INVESTIGATIONS OF GREY ALDER (*ALNUS INCANA* (L.) MOENCH) BIOMASS

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Abstract

In the time of the decrease of global fossil resources storage wood, pulp has an increasing importance as a heat energy source. In Latvia, grey alder stands occupy 189.9 thousand ha with a total growing stock of 31.1 mil. m^3. So far in most of cases grey alder is estimated as a low value tree species, because tree dimensions do not to allow obtain a significant proportion of timber quality wood. The increasing fuel shortage has caused the need for growing gray alder as a bio energy supply. Grey alder has not been analyzed intensive until now, therefore the aim of the investigation is to estimate the stand productivity and or above ground biomass; that could serve as a background for recommendations to establish grey alder stands for energy-wood production.

Grey alder biomass is dependent on wood density, but density – on wood moisture. The average newly felled grey alder wood density in April is 0.76 ± 0.011 g cm^{-3}, but absolutely dry wood density for trees felled in October, the average value of absolutely dry wood is 0.46 ± 0.005 g cm^{-3}, which is 1% more than in the spring, but these relationships are not significant Relative moisture demonstrates water content in newly felled wood. Its average value is 54.7 ± 0.5% in April and 53.5 ± 0.5% in October.

Empirical formulae are worked out for absolutely dry stem and branch biomass dependent on stem diameter.

Key words: grey alder, stand, stem volume, biomass.

Introduction

Grey alder *Alnus incana* (L.) Moench stands in Latvia take up to 6.9% or 189.9 thousand ha from the total forest area (Meža statistika, 2005). In the last 15 years, increasing areas are left for natural regeneration. These areas are frequently regenerated by grey alder. From the perspective of energy wood production, it is important to develop the methods for estimation of above ground biomass. That is one of the purposes of this investigation.

In Latvia there are optimal conditions for grey alder, that's why they are widely spread. Grey alder regeneration is successful both with seeds and root or stump shoots. The occurrence of grey alder in a number of forest types gives evidence that it can adapt to different soil conditions. Grey alder can grow in clay, sandy-clay and peat also in alluvial soils close to rivers. In fertile moraine clay and alluvial soils, it builds up the I – II yield class closed stands with high productivity (Avotiņš, 1962). Grey alder stands in rich deciduous forest type *Aegopodiosa* are highly productive. To grow theses stands can be an additional target of forest management (Bušs, 1981). Grey alder that a grove in low fertility, sandy soils often is in the form of bushes, not a single-stem tree (Kundziņš, 1937). Shoots from the grey alder stumps form coppice forests.

Coppice forests are an old form of forest management. Using shoots, wood production is faster when the area is regenerated from seeds. There are no high requirements for wood quality in this form of forest management (Kundziņš, 1937). Grey alder needs to be grown in pure stands due to their short rotation. Admixture with other tree species cannot increase the stand productivity, but only creates difficulties in thinning and use. Grey alder management is of low cost, simple, and safe (Mangalis, 2004).

In coppice forests grey alder reaches the dimensions suitable for fuel-wood at the age of 10-15 years. In this period 100 m^3 of fuel-wood can be obtained from one ha. It is not useful to continue to grow the stand up to 30 years, since the wood volume increment is lessening (Bušs, 1996). At the age of 25 years, grey alder yield can be more than 200 m^3 ha^{-1}. Other tree species require 3-4 times longer period to reach the same volume. The previously specified final cutting (rotation) age for grey alder is 31 year, which is a considerably shorter period than for other tree species (Lange, et al., 1978). In fertile soils (stand yield class I) trees can reach even 26 m in height and 30 cm in diameter. Yield increment at the age of 20 years: 10 m^3 ha^{-1} (Mūrnieks, 1963).

Birch and grey alder or above ground biomass increment lines are of the same shape; however, they are displaced in time. If several aphacelous trees are excluded, in the birch stand at the age of 15 years and in the grey alder stand at the age of 10 years the above ground biomass reaches 40 t ha^{-1}. For both species up to the age of 30-35 years, branches and foliage make up relatively small portion compared to all or above ground biomass. Only after this age, depending on the shape of the crown, differences appear in the total tree or above ground biomass.

The annual stem increment for both species is quite similar. In stands older than 10 years it is 4.5-7.6 t ha^{-1} a year. The biomass of branches is a bit smaller in grey alder stands due to faster natural pruning.

After the age of 10 years, annual biomass increment in birch stands is from 0.25 to 0.70 t ha^{-1} $year^{-1}$, but in grey alder stands - from 0.45 to 1.7 t ha^{-1} $year^{-1}$.

The highest differences are between the birch and grey alder stands, and annual foliage biomass. In stands of both species up to the age of 10 years there is approximately an equal annual foliage biomass (2.4 - 2.5 t ha^{-1} year) produced. With increasing age the annual birch foliage biomass increases. In birch stands it may reach up to 3.38 t ha^{-1} per year and in grey alder stands – 2.98 t ha^{-1} per year. In investigations of the ecosystem of birch and grey alder stands they may be considered to be similar in biomass and wood annual increment (Utkins, Guļbe et al., 2005).

Grey alder biomass is dependent on wood density, but density – on wood moisture. Air-dry timber density (moisture 15%) is different among tree species. Alder wood belongs to a light wood group with a density of 0.40-0.50 g cm^{-3}. To this group also belong the aspen, pine, spruce, lime and willow wood. Stem wood density sometimes is higher in parts of the tree crown (Vaņins, 1950). Absolutely dry wood density for trees felled in April is not dependent on the height at which the stem sample is taken and it is 0.43 g cm^{-3}, which is in accordance with literature (Vaņins, 1950).

Grey alder wood according to its heating ability (megajoules from kg of weight – MJ kg^{-1}), in comparison with other Latvian tree species, is in the third place after Norway spruce and Scots pine wood. Wood of coniferous trees has resin, which contains high proportion of hydrogen, that's why the heating ability of coniferous trees is higher. Heating ability for pine is 20.59 MJ kg^{-1}, for spruce – 20.31 MJ kg^{-1}, for grey alder – 20.05 MJ kg^{-1}, for oak – 19.87 MJ kg^{-1}, and for birch – 19.64 MJ kg^{-1} (Dolacis et al., 1999).

The aim of the research:

- to determine newly felled and absolutely dry wood density;
- to measure relative moisture % for freshly cut wood;
- to determine proportion dry substance for newly felled grey alder;
- to work out formulae for calculation of dry grey alder biomass.

Materials and Methods

Material for the investigation was collected in 2005 in Zemgale.

For analysis of stem volume and biomass, 111 sample trees were cut in the stage when there was no foliage in April and October. At the same time, the stem and branch weight (kg) was measured in naturally dry conditions. The length of the sample trees was from 1.55 to 17.06 m and the 1.3 m height diameter - from 0.2 to 14.8 cm (Sarma, 1949).

At the 1.3 m height and the height of ¼, ½ and ¾ from the total length of the stem, samples (cross cut discs) were taken. From these samples (2 from each disc), the wood density in naturally fresh and dry wood was measured. Wood density was measured for 19 trees in April and for 15 trees in October.

Grey alder biomass depends on wood density, but the latter – on the wood moisture.

The wood moisture is the relation between ground wood and volume; its unity of measure is g cm^{-3} or kg m^{-3}.

The formula for the calculation of wood relative moisture W_0:

$$W_0 = \frac{G_1 - G}{G_1} * 100, \qquad (1)$$

where

G_1 - damp wood weight;

G – absolutely dry wood weight.

Statistical data analyses were made according to generally recognized methods of biometry (Liepa, 1974; Arhipova, 2003).

Results and Discussion

Naturally fresh grey alder wood density

The average density of naturally fresh grey alder wood was 0.76 g cm^{-3}, which was obtained from various samples at different heights (Table 1). Average wood density from tree to tree varied from 0.67 g cm^{-3} to 0.85 g cm^{-3}, the

Table 1

Naturally fresh grey alder wood density, g cm^{-3}

Stems	Locality of disc cut from butt end				Average
	1.3	1/4	1/2	3/4	
average	0.72	0.74	0.78	0.80	0.76
s*	0.050	0.052	0.062	0.061	0.047
s_x*	0.011	0.012	0.014	0.015	0.011
s,%*	6.9	7.0	7.9	7.7	6.2

**s – standard deviation; s_x* – standard error; s% - ratio of variation*

Table 2

Absolutely dry grey alder wood density for samples taken in October

Stems	Locality of disc cut from butt end				Average
	1/4	1.3	1/2	3/4	
Average	0.47	0.46	0.46	0.47	0.46
s	0.02	0.02	0.02	0.03	0.02
s, %	5.3	4.7	5.0	5.9	4.5
s_x	0.007	0.006	0.006	0.007	0.005

ratio of variation - 6.2%. In individual naturally fresh stem, wood density gradually increased from the height of 1.3 m to the top of the tree. The wood density ratio varied little among trees of diverse heights - from 6.9% to 7.9%.

There are significant differences between naturally fresh wood densities at different tree heights, for $F_{fakt} = 9.02 > F_{0.05} = 2.60$.

The smallest significant difference for comparison of gradation classes was found $\gamma_{0.05} = 0.036$. Wood density differences were not significant between the samples taken from 1.3 m height and ¼ of stem height. At ½ and ¾ of stem height wood was significantly denser.

Between wood density at 1.3 m height and ½ and ½ of the stem height a rather high correlation was found, which was characterized by the ratio determination of the regression slope R^2=0.59-0.60. Causation of wood density for samples taken from 1.3 m and ¾ of stem height was much weaker (R^2=0.34). It can be concluded that naturally fresh wood density in the crown part of the tree is more variable.

Absolutely dry wood density

For sample trees, which was cut in April, absolutely dry wood density at the height of 1.3 m was 0.42 g cm^{-3}, at ¼ from the tree height - 0.41 g cm^{-3}, at ½ 0.43 g cm^{-3}, and at ¾ at the 0.45 g cm^{-3}, but absolutely dry grey alder wood density in all samples taken from April was 0.43 g cm^{-3}.

The average of absolutely dry grey alder wood essentially was not affected by the place from where in the tree sample was taken (0.43 g cm^{-3}). The density of the tree gradually increases from bottom to top, but the differences were not significant. It was proven by the results of dispersion analysis: $F = 2.36 < F_{0.05} = 2.60$, but naturally fresh wood density depends on moisture content, which varies from tree to tree.

In order to increase the sample size for absolutely dry wood density evaluation, on October 15 different sized grey alders were felled (Table 2).

There were no wood density differences depending on where the stem sample was taken for grey alders felled in October. The average wood density was 0.46 g cm^{-3}. The wood density differences at diverse heights of trees were negligible – less than 1%. The density of individual trees varied and was unimportant; the standard deviation for the analyzed trait did not exceed 0.02-0.03, ratio of variation - 5.9%. Density differences among trees also were small – 0.42 - 0.49 g cm^{-3}.

Proportion of dry matter in stems of grey alder and wood moisture

In April, the average value of the proportion of dry biomass in stem of grey alder was 0.45, which means that the weight of one cubic meter of absolutely dry grey alder was 450 kg (Table 3). At different heights of trees there was no significant difference, which is confirmed by the average value of trait.

Among different trees the proportion of absolutely dry biomass had small variation, the differences between trees

Table 3

Proportion of dry biomass in grey alder stems in April

Stems	Locality of disc cut from butt end				Average
	1/4	1.3	1/2	3/4	
Average	0.45	0.46	0.46	0.46	0.45
s	0.02	0.02	0.02	0.03	0.02
s, %	3.7	4.2	4.2	5.9	4.0
s_x	0.004	0.005	0.005	0.009	0.005

Table 4

Proportion of dry biomass in grey alder stems in October

Stems	Locality of disc cut from butt end				Average
	1/4	1.3	1/2	3/4	
Average	0.47	0.46	0.46	0.47	0.46
s	0.02	0.02	0.02	0.03	0.02
s, %	5.3	4.7	5.0	5.9	4.5
s_x	0.007	0.006	0.006	0.007	0.005

were not significant, because $F = 0.023 < F_{0.05} = 1.75$.

In October, the proportion of absolutely dry biomass in grey alder stems was 0.46 (Table 4), which was 1% more than in the spring, however, these relationships did not prove significant.

Differences among trees were negligible, which was indicated by the standard deviation for trait – 0.02. The low value for the ratio of variation (4.5%) confirmed this conclusion.

Absolutely dry grey alder biomass

For estimation of grey alder biomass, a total of 111 trees with 1.3 m tree height in diameter of 0.2 to 14.8 cm were felled. All samples were subdivided into 2 parts – trees with an average height diameter less than 3 cm and more than 3 cm. It was impossible to work out empirical formula for both groups together because of the bend of the curve.

The proportion of fresh branch mass in total tree biomass varied from 1.6 to 32.5%, depending on the development of the tree crown, the number of branches, and the light conditions.

From the data, empirical formula for calculation of grey alder biomass was derived. Best suited was the second layer parabola (Figure 1).

Absolutely dry grey alder biomass (Y) depending on its average height diameter (up to 3 cm) (X) can be calculated according to formula (2):

$$Y = 0.1437x^2 - 0.1218x + 0.0769. \qquad (2)$$

The determination ratio of the formula (1) is $R^2 = 0.976$, which means that the tree diameter explains 97.6% of the total dispersion of biomass. The equation is valid for young trees that were growing in forest stands, not on edges of the forest or the ditches.

Newly felled (fresh) grey alder with average height diameter of 13 - 15 cm is close to or even exceeds 100 kg.

Absolutely dry grey alder biomass is best described in Figure 2.

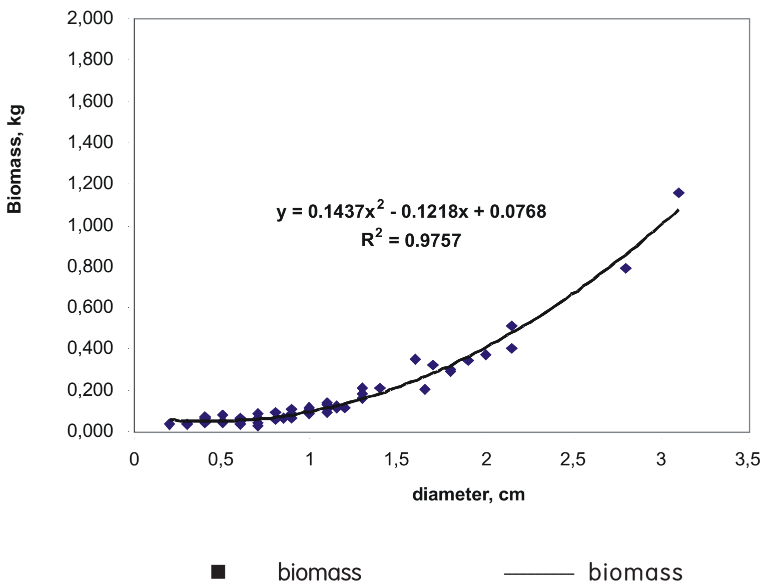

Figure 1. Absolutely dry grey alder biomass depending on its 1.3 m height (for trees up to 3 cm) diameter.

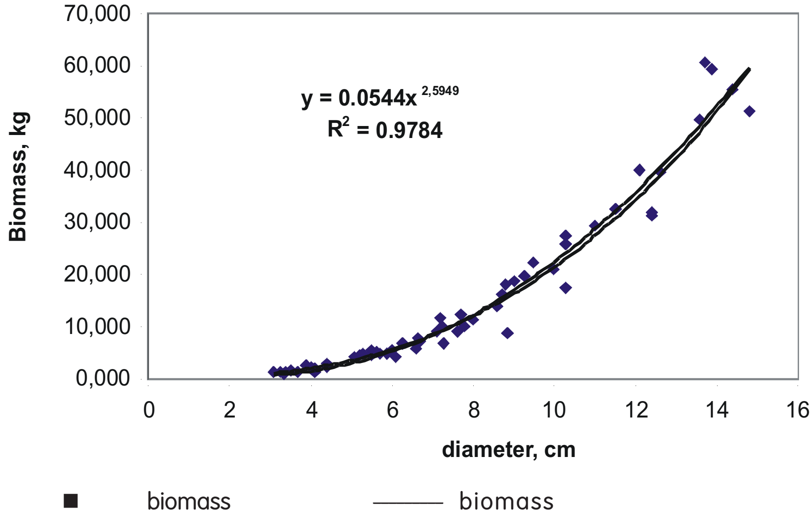

Figure 2. Absolutely dry grey alder biomass depending on its 1.3 m height (for tress over 3 cm) diameter.

Absolutely dry grey alder biomass (Y) depending on its average height diameter (for trees over 3 cm) (X) can be calculated according to formula (3):

$$Y = 0.0544x^{2.5949} \quad (3)$$

Conclusions

Newly felled (fresh) grey alder wood density in April was 0.76 ± 0.011 g cm^{-3}. Naturally fresh stem wood density in the tree crown was more variable. There were significant differences in wood density among samples taken from different heights of stem. From bottom to top of the tree, the wood density was gradually increasing, but difference end was not significant.

For trees felled in October, the average value of absolutely dry wood was 0.46 ± 0.005 g cm^{-3} which was 1% more than in the spring, but these relationships were not significant.

Relative moisture of the tree in April and October was almost equal – it differs only slightly more, than 1% but was insignificant. It is 54.7 ± 0.5 % in April and 53.5 ± 0.5 % in October.

Parabola (2) or the function of degree (3) can be used for the calculation of grey alder stem biomass depending on its stem diameter.

The cutting of grey alder after the vegetation period (the stage without foliage) ensures that organic matter stays in the forest, decays and releases nutrients necessary for growth of the next forest generation.

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