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Investigations on the Correlation Pattern in Even-Aged Stands of Larch

III. Static Description of Phenotypic Correlations Between Neighbouring Observations[1])

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(Received 4th September 1995)

Summary

The main topic of this study is a static description of spatial neighbourhood correlation patterns of stands of larch, i. e. an analysis of the correlations between neighbours at only one point in time. For these investigations extensive data sets from 9 field trials with a varying number (8 to 23) of "entries" (*Larix europaea, Larix leptolepis,* hybrids) have been used. The trials are slightly different in their ages (7 to 11 years). Single tree measurements of these trials were available for the traits height and diameter at breast height. Additionally, the diameter values have been transformed and analysed as individual basal areas.

The correlative structure of these trials for measurements of neighbouring individuals (regular square spacing with spacings 1.5 m x 1.5 m, artificial thinning procedures for only 2 of the trials) has been described by 12 different correlation coefficients. These coefficients are defined by considering quite different spatial configurations of competitive neighbourhoods. In these procedures and analyses the diagonally located neighbours of a subject tree and its missing neighbours too are explicitly considered.

For the trait height one obtains for all trials a quite uniform correlation pattern: positive correlations with intermediate or small numerical amount between the trait measurement of a subject tree and the corresponding value of its neighbourhood (for different spatial definitions of neighbourhood) and negative correlations of similar numerical amount between the trait measurement of a subject tree and the number of missing neighbours in its neighbourhood.

The correlations for the trait diameter are throughout very small. In most of the field trials one obtains stronger spatial neighbourhood relationships for height than for diameter.

The correlation between height and diameter varies between 0.63 and 0.94. This correlation, therefore, exhibits a considerable variability. The estimates of the correlation coefficients as well as the detected relationships are of high reliability since the correlation calculations of this study are based on large numbers of observations (smallest sample size = 199, largest sample size = 6649).

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Key words: correlation pattern, phenotypic correlation, neighbourhood correlation, height, diameter, individual basal area, competition, larch, static description.

FDC: 232.11; 228.5; 181.6; 165.5; 174.7 *Larix.*

Zusammenfassung

Für die statische Betrachtung des räumlichen Korrelationsmusters von Lärchenbeständen, d. h. für die einmalige Analyse der Nachbarschaftskorrelationen eines Bestandes zu einem bestimmten Zeitpunkt seiner Entwicklung, wurden 9 Versuchsflächen mit einer unterschiedlichen Anzahl (8 bis 23) an „Sorten" (Europalärchen, Japanlärchen, Hybriden) ausgewählt, die zu etwas verschiedenen Altersstufen (7 bis 11 Jahre) einzelbaumweise vermessen wurden. Die erhobenen Merkmale sind „Höhe" und „Durchmesser". Zusätzlich werden die Durchmesserwerte transformiert und als individuelle Grundflächen ausgewertet.

Die Nachbarschafts-Korrelationsstruktur der im quadratischen 1,5 m x 1,5 m Verband angelegten und (mit Ausnahme zweier Flächen) auch nichtdurchforsteten Lärchenbestände wird durch 12 verschiedene Korrelationskoeffizienten beschrieben, die durch die Heranziehung von unterschiedlichen räumlichen Nachbarschaftskonfigurationen definiert werden. Dabei werden auch diagonal entfernt stehende Nachbarn sowie auch fehlende Nachbarn explizit in die Ansätze und Auswertungen mit einbezogen.

Für das Merkmal „Höhe" erhält man für sämtliche Versuche ein sehr übereinstimmendes Korrelationsmuster: positive Korrelationen mittlerer bis geringer numerischer Höhe zwischen dem Merkmalswert eines Baumes und dem entsprechenden Wert für seine Nachbarschaft (bei unterschiedlichen räumlichen Definitionen von Nachbarschaft) und negative Korrelationen vergleichbarer Größenordnung zwischen dem Merkmalswert eines Baumes und der Anzahl Fehlstellen in seiner Nachbarschaft.

Die Korrelationen für das Merkmal „Durchmesser" sind durchweg sehr gering. In den meisten Versuchen ergeben sich für „Höhe" straffere räumliche Nachbarschaftskorrelationen als für „Durchmesser".

Die Korrelation zwischen „Höhe" und „Durchmesser" schwankt zwischen 0,63 und 0,94 und zeigt somit eine beträchtliche Variationsbreite.

Den geschätzten Korrelationskoeffizienten sowie den zwischen ihnen aufgefundenen Größenbeziehungen kommt eine hohe Zuverlässigkeit zu, da diese Korrelationsberechnun-

gen auf sehr großen Anzahlen von Beobachtungswerten beruhen (kleinster Stichprobenumfang = 199, größter Stichprobenumfang = 6649).

Introduction and Problem

A deeper insight into the spatial neighbourhood correlation patterns is of major interest for many applications in silviculture and forest tree improvement programs. Phenotypic correlations between measurements for neighbouring individuals have been, therefore, widely used in the literature. Such studies are, of course, closely related to an application and analysis of competition indices and measures of stand density. A literature review and a comprehensive discussion of these relationships has been presented in HÜHN and LANGNER (1995). For a discussion of all these introductory and methodological topics we, therefore, refer to this paper and, additionally, to a former publication (HÜHN and LANGNER, 1992).

In this paper, some empirically-based contributions to the analysis of spatial correlation patterns of even-aged populations of larch will be presented, where the following main topics are considered:

No. 1. Calculation of phenotypic correlations between neighbouring observations for quite different spatial configurations of neighbourhoods.

No. 2. Comparison of the spatial correlation patterns for height, diameter at breast height and individual basal area.

No. 3. Evaluation and analysis of the resulting effects of missing trees on the spatial correlation pattern. The extensive data sets used in this study are based on field trials which have been established as regular square lattices. But, the really existing spatial configurations at the time of measurement are, of course, nonregular.

In the present study, all investigations on spatial correlation patterns are restricted to an only static description, that means an analysis of spatial patterns at only one certain age or stage of stand development. A comprehensive and critical discussion of the disadvantages and limitations inherent to static competition indices has been published by BURTON (1993).

A dynamic description with an analysis of temporal changes and time trends of the spatial neighbourhood correlation patterns during stand development has been discussed in HÜHN and LANGNER (1995). This dynamic analysis has been based on the successive measurements of only one field trial at several ages. In such an approach, the range of included environmental conditions is, of course, extremely limited (1 location).

In the present study, however, several field trials at quite different locations have been included representing a wide range of environmental conditions. But, on the other hand, the limitations of these investigations are their static description at only one age.

Material and Methods

The investigations of this study are based on data sets of single tree measurements for height and diameter at breast height for several even-aged larch populations. The plant material of the nine field trials consists of 3 groups of different origin (*Larix europaea, Larix leptolepis*, and their hybrids). In a former publication (HÜHN and LANGNER, 1992) a general introduction into the problems of spatial correlation patterns and a representation of the underlying concepts has been given. Furthermore, this paper contains a detailed description of the nine field trials (sites, entries, dates of establishment of the plantations, replications, plot sizes, plant distances, measurements, population sizes). Only some of the most important characteristics with particular relevance for the present study have been compiled in *table 1.*

The numbers of measurements for height and diameter in field trials No. 1 and No. 4 differ considerably (*Tab. 1*). For these 2 trials the trait height has been only measured for those individual trees which had been removed from the stand by thinning. For the intended neighbourhood correlation studies, however, the height measurements for the neighbours of the removed individuals are also needed. These values were estimated by applying the relationship between diameter and height. This extremely strong relationship has been calculated for the measurements of diameter and height of the thinned individuals. The original lists of data contain several subject tree measurements with height values, but zero diameter values. Whatever the real reasons for these zero values may be: all those diameter values = O have been excluded from the analyses. This procedure explains the minor discrepancies between the numbers of measurements (= population sizes) for height and for diameter in field trials No. 2, 5, 6, 7 and 8 in *table 1.* For all further information on the plant material, characteristics of the sites, design and analysis of the field experiments etc. we refer to HÜHN and LANGNER (1992).

The 9 field trials have been established as regular square spacing (1.5 m x 1.5 m). Systematic thinning has been carried out for only 2 of the trials. To eliminate all irregular neighbourhood configurations from the calculation of the spatial neighbourhood correlation patterns, all border trees of the plantations were dropped from the analyses. As a consequence, only observations with a complete array of neighbours were included in these analyses. These potential neighbours, however, may be still living or already missing at the time of measurement.

Simple product moment correlation coefficients were calculated between each single tree measurement and several

Table 1. – Some characteristics of the 9 field trials used in this study.

field trial no.	location	no. of entries	year of establishment	planting age (in years)	replications	plot size	measurement at age (in years) height	diameter	population size height	diameter
1	Oberraden	8	1972	1	4	6 x 6	11	11	308	607
2	Wissen	15	1974	2	4	3 x 3	9	9	264	260
3	Lohne	16	1976	1	4	3 x 3	11	11	262	262
4	Berlin	18	1977	2	4	3 x 3	7	7	199	579
5	Fürstenau	21	1977	1	4	3 x 3	8	9	716	714
6	Hesepe	16	1978	2	4	3 x 3	8	9	567	564
7	Kleinheubach	23	1978	2	3	4 x 4	10	10	953	935
8	Gammelsbach	18	1979	2	3	4 x 4	9	9	685	674
9	Segendorf	18	1979	2	3	4 x 4	9	9	592	592

measures which are based on individual tree measurements of the competing neighbours of the subject tree. Different definitions of spatial configurations of neighbours which are considered as effectively competing neighbours of the subject tree lead to 12 correlation coefficients r_1, r_2, r_3, ..., r_{12}, respectively (see, *Figure 1*):

r_1, r_2 and r_3 = correlation between subject tree X and sum of its direct, diagonal and total neighbours.

r_4, r_5 and r_6= sum in the previous definition is replaced by mean.

r_7, r_8 and r_9 = correlation between subject tree X and one of the direct, diagonal or total neighbours.

r_{10}, r_{11} and r_{12} = correlation between subject tree X and number of missing values among the direct, diagonal or total neighbours.

In this terminology, the neighbours D, B, E and G of the subject tree X in *figure 1* are "direct" neighbours, while the neighbours A, C, H and F are "diagonal" neighbours (*Fig. 1*).

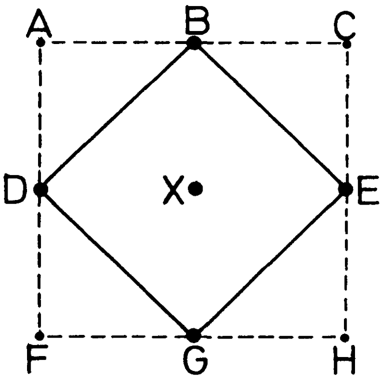

Figure 1. – Competing neighbours (direct and diagonal) for subject tree X.

The correlation coefficients r_1, r_2 ..., r_{12} are calculated as simple phenotypic correlations based on the individual phenotypic measurements. For further explanations (simultaneous application of sums and means of the competing neighbours of the subject tree; interpretation of the correlation coefficients r_{10}, r_{11} and r_{12}; tests of significance for deviations from zero of a correlation coefficient and for differences of 2 correlation coefficients) see HÜHN and LANGNER (1995).

The plant material of each of these 9 field trials consists of a varying number of different entries (*Table 1*) originating from 3 groups (*Larix europaea, Larix leptolepis*, and their hybrids). In this paper, however, no separate calculation of the correlations r_1, r_2, ..., r_{12} for individual entries or for groups of entries have been calculated. All correlation coefficients from this study are based on the collected total plant material.

Results and Discussion

The correlation coefficients r_1, r_2, ..., r_{12} are presented in *table 2* (height), *table 3* (diameter) and *table 4* (individual basal area). Since each field trial has been measured at only one age no temporal changes and time trends of the correlation patterns can be analysed. Furthermore, the results for the 9 field trials can be only compared in a limited sense since the trials differ in their ages at the time of measurement. These ages, however, are not too much different (7 to 11 years). Comparisons between the trials, therefore, may be carried out cautiously.

The 9 field trials represent a wide range of environmental conditions. The numerical results from *tables 2* to *4*, therefore, reflect the sensitivity of the spatial correlation pattern results with regard to varying environmental conditions.

In the subsequent chapters the results for height (*Table 2*), diameter (*Table 3*) and individual basal area (*Table 4*) are discussed in a concise manner. For many explanations and interpretations we refer to the analogous discussions in HÜHN and LANGNER (1995).

For "height" (Table 2)

1. In each of the 9 field trials, the signs of the correlation coefficients r_1, r_2, ..., r_{12} exhibit a relatively uniform pattern: r_1, r_2, ..., r_9 are positive and r_{10}, r_{11} and r_{12} are negative (clear exception: trial no. 3; slight exceptions: trials no. 4 and no. 8). The positive correlations between the height value of a subject tree and its diverse neighbourhood-values and the negative correlations between the subject tree height and the number of missing trees in its neighbourhood are of intermediate or small numerical amount. That means: In the juvenile ages of these trials (7 to 11 years) one obtains a still reduced competitive pressure between neighbouring trees.

2. For each trial one obtains the relationship:

$$|r_2| \leq |r_1| \leq |r_3| \quad (1)$$

That means: The correlation between a subject tree and the sum of its diagonal neighbours is lowest, the correlation with the sum of all neighbours (direct and diagonal) is largest and the correlation with the sum of its direct neighbours is intermediate.

3. For the correlations with the means of the competing neighbours (direct, diagonal, total) one obtains (slight exceptions: trials no. 1, no. 2 and no. 9):

Table 2. – Correlation coefficients r_1, r_2, ..., r_{12} for height at the 9 field trials.

correlation	field trial no. 1	size	2	size	3	size	4	size	5	size	6	size	7	size	8	size	9	size
r_1	0.07	303	0.28***	240	-0.17**	220	0.41***	199	0.45***	716	0.42***	567	0.33***	952	0.15***	683	0.28***	587
r_2	0.07	288	0.26***	260	-0.01	252	0.37***	199	0.38***	716	0.35***	567	0.31***	953	0.07*	681	0.28***	586
r_3	0.10*	308	0.34***	263	-0.28***	262	0.46***	199	0.47***	716	0.45***	567	0.38***	953	0.15***	684	0.32***	591
r_4	0.13**	303	0.16**	240	0.23***	220	0.62***	199	0.47***	716	0.47***	567	0.44***	952	0.24***	683	0.31***	587
r_5	0.06	288	0.27***	260	0.13**	252	0.55***	199	0.38***	716	0.37***	567	0.36***	953	0.24***	681	0.32***	586
r_6	0.10*	308	0.30***	263	0.26***	262	0.64***	199	0.48***	716	0.47***	567	0.47***	953	0.30***	684	0.38***	591
r_7	0.07*	773	0.10**	614	0.18***	478	0.45***	729	0.30***	2691	0.30***	2227	0.30***	3334	0.17***	2252	0.22***	1866
r_8	0.05	683	0.23***	614	0.11***	635	0.38***	676	0.24***	2662	0.24***	2224	0.23***	3315	0.16***	2227	0.22***	1831
r_9	0.05*	1456	0.17***	1228	0.15***	1113	0.41***	1405	0.27***	5353	0.27***	4451	0.27***	6649	0.16***	4479	0.22***	3697
r_{10}	-0.08	308	-0.30***	264	0.32***	262	0.04	199	-0.20***	716	-0.01	567	-0.06*	953	-0.02	685	-0.16***	592
r_{11}	-0.01	308	-0.16***	264	0.10	262	-0.12*	199	-0.20***	716	-0.04	567	-0.13***	953	0.04	685	-0.15***	592
r_{12}	-0.06	308	-0.28***	264	0.37***	262	-0.07	199	-0.26***	716	-0.04	567	-0.12***	953	0.01	685	-0.19***	592
height-diameter	0.77***	308	0.63***	260	0.78***	262	0.84***	199	0.94***	714	0.92***	564	0.93***	935	0.90***	674	0.85***	592

***), **) and *) = significance at 1%, 5% and 10% level of probability, respectively

Table 3. – Correlation coefficients r_1, r_2, ..., r_{12} for diameter at the 9 field trials.

correlation	field trial no. 1	size	2	size	3	size	4	size	5	size	6	size	7	size	8	size	9	size
r_1	-0.34***	580	0.08	236	-0.18***	220	0.33***	578	0.27***	714	0.27***	564	0.26***	932	-0.02	671	-0.10**	587
r_2	-0.12***	564	0.05	256	-0.07	252	0.34***	578	0.20***	714	0.22***	564	0.23***	935	0.07*	670	0.04	586
r_3	-0.32***	599	0.09	259	-0.34***	262	0.39***	578	0.28***	714	0.29***	564	0.30***	935	0.03	673	-0.05	591
r_4	-0.21***	580	-0.02	236	0.23***	220	0.40***	578	0.26***	714	0.28***	564	0.33***	932	0.03	671	-0.09**	587
r_5	-0.04	564	0.05	256	0.00	252	0.41***	578	0.18***	714	0.22***	564	0.27***	935	0.22***	670	0.08*	586
r_6	-0.21***	599	0.04	259	0.15**	262	0.46***	578	0.28***	714	0.29***	564	0.36***	935	0.17***	673	-0.01	591
r_7	-0.16***	1395	-0.03	599	0.17***	478	0.27***	2023	0.14***	2678	0.16***	2204	0.20***	3193	0.03	2179	-0.06***	1866
r_8	-0.03	1324	0.02	602	0.00	635	0.27***	1958	0.10***	2652	0.13***	2200	0.17***	3188	0.15***	2154	0.05**	1831
r_9	-0.09***	2719	-0.00	1201	0.08***	1113	0.27***	3981	0.12***	5330	0.15***	4404	0.19***	6381	0.09***	4333	-0.01	3697
r_{10}	0.25***	607	-0.11*	260	0.35***	262	-0.07*	579	-0.14***	714	-0.06	564	-0.05	935	0.06	674	0.07*	592
r_{11}	0.13***	607	-0.04	260	0.13**	262	-0.12***	579	-0.11***	714	-0.05	564	-0.08**	935	0.08**	674	0.02	592
r_{12}	0.24***	607	-0.09	260	0.43***	262	-0.12***	579	-0.15***	714	-0.08*	564	-0.09***	935	0.09**	674	0.05	592

***), **) and *) = significance at 1%, 5% and 10% level of probability, respectively

Table 4. – Correlation coefficients r_1, r_2, ..., r_{12} for basal area at the 9 field trials.

correlation	field trial no. 1	2	3	4	5	6	7	8	9
r_1	-0.34***	0.03	-0.04	0.34***	0.22***	0.28***	0.26***	0.00	-0.12***
r_2	-0.14***	0.03	-0.04	0.37***	0.15***	0.22***	0.23***	0.15***	0.04
r_3	-0.35***	0.04	-0.20***	0.42***	0.23***	0.30***	0.30***	0.10***	-0.08*
r_4	-0.20***	-0.05	0.22***	0.38***	0.21***	0.28***	0.29***	0.03	-0.09**
r_5	-0.06	0.01	0.03	0.40***	0.14***	0.21***	0.24***	0.23***	0.07*
r_6	-0.22***	-0.01	0.16***	0.44***	0.23***	0.29***	0.33***	0.19***	-0.02
r_7	-0.15***	-0.05	0.17***	0.25***	0.12***	0.17***	0.18***	0.03	-0.06***
r_8	-0.05*	-0.01	0.02	0.26***	0.08***	0.13***	0.15***	0.16***	0.04*
r_9	-0.10***	-0.03	0.09***	0.25***	0.10***	0.15***	0.16***	0.09***	-0.01
r_{10}	0.23***	-0.09	0.35***	-0.05	-0.12***	-0.06	-0.05	0.07*	0.10**
r_{11}	0.13***	-0.05	0.13**	-0.11***	-0.08**	-0.04	-0.07**	0.08**	0.04
r_{12}	0.23***	-0.09	0.43***	-0.10**	-0.13***	-0.07*	-0.08**	0.10***	0.08*
height- individual basal area	0.72***	0.63***	0.73***	0.81***	0.87***	0.89***	0.86***	0.84***	0.79***

***), **) and *) = significance at 1%, 5% and 10% level of probability, respectively

$$r_5 \leq r_4 \leq r_6 \qquad (2)$$

This implies: The correlation is lowest for the mean of the diagonal neighbours, largest for the mean of all neighbours and intermediate for the mean of the direct neighbours. The correlations, however, are numerically similar (particularly r_4 and r_6 in trials no. 1, no. 3, no. 4, no. 5, no. 6 and no. 7; r_4 and r_5 in trials no. 8 and no. 9; r_5 and r_6 in trial no. 2).

4. No clear relationship exists between the numerical amount of the correlations (direct, diagonal, total) based on the means of the competing neighbours and the corresponding correlations based on the sums of the competing neighbours. For most of the field trials one obtains:

$$r_1 < r_4;\ r_2 < r_5;\ r_3 < r_6 \qquad (3)$$

Both correlations, however, are numerically very similar.

5. For each field trial, the values of the correlations r_7, r_8 and r_9 are numerically very similar. The numerical amount of these correlations, however, strongly depends on the individual site (see, for example: trials no. 1 and no. 4).

6. For each field trial, the predominantly negative correlations r_{10}, r_{11} and r_{12} are similar in their numerical magnitude (slight exception: trials no. 2 and no. 3 with significantly smaller coefficients for the correlation between subject tree X and number of missing values among the diagonal neighbours). For the absolute values of the correlations r_{10}, r_{11} and r_{12} no unique relationship (inequalities) exists.

Because of the large numbers of observations (smallest sample size = 199, largest sample size = 6649) most of the correlation coefficients from *table 2* are significantly different from zero.

For "diameter" (Table 3)

1. The patterns of signs for the spatial correlation coefficients r_1, r_2, ..., r_{12} are quite different for the 9 field trials. No unique patterns can be detected for these sites which represent a wide range of environmental conditions. The results from *table 3*, therefore, confirm the pronounced sensitivity of the spatial correlations for diameter with regard to varying environmental conditions.

2. The correlations r_1, r_2 and r_3 are not too much different from each other. In most cases, r_1 and r_3 are more or less similar while r_2 is clearly smaller in its absolute numerical amount.

3. In most cases, the correlations r_4, r_5 and r_6 are roughly similar with comparable r_4 and r_6 and slightly contrasting r_5-values.

4. The correlations based on the means of the competing neighbours (direct, diagonal, total) are approximately equal to the correlations based on the sums of the competing neighbours (direct, diagonal, total).

5. For each trial, the correlations r_7, r_8 and r_9 are very similar.

6. For each field trial, the correlation coefficients r_{10}, r_{11} and r_{12} are coincident in their signs. These signs, however, may be positive or negative for different sites. r_{10}, r_{11} and r_{12} are also similar in their numerical magnitudes (exceptions: trials no. 1 and no. 3 with clearly smaller r_{11}-values). With respect to the

triples (r_{10}, r_{11}, r_{12}) the field trials don't differ too much from each other, although there exist a few clearly contrasting pairs of field trials, for example trials no. 3 and no. 5 with values 0.35 and −0.14 (for r_{10}), 0.13 and −0.11 (for r_{11}) and 0.43 and −0.15 (for r_{12}).

The correlation coefficients from *table 3* are based on large numbers of observations (smallest sample size = 220, largest sample size = 6381). Most of these coefficients are, therefore, significantly different from zero. In spite of these statistical facts, most of the correlation coefficients from *table 3* are numerically very small. Because of the juvenile ages of the trials this result, however, must be expected.

For "individual basal area" (Table 4)

1. The correlation between height and diameter is slightly stronger than the correlation between height and individual basal area.

2. The correlations r_{10}, r_{11} and r_{12} are practically identical for diameter and for individual basal area (for each field trial).

3. For some of the field trials the correlations r_4, r_5, ..., r_9 are slightly stronger for diameter than for individual basal area (trials no. 4, no. 5 and no. 7) while the remaining trials exhibit approximately identical correlations r_4, r_5, ..., r_9 for these 2 traits.

4. The correlations r_1, r_2 and r_3 are practically identical for diameter and for individual basal area (exception: field trial no. 3 where these correlations are slightly stronger for diameter than for individual basal area).

Comparison "height- diameter"

1. The correlation between height and diameter varies between 0.63 (trial no. 2) and 0.94 (trial no. 5). This correlation, therefore, exhibits a considerable variability which may be due to environmental differences and/or different ages of the trials, different mean heights and different competitive pressures.

2. In most of the field trials one obtains stronger spatial neighbourhood relationships for height than for diameter (slight exceptions: trials no. 1 and no. 3).

For a critical discussion of the limitations and restrictions of the numerical results on spatial neighbourhood correlation patterns imposed by the numerous simplifying assumptions we refer to HÜHN and LANGNER (1995).

Main Conclusions

With regard to practical applications the spatial neighbourhood correlations r_7, r_8 and r_9 are of particular interest. They are based on pairs of individual neighbouring trees while the remaining correlations are based on sums of neighbours, means of neighbours or numbers of missing neighbours.

In most of the field trials one obtains stronger relationships for height than for diameter.

The numerical values of the correlation coefficients r_7, r_8 and r_9 are practically identical for height as well as for diameter: For the means (over the 9 trials) one obtains $r_7 = 0.23$ (= correlation between a subject tree and one direct neighbour), $r_8 = 0.21$ (= correlation between a subject tree and one diagonal neighbour) and $r_9 = 0.22$ (= correlation between a subject tree and one neighbour (direct or diagonal)) for height and $r_7 = 0.08$, $r_8 = 0.10$ and $r_9 = 0.08$ for diameter. For both traits, therefore, the different spatial neighbourhoods (direct neighbours, diagonal neighbours, all neighbours) are of no differential influence on the numerical amount of the resulting neighbourhood correlations.

Expressed in the regression point of view, the previous results are: 5% of the variability in the trait height can be explained by a dependence on the height measurements of the neighbouring trees, while this percentage is reduced to only 1% for the trait diameter.

Acknowledgement

The authors gratefully acknowledge the cooperation and help provided by Mrs. H. JENSEN, Mrs. E. BÜLL, Mrs. B. PALLASCH, Dr. J. KLEINSCHMIT and Mr. K. ROETHER.

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