Edge Effect on Forest Stand Growth and Development

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Abstract

Edge, pre-edge and interior zones were distinguished in the forest compartments of Scots pine, Norway spruce, Common birch and Common alder stands. The edge zone is located at 10-12 m, pre-edge at 12-27 m distance from the borderline. The most favourable growth conditions for trees at the stage of stand formation are in the pre-edge zone. In the beginning trees are characterized by faster growth, however, later it approaches the growth of trees in the interior zone. In the edge zone, during stand formation plants suffer from additional competition for sunlight and nutrients on account of the adjacent stand, leading to the formation of sparsely stocked stands with lower and thicker trees. Growing more sparsely, trees later attain higher yield than trees growing in the interior part. The edge zone trees of lower diameter and height ratio form a buffer zone of the stand and increase its stability.

The highest differences in the growing stock volume of stands growing in the edge zone and comprising 38-47 m^3/ha at maturity, as compared to the volume of stands growing in the interior part of compartments, were found in Scots pine and Common alder stands, while the least – 8 m^3/ha – in Norway spruce stands. Volumes of trees growing in the pre-edge zone, as compared to the volumes of stands growing in the interior part, remain higher up to maturity in Scots pine by 3-4, Norway spruce by 1-2, Common birch by 9-10 and in Common alder stands by 1-3 %.

Stand yield formation in the edge zone of a compartment is closer to the normal or slowed types, while in the interior and pre-edge parts – to the accelerated or normal types.

Key words: stand zones, differences in tree height, diameter, yield and its formation

Introduction

Lithuanian forests are distinguished by a great diversity of forest sites and are highly fragmented. More than one third of all sampling units of the national forest inventory (NFI) fall within two or more compartments (Kuliešis *et al.* 2003). The appearance of trees, their growth and stand formation in the edge zone bear a certain character. The appearance and growth of trees in the edge zone is affected by microclimatic conditions formed due to varying light penetration depth and width of the shaded belt (Wales 1972; Matlack 1994), different wind movement and air exchange processes (Oliver and Larson 1996). Differences in tree growth in the edge zone are influenced by the competition between mature and young trees for nutrients and sunlight. In older age the roots of trees may spread up to 40 m away from the trunk and further (Lyr and Hoffmann 1967). Lighting of trees growing in the forest edge or under crown cover depends on crown elevation and stand boundary exposition. The influence of stand on trees growing in the edge is revealed at a distance from 15 m (Ranney *et al.* 1981) to 65 m and still further (Franklin and Forman 1987). As the results of some researchers indicate, the edge is not a mixture of two stands (Wales 1972; Ranney *et al.* 1981; Neumann and Starlinger 2001; Tomppo 2002). It consists of even more tree species, both larger-dimensioned and able to grow within the range of higher shading, characteristic of each of the adjacent stands.

Edge identification is important both for the estimation of tree growth peculiarities and for the description of each compartment. During forest inventory, a frequent question is what with sample plots occurring at the edge should be done. This question has been tackled by many scientists, the influence of the edge on sampling and estimation of forest characteristics have been analysed, sampling methods have been improved (Fish 2000; Антанайтис *et al.* 1975; Kuliešis and Kasperavičius 2000). Plots occurring on the edge or close to it, practically are often eliminated or transfered from the edge. Under different growth conditions and growing results, stand characteristics and their deviations in the edge zone may be distorted. Taking into account the results of continuous forest inventory in the Dubrava and Jūre forests, it was suggested to make a strict fixing of compartment edges during sampling inventory and to divide plots into sectors (Kuliešis 1996).

Studies conducted in Lithuania have revealed essential differences in parameters between trees growing at the edge between stand and field (Deltuva 1999), on the outskirts of forest glades (Saladis 1998) and those growing in the interior of stands. Literature analysis shows that the properties of stands growing in the edges of forest compartments have not been studied, neither were their differences compared to the interior part of stands. The questions what stand structure of is in respect of time span, how various stand indices change and what the peculiarities of stand formation are in different parts of the compartment has not been answered yet.

The aim of our work was to study the homogeneity of forest compartment and the peculiarities of stand growth, formation and growing stock volume accumulation in different compartment zones.

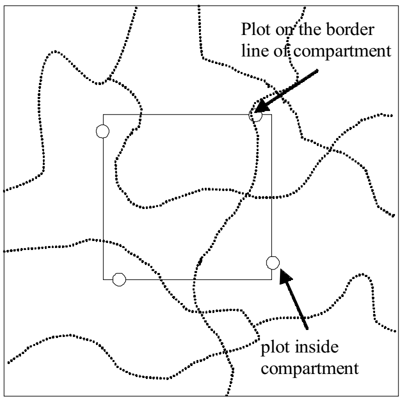

Figure 1. Location scheme of permanent NFI plots in Lithuanian forests (O - position of plot, ····· - borderline of compartment)

Materials and methods

Edge zones in forest compartments comprise a significant portion of Lithuanian forest area. Lithuanian forest land occupies 2069.1 thous. hectares, among them stands – 1967.7 thous. hectares (*Lietuvos miškų* ... 2004). In our work, the studied Scots pine, Norway spruce, Common birch and Common alder stands were inventoried in 976.5 thous. compartments which occupy 88% of the area of all Lithuanian forest stands. The greatest portion of all studied compartments cover Scotch pine stands – 38.5%, more than a quarter (26.9%) – Norway spruce stands, one quarter (25%) – Common birch stands and less than one tenth (9.1%) Common alder stands.

For the study, plots representing all forests of the country and measured during NFI were used (Kuliešis *et al.* 2003). Thus, the object of the study is the general array of stands of the selected tree species, represented by sampling units – permanent circular plots, their sectors and angle count plots. According to the NFI sampling scheme (Kuliešis *et al.* 2000; 2003), permanent circular and angle count plots completely represent all stand zones: interior, pre-edge and edge (Fig.1,2). Allocating permanent sampling plots in precisely projected points, some plots occur within the interior of a compartment, some occur in the edge zone. All plots of the edge zone are divided into sectors according to the borderline separating one forest compartment from another. Divided into two sectors, each plot represents two different neighbouring compartments in their edge zones. All undivided into sectors plots represent the interior zone of a compartment. The pre-edge of stands is represented by angle count plots allocated at 20 m distance from the centre of divided into sectors permanent plots (Fig. 2). The edge zone of a compartment is represented by a sector which on average is half the size of a circular plot, i.e. up to 12.62 m wide. Representation of the width of the edge zone may undergo insignificant changes with the changing size of a plot sector. The width of the pre-edge zone of a forest compartment may also change depending on the mean stand diameter. Angle count plots under mean stand diameter of 20 cm and angle count factor K=2, on average represent a zone of 14 m wide (Fig. 2).

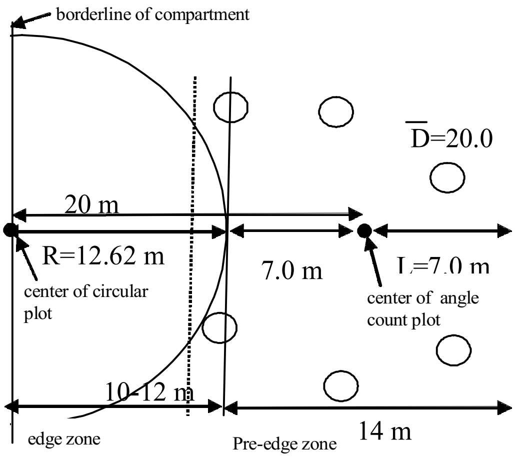

Figure 2. Scheme of the edge and pre-edge zone representation by NFI permanent and angle count plots

The data of 2,531 complete permanent inventory plots and 1,787 sectors, as well as the data of angle count plots allocated by one around each sector, were used (Table 1.). Most inventory plots represent 41 – 80-year-old stands. The used number of inventory plots allows to ascertain differences in the characteristics of stands of the main tree species in different parts of compartment, their statistical significance at the 0.68 probability level, depending on stand age and site productivity.

According to the measured sample tree heights and diameters at 1.3 m height, the mean height of each

Table 1. Number of sampling units, used in the study

Forest type	Number of		
	Plots	Sectors	Angle count plots
Scots pine	1208	688	688
Norway spruce	484	376	376
Common birch	602	445	445
Common alder	237	278	278

1st storey tree in an inventory plot was estimated. Based on tree diameter and height, the volume of each tree was estimated (Kuliešis *et al.* 2003) applying form factor equations. According to the mean height and volume of trees growing in different parts of compartment, stand stocking level was estimated. Variation of each of the mentioned indices was estimated relying on the data of plot sectors or angle count plots representing different compartment zones. Thus, the following main characteristics are ascertained for each compartment zone: mean height, diameter, mean volume, stocking level of the 1st storey within the range of 10-year age class, as well as the standard deviation of all these indices. All stand characteristics in different zones of compartment were estimated using the NFI data processing software. Applying regression analysis, dependance of all forest stand characteristics on age has been determined. Regression equations were chosen according to the value of the highest regression deviation index R^2. The data were analysed using the MS Excel and Statistica software.

To evaluate the significance of differences of the fitted mean stand characteristics in the interior part of compartment with the indices of stands growing in the edge or pre-edge zones, method for the estimation of differences of the two means is applied (Гмурман 1972). Siginificance of the difference:

$$\Delta X = \overline{X_1} - \overline{X_2} \tag{1}$$

of the two means is estimated relying on statistics

$$t = \frac{\Delta X}{\sigma_{(\overline{X_1}-\overline{X_2})}} \tag{2}$$

where:

ΔX – difference of the mean values of the compared traits,

$\overline{X_1}, \overline{X_2}$ – mean values of the first and second compared traits,

$\sigma_{(\overline{X_1}-\overline{X_2})}$ – standard deviation of the difference in the mean values;

$$\sigma_{(\overline{X_1}-\overline{X_2})} = \sqrt{\sigma_{X_1^2} + \sigma_{X_2^2}} \tag{3}$$

where:

$\sigma_{X_1^2}$, $\sigma_{X_2^2}$– fitted standard deviations of the first and the second mean value.

Differences between the two mean values are siginificant when:

$$t > t\alpha \tag{4}$$

$t\alpha$ – statistics of t value under probability α, $t_{0.683}=1$, $t_{0.95}\approx 2{,}0$ (Fišas 1968; Кокрен 1976).

In case the analysed stand zone characteristics change within the limits of confidence interval of comparable zones, it is possible to state that differences of the analysed indices of these zones are statistically insignificant. On the contrary, when the compared values of characteristics occur outside the range of confidence interval of comparable zones, it is possible to state that such values have statistically significant differences.

Results

Stand Characteristics in Different Forest Compartment Zones

The mean stand height, diameter, stocking level and tree volume were analysed in different forest compartment zones, *i.e.* edge, pre-edge and interior. Variation of the mentioned indices, dependance of the mean values and their variation on age, the range of confidence intervals of the main indices was studied in each compartment zone. Differences in the characteristics of trees growing in different compartment zones and their statistical significance were ascertained.

Tree Height

The mean heights of trees and their variation were analysed for Scots pine, Norway spruce, Common birch and Common alder stands depending on their age. The variation of height, as well as that of other indices, was estimated within the range of each age class. To fit the dependance of the standard height deviations on age, a parabolic equation of the second degree was the best (Fig. 3). The highest standard mean height deviations, except Scots pine, are found in the edge and pre-edge zones of compartment.

The mean heights of stands within the range of ten year age class were estimated with 0.2–0.6 m accuracy. Applying the fitted standard height deviations of trees growing inside the compartment and in the edge zone, height variation limit (eq. 2) for each age class, the so-called confidence interval at the 0.683 probability level, was ascertained. Standard deviations of trees growing in the edge and pre-edge zones differ insignificantly among themselves (Fig.3), therefore, to compare the heights of trees growing in the pre-edge and inside the compartment, the same confidence interval was applied comparing the mean heights of the interior and edge zones (Fig. 4).

With increasing age, fitted standard height deviations of Scots pine, as well as those of other tree species, increase (Fig. 3). Higher variation of mean

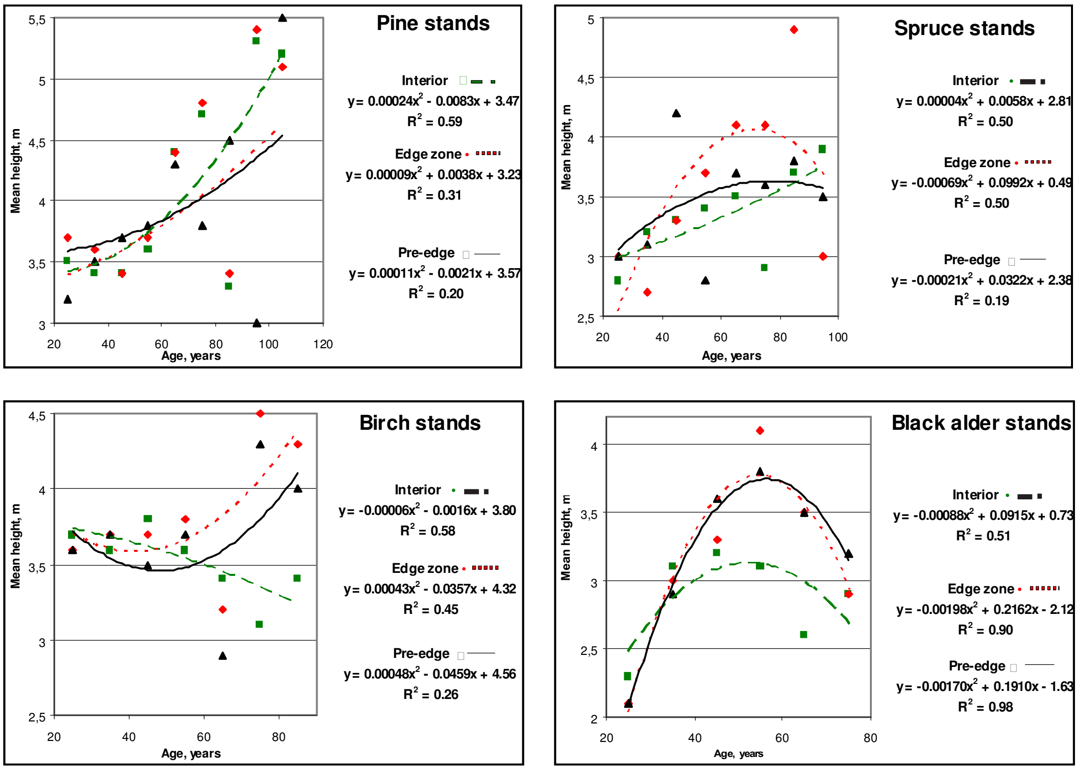

Figure 3. Dependance of mean standard height deviations (y) on age (x) for trees growing in different parts of compartment

heights in Scots pine stands (3.4 – 4.4 m) may be explained by a naturally greater diversity of their growth conditions, as compared to Norway spruce and Common alder (3.2-4.4 m) stands.

To fit the mean height of trees, the most suitable in this case logarithmic equation was applied (Fig. 4). The mean heights of Scots pine in the edge zone are lower than the mean heights in the compartment interior, excluding 25-year-old stands. With increasing Scots pine stand age, differences of stand heights in the edge and interior zones of compartment increase. Scots pine heights in the pre-edge of compartment are higher than in the edge zone, but there is almost no difference between them and mean heights inside the compartment. It is possible to assume that the growth in height of Scots pine trees, growing further than 10 m from the edge, is not affected by edge conditions.

The mean heights of Norway spruce and Common birch trees are more affected by the edge zone as compared with Scots pine trees. With increasing stand age, height differences of trees growing inside the compartment and at the edge increase, and at the age of 75–95 years the differences for Norway spruce comprise 1.5 – 1.7 m, those for Common birch – 1.2 – 1.4 m. In the pre-edge zone, *i.e.* on average 20 m away from the edge, height differences in 25 – 45 - year-old Norway spruce and Common birch stands, compared to heights inside the compartment, are insignificant. Mean heights of 75 – 95 - year-old trees in the pre-edge zone exceed heights in the edge zone for Norway spruce – by 1.1-1.2 m, for Common birch - by 0.8 – 0.9 m. The mean heights of 75 – 95 year-old trees growing in the pre-edge zone are lower than mean heights of trees growing inside stand only by 0.2 – 0.3 m, which shows termination of the influence of the edge zone on the growth of Norway spruce and Common birch trees at 20 m distance from the edge.

Height differences of trees growing in the edge zone of Common alder stands, as compared to tree heights inside the compartment, change insignificantly with time. They have rather stable, by 0.5–0.6 m lower than the average, heights inside the compartment. The heights of trees growing 20 m away from the edge zone almost fail to differ from tree heights inside the compartment (Fig. 4). The differences of mean heights fail to exceed 0.3 m.

The mean heights of trees in the edge zone are by up to 1,7 m lower as compared to tree heights inside the compartment. This is a general and very distinctive regularity, determined studying stands of all tree species. However, as the presented data (Fig.4) indicate, not in all cases the ascertained height differences are valid due to a comparatively high variation in heights and sometimes insufficiently measured number of trees. The mean tree heights of all species growing in different parts of compartment at the juvenile stage fall within confidence interval (at the 0.683 probability level) of tree heights measured in the interior and pre-edge zones of compartment. However, starting already with the year 55, the mean heights of trees growing in the edge zone of Norway spruce and Common birch stands are essentially lower (at the 0.683 probability level) than the heights of trees inside compartment. The mean heights of trees in the edge zone of Scots pine and Common alder stands, although stay within the limits of confidence interval, but they are lower than the height of trees growing inside compartment. The mean height of all tree species growing in the pre-edge zone 20 m away from the edge falls within the confidence interval of heights in the whole range of ages (Fig.4).

rate of growth in height gradually accumulates and the retarded growth in height increases with age.

Tree Diameter

The mean tree diameters inside compartment were estimated according to the measured tree diameters in circular plot, while in the edge zone – based on measured tree diameters in plot sectors. The mean tree diameters, confidence intervals of their variation, ascertained according to the standard deviations of differences in the mean diameters were compared and analysed directly, *i.e.* without their alignment in advance (eq. 2, Fig. 5). It was inspired by a rather stable changeability tendencies of the mean diameters in different parts of compartment, typical of some tree species (for example Norway spruce) turning-points, which could disappear owing to alignment.

The mean diameter of Scots pine trees growing

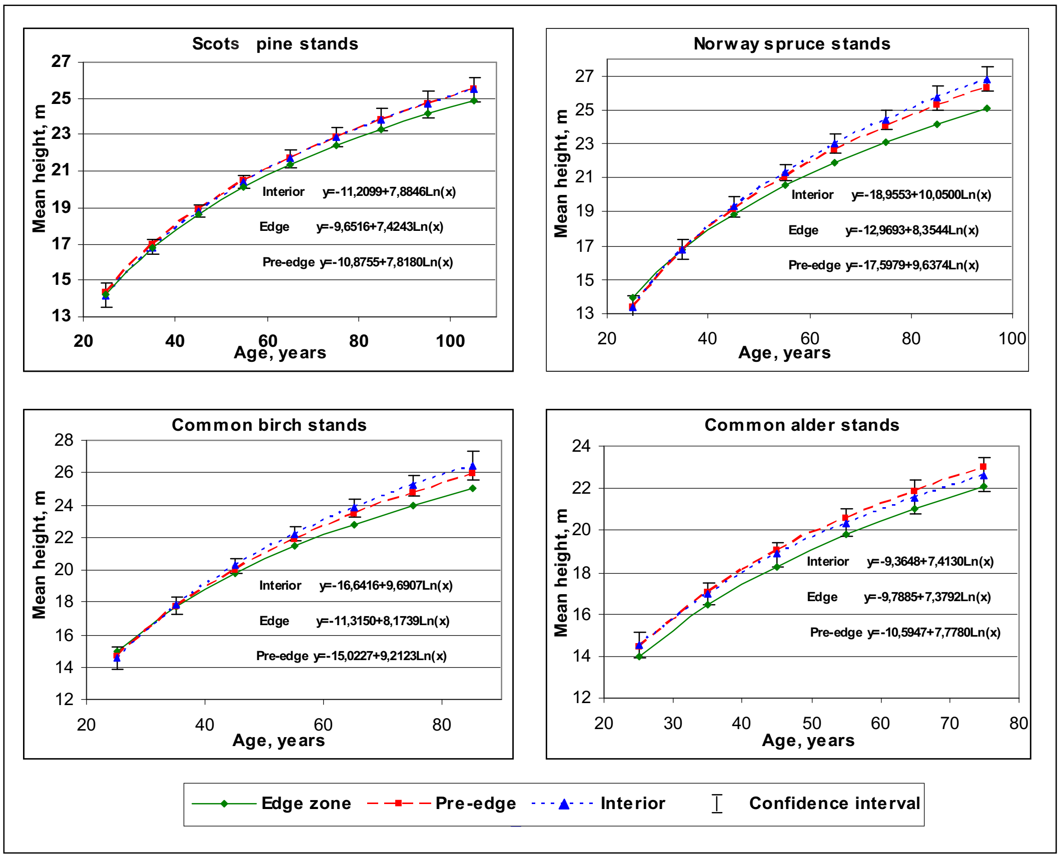

Figure 4. Comparison of tree heights inside compartment, in the edge and pre-edge zones

Lower mean heights of trees growing in the edge zone can be logically explained. In the edge zone trees grow receiving initially less sunlight or even are suppressed by trees of the adjacent stand, growing under the conditions of lower density which gradually leads to the formation of tree groups with lower intensity of the growth in height. Lost at the juvenile stage the

in the interior and edge zones of compartment, depending on age, change according to the relationship which is close to the linear one (Fig. 5). The mean diameter of Scots pine trees growing in the edge zone is by 1.1–3.4 cm higher than that of trees growing inside. The differences are more distinct at the juvenile stage when trees growing in the edge zone have

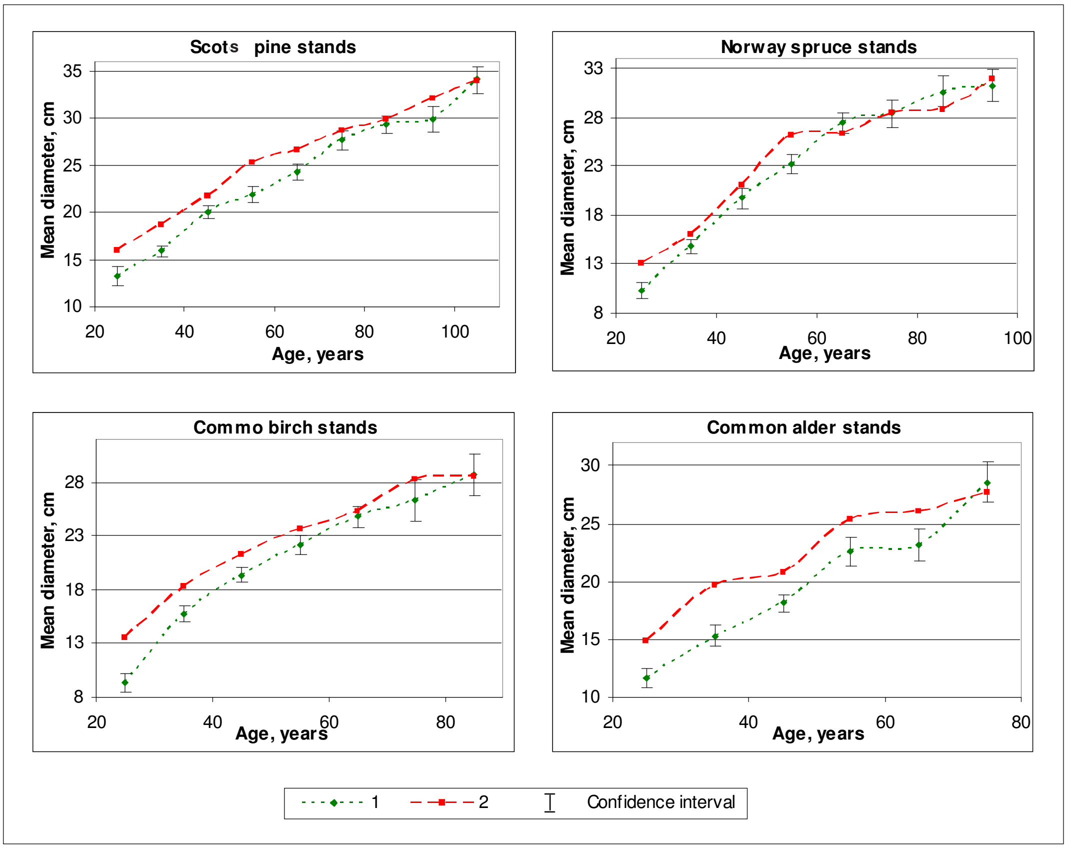

Figure 5. Comparison of mean diameter differences of trees growing in the interior (1) and edge zones (2)

better possibilities to take advantage of available growth space. The mean diameters of pine trees in the edge zone up to 70 years differ essentially (at the 0.683 probability level) from tree diameters inside the compartment (Fig.5). Diameter differences of older trees remain, however, most often they are statistically insignificant.

The mean diameter of Norway spruce trees growing in the edge zone at the age of 25–55 yr. are by 1.2–2.9 cm higher than the diameters of trees growing inside the compartment, while the mean diameters of the 65-year-old and older Norway spruce stands in the edge zone the diameters inside the compartment are equal due to a high vulnerability of Norway spruce stands at this age. In the curve of the mean diameter dynamics of the 65–year–old Norway spruce stands a turning – point in the reduction of diameter change due to the die-back of larger trees under the impact of wind, pests and drought is observed (Fig.5).

The mean diameters of Common birch trees growing in the edge zone are by 1.8–4.1 cm higher than the diameters of trees inside the compartment. These differences are sufficiently distinctive and statistically significant within 25–55 yr. range at the 0.683 probability level.

The mean diameters of Common alder trees growing in the edge zone are by 2.7–4.4 cm higher than these of trees inside the compartment. These differences are statistically significant within 25–65 yr. age interval at the 0.683 probability level (Fig. 5). It must be noted that the differences in Common alder trees growing in the edge zone and inside the compartment are the highest, as compared to other tree species. This is predetermined by more favourable for Common alder growth conditions (not only light, but also soil and moisture regime) in the edge zone, in which the diameter increment becomes especially significant.

Partially reduced growth of trees in height and considerably increased growth in diameter, ascertained by our studies, reveals that conditions in the edge zone are adequate to stand growth under heavy thinning out at the juvenile stage.

Growing Stock Volume

Growing stock volume in each of the zones was estimated by the ratio method applied in the national forest inventory (Kuliešis *et al.* 2003). Standard deviations of the mean growing stock volumes depending on age were fitted using a parabolic regression equation of the second degree (Fig.6). The highest indices R^2=0.63–0.98 of the growing stock volume standard deviation were obtained evaluating a situation inside the compartment, especially in Scots pine, Norway spruce and Common birch (R^2=0.88–0.98) stands. The least indices R^2 were obtained assessing the pre-edge zone (R^2=0.41–0.66).

intensive growth, growing stock volumes in the edge zone of Scots pine stands exceed growing stock volume inside the stands. At the age of 95–105 years, growing stock volume of the edge zone exceed growing stock volume of the inside zone by 44–47 m^3/ha,

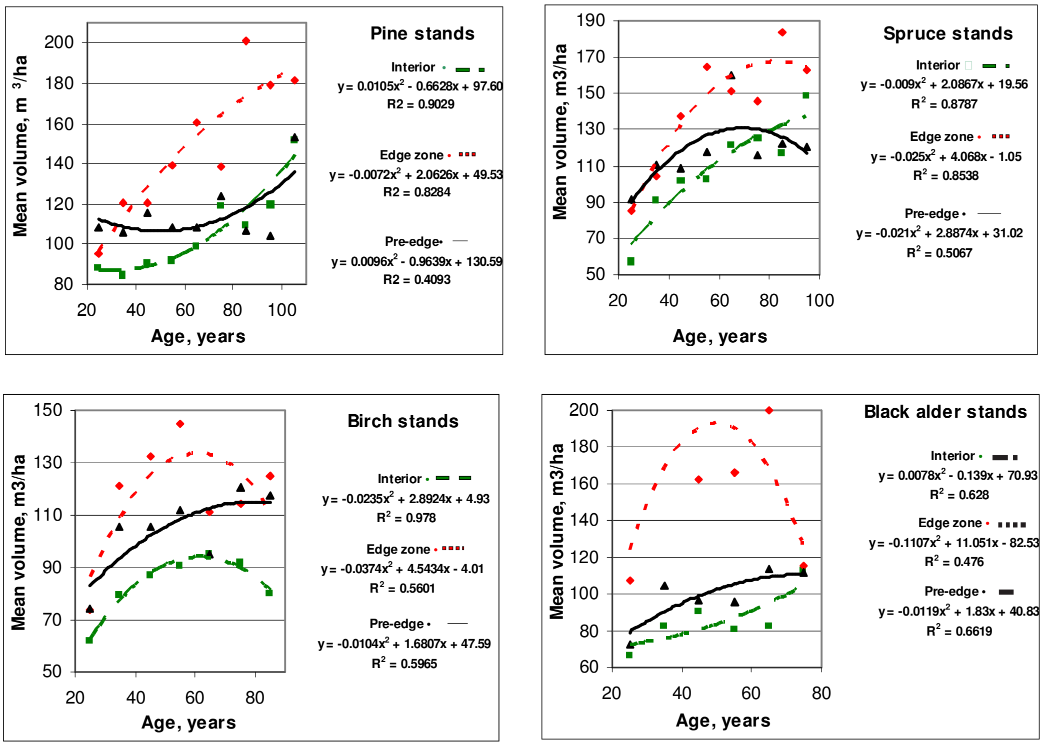

Figure 6. Dependance of mean growing stock volume standard deviations on age in stands growing in different parts of compartment

The least standard growing stock volume deviations of all tree species are found in the most homogeneous interior part of compartment (65 – 145 m^3/ha), the highest – in the edge zone (85 – 190 m^3/ha, while pre-edge occupies an intermediate position (80 – 135 m^3/ha). Standard growing stock volume deviation inside the compartment of Common birch and Common alder stands (60 – 100 m^3/ha) are by 10 – 45 m^3/ha less to compare with Scots pine and Norway spruce (70 – 145 m^3/ha) stands.

Growing stock volume dependance on age for Norway spruce, Common birch and Common alder stands was best expressed by a logarithmic equation (Fig. 7). Study results represent stands growing not only on different sites, but also in different density conditions. An especially high variation of stand density is characteristic of the edge zone. Due to this reason, R^2 indices of the mean growing stock volumes depending on age are sufficiently low.

Growing stock volume of Scots pine stands, growing in the edge zone, up to the age of 25 years is by 12 m^3/ha lower as compared to the volume inside the compartment (Fig. 7). Later, due to a more

or by 14–15%. Growing stock volume at 20 m distance from the edge of compartment remains by 3–4% higher as compared to the volume inside the compartment up to the age of 95–105 years. It shows only an insignificant influence of the edge zone on growing stock volume 20 m away from the edge.

Tendencies of growing stock volume differences of Norway spruce stands growing in the edge zone remain similar to Scots pine stands, however, they are significantly weaker. Growing stock volume of the 25-year-old Norway spruce stands in the edge zone is by 4 m^3/ha lower, that of 35-year-old becomes equal, while that of 95-year-old stand only by 8 m^3/ha exceeds growing stock volume inside the compartment (Fig. 7). Lower differences of Norway spruce growing stock volumes, compared to Scots pine stands, may be explained by differences in Norway spruce stand formation, their lower resistance to winds and pests. Differences in the growing stock volumes at 20 m distance from the edge are observable only up to the age of 65–75 years, later these differences disappear. In the pre-edge zone of 25–55-year-old stand, a significantly higher growing stock volume is

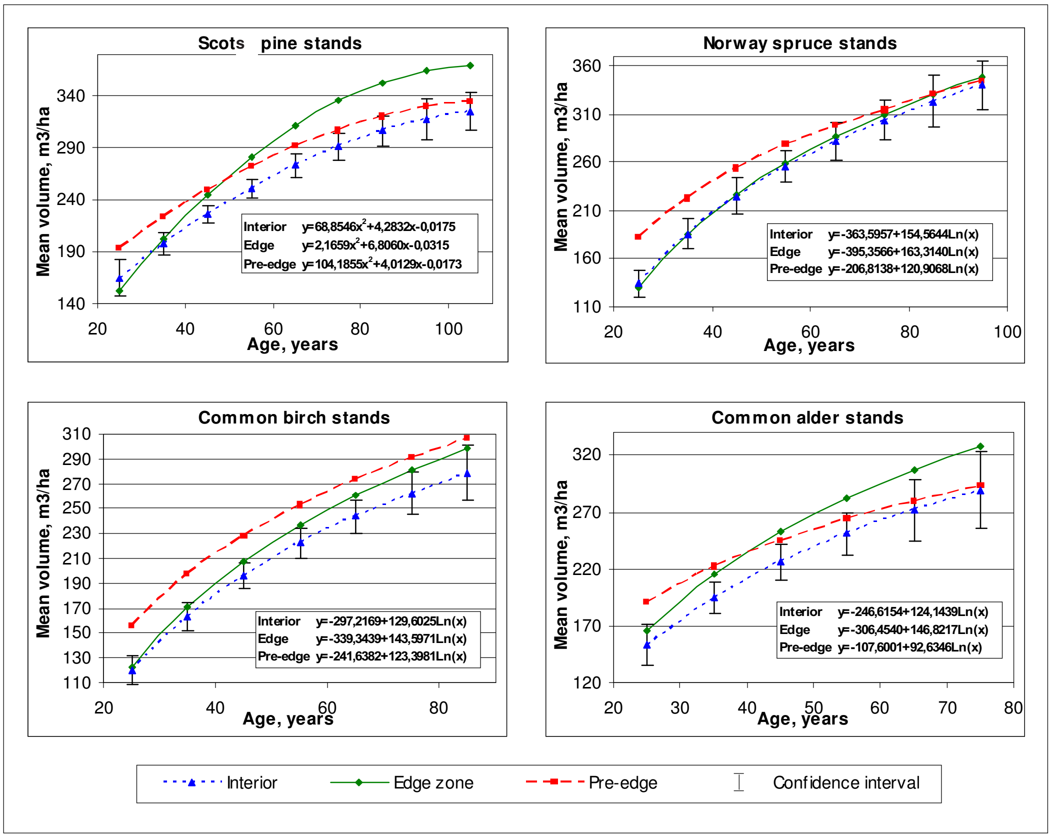

Figure 7. Comparison of mean growing stock volumes in the interior, edge and pre-edge zones of compartment

observed (40–50 m^3/ha) as compared to the edge and interior zones of the compartment. This is due to a greater protection of pre-edge trees against adverse factors and a more successful exploitation of growth conditions in the pre-edge zone, as compared to Norway spruce trees growing in the edge zone.

Growing stock volume of Common birch stands growing in the edge zone is by 3–20 m^3/ha higher as compared to the volume of Common birch stands growing inside the compartment. With increasing stand age, diferences increase. A rather stable growing stock volume increase of 28–35 m^3/ha is observed in Common birch as well as Norway spruce stands at a distance of 20 m from the edge.

Growing stock volume of Common alder stands growing in the edge zone is by 13-38 m^3/ha higher as compared to the volume inside the compartment. With increasing age, the growing stock volume differences increase. A more distinct growing stock volume increase (13–27 m^3/ha) at the distance of 20 m from compartment edge is observed up to the age of 55 years.

Having estimated the mean growing stock volume values of every tree species, their standard deviations by age classes and confidence intervals were ascertained, in which the differences in stand volumes in different compartment zones are not statistically significant (Fig.7). Summarizing analysis data of tree volumes in the edge zone, it was found that the growing stock volume of Scots pine stands growing in the edge zone is statistically significantly (at the 0.683 probability level) higher than the volume of trees growing inside the compartment starting with the age of 45 years. Growing stock volumes of 35 – 45-year-old Scots pine stands in the edge zone, while in the pre-edge zone the volumes of older than 80-year-old Scots pine stands are higher than the volumes of stands growing inside the compartments, however, these differences are not statistically significant. Growing stock volumes of Scots pine stands growing in the edge zone up to the age of 35 are lower than inside the compartment, however, statistically these differences are insiginificant as well.

The tendencies of volume differences in different parts of compartment are similar both for Scots pine and Norway spruce stands, but the growing stock volume differences of Norway spruce stands growing inside and in the edge zone in the whole range of ages are statistically insignificant. Statistically significantly (at the 0.683 probability level) higher are the volumes of Norway spruce stands growing in the pre-edge zone up to the age of 60 years.

In Common birch stands statistically siginificant growing stock volume differences are in stands growing in the pre-edge zone and inside the compartment almost in the whole range of ages, while volume differences of stands growing in the edge zone and inside compartment are statistically siginificant only within the age range of 50–70 years. Common birch stands usually contain Norway spruce trees which are wind-sensitive in the edge zone. Growing further from stand edge, Common birch and Norway spruce trees experience more favourable conditions for their survival and growth.

The volume of Common alder stands growing in the edge zone already at the age of 30 years becomes statistically siginificantly higher, in the pre-edge zone it is statistically siginificantly higher up to the age of 50 years.

Volume differences of stands growing in the edge and pre-edge zone, as compared to volumes of stands growing inside the compartment, depending on age, may be compared with the volume change tendencies of more heavily thinned out stands in the juvenile stage. Trees growing more sparsely at the juvenile stage, during stand formation attain a significantly lower volume, however, they considerably longer sustain the tendency of intensive growth and in older age attain a significantly higher volume than trees growing under denser conditions inside the compartment. It also shows that stand yield formation in different parts of the compartment is of a different type (Kuliešis 1989). The results of mean diameter changes of trees growing in the edge and interior zones of the compartment confirm this assumption. This assumption was also tested by analysing stocking level variation tendencies in different parts of compartments.

Stand Stocking Level

Most researchers have noticed that stand stocking levels in Lithuania have a tendency to decrease with increasing stand age. The question is whether these tendencies remain the same in different parts of the compartment. Answering of this question as well as ascertainment of stocking levels in different parts of the compartment have aided determination of stand formation peculiarities in different parts of the compartment, i.e. in the interior, edge and pre-edge zones.

Standard stocking level deviations of all tree species in different parts of the compartment sustain similar tendencies of variation to standard growing stock volume deviations, *i.e.* the lowest – inside the compartment and the highest – in the edge zone, differences comprise up to two and more times.

The lowest stocking level for stands of all species in the investigated range of ages is in the interior zone of stand, when the highest – in the edge zone for Scots pine and Common birch stands after 50 years of age, while for Norway spruce – after 80 years of age. The highest stocking level up to the above mentioned age is in the pre-edge zone of stands (Fig. 8).

For most species it is possible to determine age ranges in which the stocking level in the edge and pre-edge zones is statistically significantly higher than the corresponding stocking level inside the compartments. Stocking level in the edge zone of 50-year-old and older Scots pine stands, while in the pre-edge zone that of the 30–60-year-old stands, is statistically significantly higher than the corresponding stocking level inside the compartment (Fig. 8). The same was determined for the stocking levels of Norway spruce stands in the edge zone at the age of 85–95 years and in the pre-edge zone at the age of 25-75 years, for Common birch stands in the edge zone at the age of 45–85 years, while in the pre-edge zone at the age of 35–85 years. The stocking level of Common alder stands in the edge zone within the whole age interval is statistically significantly higher than the stocking level inside the compartment. Difference of stocking levels in the pre-edge zone, as compared to stocking level inside the compartment, for Common alder is statistically insignificant (Fig. 8).

The dynamics of Scots pine stand stocking level shows that in the pre-edge zone, as well as inside the compartment, Scots pine stands are formed according to yield formation type, closer to the accelerated one, while in the edge zone – according to normal or even slowed yield formation type (Fig. 8, Kuliešis 1989).

The dependance of Norway spruce stand stocking level on age is the most obvious among respective dependances of other species. With increasing Norway spruce stand age from 25 to 95 year, the stocking level inside the compartment increases from 0.60 to 0.69, in the edge zone – from 0.61 to 0.77. In both zones of the compartment, in the edge zone more, while inside less expressed is stand yield formation tendency according to the slowed type. In the pre-edge zone, Norway spruce stands which since the juvenile stage are forming under the conditions of higher density, a decrease in the stocking level is observed (from 0.77 to 0.73), as an attribute of accelerated stand yield formation.

The stocking level of Common birch stands with increasing age from 25 to 85 years inside the compartment decreases from 0.79 to 0.76, in the pre-edge zone remains stable (0.85), while in the edge zone it augments from 0.79 to 0.93. The character of stocking level dynamics in Common birch stands inside the compartment reveals their formation close to the accelerat-

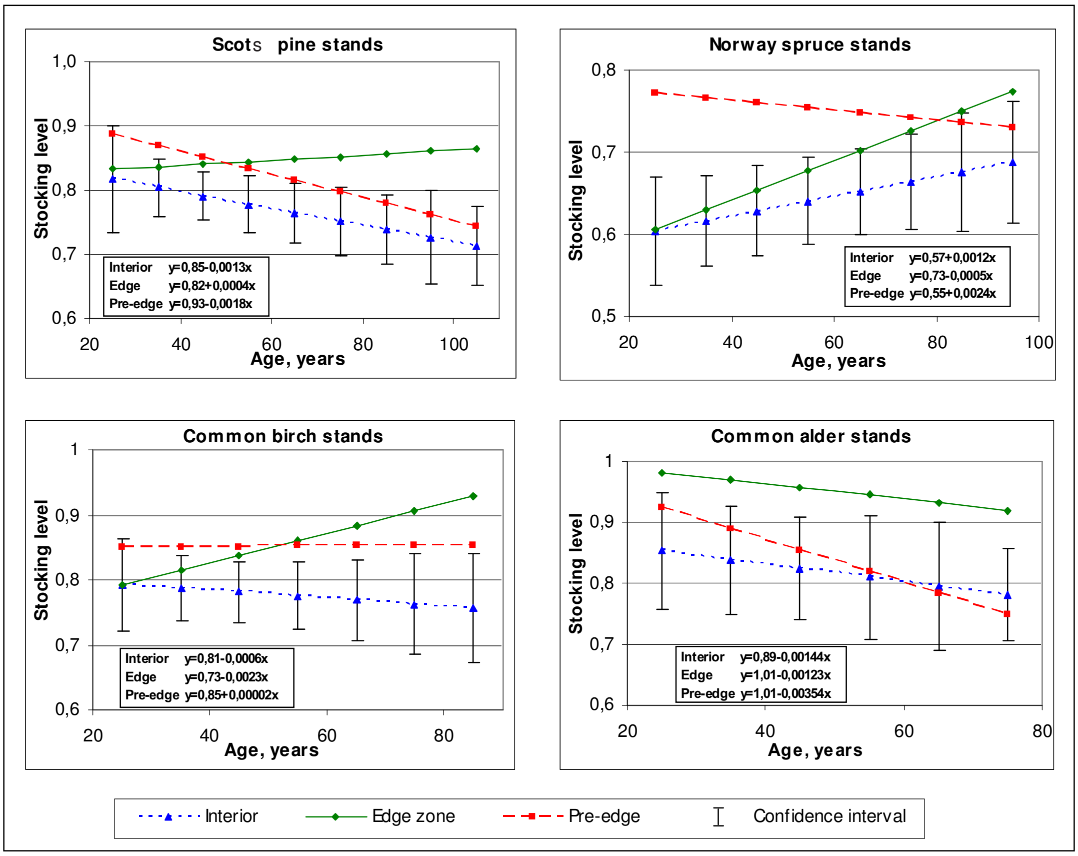

Figure 8. Comparison of stand stocking level in the interior, edge and pre-edge zones of compartment

ed yield formation type, in the pre-edge zone – close to the normal, while in the edge zone – close to the slowed stand yield formation type.

The stocking level of Common alder stands in all parts of the compartment decrease with increasing age. The stocking level of Common alder stands with increasing age from 25 to 75 years inside the compartment decreases from 0.85 to 0.78, the most intensively it decreases in the pre-edge zone – from 0.93 to 0.75, the least intensively – in the edge zone – from 0.98 to 0.92. At the juvenile stage, in contrast to other stands, Common alder stands in the edge zone attain the highest stocking level. Of course, with increasing age, it has the least probability to further increase. In this respect Common alder stand formation in the edge zone is mostly close to the normal stand yield formation type. The stocking level in the pre-edge zone, although lower than in the edge zone, with time decreases more intensively. This shows the existence of more intensive competition conditions and less volume increment accumulation possibilities in the pre-edge zone than in the edge zone of Common alder stands.

A comparison of stand stocking levels in the interior, edge and pre-edge zones of the compartment has been made, their dynamics analysis has shown that stand yield formation in different parts of the compartment has different tendencies. Stands growing in the edge zone are formed according to the type closer to the normal (Common alder) or slowed (Scots pine, Norway spruce and Common birch stands) stand yield formation type. Inside the compartment, stands of almost all species are formed according to the type close to the accelerated yield formation type. In the pre-edge zone, stands in most cases are formed according to the intermediate between normal and accelerated (Common birch, Norway spruce) or accelerated (Common alder, Scots pine) stand yield formation types.

Discussion and conclusions

Results obtained during the study, the ascertained stand structure, tree growth and stand formation regularities in the edge zone mainly complement study data presented by other authors on tree growth in clumps, gaps, near forest glades or forest border (Oliver *et al.* 1996; Kenstavičius *et al.* 1984; Saladis 1998; Кайрюкштис, Озолинчюс 1985; Кайрюкштис, Скуодене 1985). According to our data, stands growing in the edge zone are of lower density, higher mean diameter and lower mean height, as compared to trees growing inside the compartment. The determined average interval of 5-7 years between fellings is sufficient to sustain growth differences of planted young trees at the stand border during the whole subsequent stand growth period.

According to the determined tree growth peculiarities in clumps, gaps or openings (Oliver *et al.* 1996; Saladis 1998), it is possible to find an analogy with tree growth in different parts of the compartment. Based on the peculiarities of tree growth in gaps, two zones are singled out – trees growing by an open area and trees having no contact with an open area, *i.e.* growing inside the gap (Oliver *et al.* 1996). Similarly, two zones are singled out for trees bordering forest glade (Saladis 1998). Our studies have shown that analogous to the gap of trees, to trees bordering forest glade and to the glade itself, zonation principle is applicable also to the whole stand. Trees growing in the edge, pre-edge and inside the stand differ by the initial density, other initial growth conditions and determined based on them differences in tree height and diameter growth, as well as in stand stocking level and yield.

Yield formation differences in trees growing in the edge zone, pre-edge and inside the compartment basically provide no background to state that stand yield losses may occur due to the edge. Such conclusions, drawn only according to tree height differences (Kenstavičius *et al.* 1984), are groundless. Much more favourable growth conditions due to a lower density, more intensive thinning out not only increase losses, but also exceed the yield of trees growing inside the compartment. The volume of trees growing in the edge zone in mature age are up to 15–20%, while in the pre-edge zone up to 1–10% higher than stand volumes inside the compartment.

The results of our studies have shown that the compartment according to its structure is not homogeneous also from the viewpoint of stand yield formation. Trees growing in the edge zone may experience competition from the adjacent stand for some time, however, having eliminated it, they have more space than those growing inside the compartment. Better spatial growth conditions may be experienced in the pre-edge zone as well. However, in the pre-edge zone more favourable growth space and less influence of the neighbouring stand is experienced already at the juvenile stage, therefore, in this zone higher volumes and increments are observed earlier, as well as greater competition among trees. Regularities of stand height, diameter, volume and stocking level dynamics with increasing age show stand yield formation type in the edge zone being closer to the normal or slowed types. Inside the compartment and in the pre-edge zone, stands are usually formed according to the accelerated type and only the formation of spruce, partially that of birch stands, may be attributed to the normal formation type.

The greatest growing stock volume differences of stands growing in the edge and pre-edge zones, as compared to stands growing inside the compartment, are found in Scots pine, Common birch and Common alder stands, while the least in Norway spruce stands. The growing stock volume of Norway spruce trees, able to grow under lower light conditions and more sensitive to wind in older age, is more even in the whole stand. The zonation of Norway spruce stands, as compared to the stands of other tree species, is more weakly expressed.

The revealed regularity allows to better understand compartment structure, its inevitable zonation during forest regeneration after felling. Undoubtedly, this regularity should be taken into account during forest inventory and planning, changing compartment areas, configurating, planning clear-felling areas and felling time intervals. A clearly expressed lower yield in the interior part of compartment may be one of the reasons for volume decrease in standwise forest inventory. Ignoring uniform location of plots in all zones of the compartment, concentrating inventory plots in the central part, incompletely representing the edge and pre-edge zones, it is possible to distort the data of objective forest inventory.

References

Antanaitis, V. 1961. Sklypinis miškų ūkis ir sklypinis miškotvarkos metodas [Sample Forestry and Sample Forest Inventoory Method]. *Mūsų girios*, 8. (157). P. 4–8.

Antanaitis, V. ir Deltuvas, R. 1988. Miškotvarka [Forest Management Science]. Vilnius: Mokslas. 300 p.

Brukas, A., Jakubonis, S., Kuliešis, A. ir Rutkauskas, A. (Eds.) 2002. Lietuvos miškotvarka ir jos raida Lithuanian Forest Management Science and its Development]. Kaunas: *Naujasis lankas*, 188 p.

Deltuva, L. 1999. Miško pakraščių ekologinių sąlygų ypatumai ir jų poveikis fitocenozių komponentams Daktaro disertacija [Ecological Peculiarities of Forest Edges and their Influence to Phytoassociation]. Doctoral Thesis]. *Lietuvos žemės ūkio universitetas*, 180 p.

Deltuva, L. ir Morozas, V. 2000. Pamiškės efektas eglynų sudėčiai ir strukūrai [Forest Edge Effect to Spruce Stand Compositions and Structure]. *Miškininkystė*, 1–2 (45–46): 5–11.

Fish, S. 2000. Combining geostatistics information systems to provide locally specific estimates of basal area and volume per hectare from forest inventory plots (Pro gradu thesis for Master of Science in Agriculture & Forestry, in the field of Forest Mensuration and Management, Helsinki, 2000).

Franklin, J. F. and Forman, R.T.T. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. *Landscape Ecology* 1: 5-18.

Kenstavičius, J. 1978. Miško sklypų formavimas – atsakingas miškotvarkos ir gamybos uždavinys [Formation of the Forest Samples – Principal Goal of Forest Management and Exploitation]. *Girios*, 1 (352): 1–5.

Kenstavičius, J., Jakubonis, S. ir Ožeraitis, V. 1984. Gretimo medyno įtaka želdiniams [Influence of the Adjacent Stand to Plantations]. *Girios* 5: 8–10.

Kuliešis, A. 1989. Medynų našumas ir jo panaudojimas [Stand Productivity and its Use]. Vilnius: *Lietuvos agroleidykla*, 141 p.

Kuliešis, A. 1996. Miško prognozavimo ir informacinės sistemos bei nacionalinės miško inventorizacijos bazinės struktūros sukūrimas [Creation of Basic Structure of Forest Prognosis and Information System and National Forest Inventory]. Kaunas. 111 p., anexes 86 p.

Kuliešis, A., Kasperavičius, A. 2000. Nacionalinė miškų inventorizacija: Darbo taisyklės 1998–2007 [National Forest Inventory: Operating Instruction]. Kaunas: *Valstybinis miškotvarkos institutas*. 148 p.

Kuliešis, A., Kasperavičius, A., Kulbokas, G. Kvalkauskienė, M. 2003. Lietuvos nacionalinė miškų inventorizacija 1998–2002. Atrankos schema, metodai, rezultatai [Lithuanian National Forest Inventory 1998-2000. Sample Scheme, Methods, Results]. Kaunas: Valstybinė miškotvarkos tarnyba. *Naujasis lankas*. 255 p.

Lietuvos miškų statistika [Lithuanian Forest Statistics]. 2004, 2004. Kaunas:Valstybinė miškotvarkos tarnyba prie Aplinkos ministerijos, 111 p.

Lyr, H., and Hoffmann, G. 1967. Growth rates and growth periodicity of tree roots. *International review of forestry research*, 2: 181–236

Matlack, G. R. 1994. Vegetation dynamics of the forest edge – trends in space and succesion time. *Journal of ecology*, 82: 113–123.

Morozas, V. ir Deltuva, L. 2002. Pamiškės efektas pušynų sudėčiai ir strukūrai [Forest Edge Effect on the Pine Stand Composition and Structure]. *Miškininkystė*, 2. (52): 54–60.

Neumann, M. and Starlinger, F. 2001. The significance of different indices for stand structure and diversity in forests. *Forest Ecology and Management* 145: 91–106.

Oliver, D. and Larson, C. Bruce. 1996. Forest stand dynamics, update edition. John Wiley & Sons Inc. 521p.

Ranney, J. W., Bruner, M. C. and Levenson J. B. 1981. The importance of edge in the structure and dynamics of forest islands, in R. L. Burgess and D. M. Sharpe (eds.), Forest islands dynamics in man-dominated landscapes, ecological studies, Volume 41, *Springer-Verlag*, New York. p. 67–95.

Saladis, J. 1999. The relationships between the gap structure, stand age, productivity, spatial distribution and competition of trees in pure Scots pine stands. *Baltic Forestry*, Vol.5, No1: 11-18.

Tomppo, E. 2002. Assessing the Biodiversity of Forest at National and Continental Level. Finnish Forest Research institute, Helsinki, Finland, p. 12.

Wales, B. A. 1972. Vegetation analysis of north and south edges of a mature oak-hickory forest. *Ecological Monographs*, 42: 451–471.

Антанайтис, В., Заунене, Н., Кулешис, А. и Юкнис, Р. 1975. Нормативы точности и методы таксации древостоев [Stand Assessment Methods and Precision Standards]. Каунас, 76 p.

Гмурман, В. Е. 1972. Теория вероятностей и математическая статистика [Probability Theory and Mathematical Statistics]. Москва, 1972, 368 p.

Кайрюкштис, Л. А. и Озолинчюс, Р. В. 1985. Некоторые закономерности взаимовлияния ели в процессе образования ценоза [Some Regularities of Spruce Relationship during Association Development Process]. Lietuvos miškų ūkio MTI darbai. T. 25: Neplynų miško kirtimų mechanizmas ir technologija, p.148–158.

Кайрюкштис, Л. А. и Скуодене, Л. П. 1985. Способ снятия стрессовой напряженности при адаптации ели к ценозу [The Method of the Destress during Spruce Adaptation to Association]. Каунас-Гирионис:ЛитНИИЛХ. 11 p.

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ЭФФЕКТ ГРАНИЦЫ ВЫДЕЛА НА РОСТ И РАЗВИТИЕ ДРЕВОСТОЯ

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Резюме

На основе изучения структуры древостоев по данным выборочной национальной инвентаризации лесов Литвы в сосняках, ельниках, березняках и черноольшаниках выделены граничная, внутренняя и пограничная зоны выдела. Граничная зона распространяется на 10-12 м, а пограничная – на 12-27 м от границы выдела. Наиболее благоприятные для роста условия в стадии формирования древостоя создаются в пограничной зоне выдела. У деревьев этой зоны в начале проявляются повышенные темпы роста, постепенно приближающиеся к темпам роста деревьев внутри выдела. В граничной зоне, в период формирования древостоя, растения страдают от дополнительной конкуренции за свет, элементы питания со стороны окраинного древостоя, из-за чего формируются более редкие древостои с более низкими и более толстыми деревьями. Редкостоящие деревья постепенно достигают большей производительности по сравнению с деревьями, растущими внутри древостоя. Деревья с большим относительным сбегом в граничной зоне образуют буферную зону. тем повышая устойчивость древостоя.

Наибольшие различия запасов спелых древостоев в граничной зоне, достигающие 38-47 м^3/га по сравнению с внутренней зоной, наблюдаются в сосняках и черноольшаниках, наименшие -8 м^3/га – в ельниках. В пограничье запасы спелых древостоев превышают запасы внутренней зоны в сосняках – на 3-4, ельниках – 1-2, березняках – 9-10% и в черноольшаниках – на 1-3%.

Формирование производительности древостоев в граничной зоне более близкое к формированию по нормальному или замедленному типам, во внутри древостоя и в пограничье – по ускоренному или нормальному типам формирования.

Ключевые слова: зоны древостоя, различия по высоте, диаметру, формирование производительности