Mean culmination increment – tree and stand growth standardization index

JONAS GRIGALIŪNAS
The Lithuanian Forest Research Institute,
4312, Girionys, Kaunas distr., Lithuania

Grigaliūnas J., 1996. Mean culmination increment – tree and stand growth standardization index. *Baltic Forestry*, 1: 38-42.

Studies on modelling the growth of Lithuanian pine stands and on the dynamics of the current tree increment have shown, that the mean culmination radial and height increments are exceptionally important for growth standardization. These derivative indices provide good growth characteristics in young and older age, reflect stand composition during its formation, remain relatively stable during forced ageing of stands, and have analogous distribution of tree number to that of diameter groups in a stand. The above mentioned peculiarities of the mean culmination increments are pointed out in this paper based on field data.

Keywords: mean culmination radial increment; mean culmination height increment; indices for growth standardization.

Introduction

For the modelling of the growth of stands and trees indexes are needed, which could more precisely express the relationship between the initial stand density (reflecting the peculiarities of stand forming) and site quality, and which could characterize the growth of trees at ageing time. Such peculiarities of an index enables the number of parameters used in the model to be reduced and more accurate models characterizing the dynamics of stands constructed. Elementary indexes and these measured readily in a stand are frequently applied. For construction of more precise and specific models derivative indexes are used, although their determination is more intricate. In the paper the properties of the mean culmination increment as an index suggested recently are revealed. The model of the dynamics of the number of trees in pine stands as well as the models of growth in height and diameter are based on these properties. Also they have been used for creating a system of assessment of anthropogenic activity (air pollution, greenhouse effect) – related changes in the dynamics of the radial increments in pine stands (Grigaliūnas 1994). In this system index kd incorporates site quality and initial density of a stand formed.

Mean culmination height (k_h) or radial (k_d) increment is a ratio of the height or diameter and age to the current increment culmination (Grigaliūnas 1994):

$$k_h = H_{zhmax} / A_{zhmax}, \text{ m/year} \quad (1),$$

$$k_d = D_{zrmax} / A_{zrmax}, \text{ cm/year} \quad (1a),$$

where: H – the height of a tree (or stand) at the point of the first height increment culmination (Z_{hmax}), m;

D – DBH at the point of the first radial increment culmination (Z_{rmax}), cm;

A – age at the moment of increment culmination, year.

Cases of using these derivative indices to characterize the increments and growth are not found in the literature. Their components, mostly culmination age (Kiviste 1988, 1991), are widely used. Therefore, the properties of indexes k_h and k_d are frequently applied for solving various forestry problems. We must also admit, that the properties of both mean culmination increments (k_h, k_d) are quite analogous. Thus, the examples of analysing these properties are given for one or another index.

Term "the mean culmination diameter increment" is not completely correct since A_{zrmax} refers to age at which a tree grows up to 1.3 m hight ($A_{zrmax} = A_{1.3} + n$), where n is the number of rings up to Z_{rmax}). Currently, the analysis is conducted on the feasibility of eliminating index $A_{1.3}$ from formula (1). It will facilitate to determine index k_d for broad-leaved species. Thus, from the standpoint of dendrometry the term will be correct.

Materials and methods

Methodical questions as well as those of information collection, arrangement and analysis have been solved applying the methods of dendrometry, forestry, dendrochronology and mathematical statistics.

Trees were selected deliberately aiming at maintaining the

general procedure of determination of index k_d in all objects. In each plot 25 trees (class II according to Kraft) per hectare, which dominated according to the diameter, were selected. Each tree was bored crossing the core. The direction of the boring for every next tree was systematically changed 90°.

The objects of investigation have been selected randomly in pure pine stands growing in different regions of Lithuania. The initial data have been collected on 89 stationary and temporary sampling plots, allocated in directly unpolluted natural and artificial 30-120-year-old pine stands of 0.6 and greater relative stocking level. The stands grow on mineral soil sites. The number of trees for height measurement (Z_h) amounted to 643, while that of trees for radial increment measurement (Z_r) – 1187. A total of 70000 annual rings have been measured. In the pollution zone of nitrogen fertilizers plant 9 temporary plots with 167 sample trees have been singled out.

The height increments were measured by a specially constructed telescopic boom. It is more convenient, for the basic distance is unnecessary. Due to disturbances by branches it often changes. The accuracy of the measurement is ± 2 cm. The radial increments were measured by a binocular microscope at the accuracy of 0.1 mm in identic hydroscoph conditions. In the same calendar year significantly pronounced rings were marked while measuring trees. It favoured the precluding of errors in determining the number of rings and their width. The rings of the culmination radial increment (and the height increments) were selected visually. For each tree indexes k_h and k_d were calculated by formula 1 and 1a. The age necessary to attain 1.3 m high was ascertained according to the signs of verticels. They remain in the bark for more than 100 years.

Results

The magnitude of the culmination increment is defined by several indices and conditions. They are: tree species, a site and its peculiarities, initial stand density, environmental pollution, a greenhouse effect, etc. This increment, no doubt, is influenced by the dynamics of climatic conditions. All factors mentioned above further influence the growth of each tree and stand. Therefore, the hypothesis that the mean culmination increment may characterize further height and diameter growth is realistic.

Observations on the growth of dominating and average trees in permanent sample plots have shown, that each curve from the family of curves of the height and diameter growth of pine stands has a peculiar mean culmination increment (k_h and k_d, respectively). Studies have revealed, that the peculiarities of these culmination increments are completely analogous (Grigaliūnas 1994). Index k_d, for example, as well as k_h, is in close relation with the mean diameter of dominating trees or stand not only in young, but also in older age. Fig. 1 shows the relation of kd with distribution distances between the radial increment curves of dominating trees in stands growing on different sites at the age of 60-70 years. The distance (l) between the lower and every upper radial curve in their family was measured in a freely chosen period of 60-70-years. The relation between k_d and the distance (l) is expressed by correlation coefficient $r_{kd} = 0.927 \pm 0.028$. A close correlation is also observed between the individual k_d of trees and their

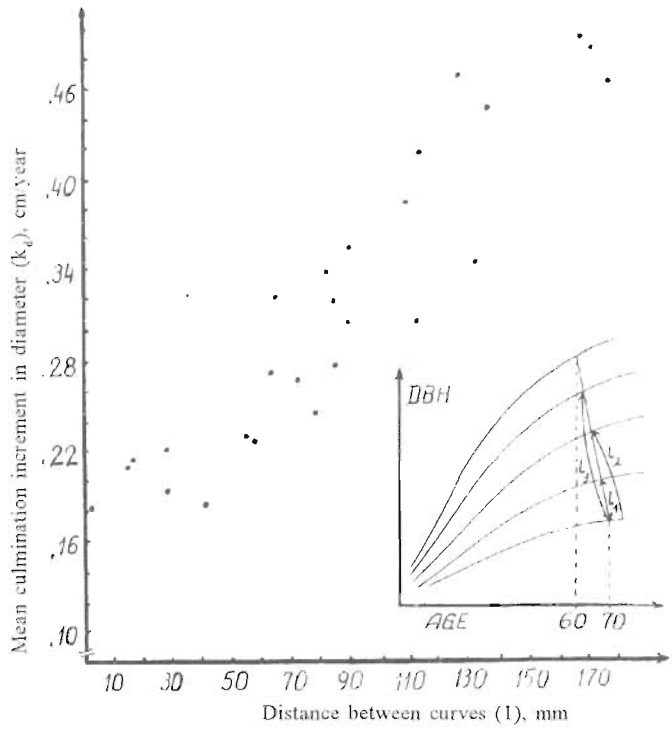

Fig. 1. The relation of mean culmination increments (k_d) of dominating pine trees with distances (l) between diameter curves in their family within age range 60-70 years (stationary sample plots)

diameters in a period of 20-25 years: $r = 0.897 \pm 0.025$. This shows low frequency of intercrosses between the curves. Therefore, indices k_d and k_h may be applied to standardize any site quality, stand composition, tree growth or the increment.

As mentioned above, in modeling stand growth the culmination age of the current increment is applied, which is the component of derivative index k_d. This age is less informative as it doesn't include other stand forming parameters. This is confirmed by the data from Table 1.

The data demonstrates, that the diameter of dominating trees at the point of increment culmination depends on stand density: with increasing density the diameter decreases. However, culmination age (CA) of the radial increment under the same site conditions in stands of different initial density is equal. This stresses its lack of informativeness. Besides, CA of the increments is very dynamic. Studies by L.Wroblewski (Wróblewski 1976) in the Suvalkai forest (SF), Rogovo (R) and Silesia (S) woods show a significant variation in CA, which depends on environmental (site, climatic conditions) changes:

Table 1. The relation of the mean culmination increment (k_d) of dominating trees and stand density (biophysical stationary sampling plot of Norway spruce)

Density of planting, N/ha	Average diameter of dominating trees, cm	Average age of the radial increment culmination (A_{zrmax}), year	Average DBH (D_{zrmax}) at the age of the radial increment culmination, cm	Average k_d, cm/year	Tree number
820	28.0	12.9	5.05	0.392	9
1600	23.4	12.9	5.38	0.417	9
3000	21.5	11.6	3.64	0.314	7
6000	21.3	11.3	3.80	0.336	6
12000	18.2	10.8	2.78	0.256	8
25000	17.3	12.4	2.81	0.222	7
100000	14.5	13.4	2.21	0.164	7

in *R* object it varies from 6-10 to 41-45, SF – from 8-29 and S – from 6 to 31 year. It is evident, that taking *CA* as well as height and diameter as standardization indices, the characteristics of growth curves due to ignoring of stand composition would significantly worsen, and to eliminate this, additional indices should be introduced. By summarizing the data in Table 1, it could be said, that each site has a peculiar increment culmination age. Without the impact of outside factors *CA* of stands growing on it is relatively constant and independed of variations in stand composition. It means, that culmination age is predetermined by site productivity.

The culmination age of pine stands growing on sites of any productivity may be changed by positive (greenhouse effect, some economic activities), or negative (environmental pollution) factors. However, its changes are accompanied by changes in other mean culmination increment components – the radial (or height) increments. Thus, the ratio expressed by the 1st equation remains almost the same. This can be seen from the data in Table 2. The forced reduction of indices A_{zrmax} and D_{zrmax} under the impact of environmental pollution demonstrates quicker ageing of a stand or tree. Consequently, the increments decrease not only at culmination age, but also at all ages (Maurin 1986). Due to induced increment decline (though index k_d as mentioned above, remains almost the same) the natural growth of a stand (tree) is distorted. Therefore, the difference in the growth of stands or trees affected and unaffected by pollutants is observed when indices k_d are the same. It has been confirmed by field measurements (Grigaliūnas 1994). These regularities show that the mean culmination radial and height increments may be used to standardize the current increment and growth, as well as estimate increment deviations from the norm (under the impact of pollution and greenhouse effect).

The condition and growth of each tree in a stand is characterized by mean culmination increment (k_d) of a tree. This is demonstrated by small dispersion of the mean culmination increments with respect to diameters (Fig. 2). Thus, the distribution of trees in a stand according to their diameters and

Table 2. Stability of the mean culmination increment (k_d) and changes in its components - age (A_{zrmax}) and diameter (D_{zrmax}) - at the maximum radial increment in the polluted environment. The pine stand in sample plot 4L was grown in polluted environment (2 km from the pollution source - nytrogen plant in Jonava). The pine stands of control sample plots are pollution free.

No of sample plot	The mean culmin. increment (k_d), cm/year	The mean culminat. age (A_{zrmax}), year	The mean culmin. diameter (D_{zrmax}), cm	Differences in %. Indexes of unpolluted stands = 100%		
				A_{zrmax}	D_{zrmax}	k_d
4L	0.463	8.47	3.92	–	–	–
2030	0.419	10.08	4.22	16.0	7.2	-10.5
1740	0.471	10.03	4.87	15.5	19.5	1.7
107	0.485	10.72	5.20	21.0	24.8	4.5
114	0.479	11.28	5.41	25.0	27.6	3.3
127	0.422	13.72	5.79	38.3	32.3	-9.7
1735	0.493	9.98	5.04	15.1	23.0	6.1
6	0.397	11.04	4.39	23.3	10.6	-16.6
14	0.485	10.38	5.04	18.4	22.2	4.5
1731	0.487	11.74	5.72	27.9	31.5	4.9
365	0.434	8.83	3.86	4.1	-1.3	-6.6
366	0.443	8.39	3.76	-4.2	-1.0	-4.5
367	0.447	9.32	4.17	9.1	-5.0	-3.6

indices k_d is identical. This confirms the already mentioned regularities and shows, that even in a young pine stand it is possible to select trees, for which, in connection with the mean culmination increment of dominating trees in a stand, the withering period can be foreseen in advance. It is purposeful in planning thinning.

Fig. 1 demonstrates close correlation between mean culmination increment (k_d) and radial growth of dominating trees. Fig. 2 shows, that the mean culmination increment reflects the growth of each tree. However, index k_d of the dominating stand part is also connected to the dynamics of the mean stand diameter (Fig. 3).

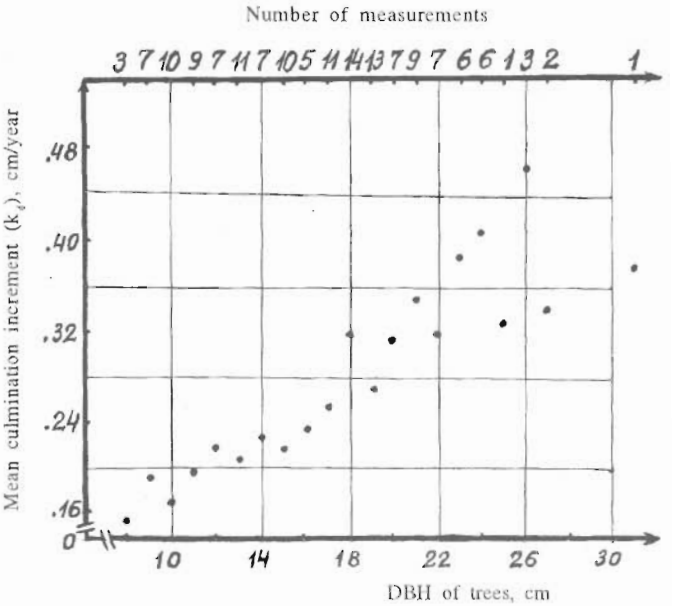

Fig. 2. The dependence between mean culmination increments (k_d) of trees and their DBH in a pine stand. Age of the stand – 49 years. A total of 149 trees were measured.

Therefore, instead of using index k_d of the mean diameter to simulate the mean diameter in a stand it is purposeful to apply k_d of dominating trees (Grigaliūnas 1994). It would considerably facilitate determination of k_d in a stand and ensure its objectiveness (the mean stand diameter as well as its k_d due to tending cuttings in young age may be altered). At that time it should be noted that most authors (Grigaliūnas 1994) consider that the effect of thinnings on the growth of dominating trees is very slight (such trees seldom change their ranks in a stand).

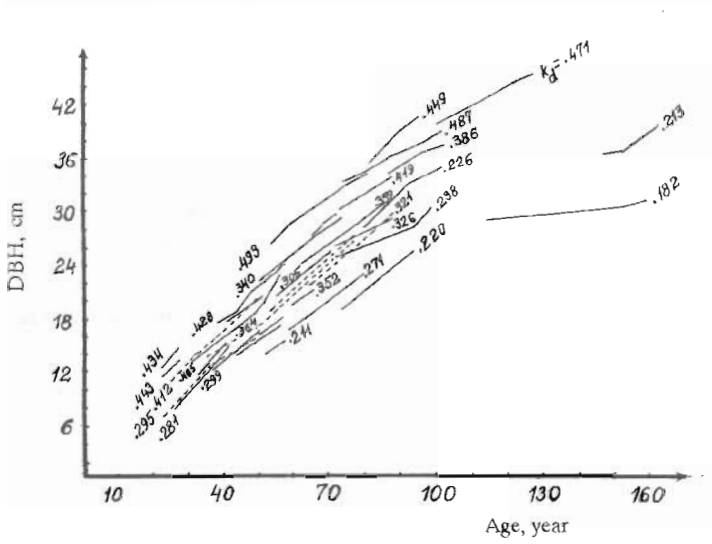

Fig. 3. The dependence between mean culmination increments (k_d) of dominating trees and growth of mean diameters of stands in the stationary sample plots. Each curve of mean diameters has its own k_d.

It is noted, that curves of the diameter within the family disperse depending on the size of index k_d. Thus, the mean culmination increment characterizes the growth without any additional site or forest type classification features and, therefore, this index (in this case k_h) acquires the character of a site quality class. It is clear from the data in Table 3. Here we find already known facts, that the same forest types of the same age may have different heights, while the height may be equal in different forest types at the same age. These regularities are followed by the mean culmination height increments. Hence, in some cases, for instance, in modelling the dynamics of a tree number (Grigaliūnas 1994), index k_h may be used as a classification element.

As mentioned above, index k_d on an identic site closely correlates with density and diameter (Table 1) since culmination age due to changes in diameter is constant. The data in Table 2 indicate that CA (A_{zmax}) and diameter in the culmination age due to significant changes in environmental conditions are unstable. However, k_d remains a relatively constant variable. As seen from Table 3 and Fig. 2, with increasing age k_d correlates with stand productivity. In all of these correlation's there are no contradictions. The increments (and the same time k_d) on an identical site are affected by the initial density, the level of environmental pollution and climatic fluctuations. Due to improvement of a site k_d increases since CA is observed when the diameter is larger. Also the conditions mentioned above determine CA. Because of changes in the conditions of the growth (abrupt increasing of local air pollution) k_d determined prior to them can't reflect further growth. This peculiarity is of paramount importance since k_d as an index standardizing the increment becomes a stable reading system for assessing variation in the increments. The

Table 3. The comparison of mean culmination height increments (k_h) of dominanting trees in pine stands of different forest types in the same age (50 year) and even height.

The mean culmination height increment of the forest types	Height at the 50 year age, m										
	13	14	15	16	17	19	20	21	22	23	24
P. oxalido-sum, P.myrtillo-oxalidosum										0.450 0.438 0.410 0.403	0.400
P.myrtillosum						0.346	0.358		0.412		
P. vaccinio-myrtillosum					0.268	0.359	0.329 0 347 0.327	0.387 0.327	0.347		
P. Vacciniosum			0.227	0.244 0.297 0.267	0.290 0.280	0.327 0.283 0.344 0.363 0.336	0.408				
P. cladoniosum	0.214 0.201	0.230	0.236	0.275 0.241	0.255						

radial increment series including k_a, which were constructed retrospectively, will be an appropriate system for assessment (Grigaliūnas 1994) of the shifts in the dynamics of increments for a long unlimited time. By comparing the increments of stands investigated with the standard ones when k_a is identical (allowing for the current climatic fluctuations and age) it is feasible to clarify the magnitude and rate of changes in the increments. In normal conditions (Fig. 3 and Table 3) the mean culmination increment may be successfully applied for modelling the dynamics of the growth of stands and trees number. It must be noted that indexes k_a and k_h and the current increment in terms of statistics are random variables. The factors unforeseen and practically unassessed may also occur. In some cases, they can distort the correlation between the indexes for a longer period. For instance, the types of the growth conditioned by morphological properties of the soil. In every case, the reliability of these indexes must be estimated by standard errors of the average parameters. Therefore, for the modelling of stand growth new data should be gleaned in many objects.

Conclusions

The peculiarities of mean culmination height (k_h) and diameter (k_g) increments of the dominating part of stand in Lithuanian pine stands allow us to state, that:

1) these increments perfectly depict growth peculiarities of trees or stands both in young and older age and may be used as standardization indices in modelling growth process, thinning of stands and the dynamics of the increment;

2) the ascertained mean culmination diameter increment being relatively constant serves as the basis for assessing dynamic equilibrium shifts of the radial increments, which occur due to changes in environmental conditions caused by anthropogenic activity;

3) index k_a incorporating stand composition and site productivity, becomes a classification unit and informative dendrometric index, being able to alter culmination age and the initial density.

References

Grigaliūnas J. 1994. Lietuvos pušynų priaugių dinamika ir jos vertinimas. Monografija. Analysis and assessment system of dynamic equilibrium shifts in increments of scots pine stands in Lithuania. Monograph. Kaunas p. 162 (in Lithuanian, large summary in English and Russian).

Kiviste A.K. 1988. Functions of growth. Handbook for students. Tartu, p. 1-60 (in Russian).

Kiviste A.K. 1991. Modeling of stands growth. Thesis of dissertation. Moscow, p. 18 (in Russian).

Maurin A. 1986. The temporize as integrant index of status trend in forest ecosystems. Monitoring of forest ecosystems. Thesis of scientific conference in Kaunas (05-06.06.1986). Kaunas – Academy, pp. 21-22 (in Russian).

Schweingruber F. H. 1989. Tree rings. Basics and applications of dendrochronology. Dortrecht/Boston/London. Reprinted in 1989, pp. 1-276.

Wróblewski L. 1976. Some questions of current height increment culmination in pine stands. Folia forest. pol., A, Nr.22, pp. 211-221 (in Polish).

Средний кульминационный прирост – показатель, нормирующий рост деревьев и древостоев

Й. Григалюнас

Резюме

Проанализированы особенности производных таксационных показателей-средних кульминационных приростов по высоте (k_h) и диаметру (k_g). Показано, что эти показатели отражают рост по высоте и диаметру в молодом и в последующем возрастах. Поэтому они могут быть применены при моделировании хода роста (по высоте, диаметру, числу деревьев). k_g, являясь относительно стабильным показателем в отношении изменения роста в результате принудительного ускоренного старения деревьев, успешно может быть использован при оценке сдвигов в динамическом равновесии текущих радиальных приростов, происходящих в результате антропогенного воздействия на окружающую среду. Одновременно k_h и k_g в статистическом отношении являются случайными величинами и при различных обобщениях должны определяться на данных ряда отдельных объектов. Таблиц 3, иллюстраций 3, библиогр. 6.

Ключевые слова: кульминационный прирост, нормирование прироста.