Basic density and crown parameters of forest forming species within Steppe zone in Ukraine

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Abstract

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The parameters of wood density (WD), bark density (BD) and tree crown characteristics are not only important for estimation of the aboveground biomass, but they also serve as indicators for the timber quality. This study had two objectives: Black locust (*Robinia pseudoacacia* L.) – an introduced species; Scots pine (*Pinus sylvestris* L.) – an aboriginal species. Black locust and Scots pine from the Steppe zone in Ukraine were compared in their WD and BD, and in the morphological parameters of their tree crowns. There were determined basic WD and BD for differently aged individuals of Black locust and Scots pine. Generally, a higher WD was found for Black locust trees. The average Black locust WD was 518 kg m^{-3}, ranging from 375 kg m^{-3} to 612 kg m^{-3}; with the average BD – 294 kg m^{-3}, ranging from 214 kg m^{-3} to 421 kg m^{-3}. The average Scots pine WD was 414 kg m^{-3}, ranging from 254 to 491 kg m^{-3}; with average BD – 317 kg m^{-3}, ranging from 178 to 433 kg m^{-3}. The dependences between WD, BD and biometric tree parameters were identified by correlation analysis. The crown diameter for Black locust and Scots pine was described with fixed prediction models. We proposed particular equations for relationships between foliage biomass and branch biomass, derived from the crown volume of the investigated species.

Keywords

Black locust, Scots pine, forestry, prediction models, tree biometric parameters, trunk wood and bark

Introduction

Human activities such as commercial felling, fuelwood gathering, fires, various agricultural and industrial activities, disturb forest ecosystems through their deforestation and forest degradation (Goussanou et al., 2016; Mykolenko et al., 2018).

There is an increasing pressure on the forest resources in Ukraine and elsewhere. Forest ecosystems in the Ukrainian Steppe play an important commercial and ecological role. This includes both higher demands on economic profitability and a stronger restricions for saving the forest land for nature conservation. To meet these conflicting demands, wood production per a unit area must be increased for the forests subject to cutting.

Databases on wood density and tree crown parameters of the forest-forming species have been developed in many countries of Europe (Hakkila, 1979; Hasenauer and Monserud, 1996; Ahtikoski, 2000; Tahvanainen and Forss, 2008; Mateyko, 2013; Schneider et al., 2015; Kovalska, 2017; Roaki et al., 2017; Viherä-Aarnio and Velling, 2017; Husmann and Möhring, 2017; Polláková et al., 2017); Southern America (Alves and Santos, 2002; Fajardo, 2016); Africa (Goussanou et al.,

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2016); and Asia (Hoffmann and Usoltsev, 2002; Chen et al., 2017).

An increase in demand for wood for energy production is leading to more intensive harvesting of timber, including crown biomass. To predict the harvested biomass in an integrated industrial and energy wood harvesting, the vertical distribution of crown biomass also needs to be known. Individual tree stem volume and biomass equations are commonly used to predict the total amount of tree crown biomass.

The commercial and ecological potential of a tree species basically consists of the trunk and the utilizable aboveground biomass of the crown. Wood formation and growth allocation are the results of mechanical and nutritional conditions, water conductivity, and the hormonal growth control agents (Lakyda et al., 2011).

Wood basic density is an important wood property for both solid wood and fiber products in both conifers and hardwoods. A high wood density implies a higher production of wood biomass per unit volume. However, wood density and crown parameters are important quality traits in mechanical processing, because they affect practically all mechanical strength properties and the hardness of timber.

The available literature sources suggest that the topic has not yet been comprehensively discovered in the Ukrainian Steppe zone.

Lakyda et al. (2016) have compiled all the available allometric equations for other natural zones, but similar equations were taken only few for the Ukrainian region. The recent studies have not included the main forest-forming tree species growing in the Northern Steppe of Ukraine. In harsh drought conditions typical for such natural zone as the Steppe, it is thought-provoking to study the mechanisms used by the trees to regulate their wood formation and to adapt to the environmental requirements.

Black locust (*Robinia pseudoacacia* L.) is a pioneer hardwood species occupying various habitats over its wide area of distribution in the temperate and cold regions of all the continents (Vítková et al., 2017).

In the Ukrainian Steppe, Black locust is used as a tree species for remediation of industrially damaged areas (Lokhmatov and Gladun, 2004). Scots pine stands have always been recreational forests. Scots pine timber is mainly used as plywood in sawmilling industry.

In the Northern Steppe, the total area of Scots pine stands is 21,472.9 ha, that of Black locust is 17,683.7 ha, which accounts for 24.6 and 20.3% of the whole forest-covered area, respectively. By origin, Scots pine stands are divided into naturally and artificially regenerated forests; natural stands cover an area of 3,693.8 ha (17.2%), whereas planted forests of this species cover 17,779.1 ha, which corresponds to 82.8% (Lovinska and Sytnyk, 2016; Sytnyk et al., 2017).

Long-term forest development programs in Steppe Zone of Ukraine aim to increase the area of the artificial forest stands. This means that the commercial importance of the two forest-forming tree species – Black locust and Scots pine is expected to increase.

Prediction models with a higher precision have not been developed yet. The aim of this study is to fill this gap – with evaluating wood density and development of prediction model for the economically usable crown parameters of Black locust and Scots pine in the Steppe forest within South Ukraine.

Materials and methods

The study was conducted in Black locust and Scots pine stands in the Dnipropetrovsk region, located in the Northern Steppe of Ukraine and covering 31,974 km^2 (47–49°N; 33–37°E).

The research sites were chosen in four forestry enterprises governed by the State Agency of Forest Resources: Dnipro, Novomoskovsk, Vasylkivka, Verchno-dneprovsk (Fig. 1). A total of 30 sample plots were established in Scots pine and Black locust stands. Their forestry-related and biometric parameters are in Table 1.

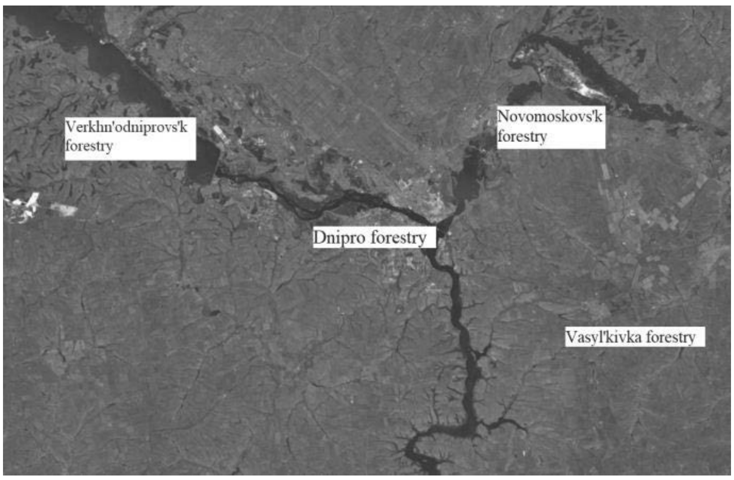


Fig. 1. Location of the study sites in Dnipropetrovsk region, Ukraine. Map. Source: Google Earth®.

Table 1. Structural characteristics of Black locust and Scots pine stands within temporary sample plots

Stand	Stand area (ha)	Total trees on TSP	Age (years)	*dbh* (cm)	Height (m)	Number of trees (trees/ha)	Basal area ($m^2 ha^{-1}$)
Bl1	0.18	182	32	12.2	12.5	1,011	11.90
Bl2	0.16	70	63	16.4	15.3	1,750	37.00
Bl3	0.20	158	12	5.7	5.7	790	2.00
Bl4	0.40	103	36	22.4	21.1	589	44.64
Bl5	0.50	107	3	3.9	5.2	506	0.61
Bl6	0.49	205	48	23.9	19.9	500	22.44
Bl7	0.25	352	58	26.0	20.0	473	25.16
Bl8	0.50	213	82	24.4	21.5	488	22.85
Bl9	0.25	99	77	24.8	16.1	396	19.17
Bl10	0.25	282	56	16.2	17.0	1,128	23.30
Bl11	0.25	227	47	16.4	14.6	908	19.30
Bl12	0.29	168	50	24.7	20.2	579	27.84
Bl13	0.18	184	43	18.6	17.4	1,106	30.18
Bl14	0.25	274	34	15.8	16.2	1,096	21.45
Bl15	0.25	197	33	15.2	13.2	792	4.46
Sp1	0.30	222	68	29.1	20.7	740	49.24
Sp2	0.20	278	33	22.0	19.9	695	26.40
Sp3	0.20	119	11	4.6	2.8	595	0.98
Sp4	0.12	92	41	26.1	23.6	417	22.27
Sp5	0.11	170	9	5.6	3.8	1,070	2.63
Sp6	0.25	214	57	20.7	21.8	856	28.90
Sp7	0.25	197	62	22.4	23.6	756	29.84
Sp8	0.25	129	61	22.4	19.7	516	20.25
Sp9	0.25	104	66	29.3	30.4	416	28.01
Sp10	0.25	112	87	24.2	22.7	448	20.57
Sp11	0.25	110	76	23.9	19.5	440	19.79
Sp12	0.25	128	83	24.5	16.8	512	24.22
Sp13	0.25	124	76	23.2	22.5	496	22.13
Sp14	0.25	51	71	40.2	30.5	204	25.89
Sp15	0.25	190	58	19.9	18.2	760	23.74

Bl, Black locust stands; Sp, Scots pine stands.

The temporary sample plots (TSP) were selected using the analysis of the non-indigenous range of the studied species within the Northern Steppe zone of Ukraine, their economic and ecological values. The areas selected for TSP were surveyed, a biometric description was made for each one, determining the average values of age, height and diameter of the plantation and its productivity. If the area corresponded to the requirements, i.e. if it was a representative unit of the plantation of these species, it was selected for establishing TSP. TSP were chosen based on the stand age, and then the replicate sampling locations were randomly assigned within each forest both for Scots pine, as well Black locust stands. Number of all trees was counted within the TSP, and diameter and height were measured for each tree.

A tree is described by the following set of key indexes: age (*a*), diameter at breast height (*dbh*), trunk height (*h*), crown diameter (*cd*), crown radius (*cr*), crown length (*cl*), crown volume (*cv*), crown surface area (*csa*), the ratio of crown length to crown diameter (*cl/cd*), the ratio of crown length to trunk height (*cl/h*), foliage biomass (*fb*) and branches biomass (*bb*). For evaluation of the influence of the sample tree age on its basic density and crown parameters, there were used tree age classes (1 class equal to 10 years).

As the first step, wood density (WD) and bark density (BD) were assessed. After cutting the sample trees within the TSP, sampling disks (of about 2–3 cm in thickness) were cut along the stem at the root collar, at 1.3 m (*dbh*) or at 0.1 relative height of trees, and at 0.25, 0.50, 0.75 of the relative tree height (Fig. 2).

The sampling disks were weighed in freshly-cut state. The volume of the studied sampling disks was analyzed as a sum of volumes of the sectors (1) into which it was divided using a special device shown in the Fig. 3

$$v = \sum_{i=1}^{n} \frac{\pi \cdot r_i^2 \cdot k \cdot t_i}{360} , \quad (1)$$

where v is volume of the section, cm^3; π is constant (3,1415); r_i is length of the *i* side of the sector angle, where *i* = 1, 2, 3, …, *n* is sequential number of the side of the angle, *k* is the value of the angle of the sector, degrees; t_i is thickness of the section within sector *i*, cm.

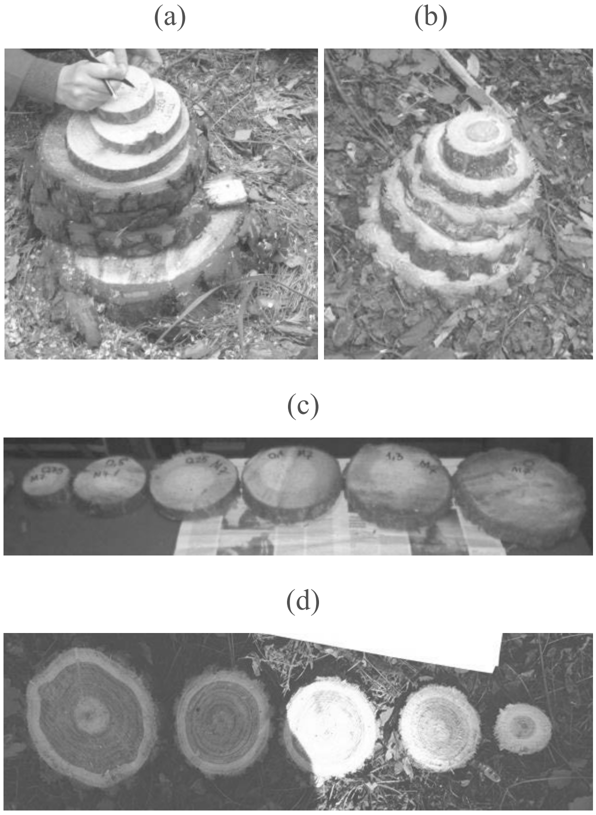


Fig. 2. Sampling disks from Scots pine (a, c) and Black locust (b, d).

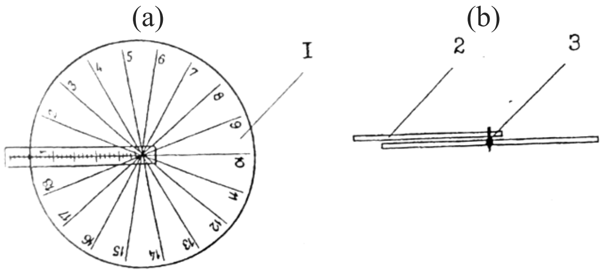


Fig. 3. Device for determining volume of sampling disks: (a) view from above; (b) side view. 1, circle with sectors; 2, ruler; 3, metal rod.

The angle was considered to equal 20º, when every section was conditionally divided into 18 sectors. Then the formula is as follows:

$$v = \frac{\pi}{18}\sum_{i=1}^{18} r_i^{\,2} \cdot t_i \qquad (2).$$

Statistical analysis of the measurements of such sections was made using the software ZRIZ (Version 2002), PLOT (Version 2002) (Lakyda 2002; Lakyda et al. 2007), where there was calculated the sum of the volumes of 18 wood cross-sections.

The bark was mechanically separated from the wood of sampling disks. The calculation of the basic density required of drying the samples at a temperature of 105 °C. The wood and bark basic density was defined as:

$$basic\ density = \frac{over\ dry\ weight\ (kg)}{green\ volume\ (m^3)} \qquad (3).$$

For definition of branch biomass, from each tree there were cut samples from different crown levels (lower, middle, top of the crown) and weighed fresh within TSP, in the same way as in case of the stem sampling disks. All branches with leaves and needles from sample trees were used for the measurement of moisture content and basic density in the laboratory. The calculation of the average basic density of branches was carried out with selected sample branches and there were also determined their volume and basic density as in the stem sampling disks (formula 1, 2, 3). Branches biomass (*bb*) was calculated using Eq. 4:

$$bb = (v_{small\ branches} + v_{big\ branches}) \cdot p_{branches} \qquad (4),$$

where $v_{small\ branches}$ (below 1 cm in diameter), $v_{big\ branches}$ (above 1 cm in diameter) are volume of branches with bark (m^3), and $p_{branches}$ is average basic branch density (kg m^{-3}).

The foliage biomass is the mass of branches with a diameter less than 1 cm, with leaves (needles), determined by weighing method within the TSP.

The crown parameters of Black locust and Scots pine trees were investigated based on the data obtained for 120 sample trees. Correlation analysis was conducted to identify the closeness of the relationship between the studied parameters.

The measurements of the projection crown length and crown diameter were carried out in two mutually perpendicular directions – North-South, West-East in accordance with the international method for determining the crown parameters (Fischer et al., 2010).

The crown volume was determined as the identical geometric figure volume: Black locust as an inverse cone, Scots pine – two paraboloids, touching by their bases.

The black locust crown surface area was calculated according to the formula 5:

$$csa = \pi \frac{1}{2}\, cd \cdot cl + \pi \left(\frac{1}{2}\, cd\right)^2, \qquad (5)$$

where *csa* is crown surface area, m^2; *cd* is crown diameter, m; *cl* is crown length, m.

The crown volume was calculated according to the formula 6:

$$cv = \frac{1}{3}\pi \left(\frac{1}{2}\, cd\right)^2 \cdot cl\,, \qquad (6)$$

where *cv* is crown volume, m^3; *cd* is crown diameter, m; *cl* is crown length, m.

The Scots pine crown surface area and crown volume were calculated according to the formula 7, 8:

$$csa = \frac{\pi cr}{6h^2}[(cr^2 + 4h^2)^{3/2} - cr^3]\,, \qquad (7)$$

where *csa* is crown surface area, m^2; *cr* is crown radius, m; *h* is tree height, m.

$$cv = \frac{1}{2}\pi cr^2 h, \quad (8)$$

where *cv* is crown volume, m³; *cr* is crown radius, m; *h* is tree height, m.

The prediction models working with the received data of basic density and crown parameters were statistically verified using Pretzsch and Dieler (2011) and the software STATISTICA (Version 12.6, 2015).

$$cd = \exp((k_0 + k_1 \cdot \ln(dbh) + k_2 \cdot h + k_3 \cdot \ln(\frac{h}{dbh}))), \quad (9)$$

where *cd* is crown diameter; k_0; . . . ; k_3 is the inversion coefficients; *h* is tree height, m; *dbh* is diameter at breast height, cm.

Results

The wood and bark density had average values ranging from 518 to 294 kg m^{-3} for Black locust, and between 414 and 317 kg m^{-3} for Scots pine (Table 2). As these data show, the average wood density was higher in Black locust. The average wood basic density of this species increased from 375 to 612 kg m^{-3} and bark density from 214 to 421 kg m^{-3}. For Scots pine these values were lower: from 254 to 491 kg m^{-3} in wood and from 178 to 433 kg m^{-3} in bark. The variations in the tree basic density for the two investigated species showed significantly greater differences in the Black locust wood and in the Scots pine bark.

The data for the Black locust WD and the Scots pine BD were indicated conditions of normal distribution, because their factual indexes of skewness and kurtosis were lower than their critical values Acr = 0.711 ($p \leq 0.05$), Ecr = 0.907 ($p \leq 0.01$) (Yantsev, 2012). Most of the Black locust parameters were characterized by negative values of kurtosis (except for BD) which suggested top-flatness of the distribution curve. At the same time, kurtosis for these parameters had positive values for Scots pine and corresponded to peakedness of the distribution curve.

The reliability of correlation coefficient was evaluated with regard to the critical index which is equal to 0.42 (Yantsev, 2012). The analysis of the obtained data of correlation coefficients for Black locust showed a moderate correlation of WD with the tree height (r = 0.45), and a significant correlation with *dbh* (r = 0.54) and the tree age (r = 0.54). The inverse correlation was observed for the relationship between BD with the measured indices of trees. These values were less significant. The significant correlation coefficient was only found for the tree age (r = –0.46).

For Scots pine, the correlation coefficients for basic density had positive values in almost each studied tree biometric factor. The most significant coefficients were registered for WD with age (r = 0.55), tree height (r = 0.48) and *dbh* (r = 0.60). There were weak direct and inverse correlations of BD with all the measured parameters.

Figures 4–5 demonstrate that WD and BD varied axially within the tree age class. The tendencies were the same for both Black locust and Scots pine. The black locust WD values were the lowest in the sample trees of 1–2 age classes, but in course of the time there was an increase to eighty years followed by a slight decrease later.

The maximum BD value was reached by the tree age 40 years, then this parameter decreased with age. The same tendency was recorded for the Scots pine BD, with a maximum at the tree age of fifty years. The situation was quite different with WD for which two maximum paeks were established – by the age of 40 and 90.

For Black locust, there were moderate positive correlations between the crown diameter and *dbh* (r = 0.60), and trunk volume (r = 0.59) (Table 3). Contrarily, there were recorded positive correlation between the crown volume and the crown area surface (r = 0.98), crown diameter (r = 0.90) and trunk volume (r = 0.72).

The Pretzsch function was a basic one for modeling the dependence of the crown diameter (*cd*) and its parameters on *dbh* and tree height. The obtained coefficients for calculation of crown diameter for sample trees of the two studied species were derived using the equations (Table 4).

Table 2. Main statistics of biometric indexes sample trees and basic density of trunk Black locust and Scots pine

Index/ Parameter	Value		Statistics			
	Min	Max	$\dot{X}$	Σ	A	E
Robinia pseudoacacia L.						
Age (years)	3	89	40.8	23.2	0.514	–0.437
Dbh (cm)	4.5	28.6	16.6	7.1	–0.256	–0.851
Trunk height (m)	5.3	22.7	14.0	5.2	–0.380	–0.628
Wood density (kg m^{-3})	375.0	612.0	499.8	68.7	0.011	–0.839
Bark density (kg m^{-3})	214.0	421.0	300.8	46.6	0.485	1.406
Pinus sylvestris L.						
Age (years)	9	90	5.49	24.57	–0.652	–0.542
Dbh (cm)	7.0	39.0	1.54	6.89	0.093	1.643
Trunk height (m)	4.5	30.0	1.46	6.54	–1.040	0.958
Wood density (kg m^{-3})	254.0	491.0	13.38	59.82	–1.182	1.348
Bark density (kg m^{-3})	178.0	433.0	13.82	61.81	–0.263	0.581

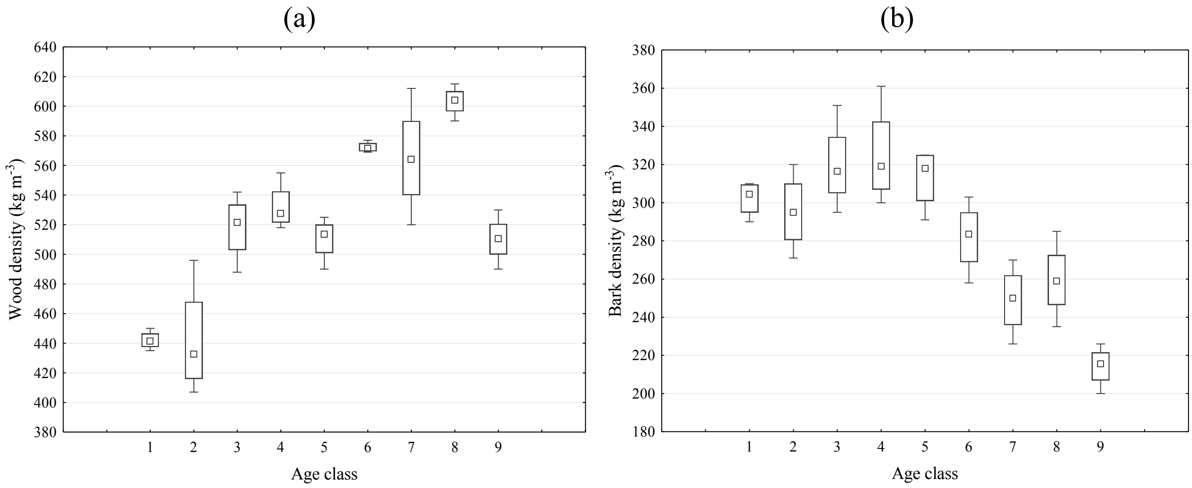


Fig. 4. Changes in wood (a) and bark (b) density of Black locust in relation to its age class. Box plots show the range, median, and 25% and 75% quartiles of basic density.

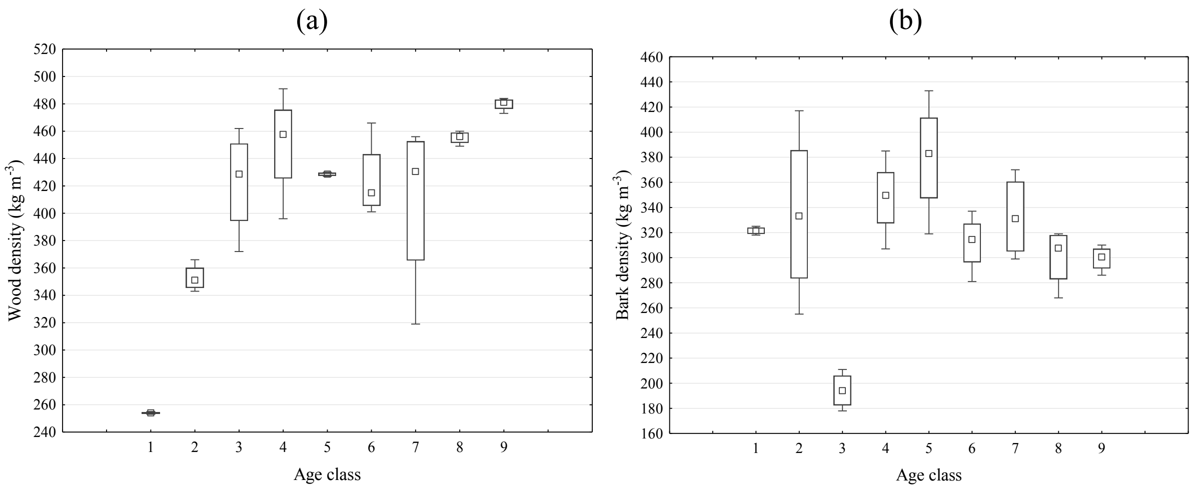
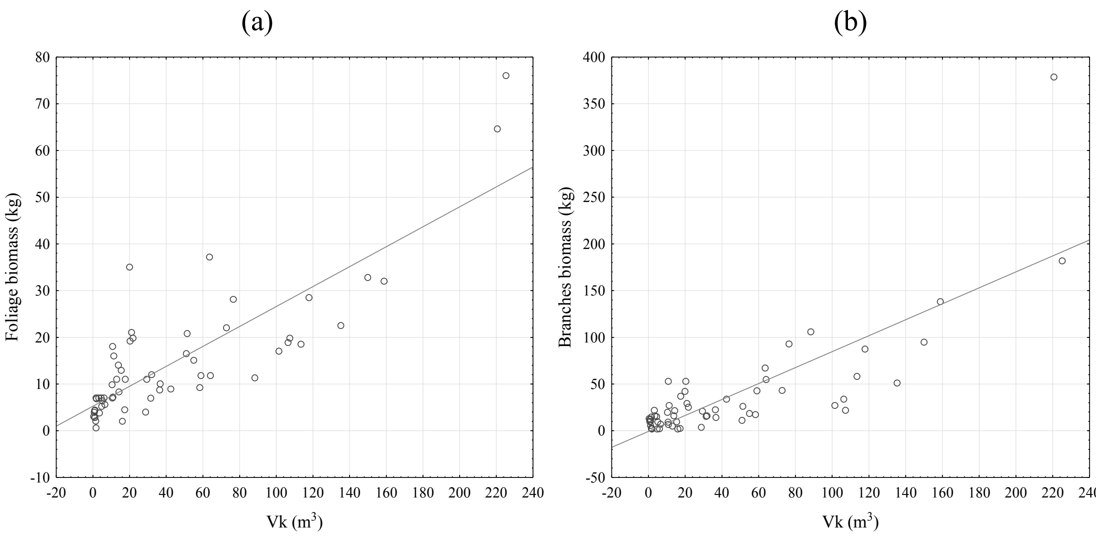


Fig. 5. Changes in wood (a) and bark (b) density of Scots pine in relation to its age class. Box plots show the range, median, and 25% and 75% quartiles of basic density.



$fb = 5.260 + 0.2134 \cdot cv$

$bb = -0.621 + 0.854 \cdot cv$

Fig. 6. Relationships between foliage (a) and branches (b) biomass from crown volume for Black locust trees

Table 3. Coefficients of correlation of crown parameters with biometric indices of trees

Index of tree	*a* (Year)	*dbh* (cm)	*h* (m)	*Cd* (m)	*cl* (m)	*cl/cd*	*cv* (m^3)	*cl/h*	*csa* (m^2)	*fb* (kg)
dbh (cm)	0.76 0.69	1								
h (m)	0.75 0.73	0.90 0.82	1							
cd (m)	0.34 0.20*	0.60 0.60	0.56 0.66	1						
cl (m)	0.62 0.35	0.67 0.47	0.75 0.40	0.41 0.23	1					
cl/cd	0.19* 0.20*	–0.05* –0.05*	0.03* 0.01*	–0.63 –0.54	0.33 0.65	1				
cv (m^3)	0.43 0.26	0.63 0.69	0.58 0.43	0.90 0.88	0.53 0.51	–0.42 –0.24	1			
cl/h	–0.36 –0.57	–0.44 –0.52	–0.48 –0.75	–0.29* –0.21*	0.14* 0.23*	0.44 0.34	–0.14* –0.08*	1		
csa (m^2)	0.46 0.30	0.69 0.70	0.66 0.48	0.93 0.87	0.63 0.64	–0.39 –0.12*	0.98 0.98	–0.15* –0.05*	1	
fb (kg)	0.36 0.35	0.62 0.70	0.48 0.33	0.45 0.69	0.47 0.39	–0.07* –0.20*	0.48 0.79	–0.10* –0.07*	0.53 0.75	1
bb (kg)	0.29 0.33	0.62 0.60	0.47 0.29	0.44 0.49	0.43 0.33	–0.12* –0.11*	0.62 0.59	–0.11* –0.08*	0.61 0.57	0.65 0.84

Conventional signs*:* Scots pine, *Black locust*; * the value not significant at the level $p < 0.05$.

Table 4. Models and coefficients of determination of crown diameter and volume

Robinia pseudoacacia L.		*Pinus sylvestris* L.	
Non-linear model	Coefficients of determination	Non-linear model	Coefficients of determination
cd = exp (((–0.063) + (0.313) · log(*dbh*) + (0.027) · *h* + (–0.269) · log(*h*/*dbh*)))	0.602	*cd* = exp (((0.283)+(0.055211) · log(*dbh*) + (0.030) ·*h* + (–0.767) · log(*h*/*dbh*)))	0.627
Linear model	Coefficients of determination	Linear model	Coefficients of determination
vc = –52.69 + 0.70*dbh* + 21.90*dc* + 3.40*lc*	0.923	*vc* = –67.7+0.40*dbh* + 21.73*dc* + 3.40*lc*	0.894

Discussion

Wood density indicates the amount of actual wood substance present in a unit of wood volume. Basic density is a gross wood characteristic; it defines wood properties and function of the tracheid structure. Basic density is correlated to the yield, the strength and volumetric shrinkage properties of sawn wood (Lindström, 1996).

In this research, there have been obtained unique results concerning the dependencies of the basic density and crown parameters on the biometric indexes for Black locust and Scots pine growing in the forest plantations of the Steppe.

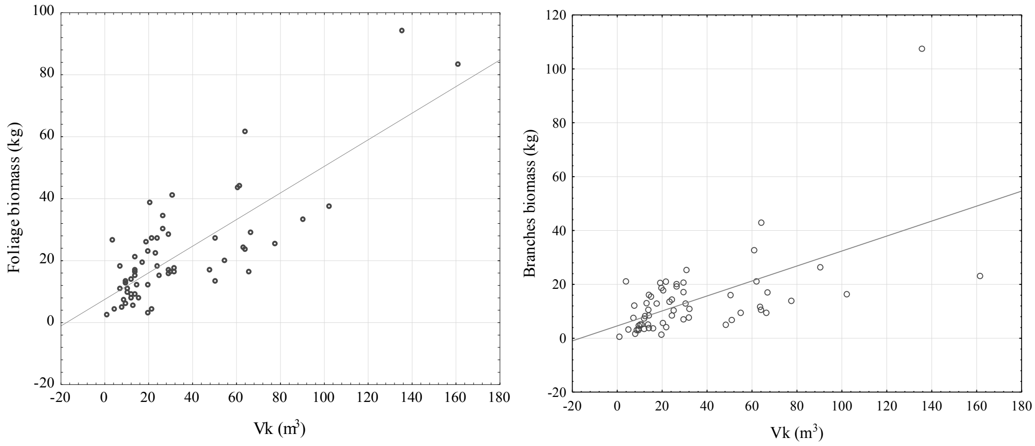
In this study, the WD significantly differed among the species investigated. This is an expected result, consistent with the studies carried out elsewhere.

At the species level, this study has found the WD for *P. sylvestris* (414 kg m^{-3}) lower than for *P. massoniana* found by Zhang et al. (2012) – 484 kg m^{-3} and Deng et al. (2014) – 477 kg m^{-3}. Pine wood density depends on cambium maturity, with density usually increasing towards the outer rings with progressive tree ageing over long time periods (Karenlampi and Riekkinen, 2004).

The mean values for the Scots pine wood density reported in our study did not deviate significantly from the data reported in the literature for another natural zone of Ukraine (Kovalska, 2017; Lakyda et al., 2016; Pasternak et al., 2014). For instance, the mean value of WD in our study was only 3% higher than the value reported by Lakyda et al. in the conditions of the Ukrainian Polissya (2016). The value of BD in our research is higher by 20 and 13% than in Polissya and Forest-Steppe of Ukraine, respectively.

Tomczak studied technical parameters of juvenile wood in Scots pine (2013). The values he obtained for the basic density of juvenile wood for pine from a regular stand were in the range 401–432 kg m^{-3}. In the study carried out by Repola (2006), there was investigated the vertical

(a) (b)



$fb = 7.517{+}0.429 \cdot cv$ $bb = 4.584 + 0.278 \cdot cv$

Fig. 7. Relationships between foliage (a) and branches (b) biomass from crown volume for Scots pine trees.

distribution pattern of the basic density in Scots pine, with possible implementation for determining the average stem wood density. Compared with our data, the result received by this author indicates lower density of the stem at breast height (412.2 kg m^{-3}) in the conditions of mineral soil sites in southern Finland. Zeller et al. (2017) report the tree-ring-wood density in Scots pine lower in mixed stands compared to monocultures. These researchers showed the lower tree-ring-wood density in mixed stands. Biomass in mixed stands calculated from stem volume and tree-ring-wood density is lower (12%) than in pure stands -- despite the measured over-yield in volume in mixed stands. Auty et al. (2014) developed a nonlinear mixed-effects model for predicting wood density in Scots pine as a function of annual ring number, radial growth increment and height of the stem.

Black locust has not been spread as a forest-forming species in other natural zones of Ukraine, that is why there were not available data about the investigated characteristics in the scientific literature. In the Steppe zone, this species has formed forest plantations over a significant area.

The average WD of Black locust displayed a typical increase with age. The established dependence may be explained by proportional variations in the xylem structural elements and in the parenchymal tissue. In addition, tracheid and wood fiber size and morphology can influence the WD significantly.

Water loss from the tissue with age and deposing secondary metabolites in the cell walls were characteristic features for this species. These factors can induce increasing basic density with the tree age.

The review of Lindström (1996) focused on variables related to the crown development and basic density. According to the author's statement, the given four independent theories of wood formation indicate that the crown development acts as a primary regulator for wood structure and basic density. In general, wood formation theories state that the stem cambial activity, growth allocation, and wood structure are functions of crown development.

Despite several studies on crown parameters, these indexes has never been modeled for the Steppe forest-forming species. Therefore, a comparison of our results with other studies would not be correct. However, important parameters for studying trees crown were proposed in a publication carried out for different forest types and species (Pretzsch and Dieler, 2011; Pretzsch et al., 2015).

Hoffmann and Usoltsev (2002) studied tree-crown biomass estimated for forest species of the Ural and of Kazakhstan. Regressions relations stated based on the foliage and green shoot biomass at various complexity levels were used as predictors diameter at the base of the crown, diameter at breast height and age. Gargaglione et al. (2010) derived allometric relations for partitioning the biomass of *Nothofagus Antarctic* to different crown classes along a site quality gradient.

Crown architecture affects the tree growth by controlling the leaf area and its capacity for effective light capture and photosynthesis (Choi et al., 2001). It seems reasonable to quantify crown traits for effective use of intensive silvicultural practices to improve the tree growth in forest plantations. Chmura et al. (2007) examined growth and crown characteristics in two families of loblolly pine (*Pinus taeda* L.) with contrasting growth – superior and average, and one slash pine (*Pinus elliottii* Engelm.) family, growing in the West Gulf Coastal Plain of Texas and Louisiana, USA, their need for light-capture and greater carbon assimilation, as this family also produces the most aboveground biomass.

Viana et al. (2012) carried-out a spatial estimation of above-ground biomass and crown biomass of *Pinus pinaster* stands and shrublands in a region located in Centre-North Portugal, by means of different approaches including forest inventory data, remotely sensed imagery and spatial prediction models. Tahvanainen and Forss (2008) proposed individual tree models for the crown biomass distribution for Scots pine, Norway spruce and birch in Finland.

The work Roaki et al. (2017) presents data on the crown structure and branch/trunk growth for 400-year-old *Pseudotsuga menziesii* trees in an old-growth forest in western Washington, USA.

The article Rautiainen et al. (2008) describes a pine and spruce crown shape modeling from the perspective of optical, passive remote sensing. The authors discuss the requirements of global crown shape models in optical remote sensing and field measurement techniques related to these approaches, and present a measurement and modeling study on the crown shape of Scots pine and Norway spruce.

Conclusions

The wood and bark basic density in Black locust within the Steppe forest plantation in Ukraine had average values of 518 and 294 kg m^{-3}, respectively, the Scots pine wood and bark density over the same territory were 414 and 317 kg m^{-3}. In both tree species investigated, the wood density increased from the youngest sample trees to the oldest ones.

Moderate correlation coefficients were obtained characterizing the relation between the Black locust wood density and tree height. The correlation dependence between the ratio of wood density to *dbh* and the tree age was significant. The most significant correlation coefficient for the Scots pine wood density was registered with the tree age, height and *dbh*.

There have been proposed predictor models for Black locust and Scots pine tree crown diameter. These models will facilitate the determining of the crown diameter in Black locust and Scots pine in the forest stands within the Steppe zone. There were also derived predictor models for the dependence of foliage and branches biomass on the crown volume.

Black locust and Scots pine foliage biomass accumulation increased with increasing crown volume. The determination coefficient in these regression equations shows their reliability and opportunity for their use in the Steppe forestry.

Therefore, it is suggested to conduct more intensive research regarding other aspects and properties of Scots pine and Black locust, such as silvicultural aspects and chemical properties of the woods, to ensure the potential utilization of these wood species.

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