Supplementary Material

Nitrogen fertilization increases wind damage in an aggrading forest

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Figure S1. Total inorganic nitrogen wet deposition from nitrate and ammonium at National Atmospheric Deposition Program (NADP) station WV18 in Parsons, WV, USA (adjacent to Fernow). Points represent annual weighted mean nitrogen concentrations – blue points indicate when the NADP quality control criteria were met and red points indicate when criteria were not met. The trend line is a three year moving average with a resolution of one year. Data and visualization generated from the NADP database (http://nadp.slh.wisc.edu).

Table S1. Tree species composition by percentage of stems and percentage of basal area (BA)
across three treatments in the LTSP experiment. Data is from pre-disturbance measurements i	n
2009 from Fowler et al. 2014.	

	Treatment						
-	Reference			+N		+N+L	
Species	<u>% BA</u>	% Stems	<u>% BA</u>	% Stems	<u>% BA</u>	% Stems	
Acer pensylvanicum	1.9	5.1	0.5	2.0	1.3	4.4	
Acer rubrum	1.4	2.4	3.6	7.6	3.0	5.2	
Acer saccharum	0.1	0.2	0.0	0.0	0.5	2.5	
Aralia spinosa	1.0	1.4	0.8	2.3	1.4	3.3	
Betula alleghaniensis	0.3	0.1	0.0	0.0	0.0	0.0	
Betula lenta	20.4	25.3	6.2	13.6	2.9	8.1	
Caprinus Caroliniana	0.2	0.4	0.2	0.7	0.3	0.7	
Fraxinus americana	0.3	1.0	0.0	0.0	0.0	0.0	
llex ambigua ambigua	0.0	0.0	0.0	0.0	0.0	0.1	
Liriodendron tulipifera	15.9	20.0	3.4	10.3	11.6	16.0	
Magnolia acuminata	2.3	1.4	0.2	0.5	1.1	1.0	
Magnolia fraseri	0.2	0.4	1.9	3.2	0.0	0.1	
Ostrya virginiana	0.1	0.2	0.0	0.1	0.4	1.5	
Oxydendrum arboreum	0.0	0.0	0.1	0.2	0.0	0.0	
Prunus pensylvanica	47.5	29.1	75.0	46.2	68.7	41.4	
Prunus serotina	4.9	8.2	6.3	9.9	4.6	9.7	
Quercus prinus	0.1	0.2	0.0	0.0	0.0	0.2	
Quercus rubra	1.4	2.5	0.6	1.8	0.7	2.2	
Robinia psuedoacacia	2.0	1.8	0.8	0.7	3.0	2.5	
Sassafras albidum	0.1	0.2	0.2	0.8	0.0	0.1	
Tilia americana	0.0	0.0	0.0	0.1	0.4	0.9	

Table S2. Species-specific hypotheses for storm damage based on published traits and responses to nitrogen and lime in fertilization and gradient studies.

Hypothesized damage outcome (relative to reference	Traits that could affect storm damage	Common name	Species
More damage in +N and +N+	Congener of Betula allegheniensis, which grows more	Sweet birch	Betula lenta
	vigorously on N-fertilized sites (*)		
Less damage in +N and +N+	Diminished growth on N-fertilized site (52)	Tulip poplar	Liriodendron tulipifera
Less damage in +N and +N+	Decreased wood density on N-fertilized site (53)		
Greater relative to other spp., and greater in +I	Shallow rooting depth and tall stature (48)	Black cherry	Prunus pensylvanica
Greater in +N+I	Diminished growth on sites with more base cations (49)		
Greater in +N+L	Diminished growth on lime-fertilized site (50)		
Greater relative to other spp., and greater in +I	Noncommercial species with relatively little information,	Pin cherry	Prunus serotina
Greater in +N+I	but congener of P. serotina		
Greater in +N+I			

Numbers in parentheses indicate reference number in manuscript, and * indicates the following reference:

Burns, Russell M., and Barbara H. Honkala, tech. coords. 1990. Silvics of North America: 2. Hardwoods; Agriculture Handbook 654. U.S. Department of Agriculture, Forest Service, Washington, DC. vol.2, 877 p.

Table S3. Results for 51 bootstrap hypothesis tests across species group, damage type, and damage severity as either percentage of stems or basal area of trees damaged from the 2009 windstorm. Comparison denotes the direction of the one-tailed test between treatments and p is the bootstrap p-value. p_{B-H} is the Benjamini-Hochberg adjusted p-value – an estimate of the false positive rate of all positive hypothesis tests from rank 1, up to and including that tests' rank.

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DefinitionThe transmissionThe t	B. lenta	All	All	Stems	+N < Ref	0.072	25	0.147		
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L tulipiferaAllAllBasal area+N> Ref0.112280.196L tulipiferaAllAllBasal area+N> Ref0.112280.196AllSnapAllStems+N> +N+L0.114290.196AllBentAllStems+N> +N+L0.116300.196P. serotinaAllAllBasal area+N< +N+L	L. tulinifera	All	All	Basal area	+N+I < Ref	0.102	27	0.193		
L tampyerAllStems+N> ket0.114290.196AllSnapAllStems+N> ket0.114290.196AllBentAllStems+N> Ref0.116300.196P. serotinaAllAllBasal area+N< +N+L	L. tulinifera	All	All	Basal area	+N > Ref	0.112	28	0.196		
AllBentAllStems+N> Ref0.116300.196P. serotinaAllAllBasal area+N< +N+L	All	Snan	All	Stems	+N > +N+I	0.114	29	0.196		
AllAllBealH $<$ HelOlloSoOlloP. serotinaAllAllBasal area $+N$ $<$ HelOlloSoOlloB. lentaAllAllStems $+N$ $<$ H+LOlloSoOlloSoP. PensylvanicaAllAllStems $+N$ $<$ H+LOlloSoOlloSoOlloB. lentaAllAllStems $+N$ $<$ H+LOlloSoOlloSoOlloB. lentaAllAllBasal area $+N$ $<$ H+LOlloSoOlloSoOlloB. lentaAllAllBasal area $+N$ $<$ HefOlloSoOlloSoOlloAllAllBasal area $+N$ $<$ HefOlloSoOlloSoOlloOlloAllAllSignificantStems $+N$ $>$ HefOlloSoOlloSoOlloAllAllAllStems $+N$ $>$ RefOlloSoOlloSoOlloOlloAllAllAllBasal area $+N + L$ $<$ RefOlloSoOlloOlloOlloOlloP. PensylvanicaAllAllAllBasal area $+N + L$ $<$ RefOlloAllOlloOlloB. lentaAllAllAllBasal area $+N + L$ $<$ RefOlloAllOlloOlloB. lentaAll <td></td> <td>Bent</td> <td></td> <td>Stems</td> <td>+N > Ref</td> <td>0.116</td> <td>30</td> <td>0.196</td>		Bent		Stems	+N > Ref	0.116	30	0.196		
B. lentaAllAllStems $+N < +N+L$ 0.125 5.2 0.257 B. lentaAllAllStems $+N < +N+L$ 0.158 32 0.252 P. PensylvanicaAllAllStems $+N < +N+L$ 0.170 33 0.262 B. lentaAllAllBasal area $+N < +N+L$ 0.170 33 0.262 B. lentaAllAllBasal area $+N < +N+L$ 0.170 33 0.262 B. lentaAllAllBasal area $+N < +N+L$ 0.236 35 0.344 P. PensylvanicaAllAllBasal area $+N > +N+L$ 0.236 35 0.344 P. PensylvanicaAllAllBasal area $+N > +N+L$ 0.253 36 0.393 P. PensylvanicaAllAllBasal area $+N > Ref$ 0.290 37 0.393 P. PensylvanicaAllAllBasal area $+N > Ref$ 0.296 38 0.393 B. lentaAllAllBasal area $+N + L > Ref$ 0.301 39 0.393 B. lentaAllAllBasal area $+N + L < Ref$ 0.360 42 0.447 AllBentAllStems $+N + L < Ref$ 0.360 42 0.437 AllBentAllStems $+N + L < Ref$ 0.360 42 0.437 AllAllBasal area $+N < +N+L < Ref$ 0.413 44 0.479 P. Pensylvanica </td <td>P serotina</td> <td>All</td> <td></td> <td>Basal area</td> <td>+N < +N+I</td> <td>0.126</td> <td>31</td> <td>0.207</td>	P serotina	All		Basal area	+N < +N+I	0.126	31	0.207		
P. PensylvanicaAllAllStems $+N < +N+L$ 0.120 32 0.262 B. lentaAllAllAllBasal area $+N < +N+L$ 0.170 33 0.262 B. lentaAllAllAllBasal area $+N < +N+L$ 0.205 34 0.308 AllAllAllExtensiveStems $+N < +N+L$ 0.226 35 0.344 P. PensylvanicaAllAllBasal area $+N < +N+L$ 0.226 35 0.344 P. PensylvanicaAllAllSignificantStems $+N > +N+L$ 0.226 36 0.359 AllAllAllSignificantStems $+N > Ref$ 0.290 37 0.393 P. PensylvanicaAllAllBasal area $+N + > Ref$ 0.296 38 0.393 P. PensylvanicaAllAllBasal area $+N + < Ref$ 0.301 39 0.393 B. lentaAllAllBasal area $+N + < Ref$ 0.360 42 0.440 B. lentaAllAllBasal area $+N + < Ref$ 0.360 42 0.437 AllBentAllStems $+N + < Ref$ 0.379 43 0.449 AllTipupAllStems $+N + < Ref$ 0.440 45 0.499 AllTipupAllStems $+N < < Ref$ 0.440 45 0.499 LtulipiferaAllAllStems $+N < < Ref$ <	B. lenta	All	All	Stems	+N < +N+I	0.158	32	0.252		
B. lentaAllAllBasal area+N< Ref0.205340.308AllAllAllExtensiveStems+N< Ref	P. Pensylvanica	All	All	Stems	+N < +N+I	0.170	33	0.262		
AllAllExtensiveStems $+N$ $+N+L$ 0.236 35 0.344 $P.$ PensylvanicaAllAllAllBasal area $+N$ $+N+L$ 0.236 35 0.344 $P.$ PensylvanicaAllAllAllBasal area $+N$ $+N+L$ 0.253 36 0.359 All AllSignificantStems $+N$ $+N+L$ 0.296 38 0.393 $P.$ PensylvanicaAllAllAllStems $+N$ $>$ Ref 0.296 38 0.393 $P.$ PensylvanicaAllAllAllBasal area $+N + L$ $>$ Ref 0.301 39 0.393 $B.$ lentaAllAllBasal area $+N + L$ $>$ Ref 0.301 39 0.393 $B.$ lentaAllAllBasal area $+N + L$ $<$ Ref 0.344 0.440 $B.$ lentaAllAllBasal area $+N + L$ $<$ Ref 0.360 42 0.437 All BentAllStems $+N + L$ $<$ Ref 0.360 42 0.437 $B.$ lentaAllAllStems $+N + L$ $<$ Ref 0.360 42 0.437 All BentAllStems $+N + L$ $<$ Ref 0.379 43 0.449 All AllAllBasal area $+N < +N + L$ 0.413 44 0.479 $P.$ PensylvanicaAllAllAllStems $+N < Ref$ 0.440 <td>B. lenta</td> <td>All</td> <td>All</td> <td>Basal area</td> <td>+N < Ref</td> <td>0.205</td> <td>34</td> <td>0.308</td>	B. lenta	All	All	Basal area	+N < Ref	0.205	34	0.308		
P. PensylvanicaAllAllBasal area+N< +N+L 0.253 36 0.359 AllAllSignificantStems+N> Ref 0.290 37 0.393 P. PensylvanicaAllAllSignificantStems+N> Ref 0.296 38 0.393 P. PensylvanicaAllAllAllStems+N> Ref 0.296 38 0.393 P. PensylvanicaAllAllAllBasal area+N+L> Ref 0.301 39 0.393 B. lentaAllAllBasal area+N+L> Ref 0.345 40 0.440 B. lentaAllAllBasal area+N+L< Ref	+N+L< Ref	< Ref	All	All	Extensive	Stems	+N > +N+I	0.236	35	0.344
AllAllSignificantStems $+N > Ref$ 0.290 37 0.393 AllAllAllStems $+N > Ref$ 0.296 38 0.393 P. PensylvanicaAllAllAllStems $+N > Ref$ 0.296 38 0.393 P. PensylvanicaAllAllAllBasal area $+N+L > Ref$ 0.301 39 0.393 B. lentaAllAllAllBasal area $+N+L > Ref$ 0.301 39 0.393 B. lentaAllAllBasal area $+N+L < Ref$ 0.355 41 0.440 B. lentaAllAllBasal area $+N < +N+L$ 0.355 41 0.437 AllBentAllStems $+N+L < Ref$ 0.360 42 0.437 B. lentaAllAllStems $+N+L < Ref$ 0.379 43 0.449 AllTipupAllStems $+N < +N+L$ 0.413 44 0.479 P. PensylvanicaAllAllAllBasal area $+N < +N+L$ 0.413 44 0.479 P. PensylvanicaAllAllAllStems $+N < Ref$ 0.440 45 0.499 L tulipiferaAllAllAllStems $+N < Ref$ 0.467 47 0.507 AllAllModerateStems $+N < Ref$ 0.467 47 0.507 AllAllAllModerateStems $+N < Ref$ 0.469 4	P. Pensylvanica	All	All	Basal area	+N < +N+I	0.253	36	0.359		
P. PensylvanicaAllStems $+N$ $>$ Ref 0.296 38 0.393 P. PensylvanicaAllAllAllBasal area $+N+L$ $>$ Ref 0.296 38 0.393 P. PensylvanicaAllAllAllBasal area $+N+L$ $>$ Ref 0.301 39 0.393 B. lentaAllAllAllBasal area $+N+L$ $<$ Ref 0.345 40 0.440 B. lentaAllAllBasal area $+N$ $<$ $+N+L$ 0.355 41 0.437 AllBentAllStems $+N+L$ $<$ Ref 0.360 42 0.437 B. lentaAllAllStems $+N+L$ $<$ Ref 0.379 43 0.449 AllTipupAllStems $+N+L$ $<$ Ref 0.413 44 0.479 P. PensylvanicaAllAllBasal area $+N$ $<$ Hv+L 0.413 44 0.479 P. PensylvanicaAllAllBasal area $+N$ $<$ Ref 0.440 45 0.499 L tulipiferaAllAllStems $+N$ $<$ Ref 0.467 47 0.507 AllAllModerateStems $+N$ $<$ Ref 0.469 48 0.495 AllAllAllBasal area $+N$ $<$ Ref 0.467 47 0.507 AllAllAllBasal area $+N$ $<$ Ref 0.467 47 0.507 <tr< td=""><td></td><td>All</td><td>Significant</td><td>Stems</td><td>+N > Ref</td><td>0.290</td><td>37</td><td>0.393</td></tr<>		All	Significant	Stems	+N > Ref	0.290	37	0.393		
P. Pensylvanica All All Basal area $+N+L > Ref$ 0.1250 300 0.393 P. Pensylvanica All All All Basal area $+N+L > Ref$ 0.301 39 0.393 B. lenta All All All Basal area $+N+L < Ref$ 0.305 400 0.440 B. lenta All All Basal area $+N + L < Ref$ 0.360 42 0.437 All Bent All Stems $+N+L < Ref$ 0.360 42 0.437 B. lenta All All Stems $+N+L < Ref$ 0.360 42 0.437 B. lenta All All Stems $+N+L < Ref$ 0.379 43 0.449 All Tipup All Stems $+N < Ref$ 0.413 44 0.479 P. Pensylvanica All All Basal area $+N < Ref$ 0.440 45 0.499 L tulipifera All All Stems $+N < Ref$ 0.467 47 0.507	P. Pensylvanica			Stems	+N > Ref	0.296	38	0.393		
B. lentaAllAllBasal area $+N+L < Ref$ 0.361 35 0.535 B. lentaAllAllAllBasal area $+N+L < Ref$ 0.345 40 0.440 B. lentaAllAllBasal area $+N < +N+L$ 0.355 41 0.437 AllBentAllAllStems $+N+L < Ref$ 0.360 42 0.437 B. lentaAllAllStems $+N+L < Ref$ 0.360 42 0.437 B. lentaAllAllStems $+N+L < Ref$ 0.379 43 0.449 AllTipupAllStems $+N < Ref$ 0.413 44 0.479 P. PensylvanicaAllAllBasal area $+N < Ref$ 0.440 45 0.499 L tulipiferaAllAllSignificantStems $+N < Ref$ 0.467 47 0.507 AllAllModerateStems $+N < Ref$ 0.467 47 0.507 AllAllAllBasal area $+N < Ref$ 0.467 47 0.507 AllAllAllBasal area $+N < Ref$ 0.467 47 0.507 AllAllAllBasal area $+N < Ref$ 0.467 49 0.495 AllAllAllBasal area $+N < N+L < Ref$ 0.467 49 0.495 AllAllAllBasal area $+N < N+L < Ref$ 0.467 49 0.495 AllAll <td>P. Pensylvanica</td> <td></td> <td></td> <td>Basal area</td> <td>+N+I > Ref</td> <td>0.301</td> <td>39</td> <td>0.393</td>	P. Pensylvanica			Basal area	+N+I > Ref	0.301	39	0.393		
B. lenta All All Basal area $+N < +N+L$ 0.345 40 0.437 B. lenta All All Basal area $+N < +N+L$ 0.355 41 0.437 All Bent All Stems $+N+L < Ref$ 0.360 42 0.437 All Bent All Stems $+N+L < Ref$ 0.360 42 0.437 B. lenta All All Stems $+N+L < Ref$ 0.360 42 0.437 B. lenta All All Stems $+N+L < Ref$ 0.360 42 0.437 B. lenta All All Stems $+N+L < Ref$ 0.413 0.449 All All All Basal area $+N < +N+L$ 0.413 44 0.479 P. Pensylvanica All All Basal area $+N < Ref$ 0.440 45 0.499 L tulipifera All All Stems $+N < Ref$ 0.467 47 0.507 All All Moderate S	R lenta			Basal area	+N+L < Ref	0.345	40	0.440		
Dr. Ichta All All Distantical IN $C, N+L$ O, S, S, J $(A, C, N+L)$ (A, S, S, S) (A, L) $(A,	B lenta			Basal area	+N < +N+I	0.355	40	0.440		
All All All Stems $NVE < Ref$ 0.300 42 0.439 B. lenta All All Stems $+N+L < Ref$ 0.379 43 0.449 All Tipup All Stems $+N + L < Ref$ 0.413 44 0.479 P. Pensylvanica All All Basal area $+N < Ref$ 0.440 45 0.499 L tulipifera All All Basal area $+N < Ref$ 0.440 45 0.499 All All Significant Stems $+N < Ref$ 0.440 45 0.499 All All Moderate Stems $+N < Ref$ 0.467 47 0.507 All All Moderate Stems $+N < Ref$ 0.469 48 0.495 All All All Basal area $+N < Ref$ 0.469 49 0.495 All All All Basal area $+N < +N+L$ 0.487 0.497 All All All Stems	All	Bent		Steme	+N+I < Ref	0.355	42	0.437		
D. Lendu All All Stems $HVE < HeI$ 0.375 43 0.479 All Tipup All Stems $+N < +N+L$ 0.413 44 0.479 P. Pensylvanica All All Basal area $+N < Ref$ 0.440 45 0.499 L. tulipifera All All Basal area $+N < Ref$ 0.440 45 0.499 L. tulipifera All All Stems $+N < Ref$ 0.467 47 0.507 All All Significant Stems $+N < Ref$ 0.469 48 0.495 All All Moderate Stems $+N < Ref$ 0.469 48 0.495 All All All Basal area $+N < Ref$ 0.469 48 0.495 All All All Basal area $+N < +N+L$ 0.476 49 0.495 All All All Stems $+N < +N+L$ 0.487 50 0.497	B lenta	All		Stems	+N+L < Ref	0.300	42	0.437		
AllInputAllStems $+N$ $<$ Ref 0.413 44 0.473 P. PensylvanicaAllAllAllBasal area $+N$ $<$ Ref 0.440 45 0.499 L. tulipiferaAllAllAllStems $+N$ $>$ Ref 0.440 45 0.499 AllAllAllSignificantStems $+N$ $>$ Ref 0.467 47 0.507 AllAllModerateStems $+N$ $<$ Ref 0.469 48 0.495 AllAllAllBasal area $+N$ $<$ Hv+L 0.476 49 0.495 AllAllAllStems $+N$ $<$ Hv+L 0.487 50 0.497 AllAllAllStems $+N$ $<$ Hv+L 0.487 50 0.497	All	Tinun		Stems		0.375	45	0.445		
L. tulipiferaAllAllStems $+N$ Ref 0.440 45 0.450 AllAllAllStems $+N$ Ref 0.458 46 0.507 AllAllSignificantStems $+N+L$ Ref 0.467 47 0.507 AllAllModerateStems $+N+L$ Ref 0.469 48 0.495 AllAllModerateStems $+N$ $<$ Ref 0.469 48 0.495 AllAllAllBasal area $+N$ $<$ $+N+L$ 0.476 49 0.495 AllAllAllStems $+N$ $<$ $+N+L$ 0.487 50 0.497	D Densulvanica			Bacal area	+N < Pef	0.415	44	0.475		
L tampieraAllAllSterns $+N + L > Ref$ 0.436 40 0.507 AllAllSignificantStems $+N+L > Ref$ 0.467 47 0.507 AllAllModerateStems $+N < Ref$ 0.469 48 0.495 AllAllAllBasal area $+N < +N+L$ 0.476 49 0.495 AllAllAllStems $+N < +N+L$ 0.476 49 0.495 AllAllAllStems $+N < +N+L$ 0.487 50 0.497	L tulinifera			Stome	+N > Ref	0.440	45	0.455		
All All Moderate Stems +N < Ref 0.467 47 0.507 All All Moderate Stems +N < Ref			Significant	Stems	+N+I > Pof	0.450	40	0.507		
All All All Basal area +N < +N+L 0.495 48 0.495 All All All Basal area +N < +N+L			Moderate	Stems	+N < Pof	0.460	4/	0.307		
All All Basararea Fix C + N+L 0.476 49 0.495 All All All Stems +N < +N+L			All	Basal area	+N < +N+I	0.405	-+0	0.455		
All All Significant Stores (N. 4 Mill 0.601 51 0.601				Stome		0.470	45	0.495		
AU AU NUMBER OF AUTO SUMME AN CANAL UNST ST DAU	All	All	Significant	Stems	+N < +N+I	0.691	51	0.691		