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The Influence of the Slenderness Coefficient on Urban Tree Stability: An Acoustic Tomography Assessment Across Seven Taxa

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Abstract

The slenderness coefficient (Tree Height / Diameter at Breast Height or H/D ratio) is a traditional metric for evaluating tree stability, but its applicability to urban trees facing unique architectural and environmental stressors is complex. This study assessed the biomechanical stability of 2,053 urban trees across seven taxa in Slovakia over a ten-year period (2015–2025) using 3D acoustic tomography. Safety factors (SF) were calculated, and the predictive capacity of the H/D ratio was evaluated using Mann-Whitney U tests and binary logistic regression models. The findings indicate that the widely accepted universal threshold of H/D > 50 is critically inadequate for urban arboriculture. Significant interspecific variability was observed in baseline susceptibility to instability. Taxa such as *Aesculus hippocastanum* and *Acer platanoides* exhibited 50% instability risk thresholds at much lower H/D ratios of 25.2 and 35.8, respectively. Conversely, the H/D ratio was an ineffective isolated risk predictor for the columnar *Populus nigra* 'Italica'. A complete inversion of the standard slenderness paradigm was observed in *Platanus x hispanica*, where instability was primarily driven by the severity of internal decay and the mechanical wind-load of massive secondary crowns rather than high slenderness ratios. Biomechanical safety evaluations and subsequent structural mitigations must transition from generalized morphometric rules to highly tailored, species-specific strategies. Ultimately, effective tree risk assessment requires integrating morphometric indicators with comprehensive internal structural assessments, utilizing tools such as acoustic tomography, to accurately account for decay and load-bearing vulnerabilities.

Key Message

The universal slenderness ratio is inadequate for urban tree stability; effective risk assessment requires species-specific strategies integrating morphometrics with acoustic tomography to accurately detect internal structural defects.

Introduction

In the urban environment, trees represent an exceptionally valuable infrastructure that provides extensive ecological, aesthetic, social, and economic benefits, including microclimate regulation, carbon sequestration, air pollutant removal, and mitigation of the urban heat-island effect (Karlinasari et al. 2018; Lüttge and Buckeridge 2020). Despite these undeniable advantages, trees pose a significant risk to public safety, human health, and property when their structural stability is compromised (Brashaw et al. 2009; Wu et al. 2018). Effective management of urban green spaces and ecosystem services constitutes a complex challenge that requires integrating the empirical experience of practitioners with a profound scientific understanding of the structure and biomechanical function of trees (Locosselli and Buckeridge 2023).

Visual Tree Assessment and its Limitations

Tree risk assessment is a systematic process of inspecting and evaluating the likelihood of tree failure and the consequent potential for injury or property damage (Kumar and Kumar 2019). In current management practice, the most widespread non-destructive technique is visual inspection, such as the Visual Tree Assessment (VTA) method. Although this method is rapid and cost-effective, it frequently fails to identify concealed anomalies that indicate internal instability or early stages of biodeterioration. Recent studies emphasize that relying exclusively on visual assessments is associated with a high degree of uncertainty and should be integrated with instrumental techniques to ensure structural stability (Linhares et al. 2021). This can lead to the radical and unnecessary felling of viable individuals or, conversely, the critical underestimation of hazardous trees. Therefore, it is necessary to utilize equipment and technologies that, when combined with visual inspection, make it possible to monitor the internal state of the tree and relate this knowledge to accurate failure prediction (Esteban et al. 2025).

Instrumental and Non-Destructive Testing (NDT)

To objectify assessment results, it is essential to combine visual inspections with advanced instrumental technologies that enable a detailed examination of the internal wood structure. Instrumental diagnostics serve as a supporting tool, particularly in questionable cases where external symptoms of decay are absent, allowing practitioners to detect internal cavities reliably and make a more informed evaluation of the tree's risk potential (Ellis and Ellis 2013, 2014; Koeser et al. 2017; Soge et al. 2021). Currently, several researched and utilized methods enhance this evaluation:

Acoustic and Sonic Tomography (SoT)

This technology is highly effective in detecting even early stages of internal decay (He et al. 2024; Emerick et al. 2025). By measuring the velocity of sound wave propagation, the software computes a multi-dimensional tomogram of the trunk cross-section, enabling precise localization of structural changes, cavities, and the evaluation of residual wall strength (Volpi et al. 2025). The acquired data significantly refine decision-making and prevent the unnecessary removal of healthy trees. Furthermore, the application of acoustic tomography demonstrably reduces the error rate in estimating the probability of trunk breakage under wind load (Dudkiewicz and Durlak 2021; Durlak and Dudkiewicz-Pietrzyk 2026).

Resistance Drilling (e.g., Resistograph)

A micro-destructive method that measures the penetration resistance of a specialized thin drill bit into the wood, allowing precise detection of dense wood layers, cavities, or advancing decay. This method is often utilized alongside acoustic tools for a comprehensive diagnostic approach (Soge et al. 2021).

Ground-Penetrating Radar (GPR)

A non-invasive technology based on electromagnetic waves, widely applied for mapping root systems beneath paved surfaces and increasingly utilized for internal trunk analysis (He et al. 2024).

Innovative Approaches (UAV and 3D Biomechanics)

Emerging approaches combine remote sensing—such as unmanned aerial vehicles (UAVs) equipped with multispectral cameras—for broad-scale pre-identification of hazardous trees (Mat Isa et al. 2025). These are increasingly integrated with advanced applied biomechanics software tools and machine learning algorithms to evaluate wood properties and calculate the precise structural resilience of a tree under load (Lorensani and Gonçalves 2025; Kolařík 2025).

Biomechanics and the Slenderness Coefficient

The evaluation of tree biomechanical stability is an extremely complex process. While instrumental diagnostics focus primarily on localized defects and internal wood integrity, the overall spatial and static stability of a tree - especially its susceptibility to stem breakage and uprooting - is largely defined by its macroscopic anatomy. In the exact sciences, this parameter is formally expressed by the slenderness coefficient (H/D ratio).

This paper presents the results of a tree stability assessment conducted via acoustic tomography, alongside the relationship between the calculated safety factor and macroscopic tree characteristics obtained by visual inspection across a broad spectrum of urban taxa.

Materials and methods

The assessed trees were chosen in the urban vegetation – parks and old parks, cemeteries, inter-block spaces as well as street lines (alleys).

A visual inspection was first conducted on each tree to document visual signs of structural instability (e.g., physical damages, exterior cavities, fungal growth) with photographic documentation and to determine the precise height of tree trunk requiring further non-destructive testing. Additional characteristic of trees (diameter of the trunk at breast height - DBH, diameter of trunk at layer of tomography, stem inclination, crown area and tree height) were measured for next data analysing.

The H/D Ratio (Slenderness coefficient) expresses the ratio of the total tree height to its trunk diameter at breast height (1.3 m above ground level). It is one of the most robust synthetic indicators of a tree's static stability, particularly concerning its resistance to stem breakage and uprooting under the influence of strong winds or heavy snow loads.

Acoustic tomography was realised on selected living trees, on trunks, at heights where some structural damages were present. For acoustic tomography measurements Fakopp 3D tomograph (Fakopp Kft. 2026) was used. According to trunk diameter and shape, 8 to 12 piezo sensors were used for measurements, based on manufacturer's recommendations (Fakopp Kft. 2026). By processing the acoustic tomography data, location of decay within the cross section (concentric or eccentric) was recorded. Safety factor (SF) of the trunk for individual tomography layer was calculated by ArborSonic 3D software using ´Uniform´ wind model (Buza and Goncz 2015). In this model SF is calculated for a tree

standing alone and exposed to the total effect of wind. Computed SF represents the ratio of the wood strength and maximal stress at a given level (height of measurement on trunk) based on assumed wind load. Beside layer tomogram, computation of SF takes into account additional data such as crown area, trunk inclination and orientation, height of tree, height of crown centre/top and other attributes.

A tree might be considered safe if SF is above 150%; in case of SF below 100%, tree is considered as hazardous with high risk level (user modified scale, Fakopp Kft. 2026).

In case of instable tree, crown reduction (up to ≤ 20% crown area with adequate crown heigh reduction) to achieve adequate stability of SF 150% was calculated.

The objective of this research was to assess the dependence of tree stability (computed SF, derived from acoustic tomography) on specific tree characteristics - slenderness ratio and DBH.

To evaluate the predictive capacity of the slenderness coefficient (H/D ratio) on tree stability, data were analysed across several tree taxa using Mann-Whitney U tests and binary logistic regression models. Statistical analyses were conducted using the Microsoft® Excel® 2021.

Results

Using acoustic tomography, a total of 2 053 trees from 7 genera were assessed across 89 localities in Slovakia over a ten-year period (2015–2025). The most frequently evaluated trees (Table 1) belonged to the genus *Tilia* (737 trees), followed by *Populus* (487 trees), *Aesculus* (459 trees), *Acer* (174 trees), *Fraxinus* (118 trees), and *Platanus* (78 trees).

Among all assessed trees, 81.39% exhibited satisfactory stability. Average damaged area in trunk cross-sections of trees with satisfying stability was 20.37%, while in the case of unstable trees it was 30.70%.

An evaluation was conducted to assess biomechanical stability, slenderness ratios (H/D), and the predicted efficacy of crown reduction interventions. The assessment identified significant interspecific variability in baseline susceptibility to instability, the manifestation of critical hazards at sub-average slenderness, and the required intensity of arboricultural mitigation.

General Susceptibility and Hazard Occurrence

The overall probability of hazard tree occurrence (Pu), expressed as an occurrence ratio (1 unstable tree per X assessed individuals), revealed that *Aesculus hippocastanum* (Pu = 2.89) and *Acer platanoides* (Pu = 3.35) are the most susceptible taxa to biomechanical instability (defined as a SF < 150%). In contrast, *Populus nigra* demonstrated the highest baseline stability among the observed taxa, with an instability occurrence of only 1 in 18.00 evaluated trees.

Table 1
Biomechanical stability parameters, hazard occurrence probabilities, and predicted crown mitigation efficacy across seven urban tree taxa.

Tree	n	U	Pu	H/D	KI	$CR_{20\ (\%)}$	RH (m)	KII
Acer platanoides	174	52	3.35	25.61	8.70	65.00	1.21	26.00
Aesculus hippocastanum	459	159	2.89	19.50	11.48	91.86	0.85	45.90
Fraxinus excelsior	118	15	7.87	24.35	39.33	87.50	1.29	-
Platanus x *hispanica*	78	9	8.67	21.81	9.75	83.33	1.56	78.00
Populus nigra	126	7	18.00	23.62	126	100	1.34	-
Populus nigra 'Italica'	361	35	10.31	26.26	20.06	84.21	1.34	90.25
Tilia sp.	737	105	7.02	23.25	24.57	77.46	1.07	122.83
n – Total number of assessed trees								

U – Number of unstable trees (SF below 150%)

Pu – Probability of hazard tree occurrence

H/D – Mean H/D ratio (slenderness coefficient) of stable trees

KI – Probability of unstable trees (SF < 150%) occurring with an H/D ratio ≤ healthy tree mean

CR_{20} – Percentage of KI trees achieving adequate stability with ≤ 20% crown reduction

RH – Mean crown height reduction (m) required for adequate stability

KII – Probability of hazardous trees (SF < 100%) occurring with an H/D ratio ≤ healthy tree mean

Slenderness Ratios and "Hidden" Risks

The mean slenderness coefficient (H/D ratio) for stable individuals varied across taxa, ranging from 19.50 in *A. hippocastanum* to 26.26 in *P. nigra* 'Italica'. Notably, the assessment isolated the probability of instability (KI) and severe hazard (KII, SF < 100%) for trees exhibiting an H/D ratio *less than or equal to* their respective taxon's stable mean (Fig. 1).

A. platanoides (KI = 8.70) and *Platanus x hispanica* (KI = 9.75) exhibited the highest probabilities of instability. Furthermore, *A. platanoides* displayed a concerning susceptibility to critical failure (KII = 26.00), indicating that even robust-appearing maples frequently present severe biomechanical deficits. Conversely, *P. nigra* showed negligible hazard occurrence at below-average slenderness ratios (KI = 126.00).

Efficacy of Crown Reduction Interventions

The restorative potential of pruning was modelled by determining the percentage of unstable trees (KI cohort) that could achieve adequate stability (SF ≥ 150%) with a crown reduction of 20% or less (CR_{20}).

For most taxa, mild to moderate pruning is highly effective. *P. nigra* achieved a 100% success rate under the CR_{20} threshold, followed closely by *A. hippocastanum* (91.86%) and *Fraxinus excelsior* (87.50%). Conversely, *A. platanoides* exhibited the lowest mitigation success rate (65.00%), suggesting that maple trees often require substantially more aggressive structural pruning (> 20%) to restore safe biomechanical parameters or entire removal.

The absolute mean reduction in crown height (RH) required to restore adequate stability ranged from an average of 0.85 m in *A. hippocastanum* to a maximum of 1.56 m in *Platanus x hispanica*, further emphasizing that structural mitigation strategies must be highly species-specific.

Comparison of slenderness coefficients (H/D ratios) and structural stability among the assessed urban tree taxa. The left panel displays the distribution and variance of H/D ratios for unstable (red; SF < 150%) and stable individuals (blue; SF > 150%), illustrating species-specific thresholds for biomechanical failure. The right panel plots the H/D ratio as a function of diameter at breast height (DBH, cm) demonstrating the allometric development of the trees and indicating the developmental stages most associated with structural instability.

Relationship Between the Slenderness Coefficient (H/D Ratio) and Tree Stability

Data were analysed using Mann-Whitney U tests and binary logistic regression models. The results (summarized in Table 2) demonstrated species-specific differences in stability thresholds and risk progression.

Table 2
Comparison of H/D ratios between stable and unstable tree groups, significance of differences (Mann-Whitney U test), and critical H/D thresholds for 50% instability risk derived from binary logistic regression.

Taxon	n Stable	Mean H/D (Stable)	n Unstable	Mean H/D (Unstable)	p-value	Critical H/D (50% risk)
Acer platanoides	122	25.61	52	28.86	0.013	35.8
Aesculus hippocastanum	300	19.50	159	24.30	0.050	25.2
Fraxinus excelsior	103	24.35	15	40.11	< 0.001	43.1
Platanus sp.	69	21.81	9	17.00	< 0.001	13.0
Populus nigra	119	23.62	7	32.69	0.005	43.5
Populus nigra 'Italica'	326	26.26	35	33.02	0.122	63.5
Tilia sp.	632	23.00	105	35.44	< 0.001	40.2

Acer platanoides

The test confirmed a statistically significant difference between the two groups, demonstrating that unstable trees possess a higher slenderness coefficient (Table 2). The slope of the logistic curve for this species is relatively gradual. This indicates that although the risk begins to rise steadily at lower values, a prolonged progression is required to exceed the critical 50% risk threshold.

Aesculus hippocastanum

There is a strong dependence between the H/D ratio and tree stability. Trees with a higher slenderness coefficient (i.e., disproportionately tall relative to their diameter) are more susceptible to a loss of stability. Due to the presence of extreme values in the data distribution, the non-parametric test confirmed a highly significant difference between stable and unstable individuals (Table 2).

Fraxinus excelsior

The test confirmed that unstable trees have a demonstrably higher slenderness coefficient, with the difference being highly statistically significant (Table 2). Logistic regression revealed that the stability boundary for ash is shifted considerably higher compared to other species. Consequently, this species exhibits substantial resilience regarding slenderness parameters.

Populus nigra

Despite a significant dataset imbalance, a statistically significant difference was confirmed, with unstable trees again exhibiting a higher slenderness coefficient (Table 2). The risk of instability remains very low across a wide range of values, but it escalates rapidly once the H/D ratio exceeds 35–40.

Populus nigra 'Italica'

This specific cultivar yielded atypical results (Table 2), which is likely related to its columnar growth habit. Although extreme outliers skewed the mean of the unstable group upward, the majority of unstable trees paradoxically exhibited a lower median H/D ratio than stable trees. Therefore, a statistical difference between the groups was not confirmed. The flat logistic curve and the extreme critical threshold suggest that the H/D ratio alone is an unsuitable predictor of risk for this cultivar.

Tilia sp.

The test confirmed an exceptionally strong statistical significance for the difference in H/D ratios (Table 2). The regression model for the genus Tilia is characterized by a very steep slope. Lindens tolerate H/D values up to approximately 35 very well, but as the value approaches 40, the risk escalates aggressively, exhibiting a more abrupt failure profile than, for example, Aesculus species.

Platanus sp.

The data for plane trees yielded entirely unexpected results, showing a trend that is directly opposite to all other analysed species (Table 2). Unlike other taxa, where risk increases with tall and slender proportions, plane tree individuals are more prone to failure when they are disproportionately thick relative to their height. Logistic regression confirmed this inverse trend with a negative slope. As values decrease toward 13, the probability of failure sharply exceeds 50%, whereas standard values above 20 indicate high stability. From an arboricultural perspective, trees with very low H/D values may represent individuals that have undergone severe pruning (topping), resulting in massive secondary crowns acting as "sails". Alternatively, the failure could be triggered by immense weight combined with a compromised root system. To investigate confounding variables, a multivariate binary logistic regression was applied to evaluate the combined influence of crown area and damage area (structural defects) on stability. Univariate analysis of damage area alone revealed a massive and highly significant difference ($p < 0.0001$): stable plane trees exhibited an average defect extent of 19.3%, while unstable trees presented with 69.0% damage. This demonstrates that decay, cavities, or mechanical damage are primarily linked to tree failure. When crown area and damage area were assessed concurrently in the multivariate model, the extent of damage emerged as the primary, strongest predictor of instability ($p = 0.012$). In the presence of significant structural damage, the overall risk is immense regardless of other variables. Consequently, crown area lost statistical significance ($p = 0.162$) within the combined model. Based on the model data, we conclude that a healthy *Platanus* can safely support massive crowns exceeding 200 m². A thick trunk or massive crown does not inherently trigger failure; rather, critical structural defects combined with the large "sail area" of the crown cause the compromised wood to succumb to wind loads.

Comparative Logistic Risk Models Across Taxa

A consolidated graphical model of binary logistic regressions (Fig. 2) represents comparison of stability behaviours across the seven evaluated tree taxa:

***Aesculus hippocastanum* (red line)**

Risk escalates earlier than in any other species, visually confirming that stability is compromised at relatively low slenderness coefficients.

***Acer platanoides* (light blue line)**

Displays a relatively gradual slope, indicating that although the instability risk begins to rise steadily at lower slenderness values, a prolonged progression is required to exceed the critical 50% risk threshold at an H/D ratio of approximately 35.8.

***Tilia* sp. (yellow line)**

Characterized by a steep curve; it maintains stability for an extended period but experiences a near-instantaneous surge in risk upon reaching an H/D ratio of roughly 40.

***Fraxinus excelsior* and *P. nigra* (light grey and dark blue lines)**

Both curves are shifted notably to the right, indicating these species tolerate the highest H/D ratios (approximately 43) before instability risk becomes dominant.

P. nigra 'Italica' (green line): A very flat trajectory that visually reinforces the statistical conclusion that the H/D ratio is not a reliable risk indicator for this columnar cultivar.

***Platanus* sp. (brown line)**

Represents statistical anomaly; while other species exhibit an upward risk trend from left to right (failing when excessively slender), the plane tree curve descends from left to right, indicating failure associated with disproportionately thick, low-slenderness morphologies.

Discussion

General Context and Rethinking Safety Thresholds

The slenderness coefficient (H/D ratio) has historically served as a primary synthetic indicator of a tree's static stability and resistance to windthrow. In traditional forestry literature, a slenderness ratio above 80 or 100 is generally considered unstable (Slodicak and Novak 2006). However, the biomechanical paradigm for urban trees is fundamentally different due to open-grown architectural characteristics and varied anthropogenic stressors. Within urban arboriculture, Mattheck et al. (2003) established a widely

referenced threshold via the Visual Tree Assessment (VTA) method, proposing that an H/D ratio exceeding 50 represents a critical likelihood of bending or failure.

Despite this established benchmark, our acoustic tomography assessment of 2,053 trees across 7 genera demonstrates that critical biomechanical instability—defined as a Safety Factor (SF) < 150%—often occurs at significantly lower slenderness values. The application of a universal "H/D > 50" threshold is therefore inadequate for accurate urban risk assessment, as our results confirm a high degree of species-specific variability in baseline susceptibility.

Taxa-Specific Stability and Morphological Vulnerabilities

Our findings directly challenge the validity of generalized slenderness limits. For example, *Aesculus hippocastanum* and *Acer platanoides* exhibited 50% instability risk thresholds at H/D ratios of 25.2 and 35.8, respectively. This indicates that these species succumb to structural instability long before approaching the classical H/D 50 limit. In contrast, *Fraxinus excelsior* and *Populus nigra* demonstrated substantial resilience, maintaining stability at much higher ratios with 50% risk thresholds of 43.1 and 43.5. Furthermore, *Tilia* spp. highlighted a unique, abrupt failure profile where stability is maintained up to an H/D ratio of 35 but degrades aggressively as it approaches 40.

These variations support the assertions of Rinn (2014, 2018), who argues that the absolute value of the H/D ratio is not a relevant standalone measure of breaking safety for urban trees unless integrated with structural integrity data and wind-load analyses. Our data reinforce that basic stability must always be evaluated through a species-specific lens.

Architectural Exceptions and the "Platanus Anomaly"

The limitations of relying solely on the slenderness coefficient are most evident when evaluating trees with atypical growth habits or significant internal decay. The logistic regression curve for *Populus nigra* 'Italica' was notably flat, indicating that the H/D ratio is a poor predictor of risk for columnar cultivars.

More remarkably, the assessment of *Platanus x hispanica* revealed a complete inversion of the traditional slenderness paradigm. Unlike other taxa that fail when excessively slender, unstable plane trees exhibited a significantly lower mean H/D ratio (17.00) compared to stable individuals (21.81). As demonstrated by multivariate regression, the extent of internal damage—rather than crown area or slenderness—was the primary predictor of instability for *Platanus*. From an arboricultural perspective, trees with very low H/D ratios often feature massive, heavy secondary crowns acting as "sails" following prior topping interventions. This finding aligns directly with the Statics Integrated Assessment (SIA) principles formulated by Wessolly and Erb (2016); high wind loads on large crowns, coupled with compromised wood capacity (decay), will drive the safety factor below the critical 150% threshold regardless of how sturdy a low H/D ratio might superficially appear.

Implications to Trees Management

The integration of acoustic tomography to calculate Safety Factors provides a considerably more precise understanding of urban tree biomechanics than morphometric ratios alone. The baseline requirement of a 150% SF utilized in our methodology parallels the standard safety margin recommended by Wessolly's SIA method to guarantee structural safety against peak wind loads. Ultimately, while the slenderness coefficient remains a useful diagnostic metric, its predictive validity is strictly species-dependent. Consequently, structural mitigation strategies must be highly tailored; while *A. hippocastanum* responds exceptionally well to minor crown height reductions (mean 0.85 m), taxa like *Acer platanoides* and *Platanus* frequently require significantly more aggressive pruning to restore safe biomechanical parameters.

Conclusions

This acoustic tomography assessment of 2,053 urban trees demonstrates that relying on a universal slenderness coefficient (H/D ratio) threshold—such as the traditional H/D > 50 benchmark—is critically inadequate for evaluating biomechanical stability in urban arboriculture. While the H/D ratio remains a valuable diagnostic tool, its predictive validity is fundamentally species-dependent and heavily influenced by architectural traits and structural defects. Our findings identify significant interspecific variability in baseline susceptibility to instability. Taxa such as *Aesculus hippocastanum* and *Acer platanoides* exhibit critical biomechanical vulnerability at much lower slenderness thresholds than traditionally accepted. Conversely, the H/D ratio proved entirely ineffective as an isolated risk predictor for species with atypical morphological habits, such as the columnar *Populus nigra* 'Italica'. Most notably, *Platanus x hispanica* demonstrated a complete inversion of the standard slenderness paradigm; in this species, instability is driven primarily by the severity of internal structural decay and the mechanical wind-load of massive secondary crowns rather than high H/D ratios. Consequently, urban tree risk assessment and subsequent structural mitigation must shift from generalized morphometric rules to highly tailored, species-specific strategies. While mild to moderate crown pruning is a highly effective restorative intervention for taxa like *Populus nigra* and *A. hippocastanum*, species like *A. platanoides* frequently demand substantially more aggressive structural pruning to restore an adequate safety factor. Ultimately, determining the true biomechanical safety of urban trees requires the integration of morphometric indicators with comprehensive internal structural assessments, utilizing tools such as acoustic tomography, to accurately account for internal decay and load-bearing vulnerabilities.

Declarations

Author contributions: All authors contributed to the study conception and design. Data collection was performed by Radovan Ostrovský and Marek Kobza. Analyses were performed by all authors. The first draft of the manuscript was written by Marek Kobza, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

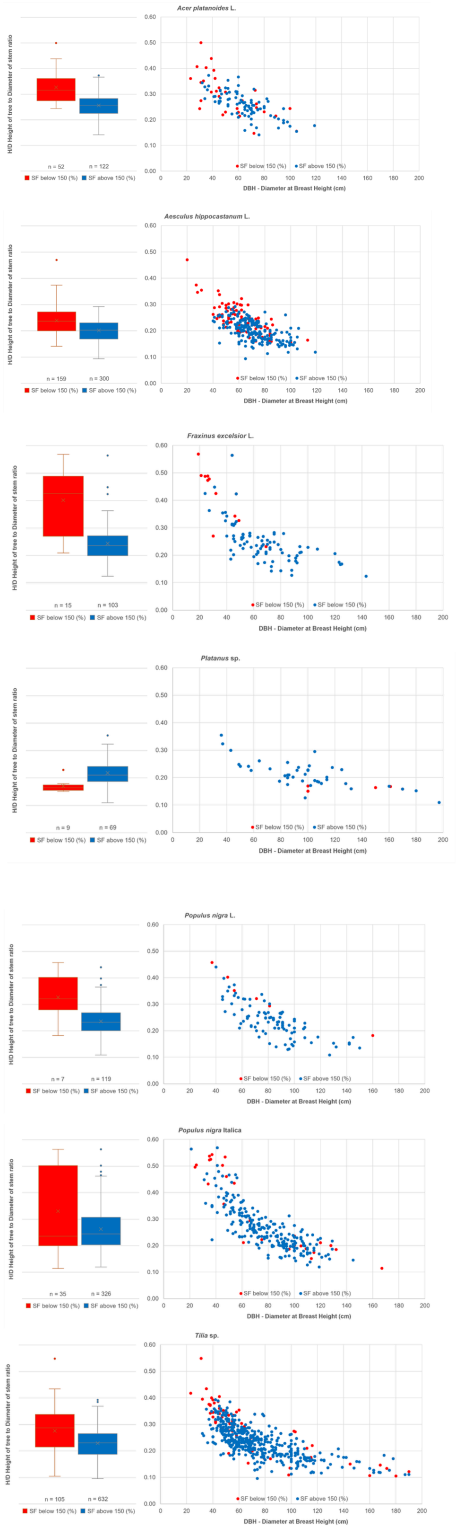


Figure 1

Slenderness Ratio Distributions and Allometric Trajectories in Relation to Biomechanical Stability Across Seven Urban Tree Taxa.

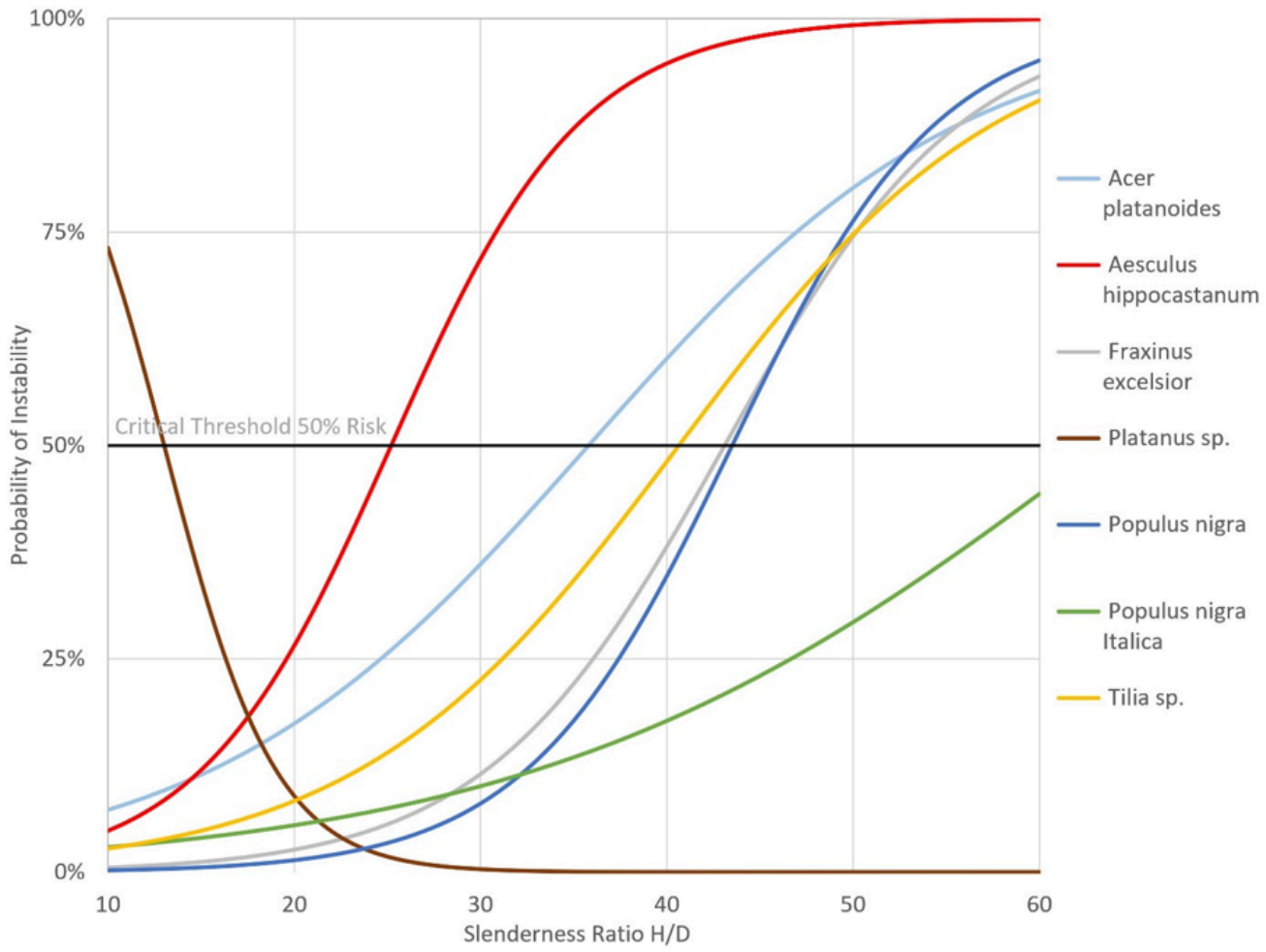


Figure 2

Comparison of logistic regression models for instability risk by taxon