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CHARACTERISTIC GROWING PARAMETERS OF SMALL-LEAVED LIME AND NORWAY MAPLE STANDS IN THE CLIMATIC CONDITIONS OF LATVIA

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In order to clarify the suitability of small-leaved lime (*Tilia cordata* Mill.) and Norway maple (*Acer platanoides* L.) for plantation forestry with a view of obtaining timber products, a study was carried out on the distribution of small-leaved lime and Norway maple in the regions of Latvia, typical stands were selected, and their growth rate and productivity were assessed. It has concluded that small-leaved lime stands and Norway maple stands in Latvia increased in terms of area from 2001 to 2017: areas occupied by small-leaved lime stands grew by 31% on average, and Norway maple stands increased by 50% on average over the period from 2010 to 2017.

It was concluded that pure and mixed small–leaved lime stands are productive stands, in which it is possible to obtain up to 100 m3 of stand volume in age class 1(1-20 years) under good growing conditions and up to 327–502 m^3 ha–1 in age classes 4 (61-80 years) and 5 (81-100 years). The study shows that pure and mixed Norway maple stands lag behind lime stands in terms of productivity. In higher quality stands, it is possible to obtain up to 276 m^3.ha -1 in age classes 4-5.

The productivity of small–leaved lime plantation forest stands depends to a great extent on the type of soil. In heavy soils, a 15–year–old plantation accounted for a stand volume of 39 m3 ha-1, while in sod–podzolic soils and sod–calcareous soils, these figures were 64,6 m3 ha-1 (16–year–old) and 103 m^3 ha-1 (17–year–old) respectively. The volume of Norway maple plantation type stands reaches 10.7 m^3 ha-1 at the age of 12. The study concludes that, with the warming of the climate, special attention should be paid to the preservation of small leaved lime (*Tilia cordata* L.) and Norway maple (*Acer platanoides* L.) in the types of forests with suitable growing conditions, which should also be considered as a valuable addition to the development of plantation forestry in Latvia.

Key words: lime, maple, pure stands, mixed stands, growth rate, stand volume.

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INTRODUCTION

European forestry is facing changes today, which are primarily attributed to warming of the climate, and the conservation of forest biodiversity has been put forward as one of the key aspects for sustainable forest development. Due to the urbanisation of rural areas, fragmentation of forest stands and population growth, it is important to maintain and potentially increase the economic value of forests.

A major future task for securing sustainable forest development is to improve the management of forest ecosystems through the diversification of tree species, while ensuring the ecological, economic and social stability of these ecosystems. From 2000–2015, in–depth studies have been, and are being carried out in countries of the European Union on improving the technology for growing different species of deciduous trees (*Alnus, Tilia, Juglans, Malus, Pyrus, Sorbus, Carpinus, Castanea, Ulmus*, etc.) with the aim of obtaining productive stands and plantations that can provide not only ecological but also economic benefits (Kjolby 1958, Barzdajan 1991, Savill 1991, Gardere 1995, Jarowski 1995, Claessens et al. 1999; Nagel et al. 2003, Semaskiene 2006, Marozas 42004, Hemery et al. 2005, European Forest Types 2007, Caquet et al. 2006 Tsakov 2007, Spiecker et al. 2009).

The key focus is on the following issues:

- clarification of the value of different species of deciduous trees;
- heterogeneity of mixtures of different species of deciduous trees in various forest management regimes;
- selection and propagation of high–quality genetic material of valuable species of deciduous trees;
- growth rate and productivity, possibilities for quality stem formation: pruning and diameter increment control;
- harvesting techniques in relation to valuable species of deciduous trees in mixed stands and pure stands;
- clarification of wood properties and wood processing techniques;
- use of valuable deciduous trees for landscape improvement;
- conservation of valuable deciduous trees as the basis for conserving biodiversity (Spiecker et al. 2009, Noble Hardwoods Network 2015).

In recent years, due to the activities of the National Forest Inventory, the latest maps showing tree species with the biggest distribution in European forest stands have been developed (Piggott and Huntley 1981, Noble Hardwood Networks 2015, Novel Map of Forest Tree Species in Europe 2015). Currently, forest stands and plantations with small leaved lime (*Tilia cordata* L.) as the main species, occupy an average of no more than 4% of the territory in the 30 European countries, and those with Norway maple (*Acer platanoides* L.) occupy no more than 3% of the territory, although they are very widespread as understory tree species (Boratynska and Dolatowski 1991, Waters and Savill 1992, Kobliha et al. 2003, Kazda et al. 200, Skovskaard and Jorensen 2004, Spiecker et al. 2009, Brus et al. 2011, Novel Map of Forest Tree Species in Europe 2015).

In fact, in those European countries with suitable growing conditions these tree species account for not more than 5% (area and stand volume) of Europe's forest area, but through skilful conservation and propagation, it is possible to expand the area occupied by them by up to 25%, increasing the composition of these species in privately owned forests, on river and lake floodplains and on plantations (Spiecker et al. 2009).

Research on the distribution of species in different regions of the world shows that the current changing environmental conditions (climate warming, substrate eutrophication and land use changes) lead to the increased migration of plant and animal species, faster biota transformation and its enrichment with indigenous and alien species. Particularly intensive biota transformation occurs in the boreo–nemoral or hemiboreal and boreal zone in the N hemisphere, including Latvia, which is located in the intermediate (boreo–nemoral) zone of the nemoral and boreal biome (Krampis 2008, 2011). This global transformation affects the composition of the plant species (Laivins 1997, Maurins and Zvirgzds 2006, Laivins et al. 2009).

Woody plants play an important role in the variability of the Latvian biota. As evidenced by historical data, the spread of broadleaved forests in Latvia reached its peak about 6,000 years ago. The area of Latvia was abundantly covered by broadleaved forests with a lot of European white elm (*Ulmus laevis*), oak (*Quercus robur*), hazel (*Corylus avellana*) and small–leaved lime (*Tilia cordata*) (Vitins 1925, Strods et al. 1999, Biota types in Latvia 2001, Prieditis 2014). In the following hundreds of years, the climate changed, the amount of precipitation increased, calcium was washed out of soil, soils became heavier, while Norway spruce *(Picea abies*) and silver birch (*Betula pendula*) (Vitins 1925) began to get established. Consequently, broadleaved forest areas started to shrink and the prevalence of broadleaved tree species, including small leaved lime, started to decrease. Nowadays, as the climate is changing, lime and oak begin to enter forest stands mostly as underbrush or understory trees, because Latvian forestry is focused on growing productive stands, choosing Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula* spp.) as the main species of trees (Bekeris 2016). Investigations show that boadleaves are not common tree species in the naturally afforested agricultural lands in Latvia (Daugaviete et al. 2017, Liepins et al. 2008).

The issue of conserving tree species that ensure forest biodiversity, such as lime (*Tilia* spp.), maple (*Acer* spp.), elm (*Ulmus* spp.), wild cherry (*Cerasus avium* Moench.), common pear (*Pyrus communis* L.), crab apple (*Malus sylvestris* (L.) Mill.) etc., and the possibilities for conserving them in the future is currently of particular importance in Latvia in the context of climate change and intensive harvesting. Research in this area has been carried out in Latvia by Gavrilova and Sulcs (1999), Krampis (2008, 2011) Laivins (1997, 2009), etc., yet a comprehensive analysis of forest inventory data on changes in the distribution of these tree species has not been conducted so far. According to the Digital Forest Map database, the distribution of lime and maple stands in different regions of Latvia is irregular (Fig. 1).

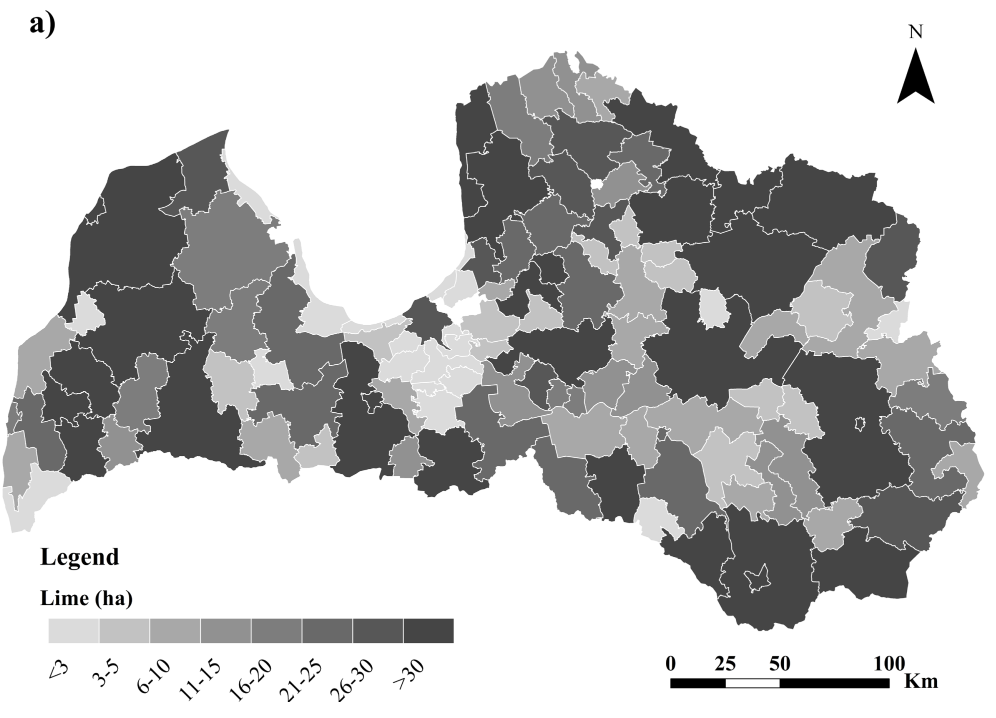
The area occupied by these tree species increased in Latvia in the period from 2001 to 2017; small leaved lime reached an area of 2202 ha, and Norway maple – 1023 ha, with an average growth of area of lime stands ± 31% (data for last 17 years) and 50% for maple (data for the last 7 years) (Fig. 2). It should be noted that the forest statistical data has only included data on maple since 2010.

In the many countries in Europe in the naturally restored small leaved lime and Norway maple forest stands with seeds and sprouts the following technologies are used for their thinning and management:

- thinning of separate groups. Scientists recommend setting the size of a group at around 0.5 ha;
- regeneration of lime and maple using cover species (tree species included in the mixture);
- thinning of young growths, taking into account optimum growth parameters, leaving 1,100 trees per ha on average (Spiecker et al. 2009);
- second thinning, during which the number of trees per area unit is further reduced, with the exception of underdeveloped and crippled saplings; it is carried out at the age of 10 to 12 years. The main attention is paid to the quality of the stems, and all trees that exhibit forked branching are removed;
- subsequent thinning at the age of 25 to 30 years reduces the number of saplings by 12% of the stand volume. The final thinning is carried out at the age of 60 to 70 years when the finest trees are cut to obtain veneer logs, leaving seed trees to create a new stand (Spiecker et al. 2009).

Recommendations for the management of Norway maple stands have been developed in some European countries, with the following main criteria emphasised:

- the desired diameter at breast height at the appropriate age;
- the desired stem quality (branch–free, without



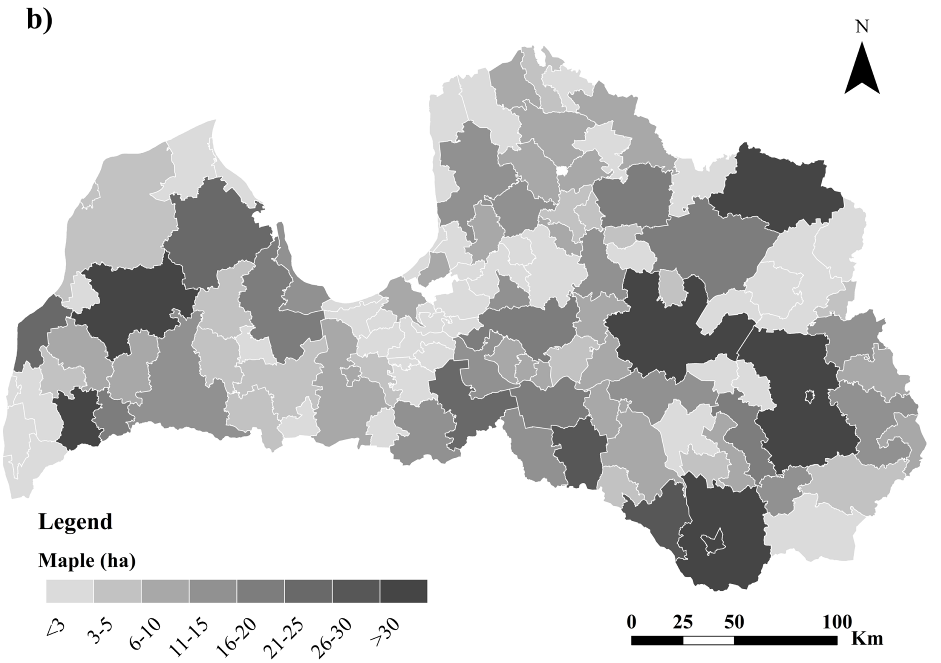


Fig. 1 Distribution of a) small leaved lime and b) Norway maple stands in Latvia, 2017.

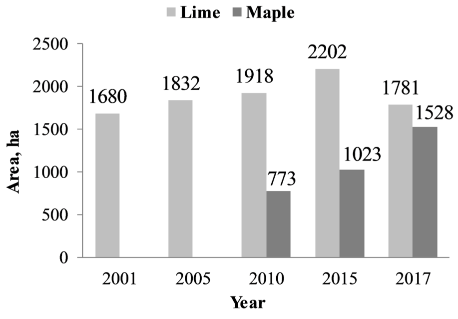


Fig. 2. Small leaved lime and Norway maple area dynamics in Latvia in 2001–2017 (http://www.vmd.gov.lv/ Digital Forest Map Database of the State Forest Register [Accessed on March 2017]).

flaws in the wood);
• achieving the desired length of tree, choosing the appropriate planting density (Savill 1991, Rossi 1993, Gardere 1995, Claessens et al. 1999, Kobliha, Hajnala and Janicek 2003, Hemery et. al. 2005, Semaskiene 2006, European Forest Types 2007, Tsakov 2007, Hein et al. 2008, Radoglou et al. 2008, Spiecker et al. 2009).

To reach a proper balance between the availability of lime and maple in Latvian woodlands, we need a well–conceived management model either by choosing forest sites with optimum growing conditions for both small leaved lime and Norway maple, or by establishing a purpose–orientated mix of the groups of both species.

The aim of this study: small-leaved lime and Norway maple growth rate and productivity in the climatic conditions of Latvia, and to evaluate their suitability for plantation forestry in the climatic conditions of Latvia.

MATERIAL AND METHODS

In order to evaluate the suitability of small–leaved lime and Norway maple, which are commonly found in Latvia, for the establishment of productive forest stands and plantation forests, an assessment of the forest database was carried out, selecting the stands where these species were the main species, and the growth rate and productivity of these stands were clarified.

The scientists of LSFRI Silava conducted a study on the growth rate and productivity of most characteristic small–leaved lime (3 forest stands and 3 plantation forests stands) and Norway maple stands (3 forest stands and 2 plantation forests stands) on both forest lands and afforestation of former agricultural lands in the territories of central regions in Latvia (Fig. 3).

The parameters for the growth rate of small-leaved lime and Norway maple: the diameter at breast height ($D_{1.3}$), the height of the trees (H), the branch–free stem length, and the annual increment of width for the last 5 years (i), the stand volume and the current stand volume increment, were measured four circular sample plots (500 m^2, R=12.62 cm) were set up in each selected stand.

The location of sample plots in the forest stand was subjective, choosing the places characteristic of the stand for their establishment. The centre of the sample plot in the field was marked with a peg, and its geographical coordinates were determined.

In each sample plot:
• all trees had their diameter at breast height measured using Mantaks Precision callipers, with an accuracy of ±0.5 cm and their Kraft class was determined;

• the height of the tree, the height of the green branch and the height of the dead branch measured with the altimeter V5 Vertex Laser, with an accuracy of 10 cm for 15 trees (5 medium, 5 small and 5 large diameter classes);

• to determine the age of the stand, cores of wood from 10 trees were extracted using an Haglof increment borer.

The age of the trees were determined using a Haglöf increment borer, by drilling bores in 10 trees at breast height (1.3 m high from the

Table 1. Growth rate parameters and wood yield of surveyed small-leaved lime forest and plantation forests stands

Legend	Stand c omposition	Forest type	Number of trees per ha	Vitality of trees*	Average tree $D_{1.3}$, cm	Average tree height, H, m	Stand basal area, m^2ha-1	Stand volume, m3ha-1	Current increment $m^3\ ha^{-1}$ per year	Industrial wood yield, %
Forest stand										
$\mathbf{L_{115}}$	6 L_{115}; 2 A_{115}; 1 B_{115}; 1 As_{115}; +S_{115}	*Aegopodiosa*	380	1	33.9	31	34.25	502	10.65	62–81
$\mathbf{L_{90}}$	10 L_{90}; +S_{90}; As_{90}	*Aegopodiosa*	240	1	34.3	30	22.23	316	4.58	67–85
$\mathbf{L_{80}}$	10 L_{80}; +P_{80}	*Aegopodiosa*	355	1	32.7	30.5	32.4	455	6.0	67–85
Plantation Forest										
L15	10 L15	BUB-base-unsaturated brown soil	1,780	1	11.6	8.8	21.06	103	4.5	–
L17	10 L17	GSC-gleyic sod-calcareous soil	1,000	1	13.6	8.6	14.46	64.4	4.25	
L16	10 L16	LSC-leached sod-calcareous soil	1,250	2	4	3.3	15.37	39	5.2	–
L15	10 L15	BUB-base-unsaturated brown soil	1,780	1	11.6	8.8	21.06	103	4.5	–

Legend: L – lime;; P –Scots pine; S –Norway spruce; B – birch; A – aspen; As – ash; 1 – healthy, undamaged stem signs for crown defoliation; 2 - healthy, undamaged stems with signs of 25% crown defoliation. Experimental plots: L_{80} - 80 years old; L_{90} - 90 years old; L_{115} - 115 years old; L_{15}; L_{16}; L_{17}

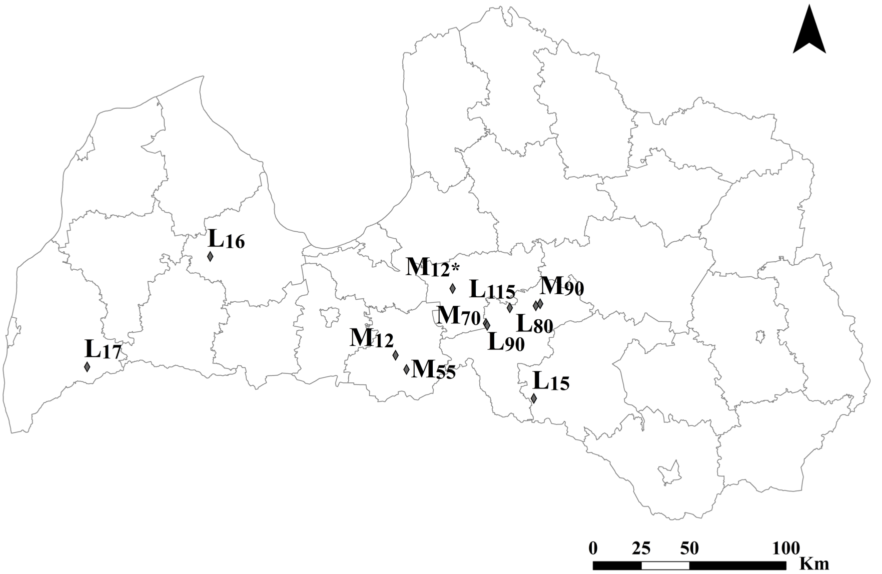


Fig. 3. Site location of sample plots of small leaved lime and Norway maple stands (Legend: L_{15} (plantation forest); L_{16} (plantation forest); L_{17} (plantation forest); L_{80} (forest stand); L_{90} (forest stand); L_{115} (forest stand) – lime/age; M_{12} – plantation; M_{12}* – forest stand; M_{55} (naturally established plantation forest); M_{70} (forest stand); M_{90} (forest stand) – lime/age; maple/age).

root collar), scanning the borehole cores and obtaining the result using the computer software WinDendro 2009b.

Small leaved lime and Norway maple vitality was determined depending on the type of forest growing conditions and management. The vitality of trees was evaluated in the selected plots, marking: 1-for healthy, undamaged stems without signs of crown defoliation; 2- for healthy, undamaged stems with signs of 25% crown defoliation; 3- for healthy, undamaged stems with signs of 50% crown defoliation; 4- for partly damaged stems, with signs of 25–50% crown defoliation, and 5- for dried–up trees.

The stand volume was calculated according to the formula:

$$Vs = G \cdot HF \qquad (1)$$

where *Vs* is the stand volume of the tree species, $m^3\ ha^{-1}$;
G is the basal area of the tree species, $m^2\ ha^{-1}$;
HF for Norway maple is calculated in the same way as for ash, elm, beech and hornbeam.
HF for small leaved lime is calculated according to the table (Forestry Tables 196, Regulations for Forest Estimation 1988, Liepa 1996, 2011).

The current stand volume increment was calculated for each individual sample plot. The current increment was calculated, using the tree borehole data from each stand and the following formula:

$$Z'_M = kG\left[\frac{2Z_D(H - 2Z_H + 4)}{10D + Z_D} + Z_H\right] \qquad (2)$$

where is the current actual stand volume increment, m^3/m^2;
k is the specific coefficient for calculating the volume of individual trees for different tree species;
G is the stand basal area, $m^2\ ha^{-1}$;
H is the average height, m;
D is the average diameter, cm;
Z_H is the current increment of average height, m;
Z_D is the current increment of diameter at breast height, mm;
$\psi = 0.7450 \cdot 10^{-4}$, $\alpha = 0.81295$, $\beta = 0.06935$, $\varphi = 1.85346$.

The current increment of the diameter was determined by measuring the annual ring width on the increment cores for the last 5 years and calculating the arithmetic average:

$$Z_D = 2\ iu, \qquad (3)$$

where i is average annual ring width, mm;
u is coefficient of bark thickness factor (Liepa 1996).

The current increment of the tree height was determined by the formula

$$Z_H = \frac{2iH(aD+b)}{cD+100} \qquad (4)$$

where
H is the average height, m;
D is the average diameter, cm;
i is the average annual ring width, mm;
a,b,c, - coefficients (Liepa 1996).

Mathematical data processing and credibility calculation was done by mathematical-statistical methods using Microsoft Office Excel 2003 software; mean data, standard deviations and relative error have been calculated using SPSS software (Arhipova & Balina 2006).

RESULTS AND DISCUSSION

The analysis of the growth rate of the pure small leaved lime stands and mixed stands selected in this study, shows that in the climatic conditions of Latvia, the average height (H) of 80 (L_{80}) and 90 (L_{90}) year–old lime reaches 30.5 m and 30 m, while the average breast height diameter (D1.3) amounts to 32.7 cm and 34.3 cm respectively (Table 1).

Studies by international authors demonstrate that small-leaved lime can reach 35–40 m in height and 100–300 cm in diameter at breast height. Noted, that lime longevity is dated up to 1000 years of age (Hein et al. 2008, Radoglou et al. 2008).

The number of trees per 1 ha in the 80 year–old pure small leaved lime stand has remained at 355 trees ha^{-1}, reaching a stand volume of 455 $m^3\,ha^{-1}$, and in the 90 year–old stand the number of trees has remained at 240 trees ha^{-1}, reaching a stand volume of 316 $m^3\,ha^{-1}$ (Table 1).

The current stand volume increment in the 80 year–old pure small leaved lime stand is observed at 6 $m^3\,ha^{-1}$ per year, and in the 90 year–old stand it is observed at 4.6 $m^3\,ha^{-1}$ per year (Table 1).

By maintaining records for the growth rate in a 115 year–old mixed small leaved lime stand (L_{115}), we can conclude that the average height (H) of small leaved lime in the old–growth forest stand has reached 31 m and the average breast height diameter ($D_{1.3}$) has amounted to 33.9 cm (Table 1).

The number of trees has remained at 380 trees ha^{-1}, accounting for a stand volume of 502 $m^3\,ha^{-1}$. The current annual stand volume increment has been calculated at 10.65 $m^3\,ha^{-1}$ per year. It should be noted that this small leaved lime stand is located in a nature reserve and the quality of small leaved lime in this stand is excellent (Table 1).

Studies by Rossi, R. (1993) and Radoglou et.al. (2009) demonstrate that the economic maturity or the highest economic productivity of small–leaved lime (*Tilia cordata* L.) and Norway maple (*Acer platanoides* L.) is reached within 60–80 years. Despite the fact that the longevity of these tree species can amount to 200 years or more, the best quality wood, however, is obtained in the age group of 60–80 years. The obtained stand volume from small leaved lime and Norway maple stands ranges from 300 to 500 $m^3\,ha^{-1}$. In fertile soils, small–leaved lime exhibits excellent parameters with a height of 35–40 m, and in soils of normal thickness the stems prune naturally and form branch–free stems with a length of approximately 2/3 of the height of the tree (Rossi 1993, Radoglou et al. 2009).

Our measurements show the similar results. In Latvia since year 1995 researchers investigate the technologies of establishment of productive

Table 2. Growth rate parameters and wood yield of Norway maple forest and plantation forests stands

Legend	Stand composition	Soil type/ Forest type	Number of trees per ha	Vitality of trees*	Average tree $D_{1.3}$, cm	Average tree height, H, m	Stand basal area, m^2ha-1	Stand volume,	Current increment $m^3 ha^{-1}$ per year	Industrial wood yield, %
Forest stand										
M_{55}	10 M_{55}	*Aegopodiosa*	2160	2	13.5	16.9	31.04	267	17.9	39–58
M_{70}	10 P_{115} 10 M_{70}	*Aegopodiosa*	370 449	2	38.2 21.6	29 23	31.04 42.44	480 177	4.2	39-58
M_{90}	4 M_{90} 6 L_{90} +S_{90}	*Aegopodiosa*	200 240	1	34.3	30	22.23	316	3.00	38-59
Plantation Forest										
M_{12}^*	6 M_{12} 4 A_{10}	*Aegopodiosa*	4,120 3,340	2	3.2 2.6	5.2 3.3	3.34 1.74	11.8 6.6	5.16	–
M_{12}	10 M_{12}	*SP-sod podzolic soil*	860	2	5.5	5.5	2.05	7.9	4.75	–

Legend: L – lime; M – Norway maple; A – aspen; 1 – healthy, undamaged stem signs for crown defoliation; 2 -healthy, undamaged stems with signs of 25% crown defoliation. Experimental plots: M55; M70; M90; M12 - 12 years old, plantation; M12*- 12 years old plantation, natural.

plantation forests with different tree species in different soils of agricultural land (Daugaviete et al. 2017).

The growth rate in 15 to 17 year–old small leaved lime plantations on former agricultural lands with different soils, such as heavy clay of gley sod–calcareous soil (L_{16}), sandy clay of brown soil (L_{15}) and sandy clay of leached gley calcareous soil (L_{17}) has been assessed (Table 1).

The growth rate records show that the productivity of small leaved lime plantation forest in both brown soil (L_{15}) and leached gley calcareous soil (L_{17}) with sandy clay as the core material can be forecast at a high level, and it is significantly lower in gley sod–calcareous soil with heavy clay as the core material (L_{16}). While the average small leaved lime height (*H*) in the first two locations has reached 8.8 m and 8.6 m with the average breast height diameter ($D_{1.3}$) of 11.6 cm and 13.6 cm respectively, the 16–year–old small leaved lime plantation in heavy clay soil has reached a height (*H*) of only 3.3 m and the breast height diameter ($D_{1.3}$) of 4.0 cm (Table 1).

The number of trees in the small leaved lime plantation on brown soil (L_{15}) has remained at 1,780 trees ha^{-1}, in the leached gley calcareous soil (L_{17}) – 1,000 trees ha^{-1} and in the gley sod–calcareous soil with heavy clay (L_{16}) – 1,250 trees ha^{-1}, accounting for a stand volume of 103 m^3 ha^{-1}, 64.6 m^3 ha^{-1} and 39 m^3 ha^{-1} respectively (Table 1). Studies have confirmed that when choosing areas suitable for small leaved lime growth, the key focus should be placed on the parameters of mechanical composition of the soil and hydrological regime, since heavy clay and water–logged areas make it harder for small leaved lime to take root and inhibit its growth.
The growth rate of Norway maple has been assessed in four forest stands (Table 2).

The records of the growth rate show that the productivity of the Norway maple stands is smaller than that of small leaved lime stands, as the average heights of trees, as well as their diameters and stand volumes are smaller. The average height (H) of the trees in the 55 year–old Norway maple plantation (M_{55}) has reached 16.9 m and the average breast height diameter ($D_{1.3}$) has amounted to 13.5 cm. The number of trees in the location has remained at 2,160 trees ha^{-1}, accounting for a stand volume of 267 m^3 ha^{-1}, but the current annual stand volume increment is still high at 17.9 m^3 ha^{-1} per year.

Studies have confirmed that the thinning of this Norway maple stand is overdue, which is also demonstrated by the small breast height diameter of the Norway maple trees. According to the data of previous studies, Norway maple can reach a height of up to 19.5 m in 20 years under good growing conditions and only 6.5 m in poor soils (Hein et al. 2008).

Studies show that Norway maple in a mixed stand of 110 year–old pine and 70 year–old Norway maple (M_{70}) reaches the average height (*H*) of 23 m and the breast height diameter ($D_{1.3}$) of 21.6 cm, while the number of trees is 440 trees ha^{-1}, accounting for a stand volume of 176 m^3 ha^{-1}. Significant parameters in this mixed stand are observed in Scots pine, which reaches the average height (*H*) of 29 m and the breast height diameter ($D_{1.3}$) of 38.2 cm, while the number of trees is 370 trees ha^{-1}, accounting for a stand volume of 480 m^3 ha^{-1} (Table 2).

The analyses of the growth rate of 90–year–old mixed stands of small leaved lime and Norway maple (M_{90}) show that such mix is highly promising, since the average tree heights (*H*) of both of these tree species have reached 30 m and 29 m respectively, and the average breast height diameters ($D_{1.3}$) have amounted to 34.3 cm and 32.7 cm respectively, while the number of small leaved lime trees is 240 per 1 ha and the number of Norway maple trees is 200 per 1 ha, accounting for a stand volume of 316.2 m^3 ha^{-1} for small leaved lime and 223.3 m^3 ha^{-1} for Norway maple (Table 1, Table 2).

The growth rate of Norway maple has been assessed in the two plantation forest areas: naturally afforested area of agricultural land with Norway maple and aspen (*Populous tremula l.*) and artificially afforested area with Norway maple

(Table 2). The data show that 12 year–old Norway maple in the mentioned plantation reaches an average height (*H*) of 5.2 m and the average breast height diameter ($D_{1.3}$) of 3.2 cm, while aspen reaches the average height (*H*) of 3.3 m and the average breast height diameter ($D_{1.3}$) of 2.6 cm (Tabl. 2). It should be noted that the number of trees in this naturally regenerating area is high: there are 4,120 recorded Norway maple trees ha^{-1} and 3,340 aspen trees ha⁻1. Studies demonstrate that choosing Norway maple as the main species requires the removal of aspen.

The records of the growth rate in the 12 year–old mixed stand of Norway maple and aspen (M12) confirm the findings of international scientists that the growth rate of Norway maple is characterised by rapid growth in youth (up to 20–25 years), which decreases in later years (Hein et al. 2008).

The 12 year–old Norway maple plantation (M_{12}) in an open area in agricultural land has the average height (*H*) of 5.5 m and the average breast height diameter ($D_{1.3}$) of 5.5 cm (Table 2). If compared with small leaved lime growth parameters at the same age, Norway maple parameters are lagging behind significantly. This can be explained by the physiological requirements of Norway maple as a heat–loving tree species, and in an open area it suffers from both low winter temperatures and spring frosts. This was also clearly demonstrated by the quality of tree stems, as many trees had several shoots, indicating that the crown bud had been damaged by spring frost or winter frost. Due to this, the stand in this plantation has only reached 7.9 m^3 ha^{-1} at the age of 12 years (Table 2).

Previous studies show that under good growing conditions, the average annual stand volume increment in Norway maple stands is 15 m^3 ha per year at the age of 27 (Hein et al. 2008). This is also evidenced by the data obtained in this study that the current stand volume increment in the 55 year–old pure Norway maple stand reaches 17.9 m^3 ha^{-1} per year. In Denmark, cumulative stand volume increment in an 80 year–old maple stand is 1,050 m^3 ha^{-1} under good growing conditions and 700 m^3 ha^{-1} under worse growing conditions (Hein et al. 2008).

Based on the growth rate data, calculations of industrial wood yield and assortment yield have been carried out according to the existing regulations (Regulations for Forest Estimation, 1988; CM No. 647 Regulation of Forest Stand Estimation, in force as of 25.06.2009).

Industrial wood yield in 70 to 115 year–old small leaved lime stands is 62–85% of the total stand volume (Forestry Tables 1963, Regulations for Forest Estimation 1988). The percentage of industrial wood yield in younger stands is still low. The assortment yield in small leaved lime stands depends on the tree parameters, the breast height diameter and the tree height. In the 70 to 90 year–old small leaved lime stands it possible to obtain saw logs, construction round timber, wood chips, pellets and firewood.

According to the data from our research, it is concluded that industrial wood yield in 55 to 90 year–old Norway maple forest stands is lower at 39–58% (Table 2). This is mainly due to the low–quality stems and multi–branching, because no timely pruning of trees has been carried out.

CONCLUSIONS

1. Having analysed the forest statistical data, it can be clearly seen that small–leaved lime stands and Norway maple stands increased in terms of area from 2001 to 2017: areas occupied by the stands of small leaved lime as the main tree species grew by 31% on average, and Norway maple stands increased by 50% over the last 7 years (2010-2017).

2. Analysis of research data shows that pure and mixed small leaved lime forest stands are productive stands, in which it is possible to obtain up to 327– 502 m^3 ha^{-1} in age classes 4 (61-80 years) and 5 (81-100 years).

3. In terms of productivity, in pure and mixed Norway maple stands it is possible to obtain up

to 276 m^3 ha^{-1} and more in age class 4-5.

4. Industrial wood yield in small leaved lime stands in age classes from 4 to 5 is 62–88% of the stand volume on average, and in Norway maple stands it is 39–59% (according to the analysed sample plot data).

5. The research data shows that small-leaved lime and Norway maple are suitable tree species for plantation forestry in Latvia's climatic conditions. The productivity of 15, 16, 17 year-old lime plantations reached 39 m^3 ha^{-1}; 64.6 m^3 ha^{-1} and 103 m^3 ha^{-1}. The productivity of 12 year-old pure and mixture lime plantations reached 7.9 m^3 ha^{-1} and 12 m^3 ha^{-1}.

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