied is substantially dominated by oaks. This is indicated by the proportion of oak in the overall stem number and basal area in height class 1. As a consequence the Shannon index calculated for height class 1 is much lower in the top stratum, due to the domination of oaks, than in the strata below (table III). The results obtained by calculating the aggregation index R according to CLARK and EVANS (1954) indicate that the thinnings carried out in the past were aimed at a formation of groups of trees of only one species in the dominating stratum. The advantage of this procedure is, that only intraspecific competition has to be considered within each group. The admixture value DM3 as well as the TD value according to FÜLDNER highlight the fact that an understory is present in the oaks as well as in chequer tree groups, so that water sprouts are prevented. This understory basically consists of beeches and hornbeams.

The complete lack of chequer trees in the lower strata is even more alarming than the competition in the upper strata (table 1) if chequer trees are supposed to represent a considerable percentage of the stand also in future stand generations. An inventory of the stand regeneration carried out by BIEDENKOPF (1999) confirms the drastic decline of this tree species beyond the collective of trees examined by the present study. This finding may have various causes. As in other cases (compare DRESCHER and MAJER, 1984) the conversion of coppices with standards to high forests mentioned above seems to make the reproduction of chequer trees difficult. Although chequer trees can withstand being shaded by other species, the phases when the regeneration is sheltered for a longer period, which are typical of high forests with a slowly progressing regeneration, seem to put them at a disadvantage in competition with other regeneration plants (cf. also BARNOLA et al. 1993, SEVRIN and KELLER 1993, WILHELM 1993, SCHÜTE and BECK 1996). Possibly, a strong treatment of the overstory, which is necessary in any case, would suffice to temporarily satisfy the need for light of the few chequer trees in the up-coming generation.

A second reason for the lack of chequer trees in the lower strata and regeneration may be according to KAUSCH-BLECKEN VON SCHMELING (1981) and DRAPIER (1993 b) that chequer trees obviously prefer a regeneration by root-shoot. Wounding of the soil favours this type of regeneration, as frequently occurs in composite forest systems, resulting from skidding after intensive cutting of underwood (WILHELM 1993). In the present case it remains unclear what role is played by game. It is true that the examined stand is fenced off, but the fence may not be in place long enough to have a positive effect on the chequer trees, which are extremely vulnerable to browsing according to GERMAIN (1993), KAUSCH-BLECKEN VON SCHMELING (1993) and EWALD et al (1994). These uncertainties may be clarified in future studies as well as the question of how important generative reproduction actually is. In the literature generative reproduction is sometimes not considered to contribute considerably to regeneration. Some authors frequently attribute bad quality and slow growth to plants reproduced generatively (NAMVAR and SPETHMANN, 1985; DRAPIER, 1993 b; GERMAIN 1993). In many stands - and also in the present case - the seeds of chequer trees may not find the conditions under which they very easily germinate according to RÖHRIG (1972): contact to the mineral soil and leaf litter cover. In the present case tending operations, e.g the reduction of hazelnuts, whose negative effect on the regeneration density of various tree species was shown by ANDRZEJCZYK and BRZEZIECKI (1995), could improve the conditions for a future chequer tree regeneration. Presently it is also unclear, if and to what extent the success of germination is favoured by specific bird species, and to what extent these birds contribute to the distribution of chequer trees.

The structural analysis of the stand presented here as well as the given references indicate the necessity of substantial, persistent and repeated thinnings in order to guarantee the satisfactory development of a desired portion of chequer trees. Using the structural indices presented, it should be possible to quantify the effect of such thinnings on the structure and composition of the stand. Thus, it is shown that the determination of spatial stand structures, particularly in multicohort stands, is extremely important, "since the horizontal and vertical structure has a decisive effect on the treatment of the stand" (PRETZSCH, 1995). According to LUNDQUIST (1995) spatial indices for the description of the situation can supplement the classical parameters, particularly in view of a purposeful silvicultural management. This was attempted by the present study and should be repeated after some time in order to extend our knowledge of the dynamic changes in the structure of mixed stands, which is, according to PRETZSCH (1993), extremely scarce at present. However, for many purposes the consideration of several different indices is to costly. Comparing the use of the indices considered here for the derivation of silvicultural decisions, indices dealing with the vertical stand structure seem to be the prevailing tools in mixed stands. For this reason the further development of models for the quantification of vertical stand structure (e. g. Latham et al. 1998) is of main interest.

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table 1: Stem numbers, basal areas and proportions of tree species for the complete stand and in various strata

Tabelle 1: Stammzahlen, Grundflächen und die entsprechenden Baumartenanteile am Gesamtbestand in verschiedenen Bestandesschichten

hc= height class	N/ha	*Quercus petraea* (%)	*Sorbus torminalis* (%)	*Fagus sylvatica* (%)	*Carpinus betulus* (%)	*Pinus sylvestris* (%)	*Acer pseudoplat-anus* (%)	*Acer campes-tre* (%)	*Corylus avellana* (%)	shrubs (%)
total	1042	12	7	34	6	<1	<1	2	31	7
hc 1	41	76	4	4	4	12	-	-	-	-
hc 2	175	39	38	13	9	-	1	-	-	-
hc 3	235	10	2	61	10	-	-	5	12	-
hc 4	591	<1	-	32	5	-	-	2	49	12
	(m^2/ha)									
total	23.22	55	22	10	5	4	<1	1	2	<1
hc 1	8.54	78	5	3	3	11	-	-	-	-
hc 2	11.93	49	39	6	6	-	<1	-	-	-
hc 3	1.92	13	5	58	9	-	-	8	7	-
hc 4	0.83	1	-	34	8	-	-	3	51	3

table 2: Crown coverage frequency per height class and for the complete stand

Tabelle 2: Überschirmungshäufigkeiten des Gesamtbestandes und unterteilt nach Höhenklassen

	crown coverage frequency (%)				
hc= height class	0	1	2	≥3	covered (%)
hc 1	67.2	30.8	2.0	0.0	32.8
hc 2	38.3	43.0	15.7	3.1	61.7
hc 3	59.7	29.4	9.0	1.9	40.3
hc 4	55.8	32.4	9.5	2.2	44.2
total	8.1	20.4	29.9	41.6	91.9

table 3: Species numbers, Shannon index and evenness according to stem numbers (H'_N, $evenness_N$) and basal areas (H'_G, $evenness_G$) of the complete stand and of various strata (the letters refer to significant differences (α = 0.05) between the strata)

Tabelle 3: Artenzahlens sowie Shannon-index und Evenness berechnet auf der Grundlage von Stammzahlen (H'_N, $evenness_N$) und Grundflächen (H'_G, $evenness_G$) sowohl für den Gesamtbestand als auch für verschiedenen Bestandesschichten. Unterschiedliche Buchstaben kennzeichnen statistisch signifikante Unterschiede zwischen den verschiedenen Bestandesschichten (α = 0.05)

	number of species	H'_N	$evenness_N$	H'_G	$evenness_G$
height class 1	5	0.85 a	0.53	0.80 a	0.50
height class 2	5	1.26 b	0.78	1.06 a	0.66
height class 3	6	1.24 b	0.69	1.34 a	0.75
height class 4	9	1.30 b	0.59	1.17 a	0.53
total stand	12	1.71	0.69	1.39	0.55

table 4: Index R for analysing the horizontal distribution patterns of various collectives and separated according to tress species (level of significance for the deviation from a random distribution ** α = 0,01, *** α = 0.001)

Tabelle 4: Aggregationsindex R nach CLARK und EVANS (1954) zur Analyse der horizontalen Verteilung verschiedener Kollektive (Bestandesschichten bzw. Baumarten). Das Signifikanzniveau für eine Ablehnung der Nullhypothese (zufällige Verteilung) lautet: ** α = 0,01, *** α = 0.001

clump	species	N	R	distribution
	Q. petraea	77	0.94	random
total stand	*S. torminalis*	44	0.84	clustered **
	F. sylvatica	218	0.82	clustered ***
	C. betulus	42	0.65	clustered ***
	all species	381	1.69	regular ***
	Q. petraea	61	0.78	random
overstorey	*S. torminalis*	41	0.63	clustered **
(height classes 1 and 2)	*F. sylvatica*	16	0.23	clustered ***
	C. betulus	12	0.22	clustered ***
	all species	128	1.32	regular ***

figure 1: three-dimensional crown map of the densest part of the stand (Sor = *Sorbus torminalis* (L.) Crantz, Que = *Quercus petraea* (Matt.) Liebl., Fag = *Fagus sylvatica* L., Car = *Carpinus betulus* L., Ace = *Acer pseudoplatanus* L., Cor = *Corylus avellana* L.)

Abbildung 1: Dreidimensionale Kronenkarte des dichtesten Bestandesteils (Sor = *Sorbus torminalis* (L.) Crantz, Que = *Quercus petraea* (Matt.) Liebl., Fag = *Fagus sylvatica* L., Car = *Carpinus betulus* L., Ace = *Acer pseudoplatanus* L., Cor = *Corylus avellana* L.)

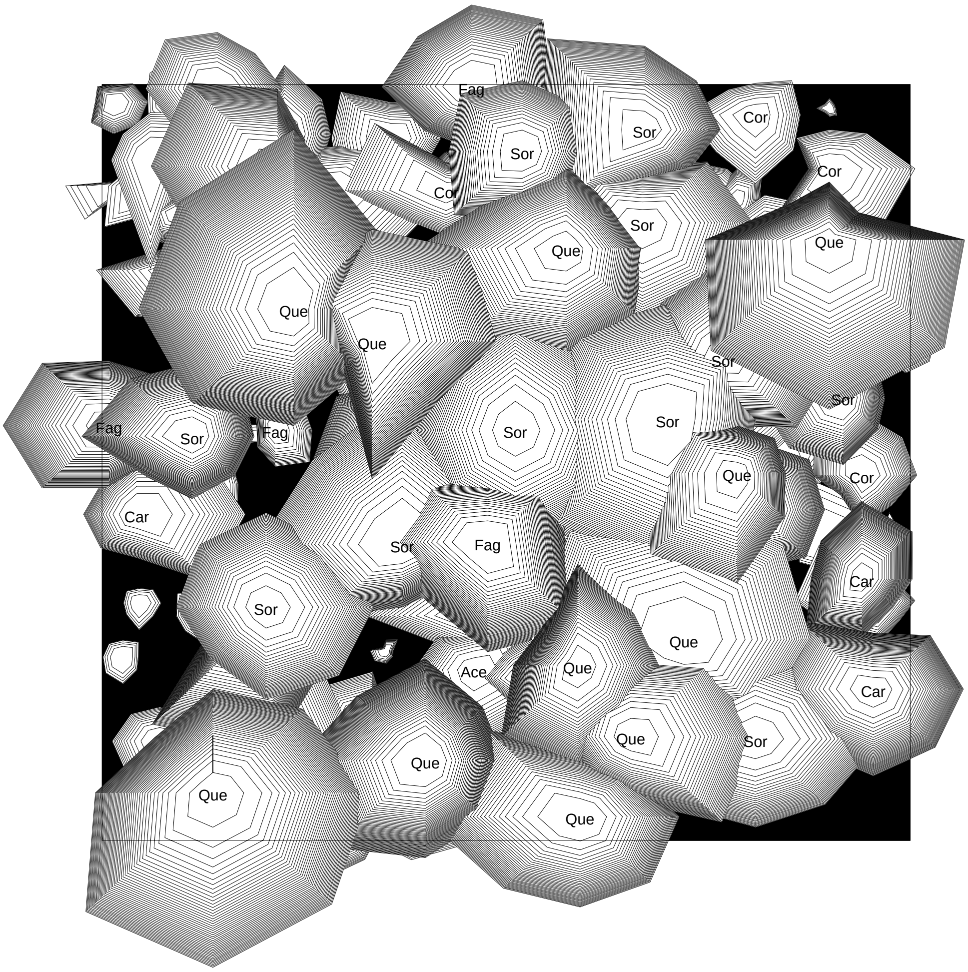


figure 2: Frequency and mean values (in the middle of the figure) of the admixture values DM3 according to FÜLDNER (1995 a) for oak *(Quercus petraea),* chequer tree *(Sorbus torminalis)* and beech *(Fagus sylvatica)* considering all stand members

Abbildung 2: Häufigkeiten und Mittelwerte (in der Bildmitte) der Durchmischungswerte (DM3-Werte nach FÜLDNER (1995 a)) für Eiche *(Quercus petraea)*, Elsbeere *(Sorbus torminalis)* und Buche *(Fagus sylvatica)* unter Berücksichtigung aller Bestandesmitglieder

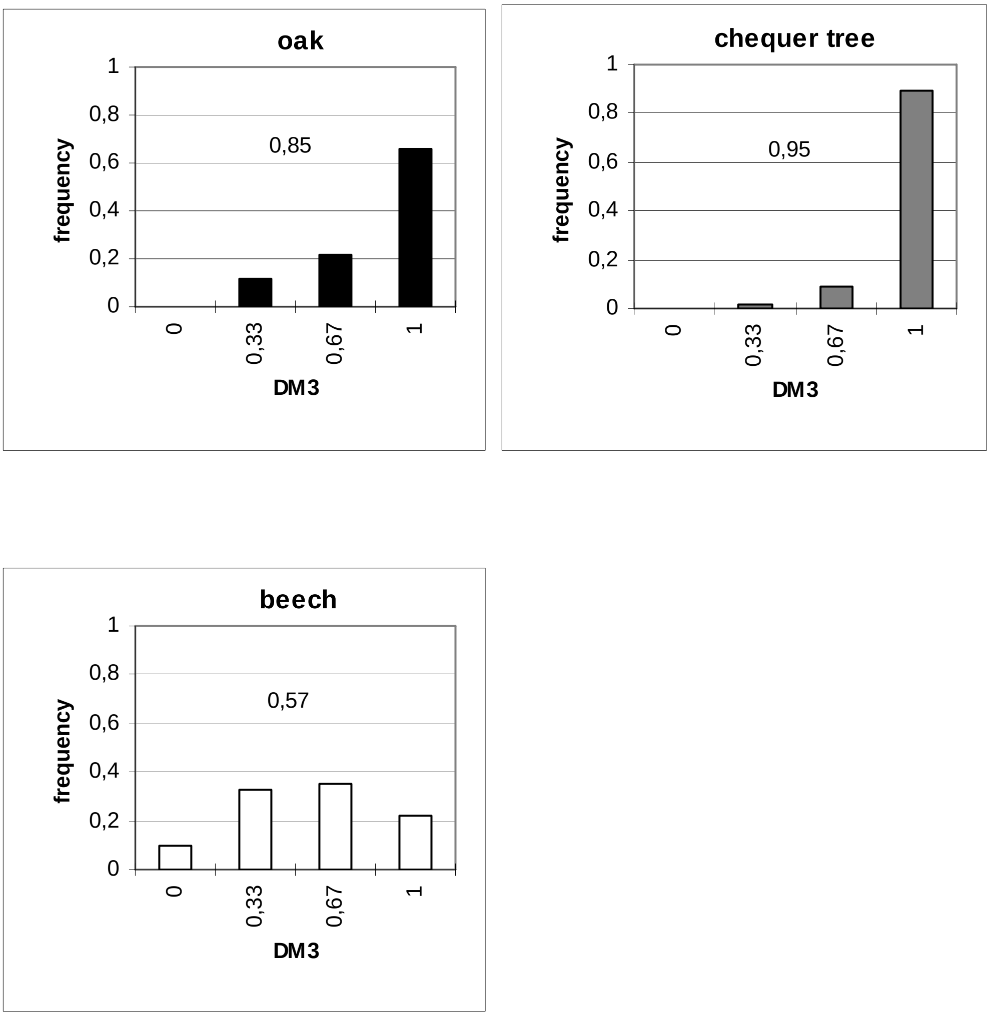


figure 3: Frequency and average values (in the middle of the figure) of the admixture values DM3 according to Füldner (1995 a) for oak *(Quercus petraea)*, chequer tree *(Sorbus torminalis)* and beech *(Fagus sylvatica)* exclusively considering the trees of height classes 1 and 2

Abbildung 3: Häufigkeiten und Mittelwerte (in der Bildmitte) der Durchmischungswerte (DM3-Werte nach FÜLDNER (1995 a)) für Eiche *(Quercus petraea)*, Elsbeere *(Sorbus torminalis)* und Buche *(Fagus sylvatica)* unter ausschließlicher Berücksichtigung der Bäume der obersten beiden Höhenschichten

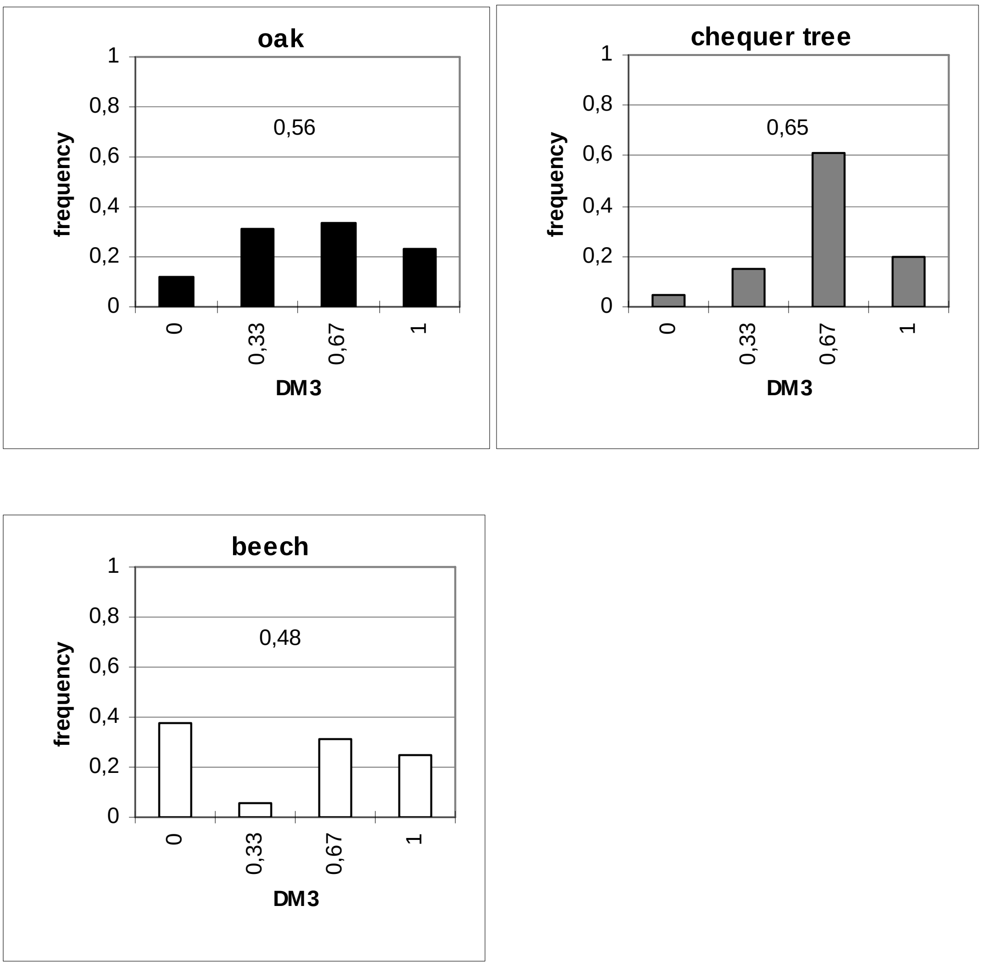
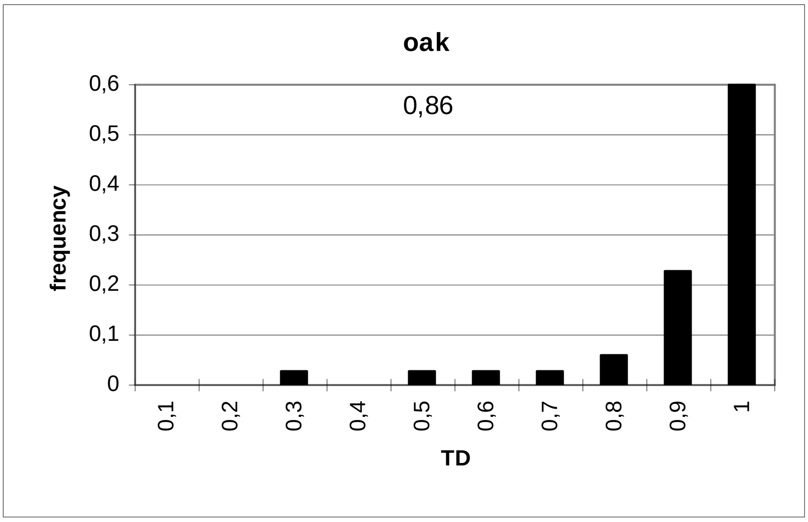
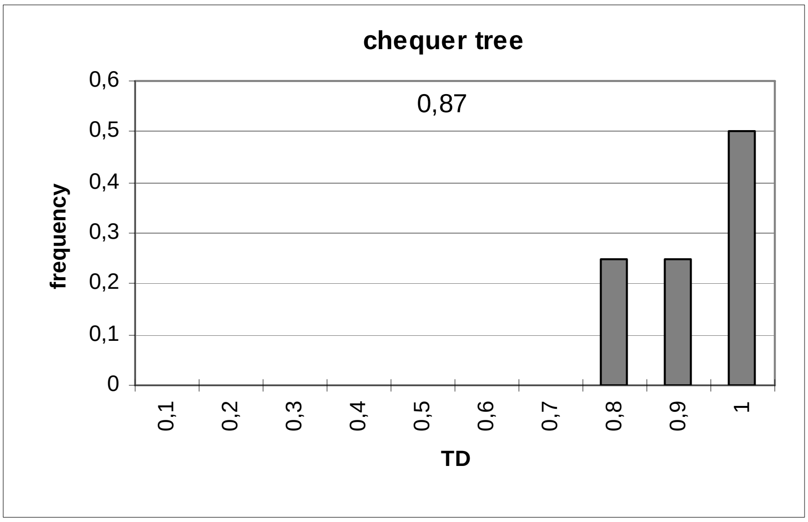


figure 4: Frequency and mean values (in the middle of the figure) of the TD-values according to Füldner (1995 a) for all individuals of the tree species oak *(Quercus petraea)*, and chequer tree *(Sorbus torminalis)* with a dbh of ≥ 35 cm.

Abbildung 4: Häufigkeiten und Mittelwerte (in der Bildmitte) der Durchmesserdifferenzierungswerte (TD-Werte nach FÜLDNER (1995 a)) für alle Eichen *(Quercus petraea)* und Elsbeeren *(Sorbus torminalis)* mit einem Brusthöhendurchmesser von ≥ 35 cm.





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