Why Trees Fail During Ice Storms: Developing Greater Ice Storm Resistant Tree Populations

Richard J. Hauer[1], Les P. Werner[1], Jeffery O. Dawson[2]
[1] University of Wisconsin – Stevens Point and
[2] University of Illinois – Urbana/Champaign

Abstract: Severe ice storms occur every year in the United States and Canada, particularly in the Midwestern and eastern regions of the United States. For example, severe ice storms regularly damage urban tree populations from Central Missouri through Ohio and the New England States. Ice storms are responsible for deaths and injuries of people and cause dramatic damage and tree loss to urban forests. Ice storms annually result in 250 million dollars in loss, and potentially billions of dollars in losses for extreme and widespread ice storms. Damage to electric distribution systems, blocked roadways, and property damage from fallen trees and limbs pose safety concerns and disrupt normal community functions.

Tree species vary in their resistance to ice accumulation. Certain characteristics, such as weak branch junctures indicated by included bark, dead and decaying branches, a broad crown, and fine branching, increase a tree's susceptibility to ice storm damage. We developed tree species resistance and susceptibility to ice storms based on our work and that from 42 primary research publications. This expanded upon our previous work and incorporated new findings with ice storms and tree damage since the early 1990's. Based on our research and that from the literature, tree failure from many ice storms is predictable and often preventable based on tree attributes and structural integrity.

We cover developing greater ice storm resistance in tree populations through tree selection and tree management practices. We will also discuss methods to incorporate mitigation, preparedness, response, and recovery planning into urban forest management to minimize the effects of ice storms on the urban forest. This research has relevance for urban foresters, arborists and others to develop ice storm resistant tree populations.

Introduction

Ice storms occur annually throughout the United States. These storms, also historically referred to as glaze storms, cause considerable damage to trees in urban and rural forests. The potential of causing significant damage to trees also can lead to property damage and death and injury to people. Annual losses from ice storms exceed $225 million in total damage to trees and property. Monetary losses to forests, individual trees, utility lines, agriculture, commerce, and property can be extensive after an ice storm. Between the years of 1949 and 2000, insured property losses from freezing rain were $16.3 billion U.S. dollars (adjusted to the value of year 2000 dollars). Actual losses are even greater as this total excludes non-insured losses. As an example, losses from a 1998 ice storm covering the northeastern United States and southeastern Canada were estimated at $6.2 billion, with less than half this amount insured.

Ice storms can be localized to widespread. For example, a major multi-state ice storm in December 1997 resulted in severe damage to trees in Oklahoma, Missouri, Kansas, Nebraska, Illinois, and Iowa. The severity of extreme wide-spread ice storms such as the January 1998 northeastern North America ice storm, can exceed several billion dollars in losses. These extreme cases tend to occur once every 10 to 20 years in a regional area with parts within this area receiving damaging ice loading. Whether localized or widespread, damage to electric distribution systems, blocked roadways, and property damage from fallen trees and limbs pose safety concerns and disrupt normal community functions.

Can steps be taken by arborists, urban forest managers, horticulturists, elected officials, or concerned citizen to prevent or minimize the damage from ice storms? Lessons learned from ice storm response over the past several decades, along with our study and published reports suggest the urban forest can be planned and managed to reduce the damage and potential costs associated with ice storms. This paper presents reasons why trees fail during ice storms and how planting a diverse urban forest that includes trees resistant to ice storms and performing regular tree maintenance to avoid or remove structural weaknesses will reduce damage caused by severe ice storms. Further, we present the need that urban forest management plans should incorporate information on the ice storm susceptibility of trees in order to: limit potential ice damage; to reduce hazards resulting from ice damage; and to restore urban tree populations following ice storms.

Where do Ice Storms Occur and How do they Form?

What is an ice storm and how do they form? The U.S. National Weather Service defines ice storms as the accumulation of at least 0.625 cm (1/4 inch) of ice on exposed surfaces. Ice accumulation on stems generally ranges from a trace to 2.5 cm (1 inch) in diameter and in extreme cases reports up to 20 cm (8 inches) of ice encasing the stem. Accumulations of ice can increase the branch weight of trees by a factor of 10 to 100 times. The severity of damage increases with greater accumulations of ice (Table 1).

Ninety percent of these storms occur between December and March. Most occur in January. The vast majority of ice storms develop when a moist winter warm front passes over a colder surface-air layer (Figure 1). Rain that falls from a warmer layer (above 0ºC/32ºF) through layers of cooler air (below 0ºC/32ºF) becomes supercooled without freezing. Infrequently, ice storms occur when the temperature at the top of clouds is greater than -10ºC (15ºF) and ice particles are in low concentration or do not form resulting in supercooled water. In both cases, ice can accumulate when the supercooled rain freezes on contact with surfaces that are at or below the freezing point.

Severe ice storms may occur over several days, cover large geographic areas, and result in several centimeters of accumulated ice. Most storms, however, usually last only a few hours with minor ice accumulation and damage. The relative likelihood of ice storms that are most prevalent in the central, northeastern, and southeastern parts of the United States is illustrated in Figure 2. Within the eastern deciduous forests of North America these storms are among the most frequent forest disturbances.

The Susceptibility of Trees to Ice Storms

Trees are damaged during ice storms for a number of reasons. The severity of tree damage and failure of parts of or whole trees depends on three factors: amount of accumulated ice, exposure to wind, and duration of the storm. The susceptibility of tree species also involves tree characteristics: weak branch junctures indicated by included bark, decaying or dead branches, tree height and diameter, increased surface area of lateral branches, broad crowns, unbalanced crowns, restricted and unbalanced root systems, and shallow rooting (Figure 3).

Included bark results from in-grown bark in branch junctures. Trees have been reported to fail at the included region and it is believed this enhances a tree's susceptibility to breakage under ice-loading. As an example, the original 'Bradford' callery pear, has branches that often break during ice storms where there is included bark in branch junctures. In comparison, the 'Aristocrat' callery pear does not regularly form included branch attachments and infrequently is damaged during ice storm events. Dead branches and decayed wood are already weakened and have a greater probability of breaking when loaded with ice. The susceptibility of trees to ice storm damage is further increased when decay is located at an included bark location.

Tree architecture plays an important role in ice storm susceptibility. As the surface area of lateral branches increases, more ice can accumulate on lateral branches. Greater ice loading results in greater branch failure. Contrary to popular belief, the wood strength of sound branches matters less than the ability of a tree to withstand breakage at branch junctures and the presence of fine branching or a broad crown that enhances ice accumulation. Trees that develop broad crowns (decurrent branching) such as Siberian elm, American elm, hackberry, green ash, and honey locust are more susceptible to damage from ice accumulation. Also, trees near the edge of forests may develop unbalanced crowns. Ice accumulation on the side with more branches can lead to greater damage from ice accumulation.

Trees also have characteristics that reduce the likelihood of damage from ice storms. First, trees with a coarse branching structure have less ice accumulation and subsequently less loading and damage. Black walnut, catalpa, Kentucky coffeetree, and sweetgum are examples. Second, trees exhibiting a conical form (excurrent branching) also tend to have greater resistance to ice storms. Example conical form trees include spruce, bald cypress, larch, and ginkgo. Trees with sound wood and strong branch attachments also tend to resist ice storm damage compared to trees with decay and structural imperfections. Finally, small stature trees such as ironwood, blue beech, and service berry also are infrequently damaged.

Tree species vary in their susceptibility to ice storms (Table 2). Planting a diverse financial portfolio is a wise investment strategy. Planting a diverse urban forest is a likewise sound investment to increase your odds of long-term benefits that urban trees provide communities. Rather than avoiding susceptible tree species to ice storms, avoid creating the majority of your tree population with susceptible species. Also, minimize planting susceptible species near locations that damage to property and infrastructure would occur if a tree failed from an ice storm.

Ice Storm Management and Prevention

Management plans should be developed for the urban forest in locations prone to ice storm damage (Figure 2). Ideally plans should develop strategies to mitigate, prepare, respond, and recover from ice storms. First, regular tree care to remove structurally defective branches, formative pruning of young trees, and proper branch removal should foster greater ice storm resistance of the urban forest. Planting a diverse urban forest that incorporates ice storm resistant tree species is beneficial. Second, plans should be developed to prepare for ice storms. These plans formulate important details such as who will coordinate the response, mobilization agreements for tree work, communication channels, budgeting, prioritization of work, and points of contact. Response and recovery from ice storms can occur without a preparedness plan, yet such a plan can easily facilitate the response and recovery phases.

The third important step, responding, involves steps taken to move a community back towards normalcy. This involves steps including removing tree risks, clearing streets of brush, detailing brush pickup schedules, organizing brush removal with staging areas, repairing damage trees, and communicating your response message to the community. Recovery is the final component and involves the final steps to returning the community to normalcy. Important components involve evaluating damaged trees for their risk for failure or alternatively their likelihood for recovery, prioritizing tree repair, documenting recovery costs for possible state and federal funding, updating tree inventories for removed trees, and developing tree replacement plans

Conclusion

Ice storm frequency and severity within the eastern United States necessitates the incorporation of ice storm information into the urban forestry planning process. While we cannot stop ice storms from occurring, we can take steps to reduce the impact of this major forest disturbance on urban forests and the interface between forests, buildings, and infrastructure.

For Additional Information on Ice Storms and Trees

Burban, L.L. and J.W Andresen. 1994. Storms over the Urban Forest: Planning, Responding, and Regreening - A Community Guide to Natural Disaster Relief. Second Edition. USDA Forest Service, Northeastern Area. 152 pp. http://www.na.fs.fed.us/spfo/pubs/uf/sotuf/sotuf.htm

Changnon, S.A. 2003. Characteristics of ice storms in the United States. Journal of Applied Meteorology 42:630–639

Changnon, S.A. and J.M. Changnon. 2002. Major ice storms in the United States, 1949–2000. Environmental Hazards 4:105–111

Croxton, W.C. 1939. A study of the tolerance of trees to breakage by ice accumulation. Ecology 20:17–73

Harshberger, J.W. 1904. The relation of ice storms to trees. Contributions from the Botanical Laboratory of the University of Pennsylvania 2:345–349

Hauer, R.J., J.O. Dawson, and L.P. Werner. 2006. Trees and Ice Storms: The Development of Ice Storm-Resistant Urban Tree Populations, Second Edition. Joint Publication 06-1, College of Natural Resources, University of Wisconsin-Stevens Point and the Department of Natural Resources and Environmental Sciences and the Office of Continuing Education, University of Illinois at Urbana–Champaign 20 pp. http://web.extension.uiuc.edu/forestry/publications/pdf/urban_community_forestry/trees_and_ice_storms_2006.pdf

Hauer, R.J., W. Wang, and J.O. Dawson. 1993. Ice storm damage to urban trees. Journal of Arboriculture 19:187– 193

Illick, J.S. 1916. A destructive snow and ice storm. Forest Leaves 15(7):103–107

Jones, K.F. and N.D. Mulherin. 1998. An evaluation of the severity of the January 1998 ice storm in Northern New England. Report for FEMA Region 1. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory. Hanover, NH. 66 pp.

Kerry, M., G. Kelk, D. Etkin, I. Burton, and S. Kalhok. 1999. Glazed over: Canada copes with the ice storm of 1998. Environment 41(1):6–33 Lemon, P.C. 1961. Forest ecology of ice storms. Bulletin of the Torrey Botanical Club 88:21–29

Lott, J.N., and M.C. Sittel. 1996. The February 1994 ice storm in the Southeastern U.S. Proceedings, Seventh International Workshop on Atmospheric Icing of Structures, June 3–7, 1996, Saguenay-Lac-Saint-Jean, Quebec, Canada, University of Quebec at Chicoutimi, and Hydro-Quebec, Chicoutimi, Quebec, Canada. pp. 259–264

Pokorny, J.D. 2003. Urban Tree Risk Management: A Community Guide to Program Design and Implementation. NA-TP-03-03. USDA Forest Service, Northeastern Area, State and Private Forestry, St. Paul, MN, USA. 194 pp. http://www.na.fs.fed. us/spfo/pubs/uf/utrmm/index.htm

Rogers, W.E. 1924. Trees in a glaze storm. Tycos 14(1):4–8

Van Dyke, O. R.P.F. Landmark Consulting. 1999. A literature review of ice storm impacts on forests in Eastern North America. Ontario Ministry of Natural Resources Southcentral Sciences Section Technical Report #112. 28 pp. http://isfratt.eomf.on.ca/pubs. htm

von Schrenk, H. 1900. A severe sleetstorm. Transactions Saint Louis Academy of Science. 10:143–150

Table 1. Ice loading index and damage to trees and structures. (Modified from Jones and Mulherin 1998)

Freezing Rain Induced Event and Structural Damage Occurrence	**Increased Ice Accumulation**
Slippery roads	
Minor ice accumulation on trees	
Tree induced outages (communications and power distribution systems)	
Bending birch trees	
Broken branches on susceptible trees	
Characteristics: fine branching, included bark, unsound wood, broad or unbalanced crowns, old or injured trees	
Examples: poplars, soft maples, beeches, willows, trees at edges of a clearing or pruned on one side	
Outages to transmission lines caused by galloping (wind-induced)	
Broken branches on resistant trees	
Characteristics: coarse branching, excurrent branching pattern, narrow crowns, young, sound trees	
Examples: white oaks, black walnut, interior forest trees	
Outages, not caused by trees, in the distribution system	
Broken branches on resistant coniferous trees	
Outages, not caused by trees, in the transmission system	
Communication tower failures	

Note: Damage to trees and structures, in order of increasing ice load. High winds concurrent with the ice load increases the level of damage.

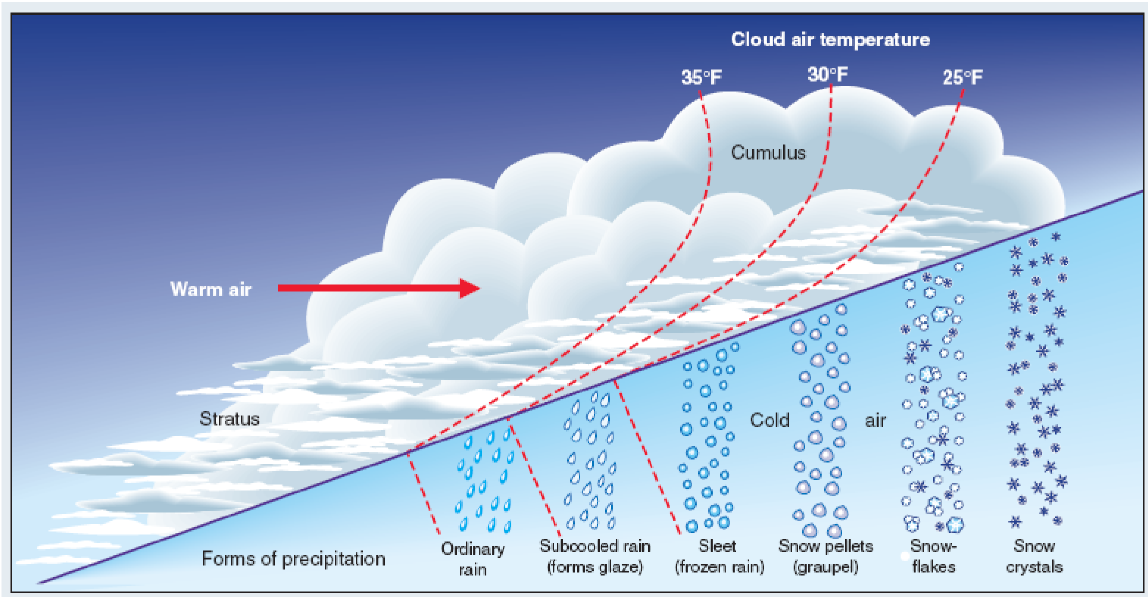

Figure 1. Forms of precipitation resulting from a warm air mass advancing over a cold air mass.

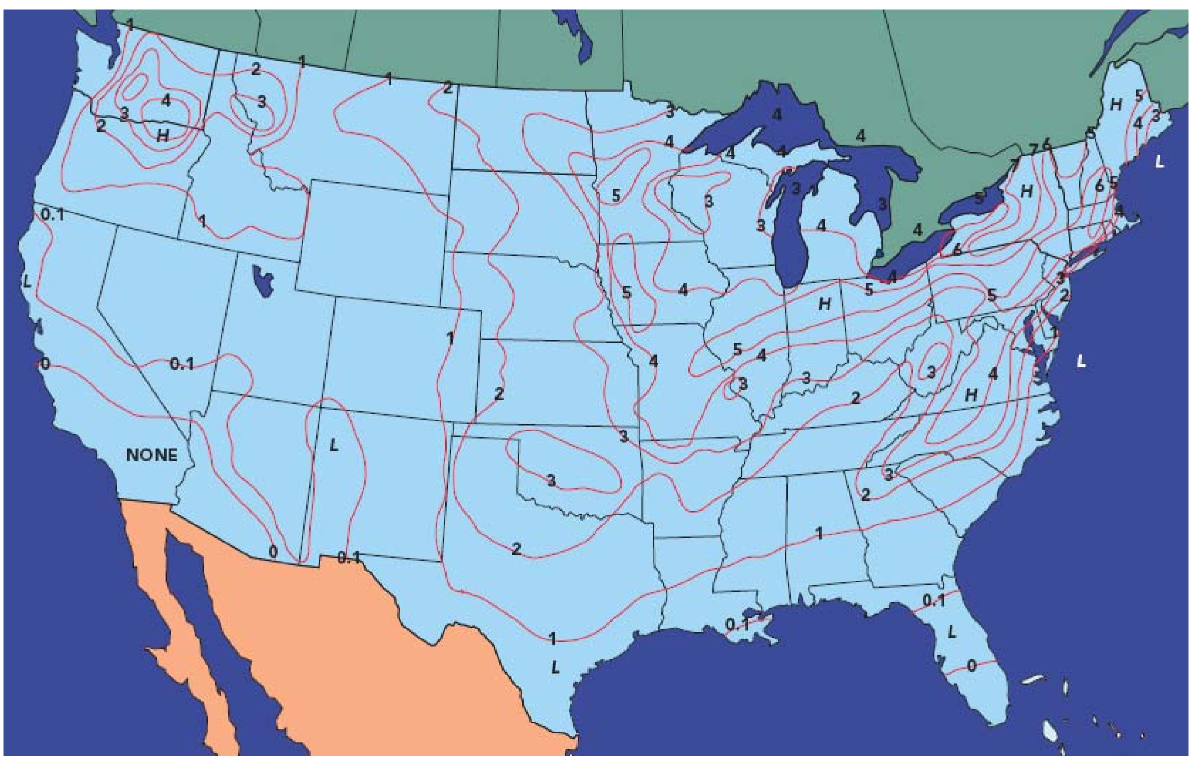

Figure 2. Annual mean number of days with freezing rain within the United States from 1948 and 2000, H = High and L = Low. (From Changnon 2003)

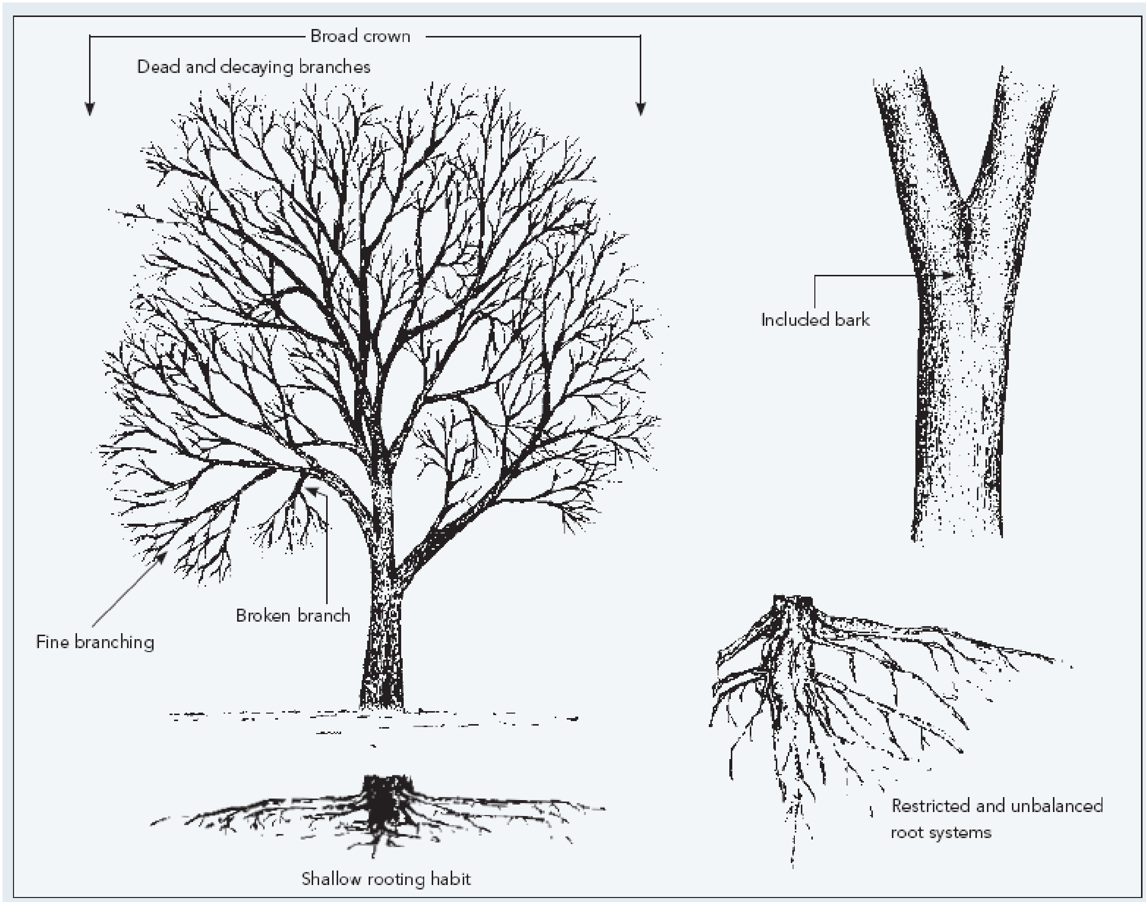

Figure 3. Tree characteristics that increase the susceptibility of trees to ice storm damage.

Table 2. Ice storm susceptibility of tree species found growing in urban areas.

Susceptible	**Intermediate**	**Resistant**
American basswood	American beech	Amur maple
American elm	Boxelder	Baldcypress
Bigtooth aspen	Chestnut oak	Balsam fir
Black ash	Choke cherry	Bitternut hickory
Black cherry	Douglas-fir	Black walnut
Black locust	Eastern white pine	Blackgum
Black oak	Gray birch	Blue beech
Bradford pear	Green ash	Bur oak
Butternut	Japanese larch	Catalpa
Common hackberry	Loblolly pine	Colorado blue spruce
Eastern cottonwood	Northern red oak	Crabapple
Honey locust	Paper birch	Eastern hemlock
Jack pine	Pin oak	Eastern redcedar
Pin cherry	Red maple	European larch
Pitch pine	Red pine	Ginkgo
Quaking aspen	Scarlet oak	Hophornbeam
Red elm	Scotch pine	Horsechestnut
River birch	Slash pine	Kentucky coffeetree
Siberian elm	Sourwood	Littleleaf linden
Silver maple	Sugar maple	Mountain ash
Virginia pine	Sycamore	Northern white cedar
Willow	Tamarack	Norway maple
	Tulip poplar	Norway spruce
	White ash	Ohio buckeye
	Yellow birch	Pignut hickory
		Shagbark hickory
		Swamp white oak
		Sweetgum
		White oak
		White spruce
		Witch-hazel
		Yellow buckeye

Adapted from Hauer et al. (1993) and published reports from 42 primary publications.