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Stem production of Scots pine and black locust stands in Ukraine's Northern Steppe

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ABSTRACT: The research paper presents the results of the assessment of the annual stem production of Scots pine (*Pinus sylvestris* L.) and black locust (*Robinia pseudoacacia* L.) stands within the Northern Steppe of Ukraine. The research team has developed two- and three-factor regression models for assessing the live biomass stocks for the fractions of the wood and bark of the stems of the Scots pine and black locust stands. The paper also presents the dependences of the live biomass of the components of the stems of the stands on their selected biometric parameters. The direct positive correlation between the fractions of the wood, bark, and stem in total with the factors of age, mean diameter, mean height and stand density for both the studied species has been identified. The results include the distribution of the total stem production of the Scots pine and black locust stands by the state forestry enterprises of the Dnipro region. The mean annual stem production of Scots pine is characterised by lower values (stem wood –2.91 $t\cdot ha^{-1}\cdot yr^{-1}$, stem bark –0.38 $t\cdot ha^{-1}\cdot yr^{-1}$) compared with the investigated species – black locust with the stem wood 4.94 $t\cdot ha^{-1}\cdot yr^{-1}$ and stem bark 1.70 $t\cdot ha^{-1}\cdot yr^{-1}$.

Keywords: *Pinus sylvestris* L.; *Robinia pseudoacacia* L.; current annual increment; allometric models; age structure

Currently, the situation related to global warming has invoked debate regarding the current forest policy to include greater species diversity and structure to effectively increase the forest health and resilience. The net annual increment of the forests has increased substantially (Spiecker et al. 1996), and the growing stock in European forests has almost doubled (Gold et al. 2006). Biomass allometric models are commonly used to estimate the carbon accumulation in the forests. Despite the recent advances in remote sensing and other survey instruments, allometric models remain fundamental to the biomass prediction and calibration of emerging technologies and new approaches for the estimation (Pretzsch 2009).

The annual increment characterises the biomass and energy balance of a system. It is also the key to a more accurate estimation of the production potential and to optimising management strategies.

The most extensively grown and economically important species in the Ukrainian Steppe are the Scots pine (*Pinus sylvestris* L.) and black locust (*Robinia pseudoacacia* L.), which are widely used in afforestation schemes for production, protection and erosion control. In the Northern Steppe, the total area of the Scots pine and black locust

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stands is 21,472.9 ha and 17,683.7 ha, which accounts for 24.6 and 20.3 % of the total forested area, respectively.

We have carried out a literature review to find the biomass and foliage area equations for the investigated species. Forrester et al. (2017) provides a detailed analysis of the published regression models for the forest-forming tree species of Europe. The authors report that the total number of equations for assessing the components of the aboveground and belowground live biomass is 107 for the Scots pine, and 27 for the black locust. However, there are no models for assessing the stem production of stands of the studied tree species in the Ukrainian Steppe.

The aim of this research is to develop mathematical models for the quantitative assessment of the live biomass stem components of the Scots pine and black locust stands within the borders of the forestry enterprises located in the Northern Steppe of Ukraine.

MATERIAL AND METHODS

Study area

The research was carried out in the central part of Ukraine, in the Dnipro region, in the forests subordinated to the State Agency of Forest Resources of Ukraine. The forest stands are located within the geographic coordinates at 49°10'N, 48°11'E. The investigated stands are selected in the conditions, which have a flat aspect, with an elevation of 112 to 140 m above sea level. The mean annual temperature in the study region is +8.5°C, the mean temperature of the coldest month (January) is –5.5°C, the mean temperature of the warmest month (July) is 23.5°C, the mean annual precipitation is 425 mm.

Field measurements consisted of two main steps: The first step included the destructive sampling of the model trees on temporary sample plots (TSPs). There were 20 Scots pine and 20 black locust TSPs, which were distributed randomly in the study area of the Dnipro region (Fig. 1). A total of 60 trees for the Scots pine and 60 for the black locust were cut. Within each TSP, all the trees were enumerated, followed by measurements of their diameters and heights.

To calculate the indices of the total production of the stem of the Scots pine and black locust stands, we have used the stand-level industrial database developed and operated by the Industrial Association "Ukrderzhlisproekt". The database, among other data, contains the detailed description of the stands under the jurisdiction of the forestry enterprises situated within the Northern Steppe natural zone and within the Dnipro region of Ukraine. We have calculated the annual production of the aboveg-

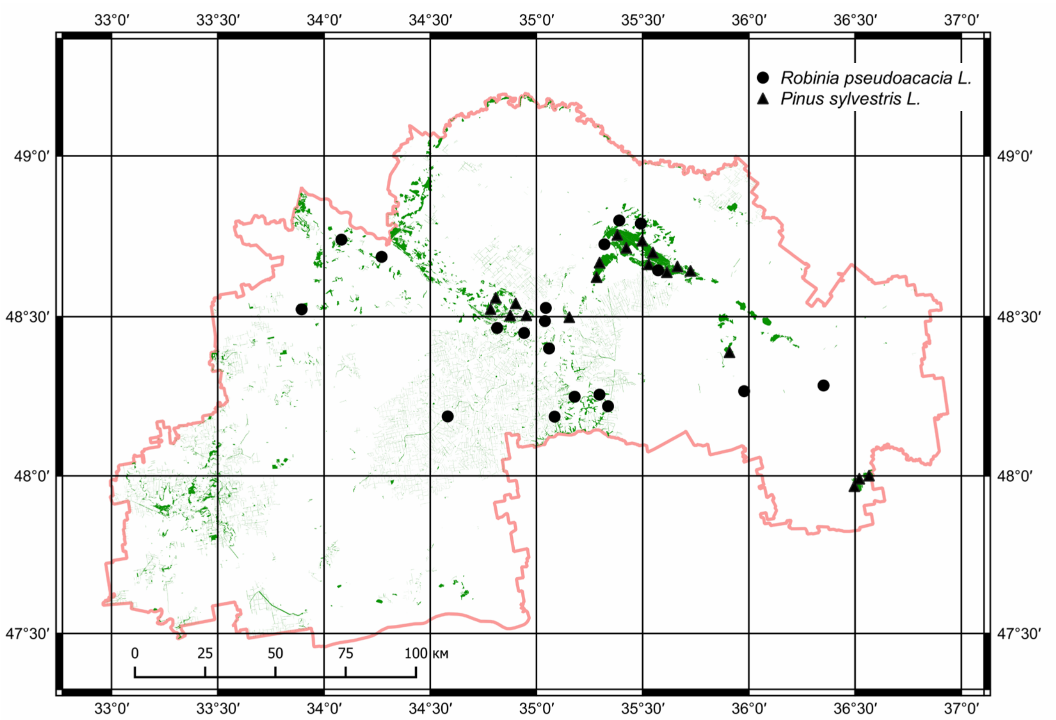

Fig. 1. The locations of the temporary sample plots in the Dnipro region

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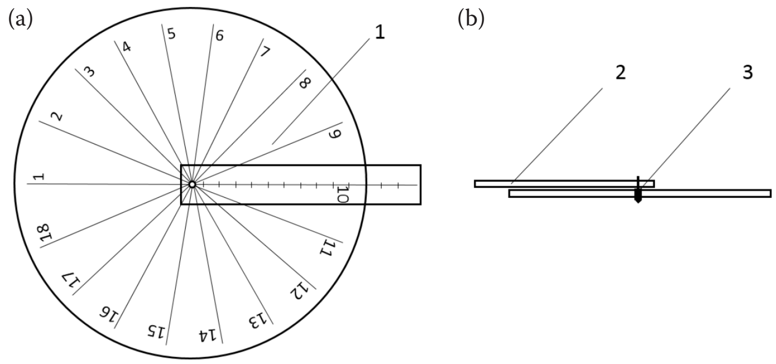

Fig. 2. The device for determining the bark thickness of the samples: (a) the view from above; (b) the side view: 1 – a circle with sectors; 2 – ruler; 3 – metal rod.

round live biomass of the stands using the allometric Equation (2) and taking the basic density of the studied biomass fractions into account. To estimate the annual production, we have chosen the stands within the following state forestry enterprises (the respective areas (in ha) of the Scots pine and black locust stands are provided in brackets): Vasylkivka (1,720.8 and 558.5); Verkhnodniprovsk (235.7 and 7,095.1); Petrykivskyi (6,435.9 and 2,051.3); Dnipro (1,121.9 and 3,077.7); Kryvyi Rih (334.5 and 1,477.6); Marhanets (85.0 and 1,805.8); Novomoskovsk military (5,742.2 and 26.9); Novomoskovsk (1,814.4 and 1,133.9); Pavlohrad (2,651.9 and 359.3); Dniprovsko-Orilskyi Nature Reserve (436.6 and 97.6).

Data collection

The input dataset for the development of the regression models for assessing the live biomass of the studied stands is represented by the primary data collected at the TSPs when processing the model trees by the destructive sampling method. The destructive sampling was conducted by the separation of the stem components into wood and bark. The bark thickness of the studied samples for both species was measured using a special device shown in Fig. 2.

The increment width was measured under MS-100 Daffodil Micros microscopes in the units of scale of an ocular-monometer with 0.01 mm accuracy. The stems were cut into 1–2 m sections and the stem wood volume was computed by Simpson's Equation (1), whose generalised view is presented below:

$$V = \left(\int_0^x g \times dx \right) \times L = \quad (1)$$

$$= [\int_0^x \left(a_0 + a_1 \times x + a_2 \times x^2 \right) \times dx] \times L =$$

$$= \left[a_0 \times x + \frac{a_1 \times x^2}{2} + \frac{a_1 \times x^3}{3} \right] \times L =$$

$$= \left(a_0 + \frac{a_1}{2} + \frac{a_2}{3} \right) \times L$$

$$= \left[a_0 \times x + \frac{a_1 \times x^2}{2} + \frac{a_1 \times x^3}{3} \right] \times L = \left(a_0 + \frac{a_1}{2} + \frac{a_2}{3} \right) \times L$$

where:

g – basal area of a linear element (m^2),

dx – height of a linear element (m),

L – distance from the root collar to the investigated height (m),

a_0, a_1, a_2 – constant ratios.

To determine the parameters of this equation, it is necessary to evaluate the cross-sectional area of a model tree stem at three relative heights. In our case, we measured this parameter at: $x_1 = 0\ h$, $x_2 = 0.5\ h$, $x_3 = 1.0\ h$. As a result of this calculation, the Equation (2) changes to:

$$V = \left(g_n + 4 g_{\frac{1}{2}} + g_v \right) \times \frac{L}{6} \quad (2)$$

where:

g_n – stem cross-sectional area at a stump height (m^2),

$g_{1/2}$ – stem cross-section area at the relative height 0.5 h (m^2),

g_v – stem cross-section area at the relative height 1.0 h (m^2),

L – stem length of a model tree (m).

For each model tree, we calculated the aboveground biomass (AGB) based on the tree diameter at breast

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height (DBH), the tree height and the wood density over the bark. We have obtained the qualitative and quantitative characteristics of the aboveground live biomass fractions at the tree and stand level. We have calculated the stem wood biomass of the stand (Ph_w, t·ha^{-1}), and the stem bark biomass of the stand (Ph_b, t·ha^{-1}). For this calculations, Sytnyk et al. (2018) has evaluated the wood and bark density (Q_w, Q_b, t·m^{-3}).

Having the AGB at the individual tree level, with the next step, we calculated the biomass stocks and the biomass increment at the stand level. For the biomass variables, we have developed separate stand-level allometric models for the stem components with independent driving factors selected from the stand-level biometric parameters (Eq. 3–8).

$$Y = a \times D^b \times H^c \quad (3)$$

$$lgY = a \times lgD^b \times lgH^c \quad (4)$$

$$Y = a \times A^b \times H^c \quad (5)$$

$$Y = a \times A^b \times D^c \times P^d \quad (6)$$

$$Y = a \times A^b \times D^c \times H^d \quad (7)$$

$$Y = a \times D^b \times H^c \times P^d \quad (8)$$

where:

D – mean stand diameter (cm),
H – mean stand height (m),
A – mean stand age (years),
P – stand density (relative stocking),
a, b, c, d – regression coefficients.

At the second stage, we evaluated the production by growth (the increment of the aboveground biomass of the tree stems) over a given census period. It is conventionally estimated as the sum of the aboveground biomass increment divided by the plot area and the census interval. The algorithm for the computation of the total annual production of the Scots pine and black locust stands includes a stage-by-stage calculation of the live biomass production by the aboveground components of their stems. The wood and bark of the stems are the target live biomass fractions. At assessment, the calculation of the current annual increment percentage of the target fractions has also been accounted for.

The current tree annual biomass increment (Z_c, m^3·ha^{-1}·yr^{-1}) is calculated by the following Eq. (9):

$$Z_c = \frac{V_a - V_{a-n}}{n} \quad (9)$$

where:

V_a – actual stem volume under the bark (m^3),
V_{a-n} – stem volume under the bark 5 years ago (m^3).

The increment percentage (P_c) is found as:

$$P_c = \frac{Z_c \times 100}{V} \quad (10)$$

where:

Z_c – the current increment (mm),
V_a – the actual tree volume (m^3).

There is no published data on the current increment of the stem bark of the stands of the studied tree species. Hence, we have made a generalisation stating that this live biomass component's current increment is proportional to the current increment of wood volume within the growing stock of a stand.

The obtained data were analysed using MS Excel (14.0, 2010) and Statgraph (5.0, 2010).

RESULTS

Prior to the regression analysis aimed at discovering the dependence of the biomass values from the separate biometric parameters, an analysis of the allometric models was carried out. The results show that the variables were not necessarily strongly correlated. The most successful model includes such indexes as the mean tree diameter and height, although the obtained determination coefficient is rather low. The stem wood and stem total biomass models demonstrate a better fit than those for the stem bark. The situation improves with the transformation of the models to logarithmic values (Table 1). The allometric models developed for the Scots pine explained 65 to 97% of the variance in the input data. In this case, the R^2 increase is nearly twofold. The addition of a third factor and, as a result, the development of multiple three-factor models in the different variations improved the allometric models due to the higher determination of the multiple correlation.

The allometric models with two input biometric indexes of the stands developed for the black locust were significantly better and explained 94 to 99% of the variance in the stem components (Table 1). The developed allometric two-factor model, the one with the input of the mean diameter and height, better described the biomass patterns, which is confirmed by a statistically significant value for the coefficient of determination. The use of the three-factor model led to increase in the determination coefficient, which explained 94 to 96% of the variance.

When determining the influence of a single influencing factor, we obtained a series of charts describing the feedback of the studied components of the stem biomass (Figs. 3–6).

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Table 1. The stand-level allometric models with the natural and logarithmic inputs for the Scots pine and the black locust stem biomass components

Component		*a*	SE (*a*)	*b*	SE (*b*)	*c*	SE (*c*)	*d*	SE (*d*)	*P* (*a*)	*P* (*b*)	*P* (*c*)	*P* (*d*)	R^2
$lgY = a \times lgD^b \times lg^Hc$														
Stem wood	SP	**1.197**	**0.133**	–0.199	0.685	**1.942**	**0.621**			**0.000**	0.775	**0.006**		0.901
	BL	**1.346**	**0.119**	1.740	1.204	–0.804	1.192			**0.000**	0.172	0.512		0.998
Stem bark	SP	**0.484**	**0.205**	–0.507	2.199	3.099	2.215			**0.030**	0.820	0.179		0.652
	BL	**0.730**	**0.176**	3.899	3.161	–2.831	3.123			0.001	0.239	0.381		0.999
Stem total	SP	**1.260**	**0.129**	0.196	0.642	**1.842**	**0.573**			**0.000**	0.764	**0.005**		0.900
	BL	1.414	0.113	1.772	1.151	–0.848	1.140			0.000	0.147	0.470		0.998
$Y = a \times D^b \times H^c \times P^d$														
Stem wood	SP	1.602	0.781	0.241	0.191	**1.267**	**0.229**	**1.019**	**0.118**	0.057	0.227	**0.000**	**0.000**	0.944
	BL	15.315	13.868	–0.817	0.508	1.451	0.696	**0.777**	**0.169**	0.293	0.136	0.061	0.000	0.935
Stem bark	SP	**1.090**	**1.175**	**0.148**	**0.427**	**0.887**	**0.495**	**1.630**	**0.254**	**0.368**	**0.734**	**0.092**	**0.000**	**0.809**
	BL	0.074	0.074	–0.180	0.433	**2.246**	**0.622**	–0.043	0.167	0.340	0.684	0.004	0.800	0.961
Stem total	SP	**2.180**	**0.957**	0.236	0.172	**1.218**	**0.206**	**1.079**	**0.106**	**0.037**	0.190	**0.000**	**0.000**	0.954
	BL	7.143	5.597	–0.621	0.407	**1.611**	**0.567**	**0.526**	**0.146**	0.228	0.155	**0.016**	**0.004**	0.961

SP – Scots pine, BL – black locust; SE – standard error, *P* – probability, R^2 – correlation coeficient, *a-d* – regression coefficients, *D* – mean stand diameter (cm), *H* – mean stand height (m), *P* – stand density (relative stocking), in bold – significant differences at α = 0.05

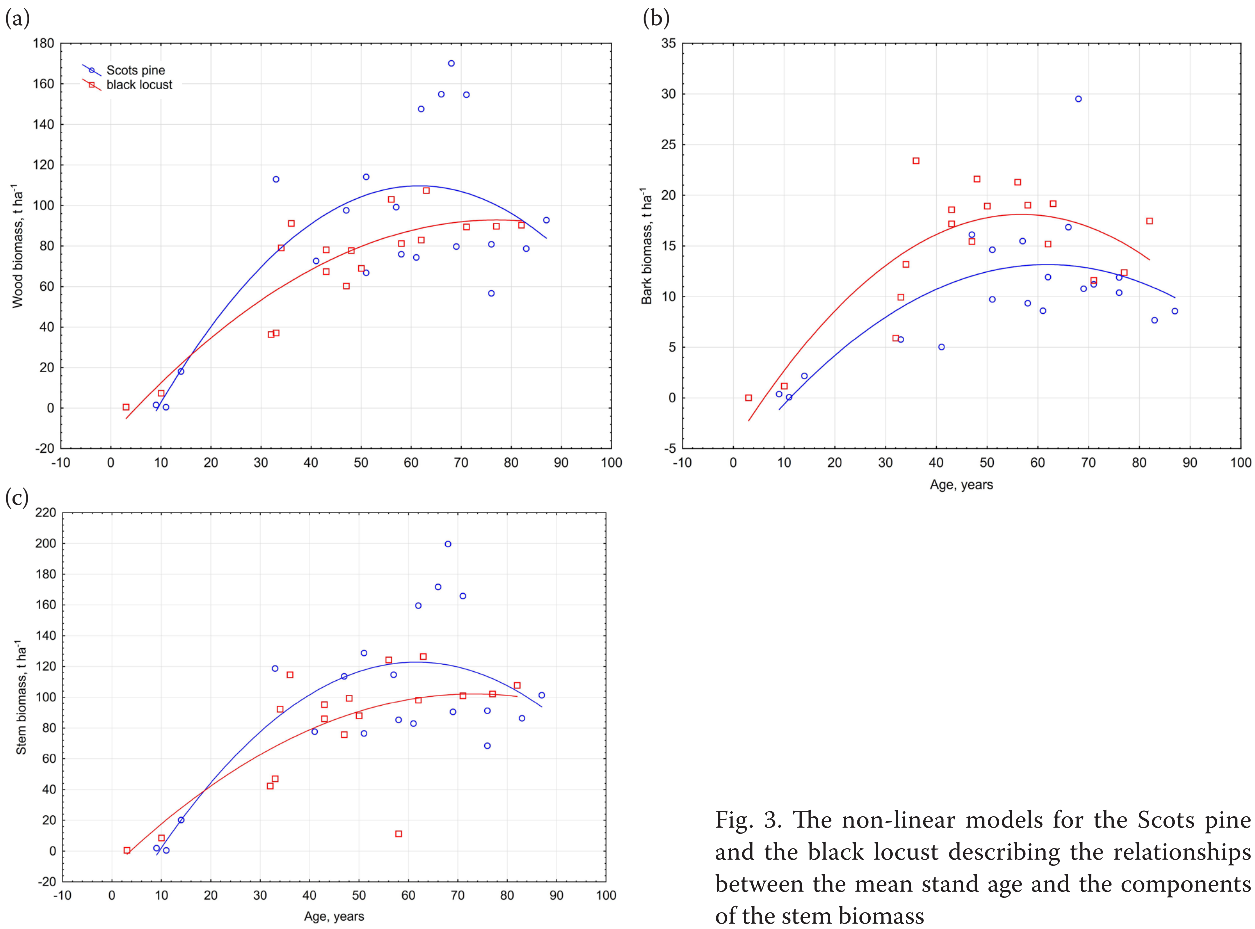

Fig. 3. The non-linear models for the Scots pine and the black locust describing the relationships between the mean stand age and the components of the stem biomass

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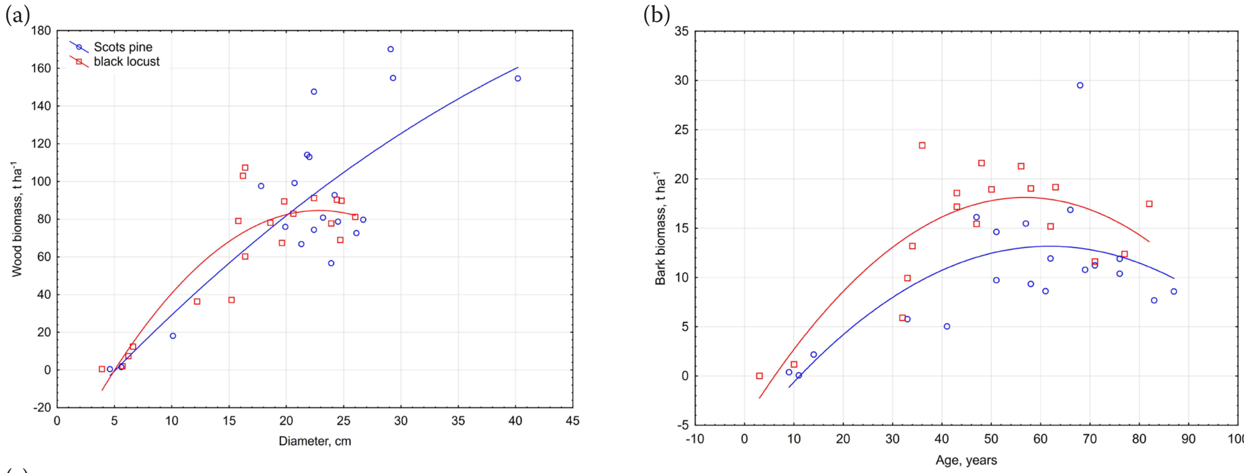

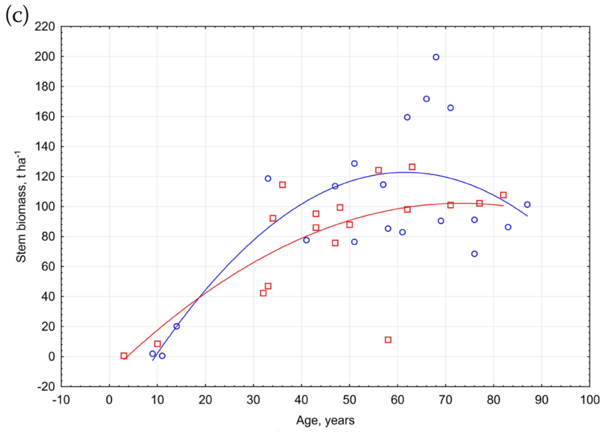

Fig. 4. The non-linear models for the Scots pine and the black locust describing the relationships between the mean stand diameter and the components of the stem biomass

The stem biomass of the Scots pine positively correlates with the stand age with the respective coefficients r = 0.598 for the wood, 0.558 for the bark and the highest – for the total stem biomass, specifically 0.607 ($P < 0.050$) (Fig. 3).

When comparing the obtained data with the other investigated species – the black locust, it becomes evident that age is a stronger predictor in this case with the correlation coefficients 0.849, 0.868 and 0.687 for the total stem, bark and stem, respectively.

The comparative analysis of the relationship of the stem biomass to the mean stand diameter proves that, for the Scots pine, the biggest contribution exists for the diameter class of 20–30 cm, where it is 15–25 cm (Fig. 4) for the black locust. For the black locust, the mean stand diameter turned out to be a strong predictor for all the researched stem biomass components with a correlation coefficient equal to 0.831 for the bark and 0.851 for the wood. A similar positive correlation was identified for the Scots pine, however, the correlation for the total stem and stem wood was closer (0.800 and 0.810), as compared to the stem bark (0.577).

For both of the species subject to this research, the mean stand height was the best predictor when assessing the stem biomass (Fig. 5). We obtained significant correlation coefficient values of 0.826 and 0.897 (the total stem biomass) and 0.838 and 0.905 (the stem wood biomass) for the Scots pine and black locust, respectively.

The bark biomass strongly correlated (0.877) with this biometric parameter for *R. pseudoacacia*, when for *P. sylvestris* this relationship turned out to be substantially less significant (0.582).

When analysing the impact of the stand density (the relative stocking) on the stem biomass accumulation, we obtained the description of the correlation parameters for the two studied tree species.

The identified dependency for the Scots pine was stronger in statistical terms (correlation coefficients of 0.685 – the total stem, 0.757 – the stem bark and 0.657 – the stem wood were registered) than those for the black locust (0.662 – the total stem, 0.658 – the stem bark and 0.624 – the stem wood).

The maximum biomass concentration, as shown in Fig. 6, is observed for the value of a stand density

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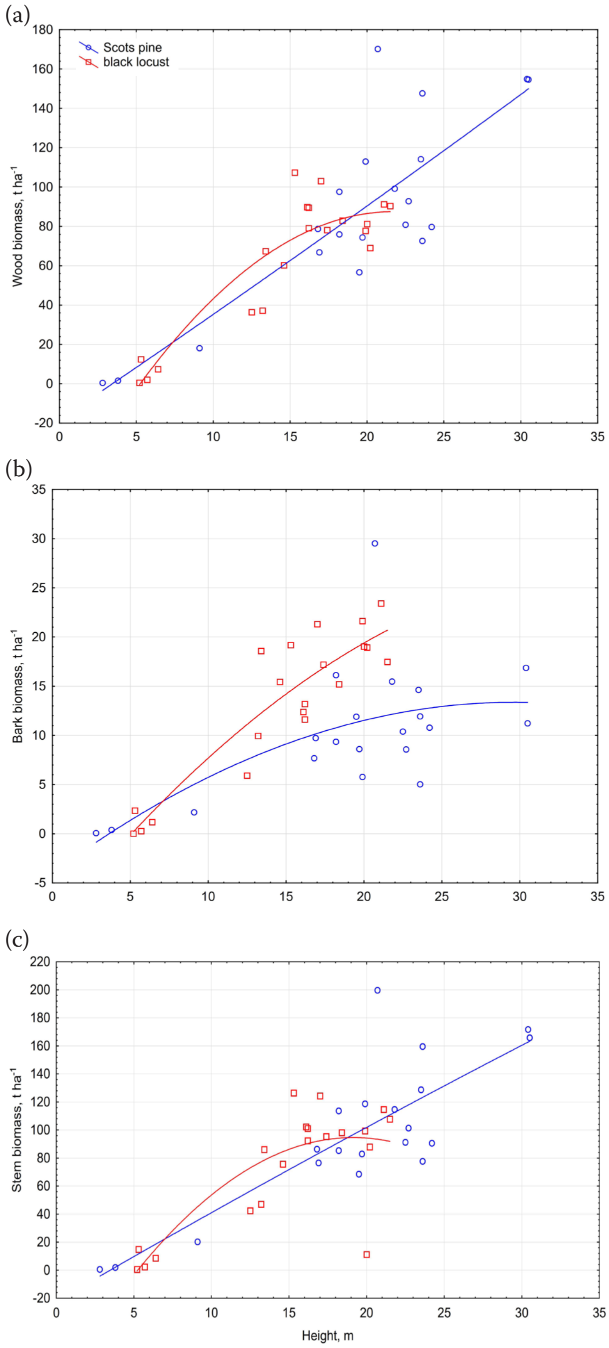

Fig. 5. The non-linear models for the Scots pine and the black locust describing the relationships between the mean stand height and the components of the stem biomass

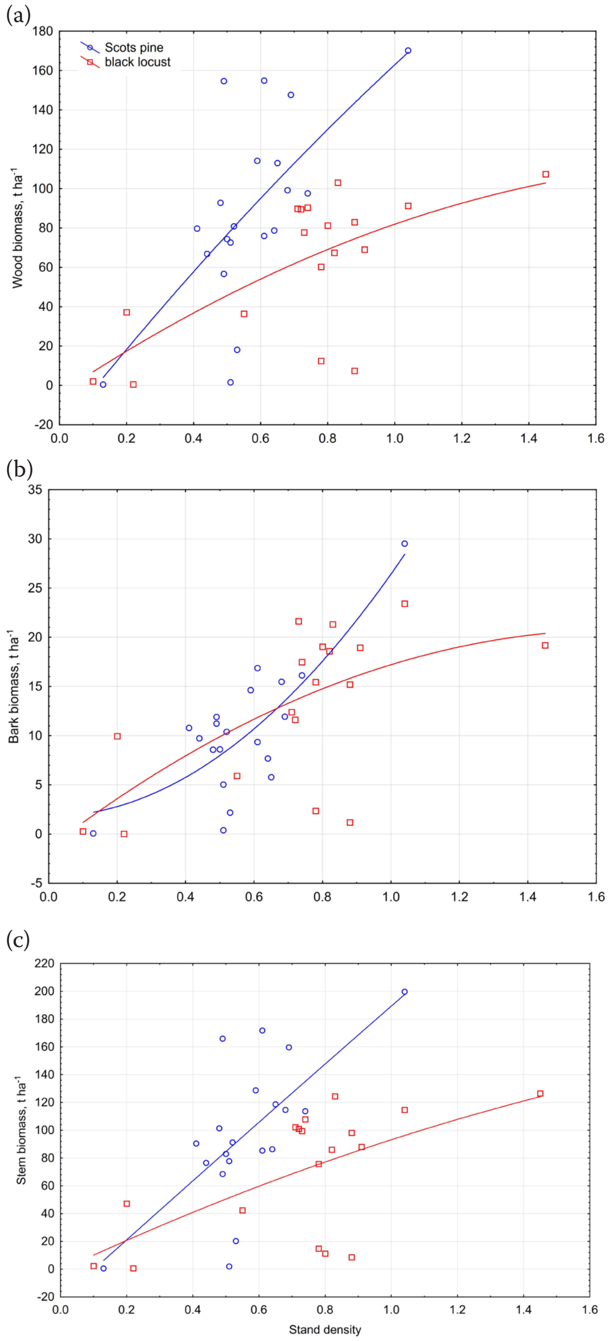

Fig. 6. The non-linear models for the Scots pine and the black locust describing the relationships between the stand density and the components of the stem biomass

equal to 0.65 for the Scots pine and 1.0 for the black locust.

The total current increment of the fractions mentioned above in the Scots pine stands is equal to 125,194.38 t·yr^{-1} (Table 2). The black locust stands within the study region feature a slightly higher value of this index, which is equal to 138,308.4 t·yr^{-1}.

DISCUSSION

The intensity of the formation and accumulation of the forest stands' annual production correlates with the biometric parameters of the trees and the stands. This depends on the inclusion of the different biometric parameters of the forest stands into a model.

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Table 2. The total stem production for the Scots pine and the black locust stands in the Dnipro region

Forestry enterprise	*Scots pine*				*Black locust*			
	Wood stem biomass (t)	Biomass increment wood stem ($t \cdot yr^{-1}$)	Bark stem biomass (t)	Biomass increment bark stem ($t \cdot yr^{-1}$)	Wood stem biomass (t)	Biomass increment wood stem ($t \cdot yr^{-1}$)	Bark stem biomass (t)	Biomass increment bark stem ($t \cdot yr^{-1}$)
Vasylkivka	133,234.8	5,329.4	16,812.1	672.5	32,941.1	2,197.2	11,327.0	679.6
Verkhnod-niprovsk	15,143.9	605.8	2,045.4	81.8	645,868.6	43,079.4	240,245.5	14,414.7
Petrykivskyi	378,132.7	15,125.3	52,158.4	2,086.4	152,863.3	10,196.0	60,769.5	3,646.2
Dnipro	77,082.2	3,083.3	10,146.1	405.8	217,875.9	14,532.3	89,364.7	5,361.9
Kryvyi Rih	13,518.4	540.7	2,091.9	83.7	101,909.1	6,797.3	39,106.1	2,346.4
Marhanets	3,275.1	131.0	515.1	20.6	73,341.0	4,891.8	28,293.7	1,697.6
Novomoskovsk military	499,609.6	19,984.4	61,091.4	2,443.6	1,624.4	108.3	580.4	34.8
Novomoskovsk	183,679.5	7,347.2	21,599.4	863.9	64,827.8	4,324.0	22,777.4	1,366.6
Pavlohrad	151,509.6	6,060.4	21,277.2	851.1	15,740.1	1,049.9	5,833.7	350.0
Dniprovsko-Orilskyi Nature Reserve	34,965.8	1,398.6	4,614.5	184.6	5,333.4	355.7	2,473.3	148.4

The mentioned matter is especially important in the light of the extremely unfavorable abiotic conditions for the afforestation and growth of the forests in the Steppe natural zone (Lakyda et al. 2019).

Sachs's curve characterises the growth dynamics of any organism. Up to a certain age, the growth rate increases, then culminates and gradually slows down afterwards. This enables one to regard the age as a fundamental factor that influences the live biomass accumulation. This factor is mediated by the edaphic, coenotic, climatic and anthropogenic factors within the ontogenesis. The necessity to account for the influence of the stochastic processes on the origination and development of organisms and their communities justifies the inclusion of the stand's age to the live biomass assessment models (McMahon et al. 2010).

Within this research, we have identified the stand age, mean diameter, mean height and relative stocking as the driving factors of the two- and three-factor models for the assessment of the live biomass. The black locust stands differ from the Scots pine ones significantly by lower values of the stem live biomass fractions, however, they feature much higher values of the live biomass of the bark. This is primarily explained by the different biological nature of the studied species resulting in the respective redistribution of the stem and bark components.

The proposed allometric models for the assessment of the live biomass of the studied stands that account for the parameters mentioned above, describe 65 to 99.9 % of the response variable variance for the black locust stands (see Table 1). The models for the Scots pine stands feature lower determination coefficients. Practically all the developed allometric models for the Scots pine demonstrate the highest value of the determination coefficient for the total stem biomass and the lowest for the stem bark. On the contrary, for the black locust stands, this index features the highest value for the stem bark. The inclusion of the set of the age, diameter and relative stocking of a stand as well as of the diameter, height and relative stocking of a stand as the driving factors leads to an increase in the analysed significance level index, and the quantity of the significant regression coefficients of the equations increases for the Scots pine stands and becomes higher than for the black locust ones.

The dynamic pattern of the annual wood production in the Scots pine stands demonstrates an increasing trend up to the age of 68 years, when its maximum is observed, followed by a decline. The proposed models feature a negative sign by the factor of the mean stand age, substantiating the above statement. The results for black locust are similar, which is very close to the age of the maximal annual

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production of 63 years. The findings are in line win the results reported by McMahon et al. (2010), stating that the total biomass accumulation represented by the increased growth depends on the stand's age.

Analysing the possibilities for including the stand diameter and height factors into the allometric models is very important with regards to the assessment of the live biomass components of the stem for the studied stands (see Figs. 4, 5). The parameters mentioned above directly depend on several abiotic factors, therefore, they reflect the dynamics of the environment. Currently, a number of publications confirm the dependence of the diameter and height on the factors diverse in nature (Henry, Aarssen 1999; Falster, Westoby 2005; Kempes et al. 2011; Mugasha et al. 2013). Some researchers justify the importance of determining the diameter-height tree allometries on a regional level by their importance as a source of variation in the tree AGB (Feldpausch et al. 2011; Mugasha et al. 2013; Chave et al. 2014). Figures 4 and 5 show a positive association of the live biomass accumulation with an increase in the stand diameter and height for both of the studied tree species. The curves, describing the total stem biomass accumulation are steeper for the black locust stands and rather shallow for the Scots pine stands. This kind of a trend is due to the faster growth of the black locust stands as compared to the pine ones.

For the two investigated species, the stem biomass had the biggest stock in the stands with the highest relative stocking. Some authors found that the relative stocking is a strong predictor for the Scots pine (Jagodziński, Oleksyn 2009a, b) and the silver fir (Jagodziński et al. 2019) stand productivity and the biomass allocation. Our study confirms this pattern for the investigated species, especially for *P. sylvestris.* It is confirmed by the height coefficient of determination of the three-factor model for both the investigated species, which also includes such input as the age and average diameter of a stand.

We have analysed and compared the results of the mean annual stem production in the study region. The Scots pine features substantially lower values (the stem wood – 2.91 $t\cdot ha^{-1}\cdot yr^{-1}$, the stem bark – 0.38 $t\cdot ha^{-1}\cdot yr^{-1}$) than the black locust (the stem wood – 4.94 $t\cdot ha^{-1}\cdot yr^{-1}$, the stem bark – 1.70 $t\cdot ha^{-1}\cdot yr^{-1}$).

There are no scientific publications reporting data on the annual production of the black locust. Its total live biomass has been studied by Bencat (1990) in comparison to that of the Scots pine. The article by Jagodziński et al. (2019) focuses on estimating the Scots pine aboveground biomass in the conditions of the lowlands of Western and Central Poland. As reported by the authors, the average stem biomass of the pine stands is equal to 53.40 ($Mg\cdot ha^{-1}$). Similar to our results, the authors informed the readers that stem biomass of the Scots pine stands increased with increasing stand height and age. In the northern lowlands in Oberlausitz of Saxony (Germany), the mean annual increment for the Scots pine stands is 10.2 $m^3\cdot ha^{-1}\cdot yr^{-1}$ (Knust 2016). Our results describing the annual stem production of the Scots pine stands are somewhat lower than those available for the Steppe regions of the Russian Federation for the comparable age groups of the stands (5.15 $m^3\cdot ha^{-1}\cdot yr^{-1}$). The research results published by Maikonen (1974) for the different age groups are similar to ours. For instance, for 47 year old Scots pine stands growing on sands, the annual stem wood production was equal to 1.89 $t\cdot ha^{-1}\cdot yr^{-1}$ and the annual stem bark production was 0.10 $t\cdot ha^{-1}\cdot yr^{-1}$. For the 30 to 50 year old pine stands in southern France (Sindani, Lejoly 1990), the annual stem wood production is reported to be 2.66 $t\cdot ha^{-1}\cdot yr^{-1}$, and the stem bark production is 0.33 $t\cdot ha^{-1}\cdot yr^{-1}$, which is also rather close to our results. Similar, albeit somewhat lower values of the annual stem production (2.63 $t\cdot ha^{-1}\cdot yr^{-1}$), were reported by Vyskot (1983) for the Brno region (Czech Republic). According to Larcher (1994), the production values reached 10–15 $t\cdot ha^{-1}\cdot yr^{-1}$ in temperate forests, which exceeds the values obtained in our research. According to Pretzsch (2009), the current level of the primary production of the Central Europe's forests is estimated at 10–20 $t\cdot ha^{-1}\cdot yr^{-1}$, which is also much higher than our results. The latter is especially relevant for the Scots pine, even though we have only assessed the stem production in this research. In our opinion, the lower annual production indices' values reflect the extremely unfavourable environmental conditions of the study region that impact the growth and the development of the trees and is mapped to the live biomass accumulation patterns.

CONCLUSION

The developed allometric models with the input two- and three-biometric indexes of the stands explained 36 to 97% of the variance for the Scots

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pine and 77.6 to 97% for the black locust in the stem wood, stem bark and total stem biomass. The correlation coefficients prove that the mean stand age and diameter are stronger predictors for the black locust stands than for the Scots pine ones. As shown by the obtained data, the average height of the stands was the best predictor in the calculation of the stem components biomass for both of the investigated species. As for the stand relative stocking, it turns out to have a tighter correlation with the stem components of the Scots pine, judging by the calculated correlation coefficients. We have quantified the annual stem wood and bark production of the Scots pine stands in the research region – 2.91 $t\cdot ha^{-1}\cdot yr^{-1}$ and 0.38 $t\cdot ha^{-1}\cdot yr^{-1}$, respectively. The annual production of the stem wood and the bark of the black locust stands in the Dnipropetrovsk region of Ukraine is equal to 4.94 $t\cdot ha^{-1}\cdot yr^{-1}$ and 1.70 $t\cdot ha^{-1}\cdot yr^{-1}$, respectively.

The proposed models for the assessment of the live biomass of the stem wood and bark of the studied tree species can serve as a basis for their practical implementation in the management activity of the state forestry enterprises situated in the Ukraine's Northern Steppe.

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