

# TREES AND WIND: A BIBLIOGRAPHY FOR TREE CARE PROFESSIONALS

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**Abstract.** Arborists and urban foresters frequently refer to “wind loads,” “sail areas,” and so forth but may have limited knowledge of the forces and underlying concepts involved. While there is extensive tree–wind literature, very little has appeared in tree care publications. This article presents a collected tree–wind bibliography and some comments on its use.

**Key Words.** Aerodynamics; biomechanics; trees and wind; wind.

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## NEED AND PURPOSE

Arborists and urban foresters are increasingly concerned with “hazard” trees, tree risk assessment, and tree biomechanics. They often refer to “wind loads,” “sail areas,” and so forth but may have limited knowledge of underlying concepts, the magnitude of forces involved, or the responses of trees. While there is extensive tree–wind literature, relatively little has appeared in tree care publications. An informal survey of tree care practitioners and academics found a limited awareness of published material. Yet tree care professionals, particularly those involved in forensics and risk management, are frequently asked to provide definitive opinions. Engineering professionals are frequently reluctant to offer supporting opinions on trees in an apparent absence of protocols or standard methods. The purpose of this article is to introduce tree care professionals to a wide range of tree–wind literature. Some explanation of sources and their interpretation and use is also provided.

## SOURCES

The work on trees and wind is scattered across a number of disciplines, each with its own literature. This is significant for at least two reasons. First, the information is not in any single literature that is either familiar to or readily accessible by tree care professionals. Second, each discipline has its own focus, and the tree care reader must interpret its literature accordingly to extract particular material that may be applicable to arboriculture and urban forestry. These literatures include the following.

**Arboriculture and Urban Forestry.** Relatively few works have appeared in this literature, and many of these have been generally descriptive or have merely surveyed damage after wind events. The more specific sources tend to be European and may be unfamiliar to non-European readers. Some have not been translated into English.

**Boundary-Layer Meteorology,** which is concerned with the movement of air over the earth’s surface and around surface obstacles.

**Civil Engineering,** which attempts to describe or model tree–wind phenomena using accepted engineering principles.

**Computer Modeling,** which is concerned with theoretical mathematics or the development of computer graphics tools but provides useful insight into the analytical complexity of describing the behavior of trees in wind.

**Disaster and Emergency Management,** which is concerned with predicting and preventing natural hazard damage.

**Forestry,** with particular emphases on windthrow (much of the work comes from the British Isles, Canada, New Zealand, and Scandinavia) and forest fire.

**Hydrology,** which is concerned with fluid drag on submerged and unsubmerged vegetation.

**Shelterbelts and Windbreaks,** with much of the work coming from the plains states of the United States, the prairie provinces of Canada, and mainland China.

**Slope Stabilization and Erosion Control,** which is concerned with the stabilizing effects of tree roots, which may be compromised by windthrow, and the wind-sheltering effects of tree crowns.

**Theoretical Biology and Botany,** which is very academically and analytically focused.

There is some contribution from one literature to another, but in many instances there is no crossover. While this may be limiting in terms of an informed, overall body of knowledge, it has allowed certain consistent findings to emerge from entirely separate lines of inquiry.

## ACCESS

Most of the subject material is found in a wide range of scholarly journals and a few books, including edited collections of articles or conference proceedings. These are most accessible at major university libraries, particularly at schools of forestry. The libraries of botanical gardens and arboreta are also good sources. Some work finds its way into trade journals in simplified form.

The Internet provides a convenient alternative to search for sources and often to access them as well. Many journals are now on-line, with indices and article abstracts available at no cost. Full text of articles can often be downloaded, sometimes at no cost but often for a fee. Libraries and institutions often subscribe for full-text access at no cost to the end user. A significant limitation is that few on-line journal materials pre-date the mid-1990s. Earlier works must still be found in printed form. Increasingly, some material is available only on-line and not in print. URL addresses, if known, are provided in the bibliography for sources not widely available in printed form.

## BIBLIOGRAPHY

The sources have been selected principally for their relevance to tree biomechanics and structure. Selection has tended to be inclusive rather than exclusive, allowing the reader to assess the usefulness of listings. A particular effort has been made to identify recent and advanced works. There has been significant contribution since the somewhat singular sources of the early 1990s (Niklas 1992; Vogel 1994; Coutts and Grace 1995). The older works (e.g., Sauer et al. 1951; Lai 1955; Mayhead 1973; Coutts 1983; Deans and Ford 1983; Putz et al. 1983; Grant 1985) refer to even earlier material.

The bibliography is certainly not complete. There are additional sources including many cited by the works listed here. There are, no doubt, many non-English-language sources that were not found.

## USE

This bibliography should be equally useful to the typical practitioner, the advanced specialist, or the researcher. The new reader may benefit from some direction to broadly instructive material. *Wind and Trees* (Coutts and Grace 1995) is a comprehensive collection with a forestry perspective. Part II, *Mechanics of Trees Under Wind Loading*, is particularly useful. *Plant Response to Wind* (Grace 1977), *Tree Stability* (Bell et al. 1990) and *Understanding Wind Forces on Trees* (Wood 1995) clearly introduce basic concepts. The *Windthrow Handbook for British Columbia Forests*

(Stathers et al. 1994) provides a straightforward treatment of the mechanics of windthrow. *Life in Moving Fluids* (Vogel 1994), widely regarded as an indispensable reference, and Chapter 9 in *Plant Biomechanics* (Niklas 1992) are excellent introductions to fluid mechanics. Vogel's Chapter 6 (1994), as well as his 1996 article in this journal, deal specifically with trees. Additional sources intended specifically for tree care include Sinn and Wessolly 1989, Wessolly 1996, Chaney 1997, Telewski 1998, Wessolly and Erb 1998, Alaoui et al. 1999, Foret et al. 1999, Coder 2000a-d, Mattheck and Bethge 2000, and Chaney 2001.

The informed reader may be able to select useful entries simply by scanning the titles and may look to the more narrowly focused or even seemingly off-point sources to find analytical or quantitative methods or experimental data applicable to particular problems.

It is conventional in the scholarly literature to use SI (*Systeme International*) units. These units are often unaccompanied by English equivalents. In day-to-day practice, wind velocity is customarily reported in miles or kilometers per hour, knots, Beaufort force numbers, or Simpson-Saffir numbers rather than the SI convention, meters per second. The reader should have access to appropriate conversion factors.

The reader should remember that wind is only one factor in the structural behavior of trees. Useful understanding of that behavior also requires knowledge of climatology, root anchorage and soils, tree biomechanics (e.g., Coder 2000d, and Niklas 1992), wood and root properties and strength, and other fields. Practical application may also require a knowledge of risk management or applicable codes and standards. These other fields are generally beyond the scope of this collection.

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**Résumé.** Les arboriculteurs et les forestiers urbains réfèrent fréquemment à des termes tels que « force des vents » et « corridors de vents », mais ils peuvent avoir une connaissance limitée des forces et des concepts sous-jacents qui sont impliqués. Même s'il y a une littérature exhaustive sur le thème « des arbres et du vent », peu d'informations apparaissent dans les publications sur l'entretien des arbres. Cet article présente une bibliographie sur le thème des arbres et du vent ainsi que certains commentaires quant à son utilisation.

**Zusammenfassung.** Arboristen und Forstleute beziehen sich gelegentlich auf Termini aus der Wetterkunde, wenn sie von Winden sprechen, aber sie haben nur begrenzte Kenntnisse über Windkräfte und ihre Entstehung. Während ausreichend Baum/Wind-Literatur erhältlich ist, so ist doch wenig davon in Veröffentlichungen für Baumpfleger erschienen. Dieser Artikel präsentiert eine Sammlung von Baum/Wind-Literatur und einige Kommentare für den Gebrauch.

**Resumen.** Cuando se habla de la relación árbol-viento, los arboristas y los dasónomos urbanos frecuentemente se refieren a “cargas de viento”, “golpe de vela” y así sucesivamente, pero pueden haber un conocimiento limitado de las fuerzas y conceptos implicados. Mientras existe una extensa literatura, muy poca ha aparecido en publicaciones relacionadas con el cuidado de los árboles. Este artículo presenta la bibliografía colectada sobre la relación árbol-viento y da algunos comentarios sobre su uso.