The influence of crown lenght on tree stability

Katarzyna Kaźmierczak, Agnieszka Jędraszak

Poznan University of Life Sciences

The study describes development of pine slenderness in 35-year-old stand, depending on the biosocial position of each tree. The relationships between slenderness and breast height diameter as well as with tree height were established; also selected characteristics of the crown (width, length, degree of crow spread and the relative length of the crown) were described.

Slenderness, crown spread, crown length, pine

Introduction

Slenderness ratio is regarded as one of the criteria of tree stability, and its average is used as a measure of stand stability. Slenderness is one of the characteristics of stem longitudinal cross-section. It is calculated by dividing the tree height to its diameter at breast height (Bruchwald 1999 Grochowski 1973, Jaworski 2004). Slenderness is also an indicator of tree resistance to damage caused by snow and wind. Pine, a dominant and economically the most important species, is considered to be relatively resistant (Zajączkowski 1991). Slenderness ratios in Poland were studied for following species: pine (Rymer-Dudzinska 1992a, b, Kazmierczak 2012), spruce (Orzeł and Socha 1999, Kazmierczak et al. 2008b), oak (Kazmierczak et al. 2008a, 2009), larch (Kazmierczak et al. 2011, 2012), oak and beech stands (Rymer - Dudzinska and Tomusiak 2000) and many species of trees from the Niepołomicka Forest (Orzeł 2007). Burschel and Huss (1997) adopted the following scale of values for conifers:

- tree very unstable - above 1.00
- unstable trees - from 0.80 to 1.00
- stable trees - below 0.80
- trees growing in isolation (single) - below 0.4

Research conducted on slenderness was also carried by Carvalho Oliveira (Rymer-Dudzinska 1992a) and Rottmann (Zajączkowski 1991). Thren proposed to take into account tree slenderness when choosing sample trees (Orzeł and Socha 1999), and Pollanschütz when determining trees (Rymer-Dudzinska 1992a). Research made by Bruchwald and Dmyterko (2010, 2011, 2012) on risk models of tree damage caused by wind, included slenderness, and being more precise, its inverse.

Aim of this study is to describe the slenderness development of 35-year-old pines depending on the position occupied by the tree in the vertical stand structure and relationships with other tree and crown features.

Materials and methods

The research material includes measurement results of 50 randomly selected pines from 35-year-old pine stand growing on fresh coniferous forest (FCF) in Zielonka Experimental Forest District. Biosocial position, according to Kraft classification, was established for each tree. Breast height diameter with bark of standing trees was measured in two directions - NS and EC (accurate within 0,1m), and the arithmetic mean of these measurements was taken as the tree diameter at breast height ($d_{1,3}$). After cutting, the tree length (accurate within 0,01m and adopted as tree height (h)) was measured. The height of the crown base, accurate within 0,01m, was also measured. Crown length l_k (m) was calculated as the difference between total height of the tree and the height of crown base, while the relative crown length l_k/h was calculated as the ratio of crown length to the tree height. Crown width d_k (m) was obtained from the crown projection area adopted from area of a circle. Crown projection area was based on the projection of tree crown characteristic points. Crown spread coefficient was calculated as the ratio of the crown diameter to the tree height d_k/h. Slenderness calculated as ratio of tree height and its DBH.

Results

Average slenderness of pines was 1.1, which describes those trees as very unstable. However, it must be noted that this is a 35-year-old stand which is still before the increment culmination and its structure is permanently transformed. There were mostly co-dominant trees in the sample group, which percentage will be reduced with age in favor to dominant trees. Slenderness variability in individual Kraft classes is on a similar level of about 10%, which is almost twice less than that determined for the entire sample of pines (Table 1, Fig.1).

Table 1. Statistical characteristics of tree crown traits in the biosocial classes

Statistical traits	All trees	Kraft's class					
		I	II	III	IVa	IVb	Va
Number of trees	50	9	10	16	8	3	4
Slenderness *s* [m/cm]							
The minimum	0,7	0,7	0,8	1,0	1,2	1,0	1,3
The maximum	1,7	1,1	1,2	1,3	1,7	1,3	1,6
The arithmetic mean	**1,1**	**0,9**	**1,0**	**1,2**	**1,4**	**1,2**	**1,5**
The standard deviation	0,2	0,1	0,1	0,1	0,1	0,1	0,1
The coefficient of variation	19,2	11,0	11,7	9,0	10,5	11,5	9,3

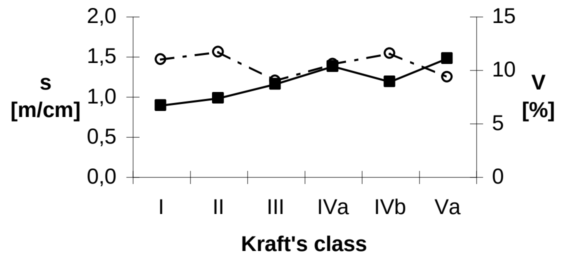

Fig. 1. The arithmetic mean of slenderness in the biosocial classes

Slenderness of trees decreases with increasing DBH, height, crown length and width, the degree of its deflection and the percentage of the crown in whole tree (relative crown length), but increases with deterioration of biosocial class (Table 2).

Table 2. The correlation diagram

Tree traits	*Kraft's class*	$d_{1.3}$	h	l_k	d_k	d_k/h	l_k/h
s	0,805	-0,937	-0,685	-0,676	-0,756	-0,640	-0,581
Kraft's class		-0,785	-0,728	-0,670	-0,682	-0,553	-0,575
$d_{1.3}$			0,845	0,800	0,780	0,594	0,655
h				0,802	0,652	0,387	0,589
l_k					0,673	0,483	0,951
d_k						0,948	0,593
d_k/h							0,476

Based on the significant relationships between slenderness and mentioned features, equations for estimating the slenderness were evaluated. The equations took the form:

$$s = 3.1149 - 0.0869 \cdot d_{1.3} - 0.0692 \cdot h + 0.3778 \cdot l_k - 5.0503 \cdot l_k / h \quad (1)$$

$$s = 2.2016 - 0.0882 \cdot d_{1.3} + 0.2041 \cdot l_k - 2.6927 \cdot l_k / h \quad (2)$$

Table 3. Multiple and partial correlation coefficients for the tree slenderness dependence on the selected characteristics of trees

Equations	$R_{multiple}$	$100R^2$	$R_{partial}$			
			$d_{1.3}$	h	l_k	l_k/h
(1)	0.9734	94.75	-0.9436	-0.34952	0.6009	-0.5894
(2)	0.9696	94.01	-0.9389		0.7110	-0.6665

With these equations slenderness of a tree can be estimated with more than 94% accuracy. There is a change in relationship between slenderness and crown length. Excluding the impact of other features, it becomes positive. This confirms that too long crown, despite initial impact on faster tree volume increase in relation to the increase in height, causes increase in slenderness, which becomes a defect for a stand.

Discussion

Research made on pine stands by Rymer-Dudzińska (1992b) showed that average slenderness decreases with age increase. The decrease in slenderness also followed the increase in the average diameter at breast height and height of the stand. The slenderness ratio increases with increasing stand density and Kraft class grading. Slenderness relationship with these features took the shape of a straight line, the strongest with age and the average diameter at breast height of stand, weaker with the height and stand density, and the weakest with of stand quality. Rymer-Dudzinska (1992a) also showed that pines slenderness is growing with deterioration of biosocial classes, as well as study of Kazmierczak (2012).

The same results were obtained for the slenderness ratio in relation to spruce from Central Sudetes, where it decreased with age and with increasing DBH, height and volume. The strongest relation was found with diameter at breast height and stand volume, weaker with age and height (Kazmierczak et al. 2008b). The study on spruce growing in Western Beskidy mountains showed that the slenderness also varies depending on their position above sea level. Spruce trees growing at lower altitudes tended to have higher slenderness (Orzeł and Socha 1999).

Research by Rymer-Dudzińska and Tomusiaka (2000) showed the dependence of slenderness in beech stands on the average diameter at breast height, age, height and percentage of bark thickness, while there was no association with the percentage of the length of the crown. Oak stands had similar results, but the relationships were stronger and there was no association of slenderness with the percentage of crown length and the percentage of bark thickness at breast height. Analysis of oak slenderness presented by Kazmierczak et al. (2009) showed significant differences in the characteristics of the tree due to the biosocial position. There was also a strong correlation between slenderness and diameter at breast height with and without bark, with cross sectional area at DBH and a double thickness of the bark at breast height; the weaker correlation was found with Kraft class, stand volume and age. The smallest correlation coefficient was obtained for the relation of slenderness with height. With the increase of all features, except Kraft class and artificial form factor (breast height), slenderness of oaks decreased. Also, other studies by Kazmierczak team (2008a) showed decreasing slenderness of oaks with increasing age, diameter at breast height, DBH increment, volume and its increment. In the case of height a reverse trend was observed, but statistically significant only in younger trees.

Age of the trees also affects the slenderness of main tree species in the Niepołomicka forest. Slenderness decreases with its increase. Deciduous trees have proven to be more slender than pine and larch (Orzeł 2007).

Research conducted by Kazmierczak et al. (2011) showed that the slenderness ratio size of larch is affected by both age and biosocial position of tree in the stand, while there was no impact of soil fertility on slenderness.

Slenderness can be shaped by breeding procedures starting from the initial planting, followed by cleaning and thinning, so as to increase the space for growth. This fact stimulates greater thickness increase compared to the increase in height, and this reduces height. It must be noted, however, that increasing in growth space is associated with crown increase, which may affect the deterioration of raw material produced.

Conclusions

1. Thicker and higher trees tend to be characterized by lower slenderness.
2. Pine trees with a longer and wider crown are also characterized by lower slenderness.
3. Slenderness increases with decreasing of trees biosocial position, and by this increasing the instability of the tree.
4. Slenderness of tested pines can be estimated with accuracy at a level of 94% based on the measures of diameter at breast height, the height and length of the crown.

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Received in March, 2014, submitted to printing in May, 2014

Katarzyna KAŹMIERCZAK, PhD (Eng), lecturert, Institute of Dendrometry and Forest Productivity Science, Department of Forest Management, Poznań University of Life Sciences, Address: ul. Wojska Polskiego 71A, 60-625 Poznań, Poland, e-mail: kasiakdendro@wp.pl ;
Katarzyna KAŹMIERCZAK, dr inż., adiunkt, Zakład Dendrometrii i Nauki o Produkcyjności Lasu, Katedra Urządzania Lasu, Uniwersytet Przyrodniczy w Poznaniu, Adres: ul. Wojska Polskiego 71C, 60-625 Poznań, Polska, e-mail: kasiakdendro@wp.pl ;
Agnieszka JĘDRASZAK, MSc. (Eng). PhD Student, Department of Forest Utilisation, Poznań University of Life Sciences, Address: ul. Wojska Polskiego 71A, 60-625 Poznań, Poland, e-mail: agnieszka.jedraszak@up.poznan.pl.
Agnieszka JĘDRASZAK, mgr inż., doktorant, Katedra Użytkowania Lasu, Uniwersytet Przyrodniczy w Poznaniu, Adres: ul. Wojska Polskiego 71A, 60-625 Poznań, Polska, e-mail: agnieszka.jedraszak@up.poznan.pl.