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Recent Advances in Critical Loads Research for the U.S.: Synthesizing tree CLs

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*The views expressed are those of the author(s) and do not represent official policy of the US EPA.

Merger of two large studies

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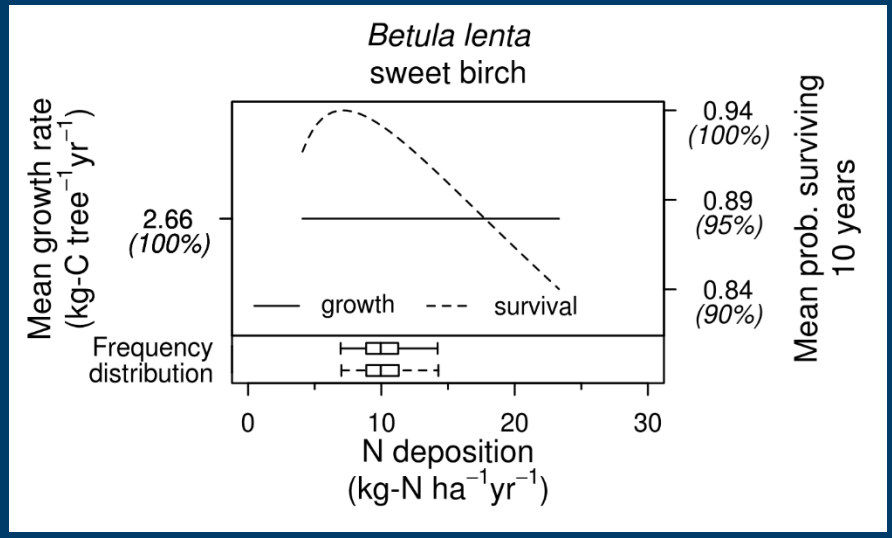
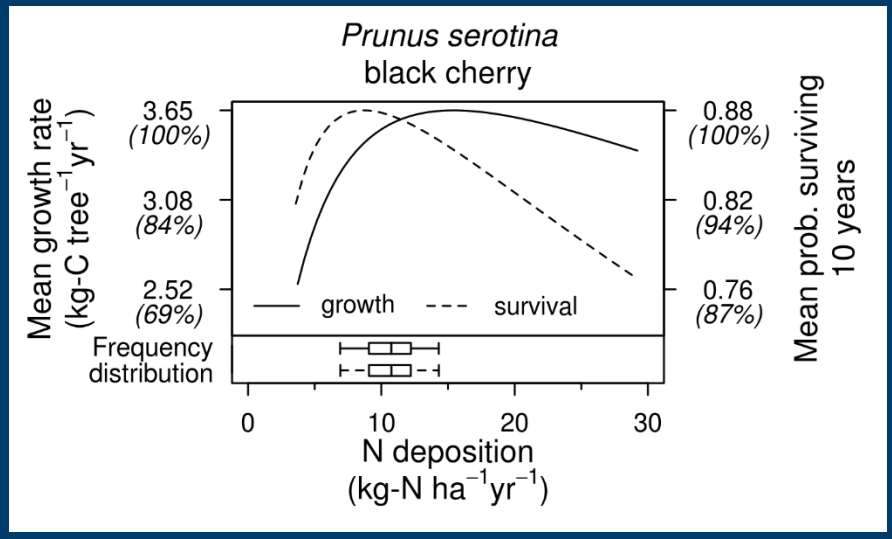
Horn et al. (the "what")

- Species-level critical loads for reduction in growth and survival for N and S deposition.
- Assess how temperature, precipitation, tree density (BA), N and S deposition, and relative height affect growth/survival.
- >100,000 plots, >2000 per spp.
- Multimodel selection (minimize AIC)
- 94 tree species across the contiguous US.
- Focus on 71 species with low collinearity issues (ViF < 3.0).





Merger of two large studies

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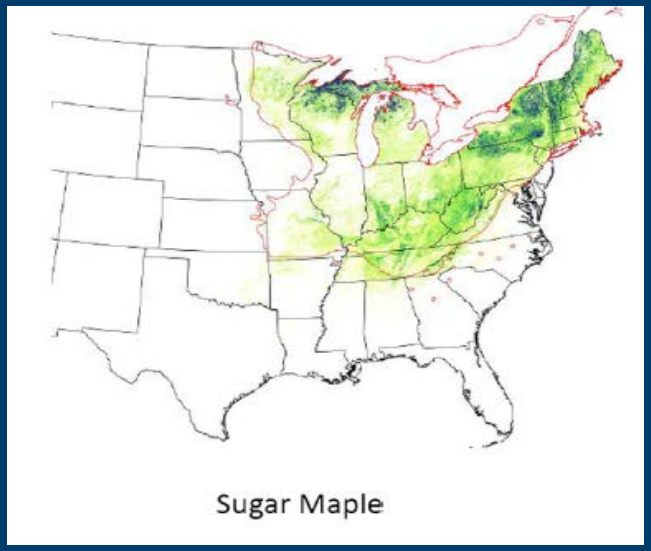
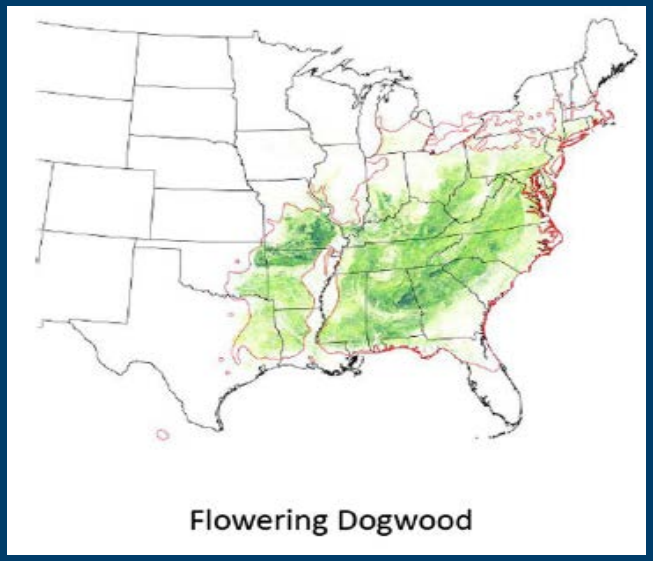




Wilson et al. 2012, 2013 (the "where")

- USFS data product on species-level distributions and abundances across the contiguous U.S for 300+ species.
- Canonical Correspondence Analyses between community composition (300 spp. BA) and 20 predictors plus Ecoregion (+54).
- Model skill assessed per species at four scales.

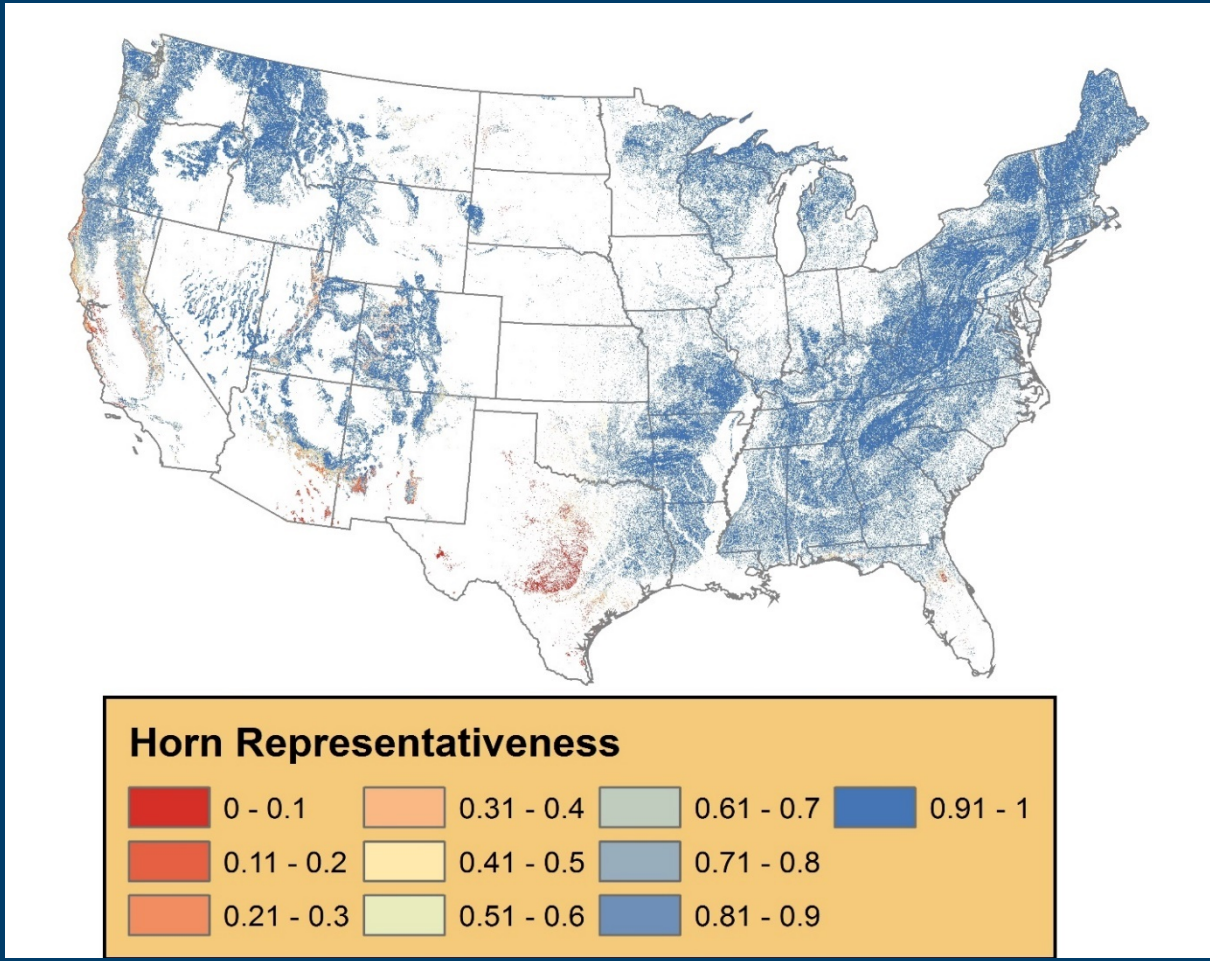
https://www.fs.usda.gov/rds/archive/Product/RDS-2013-0013

Synthesis: Vulnerability of tree species nationally to N and S deposition

- Overlay deposition with Wilson rasters for the 94 species with CLs.
- Assess “Representativeness” of the 94 Horn species to the “total forest” (BA)
- Examine “recent dep” and “reference dep levels”
- Assess % of total area and basal area (BA) exceeded (sum all species) per 250m pixel
- National - Focus on N and survival for .ppt.
- More detailed example (N and S survival) from Lindville Gorge Wilderness Area and Superior National Forest.

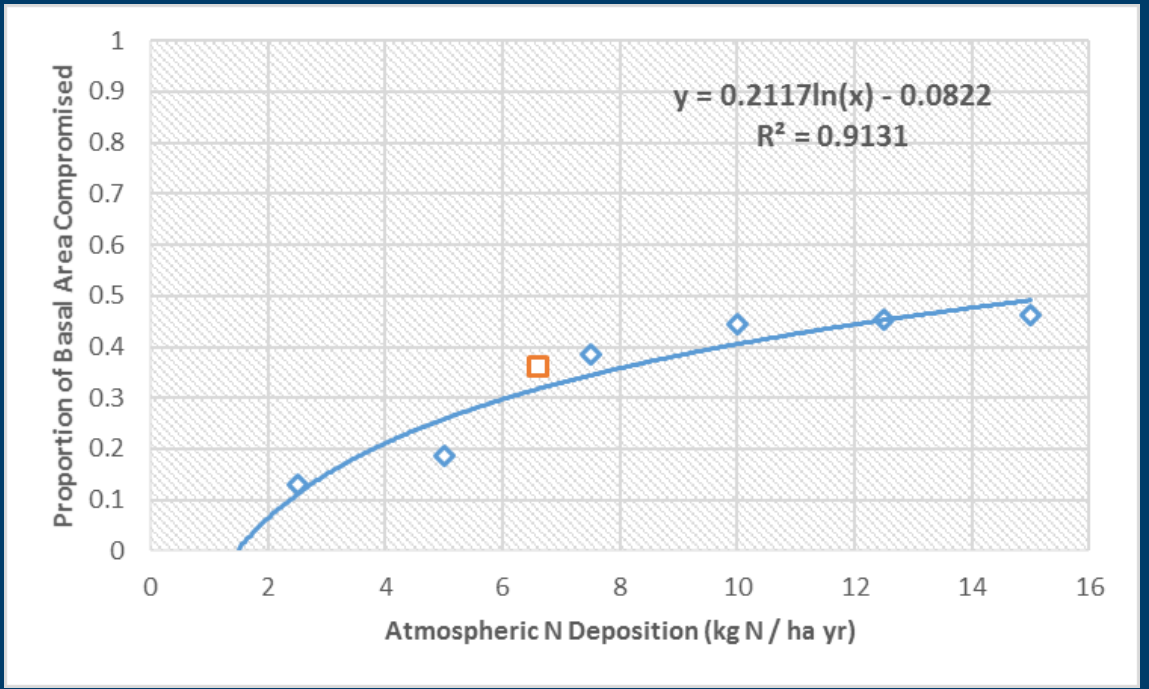
Representativeness of the “Horn 94”

- The 94 species assessed in Horn have good coverage (~ave 90%) across most forested areas.
- Gaps were in portions of the Sierras and Southwest.
- Corrected from earlier version to:
  - Exclude non-forest
  - Include western species



National Exceedances: N-survival

- Proportion of tree basal area experiencing an exceedance nationally
- TDEP (orange) and 2.5, 5.0, 7.5, 10, 12.5, and 15 kg N ha-1 yr-1 (blue).
- Large drop in BA exceeded < 5 kg (20%) compared with > 10 kg (>40%).
- 36% exceeded currently (TDEP).



National Exceedances: N-survival

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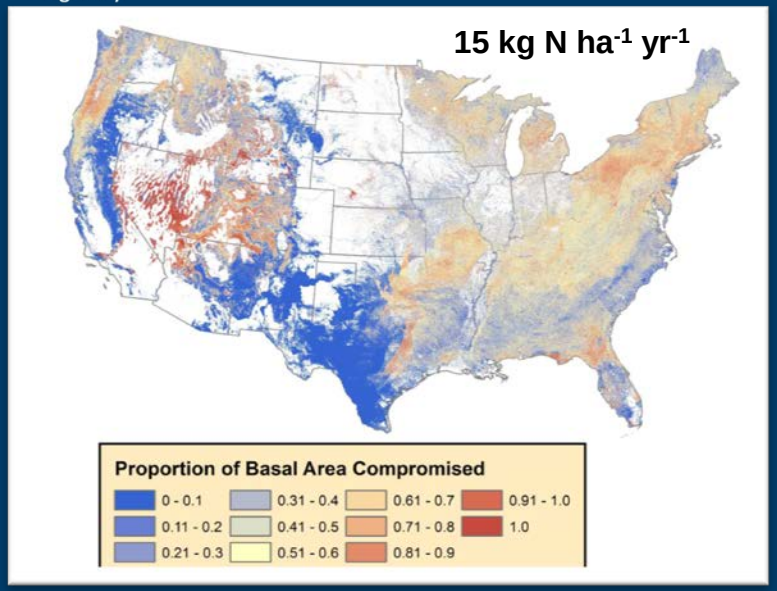
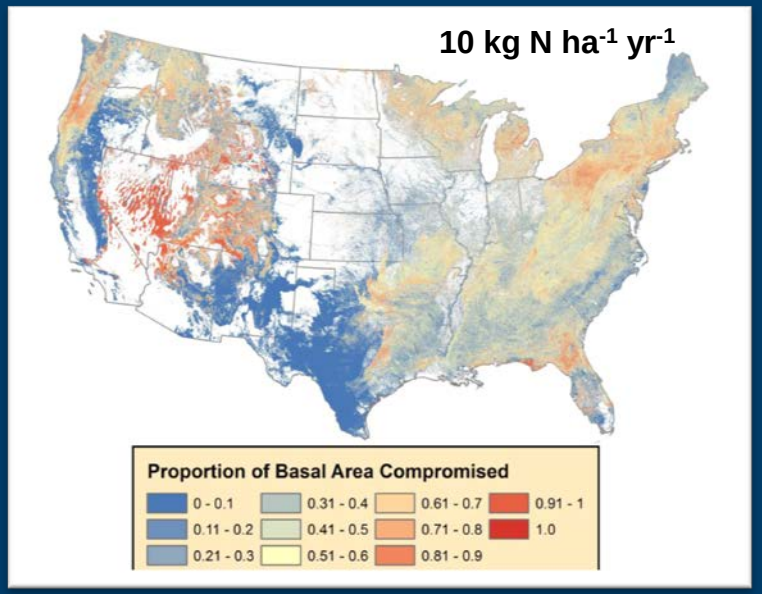
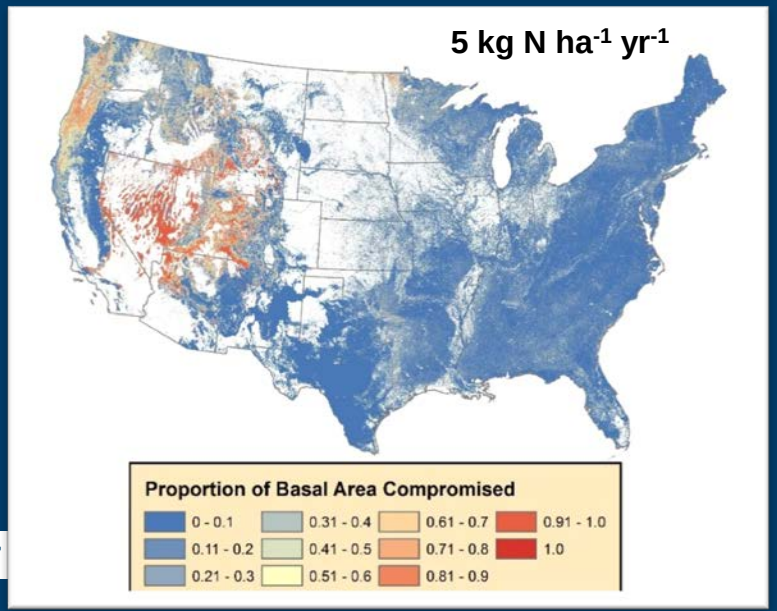
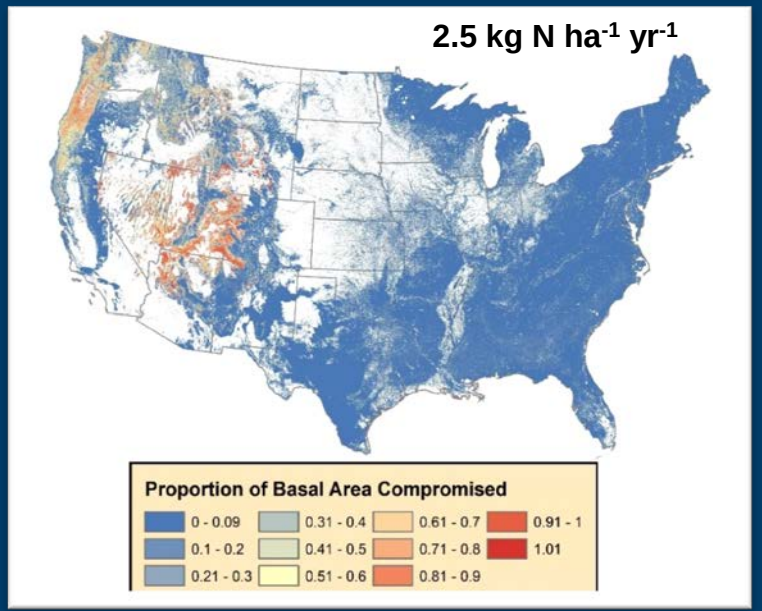


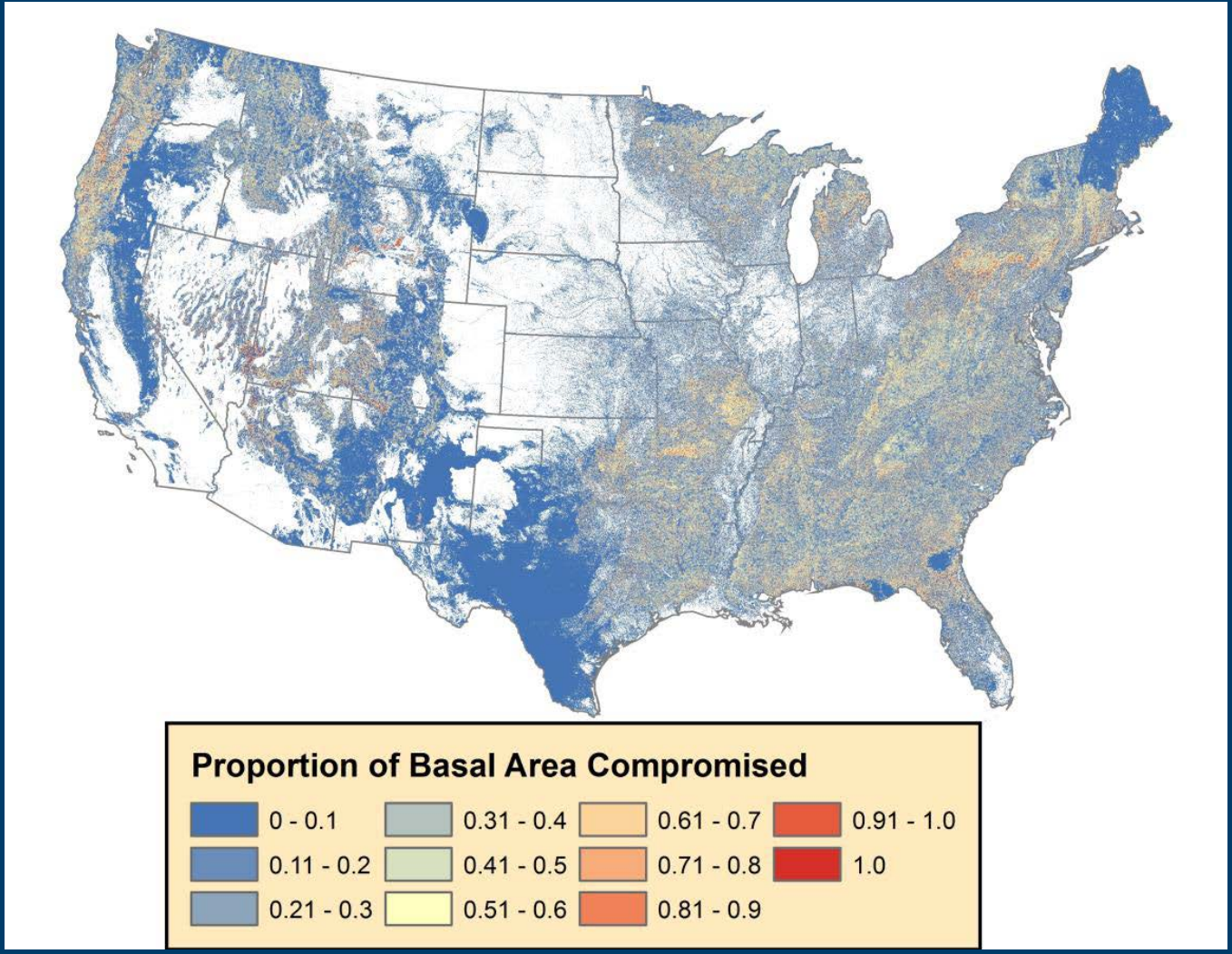






National exceedances under current deposition (TDEP 2013-2015)

- Nationally, the proportion of forest basal area compromised was 36%.
- On average 23% of the basal area in forest pixels were compromised (range: 0 to 100%).



ngs_screencap.jpg

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Example Deep Dive: Lindville Gorge Wilderness Area

(https://wallpapercave.com/free-scuba-diving-wallpaper)

Example 1: Linville Gorge Wilderness (N & S Survival)

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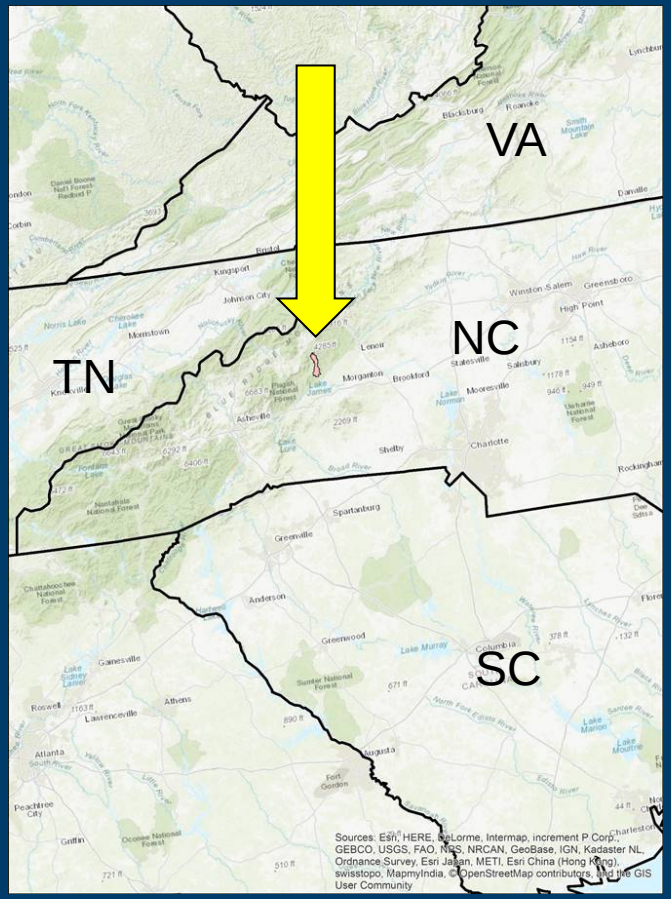
Background

- "The Grand Canyon of North Carolina"
- 3rd largest wilderness area in NC (after Shining Rock and Joyce-Kilmer).
- Very diverse plant and animal communities
- 11,786 acres
- Managed by the USFS.



Example 1: Linville Gorge Wilderness (Survival)

Representativeness:

What's in the park?

- Local plots: 88 woody species (mostly trees). (27 Horn)
- Wilson: 105 tree spp. (52 Horn)

How much coverage from Horn spp?

- 27 Horn+Local spp. comprise 72% BA
- 52 Horn+Wilson spp. comprise 96% BA

So, we capture most of the BA but not most of the species*.

(eastern hemlock, Wikipedia)

Example: Linville Gorge Wilderness (Survival)

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Deposition Trends:

- Ave N Deposition (TDEP) has gone from ~10.7 to 6.1 kg N from 2001 (2000-2002) to 2014 (2013-2015).
- S deposition has gone from 9.0 kg to 2.5 kg S.

Results:

- CLs for N range from 4.6-14.3 kg (mean 7.2).
- CLs for S range from 0.2-3.5 kg (mean 2.3).
- For N, 9 species have exceedances of survival in 2014 (16 spp. in 2001).
- For S, 8 species have exceedances of survival in 2014 (16 spp.in 2001).

GENUS	SPECIES	COMMON_NAME	m.type	sample.si	N.res_s	S.res_su	CL-N	CL-S
Acer	rubrum	red maple	NS_	120187	thresh.	decr.	5.449359	0.85922
Betula	alleghaniensis	yellow birch	NS_	16019	flat	decr.	NA	0.869832
Betula	lenta	sweet birch	NS_	10157	thresh.	decr.	7.133098	3.458966
Carya	alba	mockernut hickory	N	11273	decr.	flat	5.231272	NA
Carya	glabra	pignut hickory	S_	12081	flat	decr.	NA	2.95614
Carya	ovata	shagbark hickory	CLIM	9781	flat	flat	NA	NA
Cornus	florida	flowering dogwood	NS_	3107			4.231534	3.204885
Fagus	grandifolia	American beech	NS_	24091	thresh.	decr.	9.53727	0.248492
Fraxinus	americana	white ash	N	20060	thresh.	flat	4.649454	NA
Ilex	opaca	American holly	N	2319			7.308352	NA
Juglans	nigra	black walnut	N	6514	thresh.	flat	14.32017	NA
Liquidambar	styraciflua	sweetgum	NS_	36961	thresh.	decr.	5.148316	3.304813
Liriodendron	tulipifera	yellow-poplar	S_	27494	flat	decr.	NA	3.235306
Nyssa	sylvatica	blackgum	N	13364	thresh.	flat	5.790686	NA
Oxydendrum	arboreum	sourwood	NS_	8892	thresh.	decr.	8.193177	3.232088
Pinus	rigida	pitch pine	NS_	3149	incr.	decr.	18.45547	3.516185
Pinus	strobus	eastern white pine	S_	23371	flat	decr.	NA	1.142391
Pinus	virginiana	Virginia pine	NS_	9236	thresh.	decr.	8.667799	2.840821
Platanus	occidentalis	American sycamore	CLIM	3033	flat	flat	NA	NA
Prunus	serotina	black cherry	N	24253	thresh.	flat	8.707753	NA
Quercus	alba	white oak	NS_	46498	thresh.	decr.	6.786134	2.680743
Quercus	marilandica	blackjack oak	N	2671			7.959454	NA
Quercus	rubra	northern red oak	N	31397	thresh.	flat	5.310236	NA
Quercus	velutina	black oak	S_	21692	flat	decr.	NA	2.367909
Robinia	pseudoacacia	black locust	NS_	5488	incr.	decr.	24.34896	0.559561
Sassafras	albidum	sassafras	NS_	6227	incr.	decr.	10.66352	3.534587
Tsuga	canadensis	eastern hemlock	N	25485	thresh.	flat	5.479977	NA

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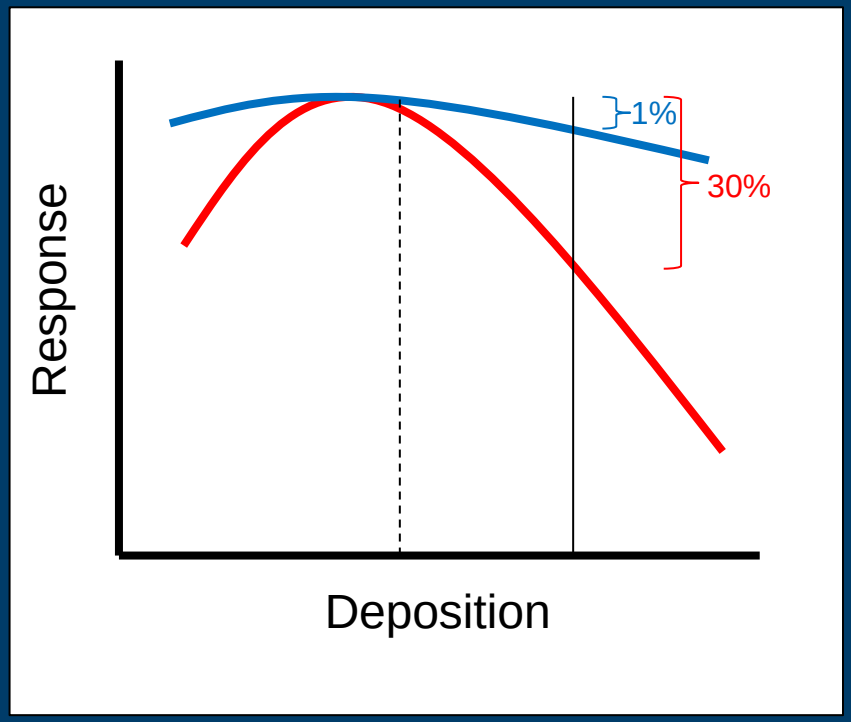
But…

not all exceedances are the same

Steepness and exceedance matter

- Steeper curves (red) will have larger effects for the same exceedance (solid black).
- A small exceedance (dashed black) will have a small effect regardless of steepness.
- So we have to examine:
  1. Magnitude of exceedance.
  2. Curve steepness



Linville Gorge Wilderness (Survival)

6 species "significantly affected" (i.e. experiencing a reduction in decadal survival ~1% or more from N or S):

- Yellow birch (-1.4%, S)
- Flowering dogwood (-5.4%, N)
- American beech (-10%, S)
- White ash (-1.7%, N)
- Black locust (-9.2%, S)
- Eastern hemlock (-0.7%, N)

GENUS	SPECIES	COMMON_NAME	m.type	sample.si	N.res_s	S.res_su	CL-N	CL-S	R-N(mea	R-S(mea
Acer	rubrum	red maple	NS_	120187	thresh.	decr.	5.449359	0.8592	0.173	0.230
Betula	alleghaniensis	yellow birch	NS_	16019	flat	decr.	NA	0.86983	NA	1.329
Betula	lenta	sweet birch	NS_	10157	thresh.	decr.	7.133098	3.45896	<CL	<CL
Carya	alba	mockernut hickory	N	11273	decr.	flat	5.231272	NA	0.691	NA
Carya	glabra	pignut hickory	S_	12081	flat	decr.	NA	2.9561	NA	<CL
Carya	ovata	shagbark hickory	CLIM	9781	flat	flat	NA	NA	NA	NA
Cornus	florida	flowering dogwood	NS_	3107			4.231534	3.20488	5.391	<CL
Fagus	grandifolia	American beech	NS_	24091	thresh.	decr.	9.53727	0.24849	<CL	9.989
Fraxinus	americana	white ash	N	20060	thresh.	flat	4.649454	NA	1.717	NA
Ilex	opaca	American holly	N	2319			7.308352	NA	<CL	NA
Juglans	nigra	black walnut	N	6514	thresh.	flat	14.32017	NA	<CL	NA
Liquidambar	styraciflua	sweetgum	NS_	36961	thresh.	decr.	5.148316	3.30481	0.447	<CL
Liriodendron	tulipifera	yellow-poplar	S_	27494	flat	decr.	NA	3.23530	NA	<CL
Nyssa	sylvatica	blackgum	N	13364	thresh.	flat	5.790686	NA	0.230	NA
Oxydendrum	arboreum	sourwood	NS_	8892	thresh.	decr.	8.193177	3.23208	<CL	<CL
Pinus	rigida	pitch pine	NS_	3149	incr.	decr.	18.45547	3.51618	<CL	<CL
Pinus	strobus	eastern white pine	S_	23371	flat	decr.	NA	1.14239	NA	0.447
Pinus	virginiana	Virginia pine	NS_	9236	thresh.	decr.	8.667799	2.84082	<CL	<CL
Platanus	occidentalis	American sycamore	CLIM	3033	flat	flat	NA	NA	NA	NA
Prunus	serotina	black cherry	N	24253	thresh.	flat	8.707753	NA	<CL	NA
Quercus	alba	white oak	NS_	46498	thresh.	decr.	6.786134	2.68074	<CL	<CL
Quercus	marilandica	blackjack oak	N	2671			7.959454	NA	<CL	NA
Quercus	rubra	northern red oak	N	31397	thresh.	flat	5.310236	NA	0.380	NA
Quercus	velutina	black oak	S_	21692	flat	decr.	NA	2.36790	NA	0.082
Robinia	pseudoacacia	black locust	NS_	5488	incr.	decr.	24.34896	0.55956	<CL	9.247
Sassafras	albidum	sassafras	NS_	6227	incr.	decr.	10.66352	3.53458	<CL	<CL
Tsuga	canadensis	eastern hemlock	N	25485	thresh.	flat	5.479977	NA	0.721	NA

% decline with current dep

How prevalent are these 8 species?

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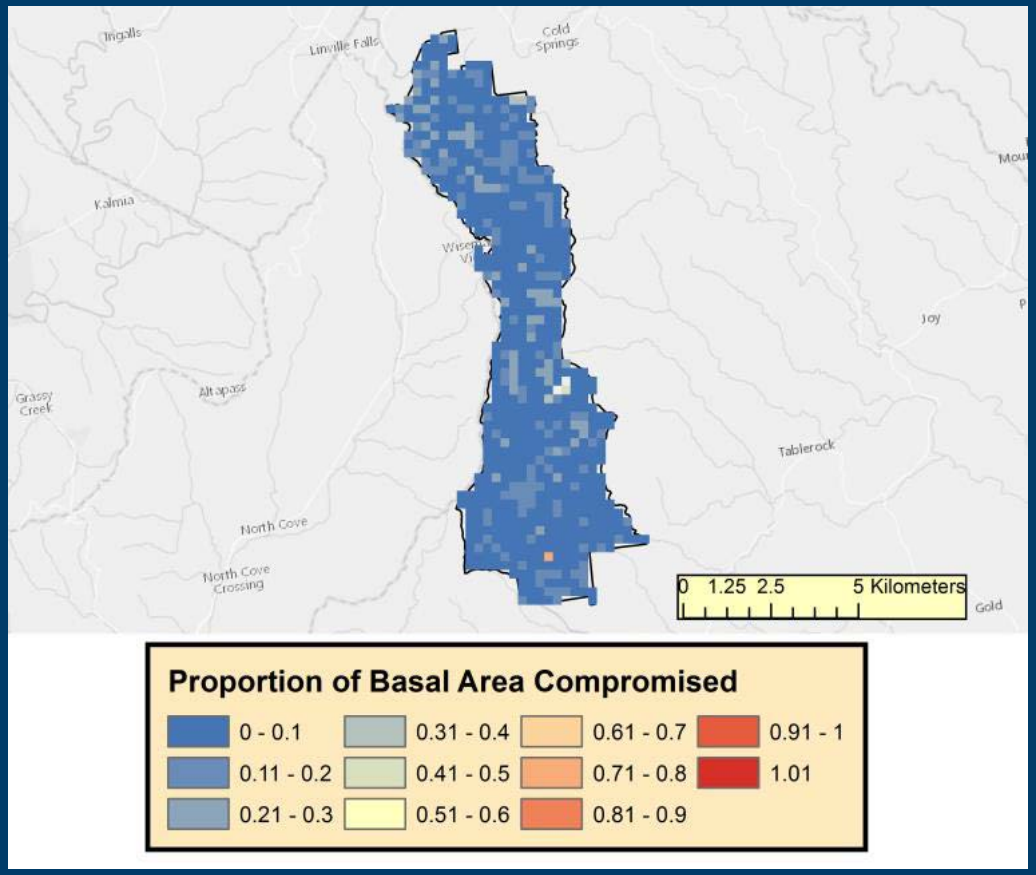
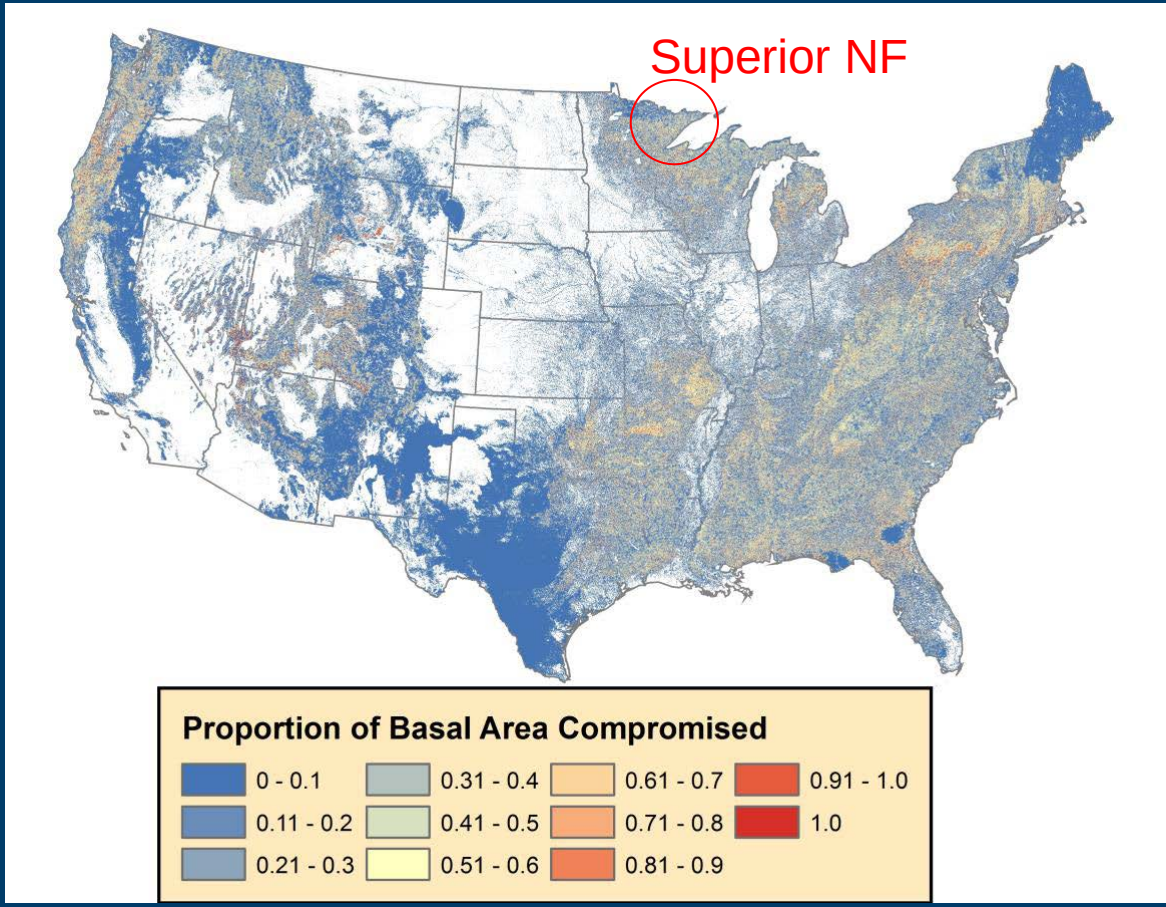
- Only 8% of the total BA significantly affected.
- But, roughly 1/3 of the park area had species that were significantly affected and relatively common (1/3 of the map is light blue).

Significantly affected (~1% decline or more)



Lots of Heterogeneity Nationally

- Variation driven by:
  - Deposition
  - Species composition



Example 2: Superior National Forest

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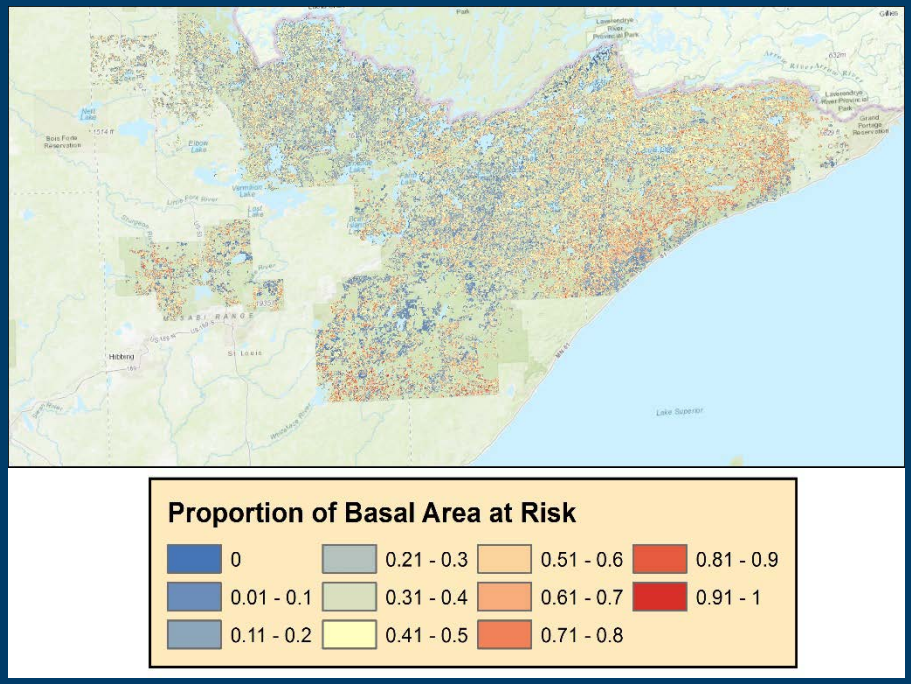
- Most of the tree species (>90%) and 99% of the BA captured by Horn species
- 97% of the park had at least one species with an exceedance.
- Survival reductions by 1% or more for 12 of 33 species in the NF (N = 1 spp., S = 12 spp).
- 31% of the area and 35% of the BA is experiencing a 1% reduction in survival or more.

Significantly affected (~1% decline or more)



Next Steps

1. Refine the methodology (e.g. including confidence).
2. Add N-growth, and S to the national analysis.
3. Repeat at all National Parks, Wilderness Areas, Forests, and other protected areas.
4. Many other ideas brought up at CLAD.

(Red maple, Wikipedia)

Summary and Conclusions

- We can make statements about the relative proportion of the forest that is vulnerable to N and S deposition for most of the contiguous US

- We can even estimate impact at current levels, and calculate target levels for a desired impact.

- Much work remains to refine the procedure and synthesize these results with other CLs, but significant progress is being made on all fronts.

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Thanks and Questions?

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Extra Slides

Useful rules of thumb

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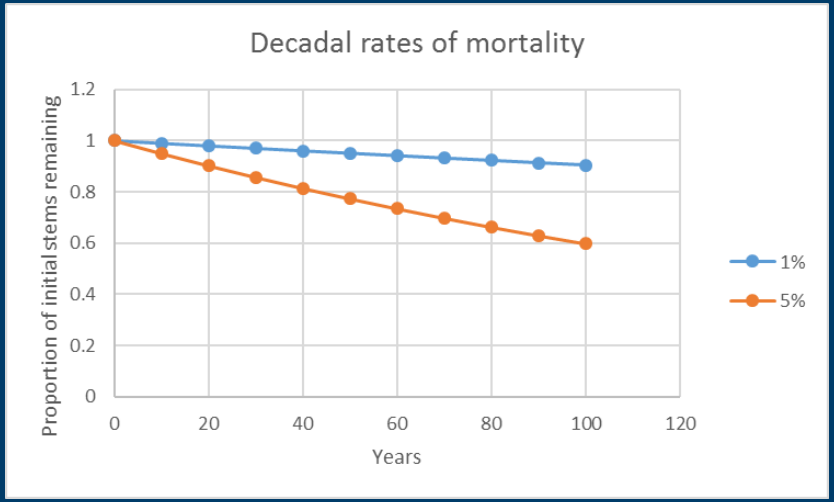
Decadal survival rates after 100 yrs.

Too big?
- A 5% reduction in 10 years means a 40% reduction in 100 years.

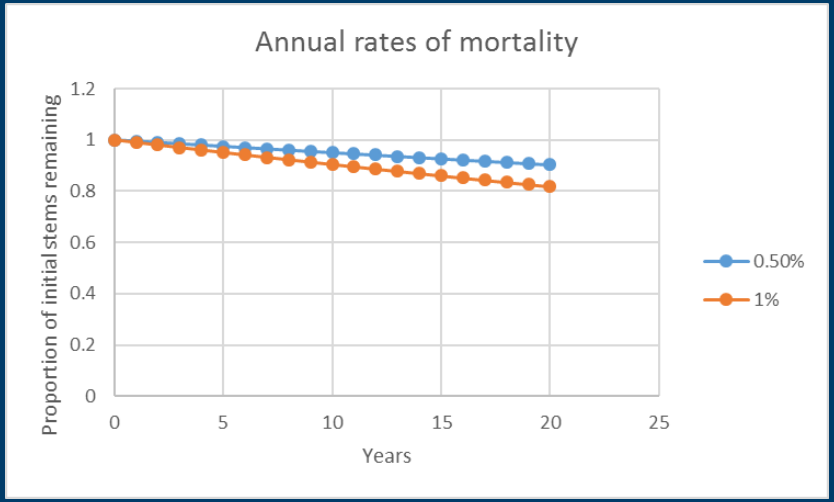
About Right?
- A 1% reduction in 10 years means a 10% reduction in 100 years.



Yearly survival rates after 20 years.

Too big?
- A 1% reduction in 1 year means a 20% reduction in 20 years.

About Right?
- A 0.5% reduction in 1 year means a 10% reduction in 20 years.



Results By State

- States with 20 highest % exceedance at 10 kg N ha-1 yr-1.
- Many show a big drop between 10 kg and 5 kg.
- Exceptions are some western states with lots of sensitive western species (e.g. Douglas fir: NV, UT, CO, WY)