Species and stand response to catastrophic wind in central New England, U.S.A.

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Introduction

- Catastrophic wind damage from hurricanes has generated much of the recent structural pattern and dynamics of the upland forests in central New England.
- Catastrophic storms like those of 1635, 1788, 1815, and 1938 occur approximately every 100-150 years.
- The hurricane of 1938 was accompanied by winds in excess of 200 km h^{-1}.

Introduction

- Despite considerable attention to post-hurricane vegetation dynamics, the actual patterns of damage and their implications in terms of landscape processes and long-term vegetation change have been little studied.

- The present study seeks to understand vegetation change by assessing wind damage at the species, stand and landscape scale.

Introduction

1. to examine species differences in susceptibility to wind damage
2. to investigate the differential susceptibility of the major forest types as controlled by composition, age, height and density
3. to examine damage by strata within stands of different age and structural differentiation
4. to use this information to explain historical changes in vegetation structure and composition

Study area

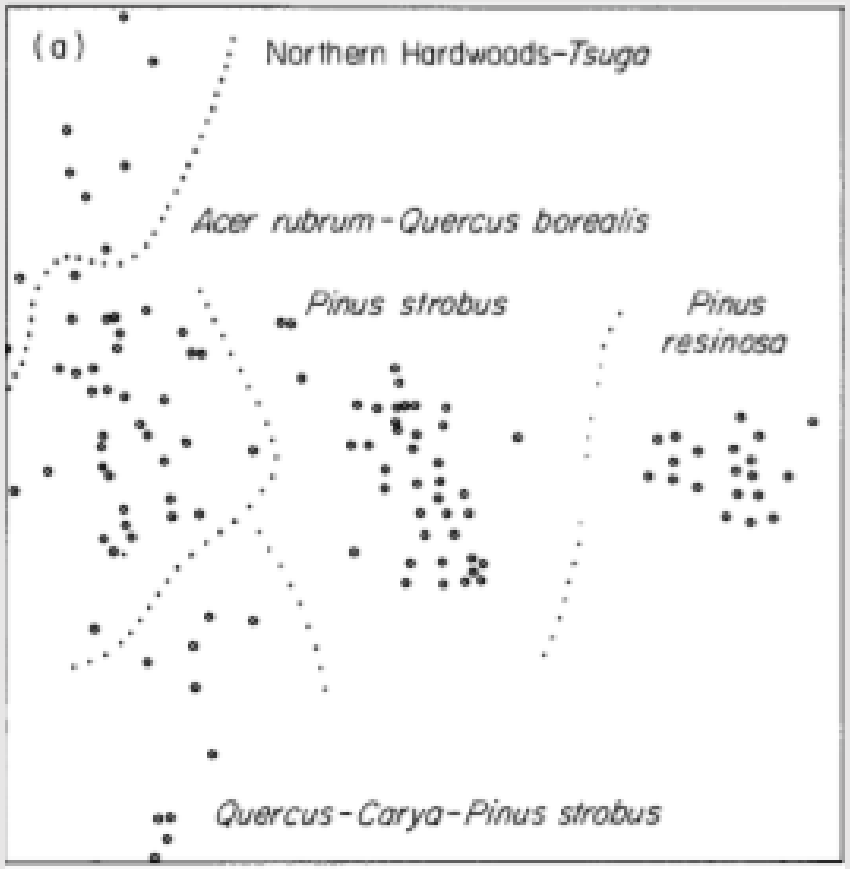
- Harvard forest in Petersham, Massachusetts (42˚30’N,72˚10’W)
- The transition Hardwood-White pine-Hemlock vegetation zone.
- The principle tree species include *Quercus borealis*(red oak), *Fraxinus Americana*(white ash), *Acer rubrum*(red maple), *Betula lenta*(black birch), *Tsuga canadensis*(hemlock) and *Fagus grandifolia*(beech).

Methods

- A total of 115 plots(0.04-0.10ha) were sampled
- Hardwoods forest…55%, conifer stands…45%
- Trees were tallied in each plot by species, height, canopy composition and damage class

Canopy composition	Damage class
Dominant	Standing
codominant	Leaning
Intermediate	Uprooted
suppressed	broken

Results –vegetation typed-



Five major vegetation types

1. *Pinus resinosa*
2. *Pinus strobus*
3. *Quercus-Carya-Pinus strobus*
4. *Acer rubrum- Quercus borealis*
5. Northern Hardwood-*Tsuga*

Results –vegetation types-

TABLE 1. Relative density of tree species in the five forest types sampled in the study area in 1937.

	Pinus resinosa	*Pinus strobus*	*Quercus–Carya–Pinus strobus*	*Acer rubrum–Quercus borealis*	Northern Hardwoods–*Tsuga*
Picea abies	0·03				
Picea glauca	0·14				
Pinus resinosa	0·82	0·02			
Prunus pensylvanica		0·01		0·01	
Betula populifolia		0·01	0·01	0·03	
Pinus strobus	0·01	0·90	0·17	0·08	0·02
Carya spp.			0·21	0·03	
Quercus velutina			0·23	0·05	
Populus tremuloides			0·03	0·02	
Fraxinus americana			0·01	0·07	0·20
Quercus alba		0·01	0·20	0·09	0·03
Acer rubrum		0·02	0·08	0·16	0·11
Quercus borealis		0·01	0·06	0·23	0·12
Betula lenta		0·01		0·04	0·11
Betula papyrifera		0·01		0·07	0·13
Betula lutea				0·04	0·15
Acer saccharum				0·03	0·01
Tsuga canadensis				0·02	0·10

Results –stand damage-

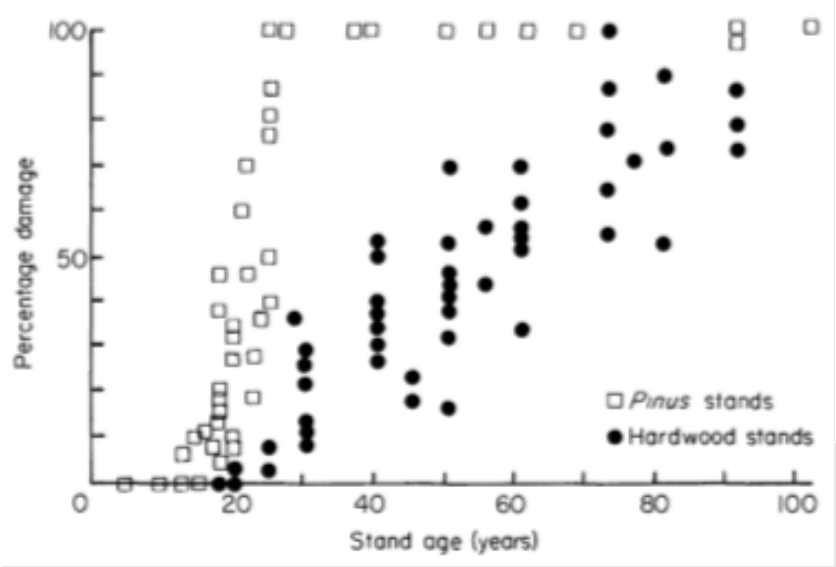
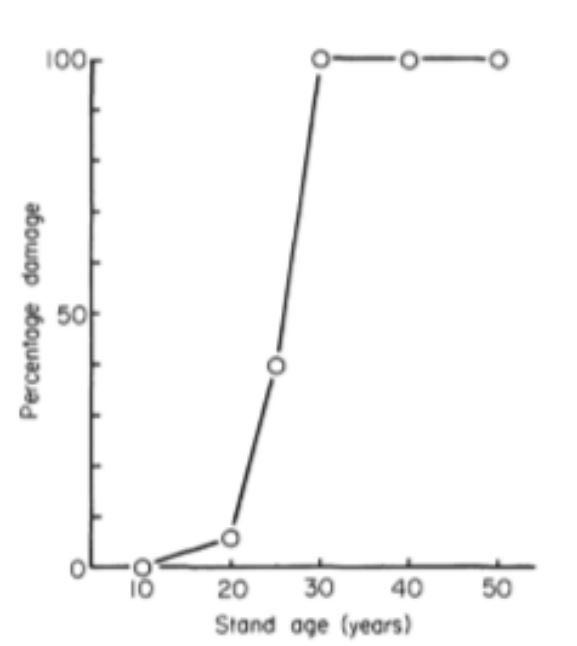


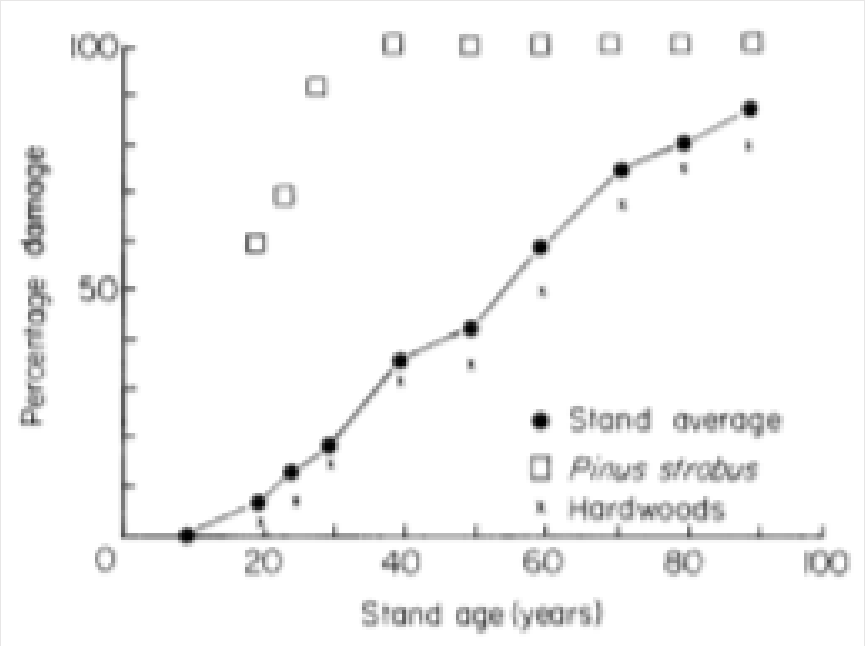
TABLE 2. Coefficients of determination of damage on stand age, height and density for the major vegetation types sampled in the study area in 1938. The highest r^2 is underlined. Significance values are given as: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Forest type (number of stands)	Age	Height	Density
Pinus resinosa (20)	0·46***	0·43**	0·002
Pinus strobus (41)	0·66***	0·63***	0·48***
Quercus–Carya–Pinus strobus (10)	0·71**	0·43*	0·65**
Acer rubrum–Quercus borealis (35)	0·44***	0·43***	0·27*
Northern Hardwoods–*Tsuga* (9)	0·56*	0·54*	0·44*
Hardwoods stands (54)	0·60***	0·46**	0·41*
Conifer stands (61)	0·61***	0·58***	0·05

- In all forest types damage exhibits a positive linear relationship with stand age, and height, and negative relationship with stand density.

Results –stand damage-

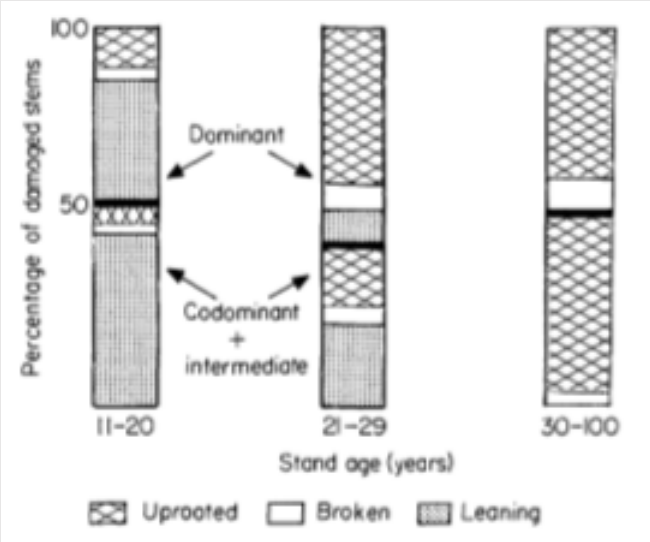




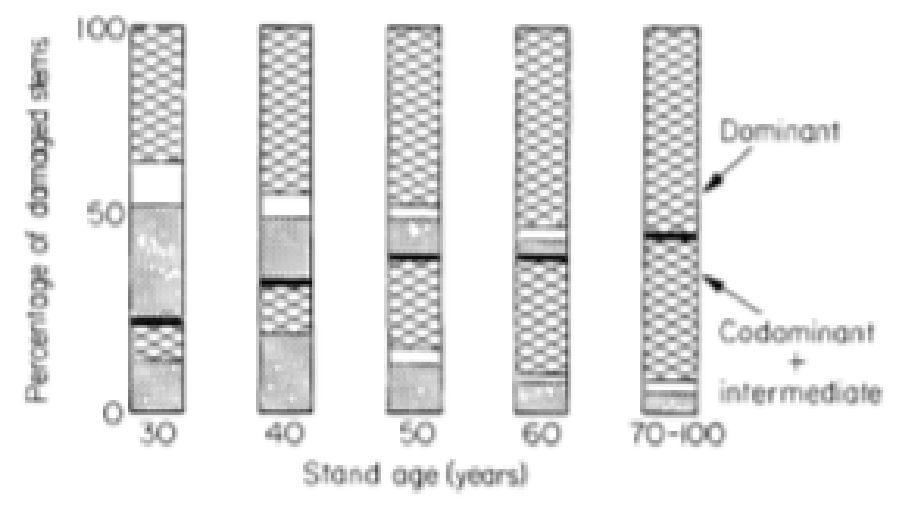
- *Quercus-Carya-Pinus strobs* appeared somewhat more susceptible than other stands, largely as a consequence of selective damage to *Pinus strobus*, which forms an emergent canopy over the hardwoods.

Results –type of damage-

Pinus strobus



Acer rubrum-Quercus borealis



- *Pinus strobus* vs *Acer rubrum-Quercus borealis*
- *Pinus strobus*: leaning→break age&uprooting
- *Acer-Quercus*: dominant→codominant&intermediate
  leaning→uprooting

Results –species damage-

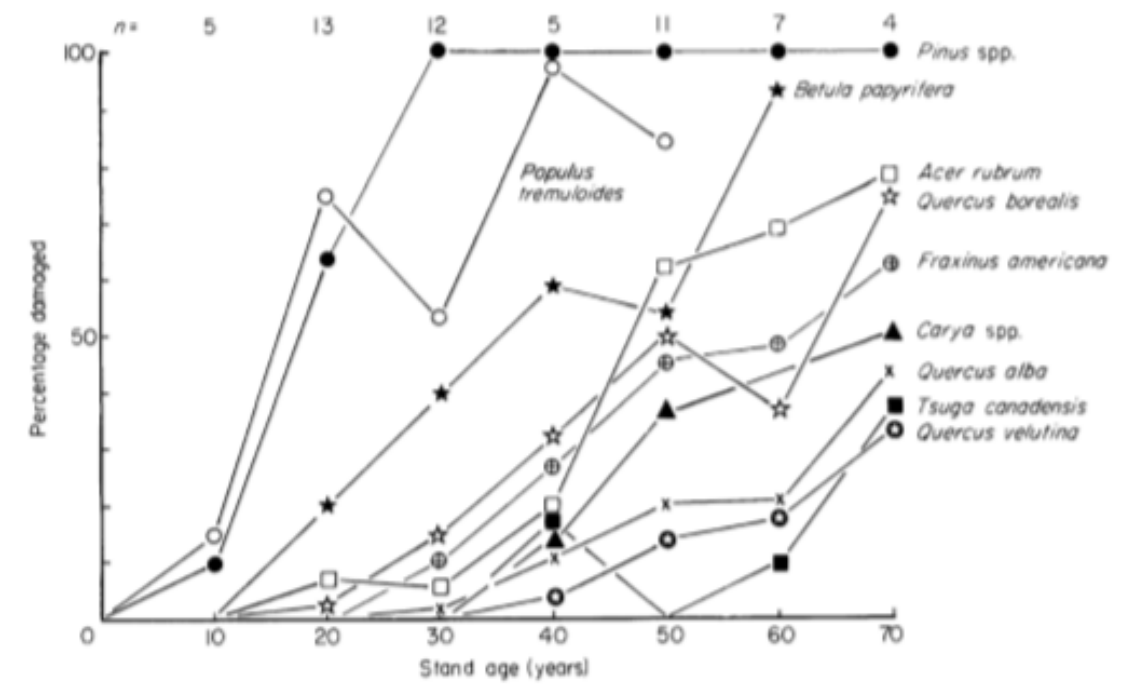
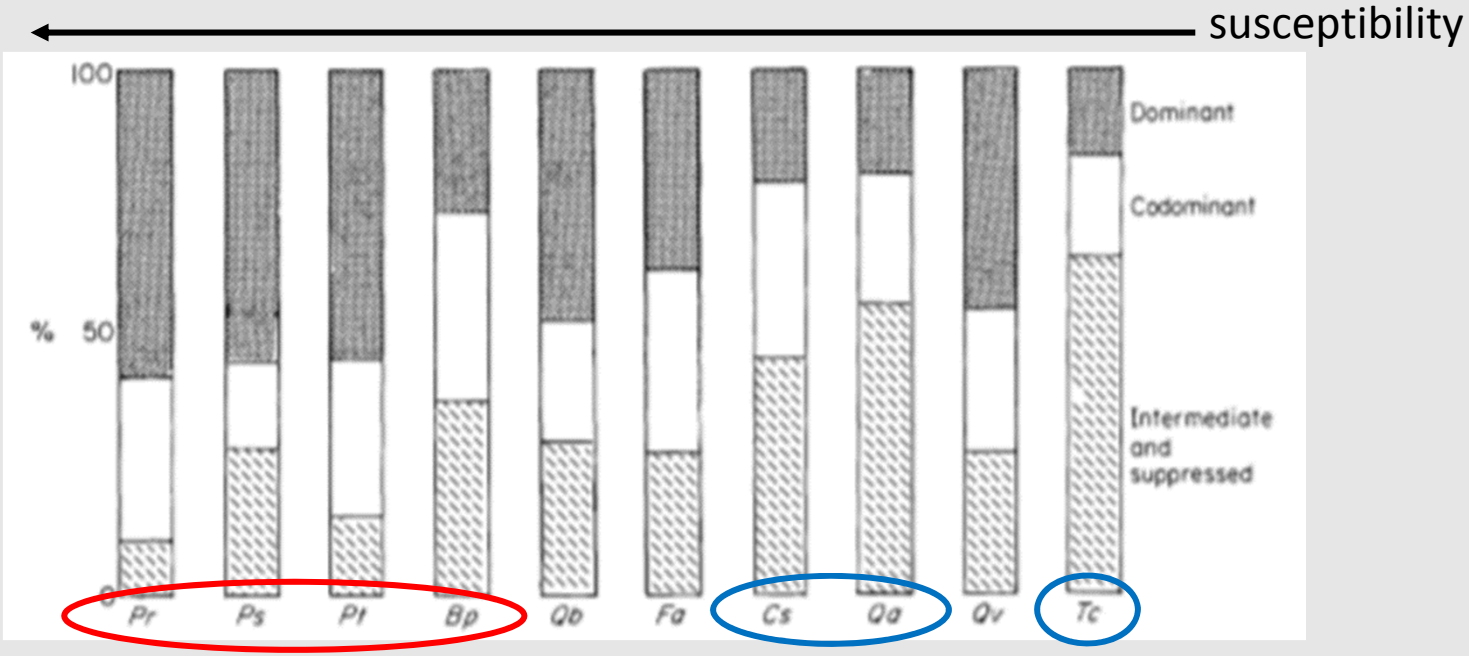


FIG. 8. Relationship between age and average percentage damage of the important tree species in all the plots following the 1938 hurricane at the Harvard Forest.

Pinus spp. > *Populus* > *Betula payrifera* > *Acer rubrum* > *Quercus borealis* and *Fraxinus Americana* > *Carya* spp., *Quercus alba*, *Q. velutina* and *Tsuga canadensis*

Discussion -species level response -



Rapidly growing,
shade-intolerant species
→occupied dominant positions
→exposed to the wind

Slower growing,
more shade-tolerant species
→occupied subordinate positions
→protected from the wind

Discussion –stand level response-

- Stand differences in response to wind appear to be adequately explained by an understanding of species susceptibilities and their relative density in the various forest types.

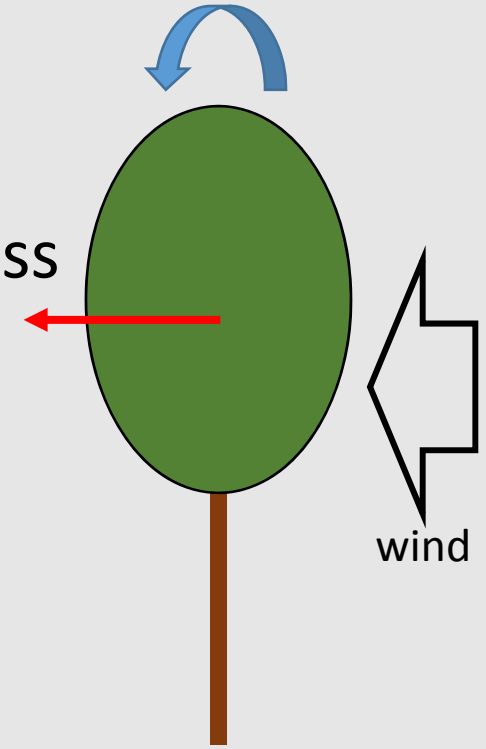
- For example, *Pinus strobus*, the most susceptible species, exhibits a similar damage curve in all types of stands.

- This consistent susceptibility of *Pinus strobus* occurred because it had a dominant canopy position.

Discussion -stand level response-

- Damage exhibited an approximately linear response with stand age.

1. Increasing the length of the turning moment
2. Increasing the canopy size
3. greater wind speed at taller heights
4. increasing the canopy surface roughness



Discussion –stand level response-

- When stand damage is slight, injury to subordinate trees occurs primarily through crushing and therefore depends on their placement relative to the windthrown overstorey trees.

- As overstorey damage and gap size increase the probability of direct damage to subordinates by wind increases.

Discussion -Forest damage and landscape processes-

- Within stands the selective removal of tree species in 1938 produced significant compositional changes.

Pinus strobus & *Pinus*-Hardwood forests

→Hardwood & Hardwood-*Tsuga* forest

1. Selective removal of Pinus in mixed stands
2. Differential destruction of conifer vs hardwood stands
3. The greater ability of hardwoods to revegetate sites through vegetative reproduction and rapid growth rate.

Summary

- Species susceptibility to wind is largely explained by canopy position. (fast-growing→greater damage)
- Damage to forest stands exhibits a positive, linear relationship with stand age and height and negative relationship with density.
- Within stands, damage shifts from the dominant trees in young stands to include trees in the codominant, intermediate and suppressed layers in older forests.