What do we really know about tree slenderness as an indicator for risk assessment?

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In forestry, slenderness has long been used as an indicator for the stability of individual trees and stands. Some years ago, this has been transferred to urban tree risk assessment (Mattheck 2002). Tree care professionals were fast to adopt it as it is very easy to apply. But the validity of this application has soon been questioned, causing a heated debate and much confusion among arborists (Fink 2009, Gruber 2007, Rust 2011, Schulz 2005). This paper reviews the literature and our recent research concerning the usefulness of using slenderness in risk assessment.

Empirical evidence

There exists not a single study on the effect of slenderness on failure rates in urban trees. In forestry, research focuses on the stability of plantations with coniferous trees which usually are much more slender than urban trees. Most studies cited in support for this indicator refer to dense, young conifer stands, often damaged by wet snow or ice (e. g. Rottmann 1986).

Several studies modeling the failure of forest trees in high winds conclude that the risk of breakage increases with slenderness (e. g. Petty and Swain 1985). These results are, however, based on assumptions that might not be valid in general, especially for urban trees. They assume the same crown type (length and weight), wood properties, and tree height.

Several studies show an unambiguous relationship between increasing slenderness and decreasing crown length and weight. In addition, slender trees with short crowns tend to have wood with higher density and strength. The most serious limitation to transferring conclusions from these models to urban trees might be, that a slender tree of the same height by definition must have a much smaller basal diameter than a sturdy tree. Since for a given bending moment, maximum tensile and compressive stresses decrease with diameter cubed, it comes as no surprise that thinner stems break more easily. Thus, slenderness and diameter are inherently confounded in most studies. While these models are a valuable tool to compare management options for plantations of coniferous trees, they clearly do not provide evidence supporting the use of slenderness in urban tree risk assessment.

Of the few studies which systematically investigated the impact of slenderness, most found no evidence supporting the hypothesis that slender trees are more likely to fail in strong winds (Braun et al. 2003, Meyer et al. 2008, Schütz et al. 2006). In a study of permanent sample plots in Sweden, slender trees were less likely to fail than sturdy trees (Valinger and Fridman 1997).

A number of further studies, which are regularly quoted in support of the proposed failure criterion have actually not conducted any research in that matter. Rather, they state the importance of slenderness as a fact without providing any evidence (e. g. Slodicak and Novak 2003). Still other studies do not contain any statements that can be related to the context they are quoted in (e. g. Putz et al. 1983).

Pulling tests on trees differing in slenderness

We subjected 15 large forest trees covering a range of slenderness to destructive pulling tests (Jillich et al. 2013). Our results show that the effect of slenderness on maximum bending moments is negligible. Most of the variation in maximum bending moments and in anchorage strength was related to the section modulus at 1 m stem height. Wood density and modulus of rupture both increased with slenderness.

Ontogenetic trends in slenderness

Inventory data of six urban tree species from seven cities across Germany were used to model regional variation of height growth, allometric scaling, and slenderness over a wide range of size and age. Variation within and between species and cities was large. Height did not reach an asymptote but declined at higher ages, presumably because of reduction cuts.

Slenderness started well above the proposed threshold and continuously decreased with age. So every planted tree starts of with a “hazardous” slenderness, and in tree risk assessment there is no objective way to distinguish between young, and therefor safe, slender trees, and old, and therefor presumably hazardous slender trees.

Our studies on urban tree populations show that there are almost no mature slender (h/d > 50) trees on which to base empirical studies on failure. This might explain why the critical slenderness of urban trees is derived from a comparison of failed slender trees from recently thinned, dense plantations with standing sturdy urban trees (Mattheck 2002).

Conclusions

Our experiments and the scientific literature do not support the use of a threshold value of slenderness in tree risk assessment. Direct observation and surveys after storms have shown a small (Schmidt et al. 2009) or no effect of slenderness on tree stability in either direction. Models are based on assumptions that might not be valid for solitary urban trees. A strong ontogenetic trend leaves much room for subjective interpretation in risk assessment.

In conclusion, we caution against basing decisions on pruning or felling on tree slenderness.

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