Underbrush Biomass in Lithuanian Forests: Factors Affecting Quantities

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Abstract

Underbrush is the constituent part of the wood biomass, which is one of a few renewable resources with an yearly increasing demand and importance. It is urgent to know what amounts of biomass suitable for fuel are available in Lithuanian forests.

The aim of this study is to estimate underbrush biomass and to determine its preconditioning factors.

To estimate the amount and distribution of underbrush biomass, data on amount of the stems and height of underbrush trees collected by the Lithuanian National Forest Inventory (NFI) and stored in the data base of the State Forest Service were used along with a developed equation describing variation in underbrush biomass over height.

The results showed that the mean aboveground underbrush dry biomass in Lithuanian forests was 860 kg/ha, totalling to about 1.6 mil. tons. The largest portion of underbrush biomass was found for common hazel (about 41 %). Mean dry underbrush biomass on very poor („a“) trophotope sites fails to reach even 0.1 t/ha, while fertile „d“ and „f“ trophotope sites comprises 1.4 and 2.2 t/ha, respectively. The highest amount of dry underbrush biomass is found in aspen stands, about 2.1 t/ha, in birch stands, about 1.9 t/ha, and in ash stands, about 1.6 t/ha, while the lowest one was found in pine stands, about 0.4 t/ha, and in spruce stands, about 0.6 t/ha.

It was found that underbrush biomass is mostly predetermined by site trophotope, dominant tree species and stand stocking level.

Key words: underbrush, dry biomass, tree height, site trophotope, dominant tree species, stand stocking level.

Introduction

Underbrush along with felling residues may be used as fuel as a renewable resource. Underbrush quantity is not yet included in thinning and final felling and their later usage estimations. Total quantity of underbrush may be important in the potential biofuel amount.

Not much attention has been paid to underbrush studies until now. Underbrush is usually described based on its abundance, species composition and morphological parameters (most frequently – average underbrush height), while integral parameters characterizing underbrush are usually not applied. Besides, without integral parameters it is quite complicated to estimate both underbrush resources and its influence on stand development. One of underbrush characterizing integral parameters is its biomass. In Lithuania forest underbrush has been insufficiently analyzed considering the mentioned parameters. Changes of underbrush abundance and species composition are recorded during the National Forest Inventory (NFI), however, any quantification of underbrush biomass resources has not been conducted in Lithuania until now, and its predetermining factors remain unknown.

In order to estimate the biomass of underbrush and its predetermining factors, it is necessary to elaborate biomass estimation methods. Direct forest biomass studies are highly labour consuming. However, it is well known that the biomass of woody plants and their separate parts (stem, crown, branches, leaves or needles) are closely correlated with morphometric parameters of plants (Kittredge 1944, Смирнов 1957, 1961, 1962, Молчанов 1974, Габеев 1976, Макаренко 1985, Горбатенко 1971, Lemke 1974, Albrektsson et al.1980, Marklund 1988, Mikšys et al. 2007). Determination of correlations between the biomass of trees or bushes and their morphometric parameters allows us to work out methods for biomass estimation for all kinds of forest areas. Patterns of changes of underbrush trees and bushes biomass differ from those of trees, especially the ones growing in the first storey, biomass patterns of changes by height (Skema et al. 2010a, Skema et al.2010b). Therefore, it is important to create a method (or methods) to identify underbrush biomass by the defined differences or by the underbrush morphometric parameters.

The basic unit in the inventory of European and world forest resources is tree stem (100 %). The biomass of branches, leaves, needles, underground portion, as well as the amount of merchantable wood may be calculated in % based on stem biomass. Kuliešis et al. (2009) found that if stems comprise 100 %, then branches comprise – 15 %, stumps and roots – 21 %, dead trees – 7 %, residues of timber industry – 29 %.

It is known that in 2009 Lithuanian forest stands contained on average 9000 stems/ha (Kuliešis et al. 2009). The highest amounts of underbrush trees and bushes were estimated in hardwood broadleaved stands (13.1–15.5 thous. trees/ha), as well as in cutting areas and forest glades (9,200–9,800 stems/ha). With stand age, the number of underbrush trees and bushes significantly decreases (Kuliešis 2003), while their diameter and height increment are directly related to stand age.

The aim is to estimate dry biomass of forest underbrush in Lithuania and to determine factors preconditioning it.

Materials and Methods

When laborating underbrush biomass estimation methods, advantages were taken from earlier studies (Skema et al. 2010a). During the study, diameters of 1,684 underbrush trees were measured at 1.3 and 0.3 m height and 218 samples of underbrush trees of common hazel (*Corylus avellana* L.), rowan (*Sorbus aucuparia* L.) and buckthorn (*Frangula alnus* L.) were selected and investigated. Trees were selected in Dubrava Experimental Training Forest Enterprise.

To estimate underbrush biomass, 6,528 sample plots singled out during Lithuanian NFI were used. The NFI Data Base of the State Forest Service provides the number of trees of underbrush species per the sample plot and mean height per the sample plot. These parameters are also related to different stand morphometric parameters. Data on the diameter of underbrush trees are not available. During the NFI, 4 height classes of underbrush were distinguished. In the calculations mean heights of each class were used: up to 0.5 m with mean height of 0.3 m; from 0.6 to 1.5 m with mean height of 1 m; from 1.6 to 3.0 m with mean height of 2.3 m; from 3.1 m and higher with mean height of 4 m.

The forest sites classification, which is applied in Lithuanian forest management, was used while analyzing impact of forest site on forest underbrush ground biomass (Karazija 1988, Vaičys 2006) (Table 1).

Data processing and their analysis was done using statistical sets of data analysis (Microsoft Excel 2003, Statistika 6.0; SPSS 19.0). Correlation and regression analysis were used to determine relationships and their strength between different parameters and to describe dependances. The reliability of differences among analysed variants was checked using the Student's *t*-test criterion and single-factor dispersion analysis (ANOVA). Complex influence of the studied parameters on dry underbrush biomass was assessed applying dispersion analysis with covariants (ANCO-

Table 1. Lithuanian forest site types

Indices of humidity	Indices of fertility				
	very poor	poor	fertile	very fertile	particularly fertile
slopes	Ša *Vacciniosa (cladoniosa)*	Šb *Vaccinioso-myrtillosa*	Šc *Oxalidosa (Hepatico-oxalidosa)*	Šd *Hepatico-oxalidosa*	-
normal	Na *Vacciniosa (cladoniosa)*	Nb *Vaccinioso-myrtillosa*	Nc *Oxalidosa (Hepatico-oxalidosa)*	Nd *Hepatico-oxalidosa*	Nf *Aegopodiosa*
temporary overmoistured	La *Myrtillosa*	Lb Myrtillosa	Lc Myrtilloso-oxalidosa	Ld Oxalidoso-nemorosa	Lf Carico-mixto-herbosa (aegopodiosa)
overmoistured	Ua *Myrtilloso-sphagnosa*	Ub *Myrtilloso-sphagnosa*	Uc Calamagrostidosa, caricosa	Ud *Filipendulosa, carico-iridosa*	Uf Urticosa
drained peatland	Pan *Ledoso-sphagnosa, Myrtilloso-sphagnosa, Myrtillosa*	Pbn *Carico-sphagnosa, Calamagrostidosa, Myrtilloso-oxalidosa*	Pcn *Caricosa, filipendulosa, oxalidosa*	Pdn *Carico-iridosa, urticosa*	-
undrained peatland	Pa *Ledoso-sphagnosa*	Pb *Carico- sphagnosa*	Pc *Caricosa*	Pd *Carico-iridosa*	-

VA). Due to dry underbrush biomass data asymmetry, a logarithmic transformation was applied. For post hoc comparisons the Tukey test was applied. Cluster analysis was used to determine the similarity of sites and stands according to mean underbrush biomass. Hierarchical clustering was applied when squared Euclidean distance was taken as the measure of similarity of objects, while to join objects the method of complete linkage was used. Significant differences in the work are considered when significance level $p < 0.05$.

Results

Underbrush biomass determination. Earlier studies have shown that the strongest correlation is between the biomass of underbrush trees and their diameters at 0.3 and 1.3 m height, slightly weaker – between biomass and the height of trees (Skema et al. 2010a, Skema et al. 2010b). Based on the study data of hazel, rowan and buckthorn sample trees, dependence of dry aboveground mass on morphometric parameters was determined and it was stated that there exists the strongest correlation between the biomass of all species and their stem diameter at 0.3 m and 1.3 m heights (values of equation determination coefficients are from 0.77 to 0.98), and slightly weaker with stem height, although it is sufficiently strong (values of equation determination coefficients are from 0.74 to 0.91).

During NFI only the height of underbrush trees is ascertained. There was no essential difference between regression equations of various underbrush species reflecting aboveground biomass dependence (Figure 1), therefore, based on the data of all three species, one equation suitable to estimate total dry underbrush biomass for all species was worked out:

$$M = N \cdot 0.003 \cdot H^{3.8844} \qquad (R^2 = 0.89), \qquad (1)$$

where: N is a number of underbrush stems per area unit; M is dry biomass, kg; H is height of stems, m.

Equation 1 is used to calculate the biomass of each height class separately and then, having summed them up, the total mass is obtained. To estimate the amount and distribution of underbrush biomass in Lithuania, data available at the NFI data base of the State Forest Service on the number of underbrush trees and their height as well as the mentioned equation of biomass dependence on height were used (1).

Underbrush biomass amounts in Lithuanian forests and their distribution by species. According to the NFI data of the State Forest Service, underbrush in Lithuania is found on 88.7% of the total forest area. There are four most common species of bushes (trees) in the underbrush of stands. Stands with prevailing (prevalence ascertained by the number of stems per area unit) buckthorn in the underbrush comprise 25.6% of all stands. Analogically, stands with prevailing rowan in the underbrush comprise 20.0%, hazel – 15.7%, bird cherry – 13.6%, other species prevail in 25% of stands (willow, honeysuckle, juniper, wahoo, viburnum, saskatoon, dogwood, crab).

The calculated mean dry aboveground biomass of underbrush (further dry underbrush biomass) in all Lithuanian forests is 860.12 ± 18.48 kg/ha per each hectare of Lithuanian forest (Table 2). In the data base there were many plots, where underbrush was not recorded at all, while the biggest recorded amount comprised even 24880 kg/ha of dry underbrush biomass. Having in mind that wood density of the main underbrush species comprises from 400 kg/m^3 to 700 kg/m^3 (Korkut et al. 2009, Korkut et al. 2008), it was obtained that on average Lithuania possesses about 0.7 m^3/ha of underbrush wood. Mean growing stock volume in Lithuania is 250 m^3/ha (Kuliešis et al. 2009). In this case mean volume of underbrush per ha would make up about 0.6 % of mean growing stock volume of trees per ha. It cannot be expected that entire stand will be evenly covered by underbrush.

Analyzing biomass structure by underbrush species in Lithuania, it was found that the greatest portion of dry biomass comprise the trees of hazel and bird cherry, 350 kg/ha and 145 kg/ha, respectively (Table 2). These species together make up about 57% of underbrush biomass. Although buckthorn and rowan

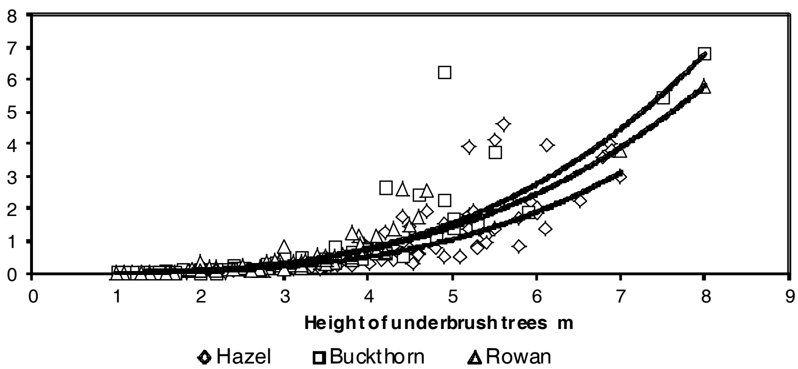

Figure 1. Dependence of dry biomass of hazel, buckthorn and rowan on height. Dry biomass of underbrush trees, kg. Height of underbrush trees, m

Table 2. Mean dry biomass, kg/ha, of underbrush species in Lithuanian forest stands with forest areas of Lithuania

Underbrush species	Dry underbrush biomass, kg/ha		
	mean	maximum values	*SEm*
Rowan	107.51	10871.57	4.64
Buckthorn	115.42	11221.10	4.85
Hazel	350.72	12560.87	12.08
Bird cherry	144.98	9845.53	7.02
Other species	141.48	15128.37	6.98
Total	860.12	24884.46	18.48

Table 3. Trees species of underbrush and their mean dry biomass, kg/ha, in Lithuanian forests with the second storey and without it

Underbrush species	Dry underbrush biomass, kg/ha			
	Stands with the second storey		Stands without the second storey	
	mean	*SEm*	mean	*SEm*
Rowan	110.1	5.9	105.3	6.8
Buckthorn	90.2	4.8	135.7	7.8
Hazel	417.9	18.1	296.4	16.1
Bird cherry	114.0	8.4	169.9	10.7
Other species	62.2	5.2	205.5	11.7
Total	794.6	23.1	913.0	27.6

are the most widely distributed underbrush species, (Kuliešis et al. 2009), however, both of them comprise only about 26% of underbrush biomass. The remaining portion of biomass consists of other less frequently occurring species of trees and bushes (willow, honeysuckle, juniper, wahoo, viburnum, saskatoon, dogwood, crab). Further they are referred to as other underbrush species.

Mean dry underbrush biomass of rowan and hazel is higher in stands with the second storey, while that of other species is higher in stands without the second storey. The total mean dry underbrush mass of all species is by about 15 % higher in stands without the second storey (Table 3).

Underbrush biomass on forest sites of various fertility and humidity is distributed unevenly. Distribution of dry underbrush biomass on sites is presented in Figure 2.

It was determined that on very fertile (Lf, Nd, Ld, Šd, Pdn, Ud) forest sites mean dry underbrush biomass is the highest. On average there accumulates from 1.1 to 2.2 t of dry underbrush biomass per 1 hectare. On fertile sites – Nc, Lc, Pc and Pcn – mean dry underbrush biomass makes up from 0.7 to 1.0 t/ha, with the only exception of Šc site – 1.6 t/ha. On infertile or slightly fertile sites mean dry underbrush biomass fails to reach even 0.5 t/ha. Total mean dry underbrush biomass of the same trophotope but different hydrotrope differs insignificantly. The values of mean dry biomass of underbrush species on various sites per area unit are presented in Table 4.

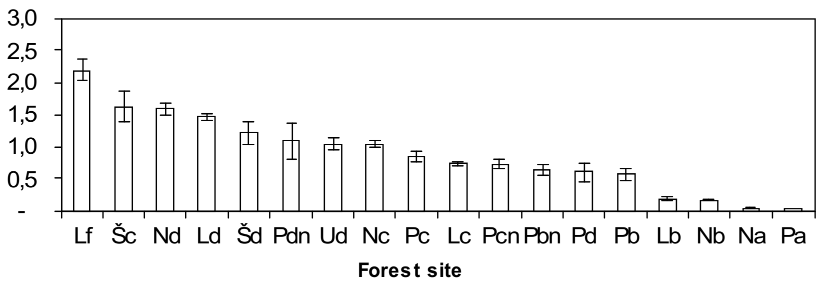

Figure 2. The average amount of dry underbrush biomass on various Lithuanian forest sites, t/ha. Dry underbrush biomass, t/ha

Table 4. Mean dry biomass of various underbrush species on the main Lithuanian growth sites, kg/ha

Underbrush biomass, kg/ha	Main growth sites									
	Na	Nb	Nc	Nd	Lb	Lc	Ld	Ud	Pc	Pcn
All underbrush species										
Mean	39.4	173.0	1042.9	1589.5	176.9	745.5	1468.5	1051.1	859.1	731.5
SEm (±)	8.1	12.5	52.3	101.0	29.6	41.0	60.0	85.1	87.9	66.4
Rowan										
Mean	0.08	37.0	236.6	127.3	56.1	171.3	90.1	67.7	46.7	85.4
SEm (±)	0.06	4.9	21.3	26.9	11.3	14.2	8.8	10.2	9.6	15.9
Buckthorn										
Mean	8.2	47.0	120.8	25.3	64.0	127.1	98.1	140.2	357.2	263.8
SEm (±)	4.1	5.3	16.1	6.0	9.8	12.4	10.7	20.2	53.5	32.6
Hazel										
Mean	4.3	38.5	474.4	993.3	13.1	189.8	802.5	278.7	38.7	61.1
SEm (±)	4.3	7.0	31.6	85.5	12.5	23.6	44.9	45.0	18.0	18.1
Bird cherry										
Mean	0	7.3	117.9	355.1	1.3	100.7	319.0	188.8	65.6	94.4
SEm (±)	0	2.6	12.6	41.0	1.2	14.1	26.3	35.5	16.3	19.3
Other underbrush species										
Mean	26.6	43.0	93.0	88.3	42.3	156.4	158.7	375.6	350.7	226.7
SEm (±)	4.6	4.1	13.8	11.8	21.0	17.7	22.1	60.2	55.2	36.7

As compared to studies conducted in Poland (Orzel et al. 2005), mean amounts of underbrush biomass per hectare obtained in this study are lower. In the Niepolomic forest in Poland underbrush biomass on average comprised 2.19 t/ha (considering that humidity of underbrush biomass comprises about 55 %, this would make up about 1 t/ha of dry biomass). In Poland the study was conducted in one forest, where underbrush was recorded, while Table 4 presents mean data of the whole Lithuanian territory covered with forest, including areas without any traces of underbrush.

The distribution of dry underbrush biomass on sites of various trophotopes was analyzed. It was ascertained that on infertile **a** trophotope sites over 66% of dry underbrush biomass comprise other species (here all underbrush species except buckthorn, rowan, bird cherry and hazel), 23% – buckthorn, 11% – hazel. With higher soil fertility, on **b** trophotope sites other species comprise only 30% of all dry underbrush biomass, buckthorn – 36% , rowan – 19% , hazel – 13%. On **c** trophotope sites hazel comprises 33% of the total dry underbrush biomass, rowan – 20%, at buckthorn and other species – 18% and 11% fall on bird cherry. On **d** trophotope sites, as well as on **c** trophotope, the highest amount consists of hazel biomass, 52%, and bird cherry biomass – 23%. On **f** trophotope sites hazel comprises 62%, and bird cherry – 28% of the total biomass.

A statistically significant influence of site fertility on dry underbrush biomass (Table 5) has been ascertained following single-factor dispersion analysis ($F = 196.9$; $p < 0.001$).

Another factor predetermining biomass distribution of underbrush and its species is dominant tree species in the stand. Mean values of underbrush biomass in various stands are provided in Table 6.

Table 5. Mean dry underbrush biomass, kg/ha, on sites of different trophotopes

Site trophotope	Mean amount of dry underbrush biomass	*SEm*
a (very poor)	29.12	5.92
b (poor)	248.95	15.30
c (fertile)	896.96	28.98
d (very fertile)	1384.58	43.60
f (particulary fertile)	2202.97	183.92

Studies of underbrush biomass dependence on the dominant species in the stand have shown that in aspen stands underbrush produces the greatest amount of biomass, about 2.1 t/ha (Table 6). The amounts of underbrush biomass ascertained in ash, birch and black alder stands were also high, exceeding mean underbrush biomass in Lithuania by a factor about 2. In pine stands, which usually grow on poor soils and provide unfavourable conditions for the growth of underbrush, amounts of biomass are not high (about 0.4 t/ha), in spruce stands – slightly higher, about 0.6 t/ha.

During studies in the Niepolomic forest in Poland (Orzel et al. 2005) it was estimated that on average dry underbrush biomass in pine stands comprised 1 t/ha, in oak stands – 1.1 t/ha, in alder stands – 1.2 t/ha, and in other stands – 1.1 t/ha. Contrary to our study, Polish researchers have found out that no statistically reliable differences were recorded in the mean dry underbrush biomass of various stands.

The biomass of underbrush species in various stands is distributed unevenly (Table 6). The highest mean dry biomass of rowan is recorded in birch and ash stands (about 0.2 t/ha), that of buckthorn – in oak and black alder stands (about 0.2 t/ha), hazel – in birch and aspen stands (about 1.3 t/ha), bird cherry – in aspen and grey alder stands (about 0.6 t/ha).

Lithuanian stands with a similar dry underbrush biomass were divided into groups using cluster anal-

Table 6. Mean dry biomass of underbrush formed by dominant tree species, kg/ha

Underbrush biomass parameters	Dominant tree species								
	Pine	Spruce	Oak	Ash	Birch	Aspen	Black alder	Grey alder	Other tree species
					Rowan				
Mean	86.6	86.6	138.3	181.9	215.6	56.6	102.1	90.8	110.1
SEm (±)	6.4	11.5	12.2	24.8	56.5	18.5	10.7	10.7	53.7
					Buckthorn				
Mean	80.0	65.1	216.7	103.6	73.3	40.2	179.0	85.0	52.6
SEm (±)	5.3	11.5	15.0	20.7	16.9	13.5	18.7	15.2	18.6
					Hazel				
Mean	146.6	303.0	373.9	881.9	1316.8	1355.3	252.2	438.9	481.4
SEm (±)	11.5	25.7	27.7	71.0	137.3	156.3	36.2	56.8	118.1
					Bird cherry				
Mean	27.6	59.2	122.7	226.1	203.5	582.9	231.3	688.0	242.9
SEm (±)	3.5	9.0	15.1	35.3	43.9	109.5	27.8	57.1	55.2
					Other underbrush species				
Mean	60.1	80.4	275.6	169.6	90.7	73.6	185.5	200.4	379.1
SEm (±)	6.2	10.6	23.2	35.3	36.8	21.1	22.6	29.9	109.5
					All underbrush species				
Mean	400.8	594.3	1127.1	1563.2	1899.9	2108.6	950.1	1503.2	1266.1
SEm (±)	18.2	39.4	45.7	93.0	166.0	180.9	61.5	89.9	176.0

ysis. The analysis included cases when dry underbrush biomass is more than 0.01 kg/ha (Figure 3).

Cluster analysis of the similarity of sands by mean underbrush biomass has revealed that growth sites may be divided into three clusters (Table 7).

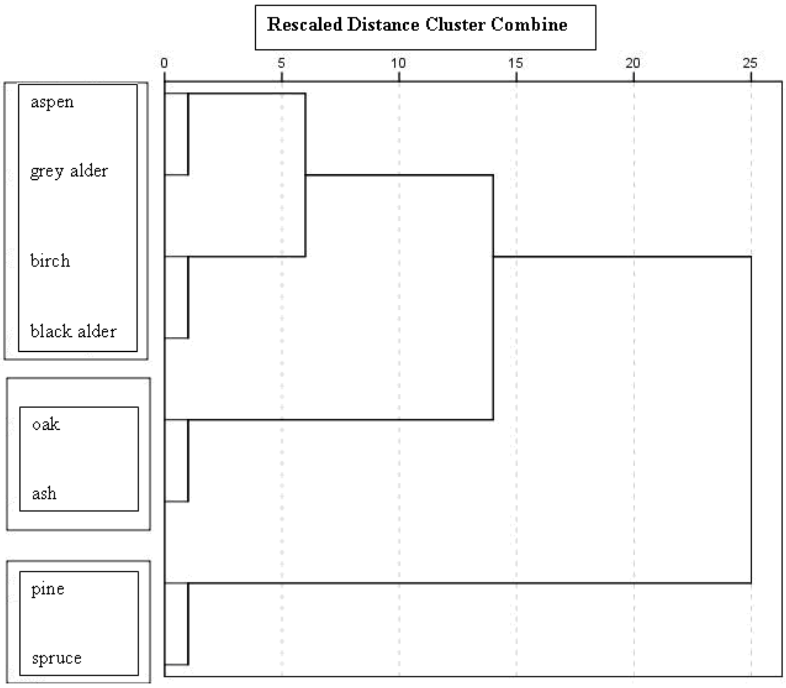

Figure 3. Dendrogram of similarity among Lithuanian stands according to mean dry underbrush biomass

Table 7. Characteristics of homogeneity of underbrush groups of stands by mean dry biomass (clusters)

Cluster	Dominant tree species	Mean dry underbrush biomass, kg/ha	*SEm*, kg/ha
I	spruce, pine	594.1	70.3
II	birch, aspen, black alder, grey alder	1344.9	145.6
III	ash, oak	2081.5	98.4

Mean values of clusters differ statistically significantly (dispersion analysis $F = 19.5$; $p < 0.01$). The values p of Tukey test comparisons between I–II, I–III and II–III clusters were 0.03, 0.004 and 0.04, respectively. The highest mean dry underbrush biomass was ascertained in the group of ash and oak stands, lower – in the group of birch, aspen, grey alder and black alder stands, the lowest – in the group of spruce and pine stands.

Correlations of stand stocking level, growing stock volume and age class with the dry biomass of underbrush were determined (Table 8).

Tendencies of underbrush biomass decline were ascertained with increasing stand stocking level, growing stock volume and age (Table 8). Statistical relations in all three cases are very weak.

With stand age, the number of underbrush bushes and trees significantly decreases, while their diameter and height increase (Kuliešis et al. 2003). Study results of Polish researchers reveal a tendency that with stand age, underbrush biomass decreases. The highest amount of underbrush biomass of 3.18 t/ha was ascertained in 21–40-year-old stands, the lowest – 1.37 t/ha in 81–100-year-old stands (Orzel et al. 2005).

Table 8. Correlations of stand stocking level, growing stock volume and age class with dry underbrush biomass

r^2	r	p
Age of the dominant tree species		
0.0066	-0.0811	<0.05
Growing stock volume		
0.0155	-0.1245	<0.05
Stocking level		
0.0184	-0.1358	<0.05

Data analysis has shown that mean underbrush biomass is lower in older stands (Figure 4).

From age class 3 to 5 mean underbrush biomass decreases, while changes in the biomass of other age classes are very insignificant. From age class 3 to 13 mean dry underbrush biomass decreases by more than 2 times (from 1.4 to 0.6 t/ha). Having analyzed the dependence of dry underbrush biomass of different stands on stand age, it was found that in pine, spruce, oak and ash stands dry underbrush biomass increases along with stand age (Table 9).

Final felling and natural maturity ages in pine, ash and oak stands are far higher than in softwood deciduous or spruce stands. Total mean underbrush biomass in older stands is lower due to the fact that with age,

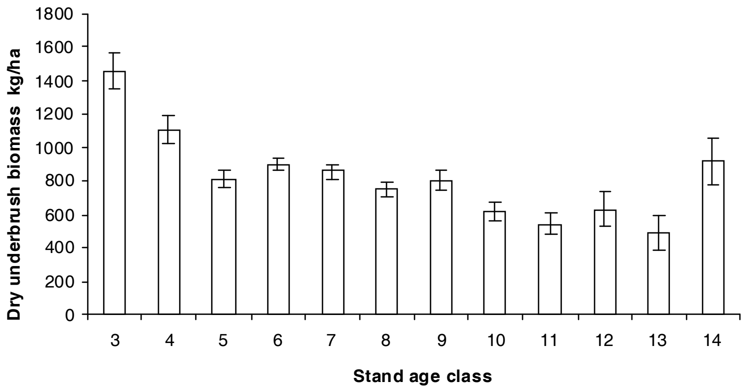

Figure 4. Mean dry underbrush biomass in stands of different age classes. Dry underbrush biomass, kg/ha

Table 9. Correlations between dry underbrush biomass and the age of dominant species in a stand

Dominant tree species in a stand	r^2	r	p
Pine	0.00001	0.0007	0.974
Spruce	0.0015	0.0391	0.184
Birch	0.0042	-0.0647	0.018
Oak	0.0005	0.0223	0.791
Grey alder	0.0005	-0.0213	0.661
Aspen	0.0113	-0.1065	0.029
Black alder	0.0029	-0.0539	0.184
Ash	0.0108	0.1037	0.255

structural distribution of stands by prevailing in them tree species and sites considerably changes. During final felling, earlier are felled softwood deciduous stands where mean underbrush biomass is considerably higher than in pine and spruce stands. The latter, especially pine stands, are felled at a significantly older age, i.e. later. Due to this older stands contain a considerably greater portion of coniferous stands, especially pine stands, and a significantly smaller portion of softwood deciduous stands. For instance, among stands up to 50 years pine stands comprise 24 % of their total area, while among those older than 50 years – even 46 % of the total area. This fact essentially predetermines lower amounts of the total mean dry underbrush biomass in older stands.

Applying the method of dispersion analysis ANCOVA, a complex influence of factors on dry underbrush biomass was analyzed (Table 10). The study data have shown that underbrush biomass depends on stand stocking level, growth site trophotope, site hydrotope and dominant tree species.

The greatest influence on underbrush biomass has forest site trophotope and dominant tree species in a stand. Less influence has stand stocking level and site hydrotope. The influence of stand age and growing stock volume on the dry underbrush biomass is not statistically reliable (Table 10). Determination coefficient, R^2, of the model shows which part of biomass dispersion is predetermined by constituent factors of the model (about 22 %). Coefficient **h²** allows to compare the influence of factors on the final result – it shows which part of the data change (biomass dispersion part) is predetermined by differences in the values of a certain factor. The values of partial ***h²*** coefficient show the part of biomass dispersion, which is determined by a specific factor, but not affected by other factors. Factors, which are not included in the model, could be preconditioned by underbrush biomass changes due to economic activities or due to propagation peculiarities and uneven distribution in Lithuanian forests.

Table 10. Complex influence of factors on the dry underbrush biomass assessed by ANCOVA method

Factor preconditioning dry underbrush biomass	p	r^2	partial r^2
Stand growing stock volume	0.617	0.000	0.000
Stocking level	0.000	0.001	0.009
Stand age	*0.094*	0.000	0.001
Site trophotope	0.000	0.013	0.094
Site hydrotope	0.000	0.001	0.005
Dominant tree species in a stand	0.000	0.007	0.054

$R^2 = 0.226$

The estimated total dry underbrush biomass in Lithuanian forests is about 1.6 mil. tons. Part of the underbrush in stands may be used for wood fuel procurement along with felling residues. Underbrush may be used for fuel production during final and tending cuttings, less frequently during sanitary or special cuttings. In self-regeneration stands underbrush may be removed even when other trees are not felled. In such cases underbrush for fuel is used only when its amounts are sufficiently high (not less than 10 t/ha), its use is economically profitable (short extraction distance, high total amount etc.) and extraction is technologically possible (tracks are available, no need to fortify tracks with felling residues – sites are dry, on „L“ hydrotope or on more humid sites felling is done when the ground is frozen or in dry periods). Small (up to 1.5 m in height) underbrush trees are usually not used for biofuel or are used only partially. Their use is not purposeful due to great labour consumption, while their biomass is relatively small to substantially increase the total amount of biofuel.

Conclusions

1. Mean dry biomass in Lithuanian forests comprises 860 kg/ha, total underbrush biomass in all forests is about 1.6 million tons. The greatest portion of underbrush biomass consists of common hazel (about 41 %), considerable portions of biomass amount bird cherry (16 %), buckthorn (13 %) and rowan (12 %).

2. Underbrush biomass significantly increases with higher site fertility. Mean dry underbrush biomass on very poor („a“) trophotope sites fails to reach even 0.1 t/ha, on poor („b“) trophotope sites it comprises about 0.2 t/ha, on fertile („c“) trophotope sites – about 0.9 t/ha, while on fertile („d“ and „f“) trophotope sites –1.4 and 2.2 t/ha, respectively. The influence of site hydrotope on underbrush biomass is insignificant; on sites of the same fertility but different in hydrotope no major differences in mean underbrush biomass were recorded.

3. It was found that in deciduous stands of Lithuania mean dry underbrush biomass is higher than in coniferous stands. The highest amount of underbrush biomass contain aspen stands – about 2.1 t/ha, birch stands – about 1.9 t/ha, ash stands – about 1.6 t/ha, while the least amounts contain pine stands – about 0.4 t/ha and spruce stands – about 0.6 t/ha.

4. The total mean underbrush biomass in older stands is lower due to the fact that with age the distribution of stands by dominant tree species in them and sites significantly changes. Among older stands considerably higher is the portion of coniferous stands, especially pine ones containing significantly lower mean underbrush biomass amounts, and far lower is the portion of softwood deciduous stands containing significantly higher mean amounts of underbrush biomass.

5. Complex assessment of the influence of various factors has shown that underbrush biomass is mostly influenced by site trophotope, dominant tree species and stand stocking level. Variation of stand and site parameters predetermines 22.6 % of dry underbrush biomass dispersion. The rest underbrush biomass dispersion may be preconditioned by the influence of economic activities, propagation peculiarities of underbrush species and its uneven distribution in Lithuanian forests.

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