Interaction of climate change, nitrogen deposition, and pest disturbance: a spatial management tool for predicting effects on forest health and setting critical loads

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- most forests in the northeastern United States are at risk of detrimental effects from N deposition, although the extent and magnitude of the risk varies spatially
- We developed a web-based GIS tool that allows land managers to assess the risk of harm from air pollution (nitrogen deposition) to forests in the northeast

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

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Project Summary

Air pollution, climate change, and forest pests are significant stressors for forest ecosystems. Resource managers need information at the same spatial scale as the forests they manage, with detail on individual species, in order to evaluate the potential impact of these stressors. To address this need, we developed an online geographic information system (GIS) tool called Nitrogen Critical Loads Assessment by Site (N-CLAS), which can be used to assess the predicted effects of air pollution (nitrogen deposition) and climate on tree species of management concern in the northeastern United States. The N-CLAS tool uses soil, climate, and air pollution data for forests plots (30 m^2) to predict which tree species at the plots are at risk from air pollution. The plot data are then aggregated for predetermined geographic areas. Tool users select tree species and geographic areas, as well as figure, table, and map output options. N-CLAS generated data can be downloaded in tabular and graphic formats.

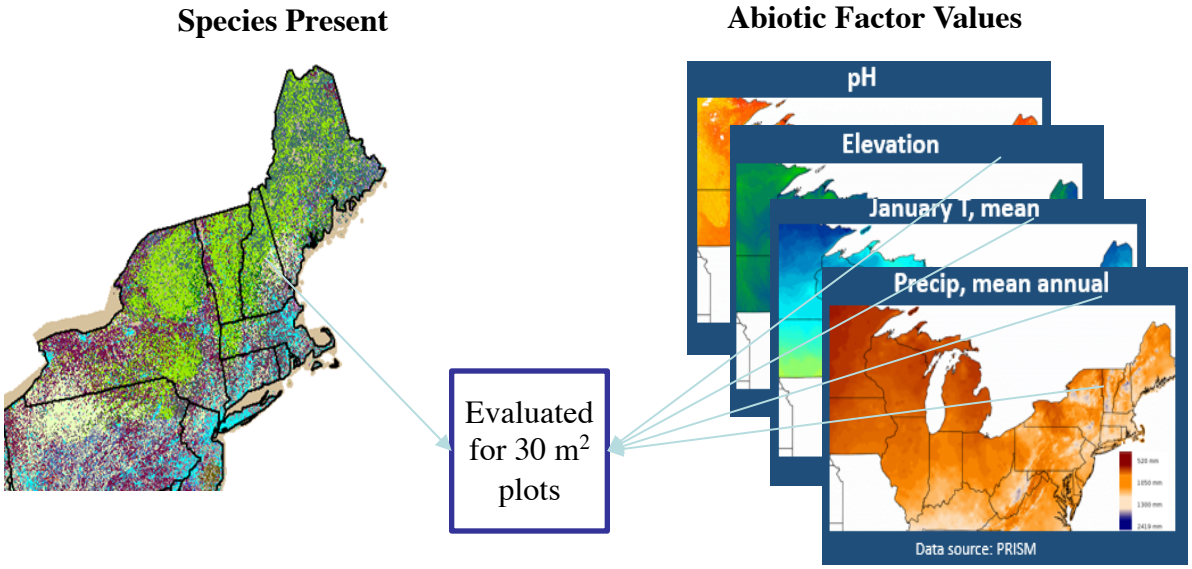
The results generated by N-CLAS predict that most forests in the northeastern U.S. are at risk of detrimental effects from air pollution, although the extent and magnitude of the risk varies spatially. Several species demonstrate high sensitivity to air pollution across large portions of the study area. These species – yellow birch (*Betula alleghaniensis*), butternut (*Juglans cinerea*), eastern white pine (*Pinus strobus*), Bigtooth aspen (*Populus grandidentata*), Quaking aspen (*Populus tremuloides*), northern red oak (*Quercus rubra*), and American elm (*Ulmus americana*) – are consistently the most at risk from air pollution across the mixed stands that they occupy. Risks to sensitive tree species are highest in the southwestern part of the study region, where air pollution is in highest. N-CLAS provides land managers easy access to a tool with significant refinement in determining air pollution risks at a scale applicable to forest management. This represents an important step towards improving our understanding of the potential risk to forests in the northeastern U.S and linking current state-of-the science to decision making processes on the ground.

Background and Justification

- Resource managers require information on the combined effects of climate and air pollution for sustainable forest management, yet information about these primary stressors is widely dispersed in the literature.
- This enhanced web-based GIS tool, N-CLAS (Nitrogen Critical Loads Assessment by Site) allows land managers to assess the cumulative effects of air pollution on forest health and sustainability, and to set targets for the purposes of land management and restoration.
- This interactive web interface provides flexibility for the user to assess heterogeneous landscapes: users can select the area and tree species of interest, as well as pre-defined options that show the level of air pollution that would not harm any of the species present (the most protective scenario) or a subset of the species present (less protective scenarios).

Methods

1. The N-CLAS tool incorporates information about species present and conditions at the site



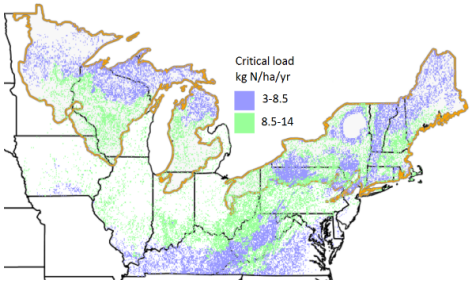
Methods

2. Then, the tool combines the information about species and site conditions with information about how sensitive each species is at each site (lavender=more sensitive; green=less sensitive)

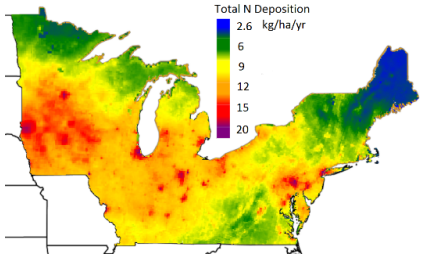
3. with the current air pollution load (N deposition)

4. to identify areas at risk (shown in red)

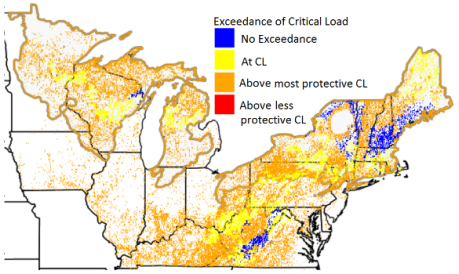
Adjusted Critical Load



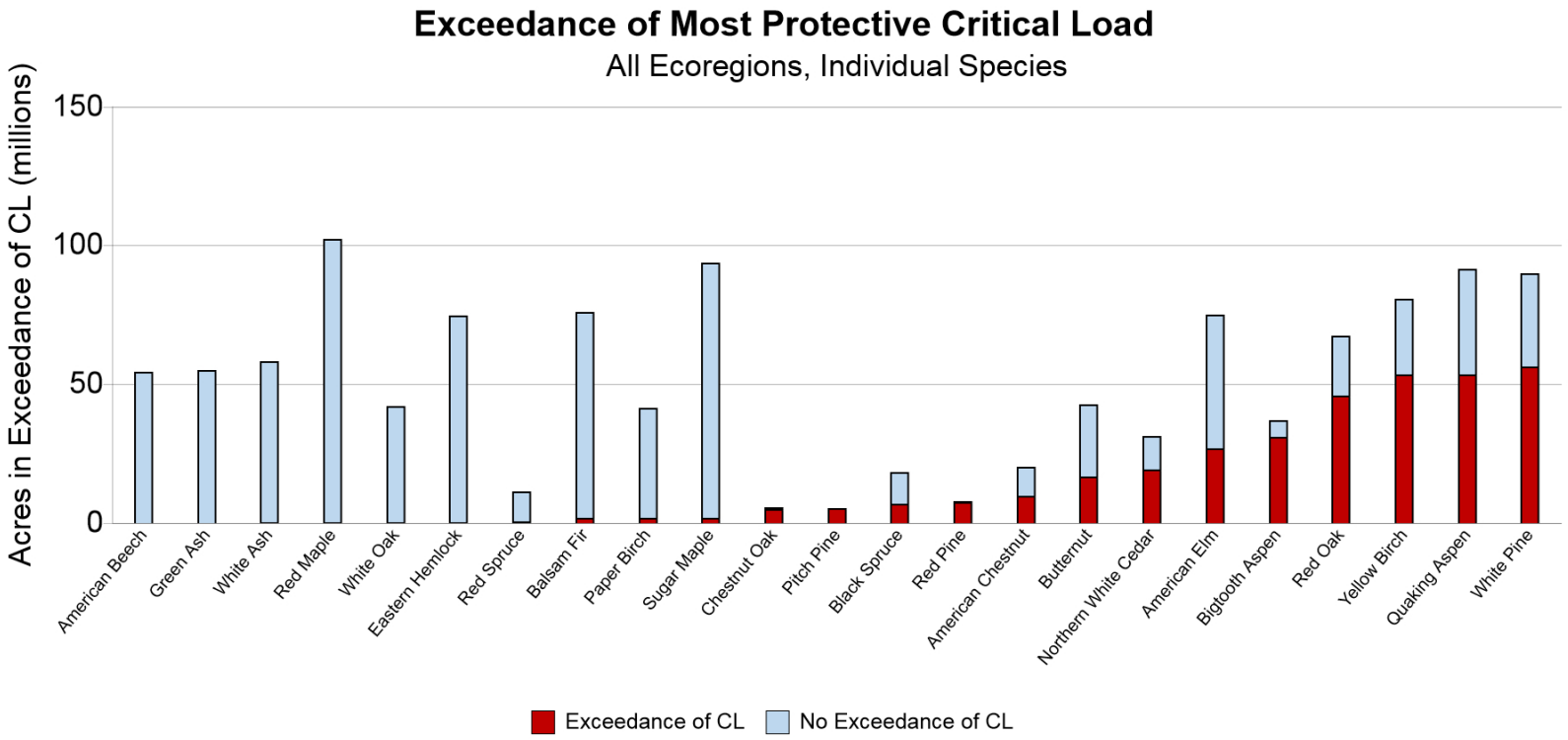
Total N Deposition



Exceedance



Results



The species with the greatest area at risk from air pollution (N deposition) include yellow birch (*Betula alleghaniensis*), eastern white pine (*Pinus strobus*), quaking aspen (*Populus tremuloides*), and northern red oak (*Quercus rubra*)

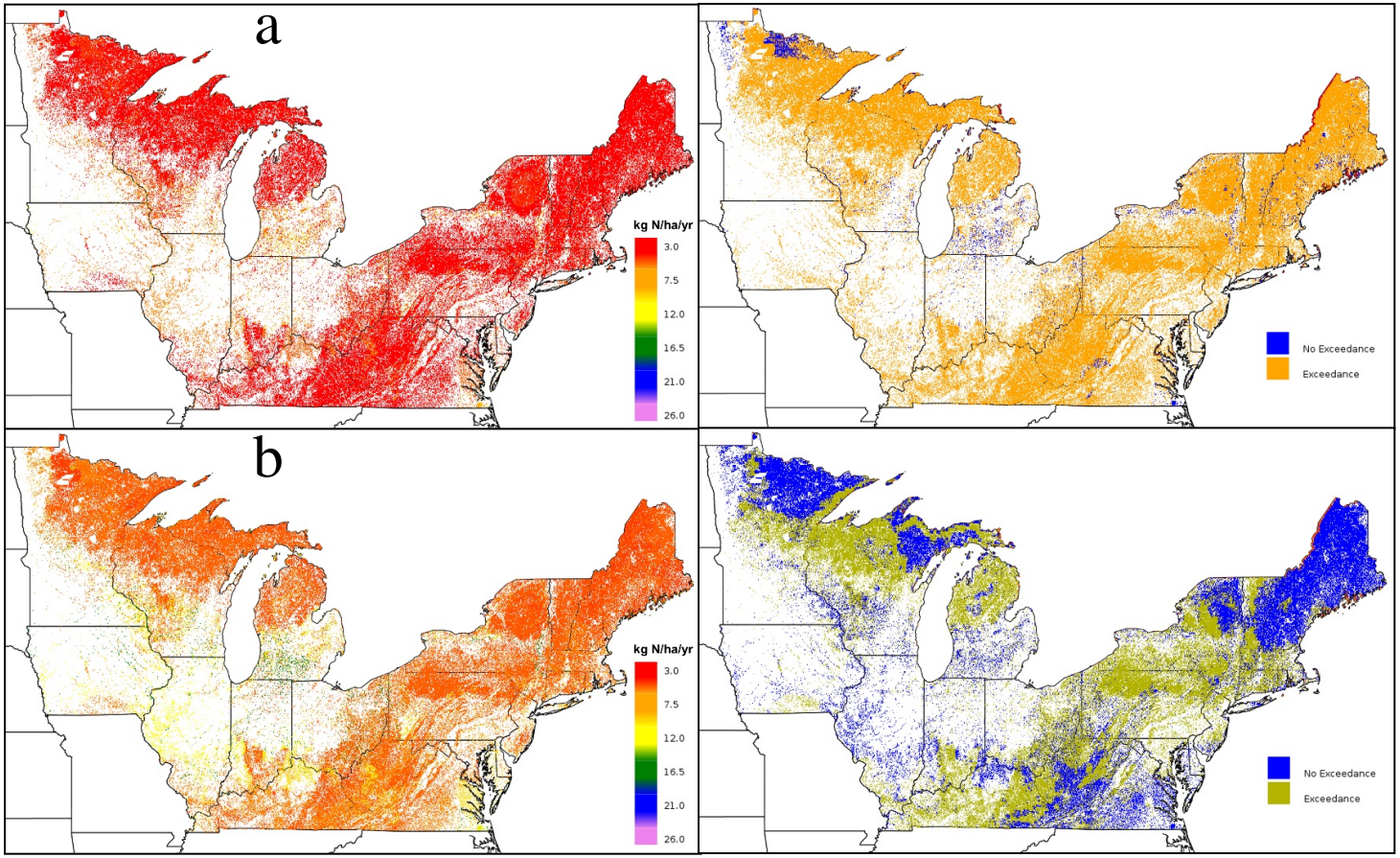
Results

Area in Exceedance of the Critical Load by Species

Species Latin name	Species common name	Species Area (million acres)	Area in Exceedance (million acres)	% Area in Exceedance
Fagus grandifolia	American beech	54.6	0.0	0.04
Fraxinus pennsylvanica	Green ash	55.2	0.1	0.24
Fraxinus americana	White ash	58.2	0.2	0.41
Acer rubrum	Red maple	102.4	0.3	0.25
Quercus alba	White oak	42.2	0.4	0.97
Tsuga canadensis	Eastern hemlock	74.7	0.5	0.60
Picea rubens	Red spruce	11.3	0.8	6.9
Abies balsamea	Balsam fir	76.1	1.8	2.3
Betula papyrifera	Paper birch	41.5	2.0	4.7
Acer saccharum	Sugar maple	93.9	2.0	2.1
Quercus prinus	Chestnut oak	5.6	5.0	89
Pinus rigida	Pitch pine	5.3	5.3	100
Picea mariana	Black spruce	18.3	7.1	39
Pinus resinosa	Red pine	8.0	7.7	96
Castanea dentata	American chestnut	20.2	9.8	48
Juglans cinerea	Butternut	42.7	16.6	39
Thuja occidentalis	Northern white cedar	31.2	19.3	62
Ulmus americana	American elm	75.0	26.8	36
Populus grandidentata	Bigtooth aspen	37.2	31.1	84
Quercus rubra	Red oak	67.5	46.1	68
Betula alleghaniensis	Yellow birch	80.8	53.6	66
Populus tremuloides	Quaking aspen	91.5	53.6	59
Pinus strobus	Eastern white pine	89.9	56.4	63

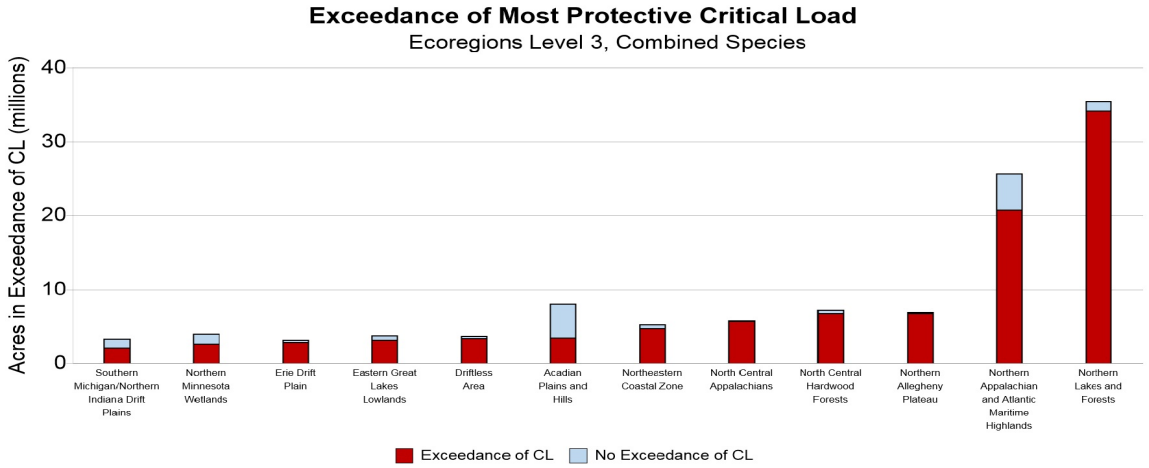
The species with the greatest area at risk from air pollution (N deposition) are shown at the bottom of the table above. The area at risk for these five species (bigtooth and quaking aspen, northern red oak, yellow birch, and eastern white pine) ranges from 31 to 56 million acres for each species.

Results

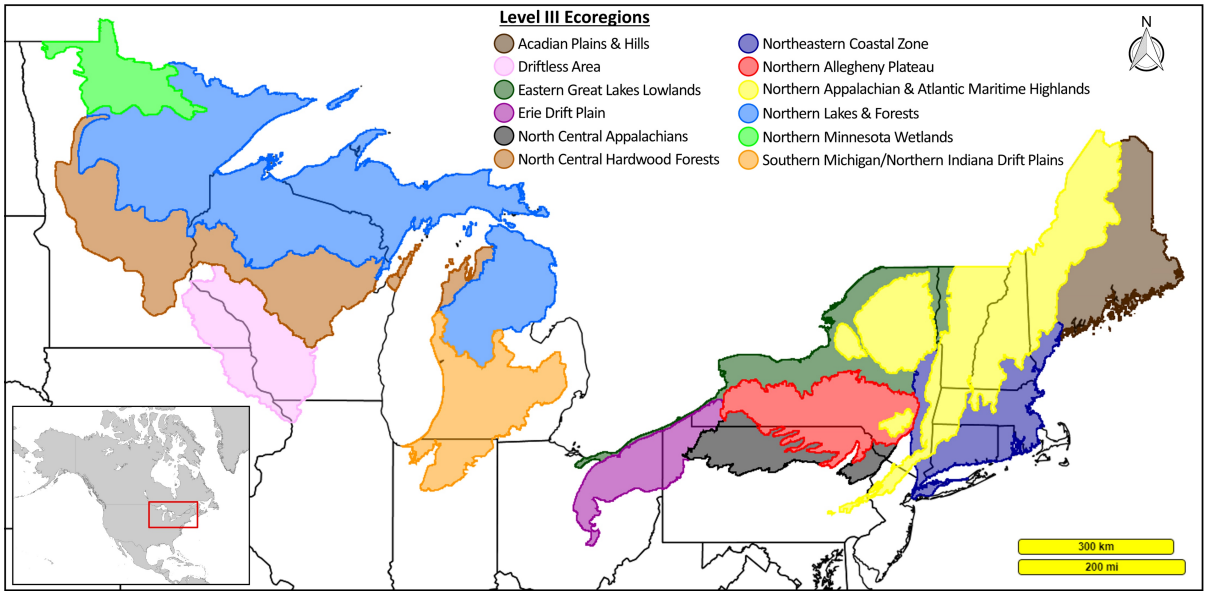


- Panel a: the level of N deposition that will cause harm to forests is shown on the left. On the right, 86% percent of the region is at risk for harmful effects from air pollution (shown in light orange)
- Panel b: the level of N deposition that will cause harm to less sensitive tree species. On the right, less sensitive species have less area at risk.

Results



- Within level III ecoregions (shown below), the extent area at risk from air pollution ranged from 64% to greater than 99% (red portion of bars, above)



Results

% Area in Exceedance of CL at Each N Deposition Level

Area:	Ecoregions Level 3
Site:	Driftless Area
Size (ac):	11,709,382
N Deposition (kg/ha/yr):	9.1 to 15.0

No Exceedance
0-24% Area in Exceedance
25-49% Area in Exceedance
50-74% Area in Exceedance
75-99% Area in Exceedance
100% Area in Exceedance

N Deposition (kg/ha/yr)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Balsam Fir	0%	0%	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sugar Maple	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	100%
Yellow Birch	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Paper Birch	0%	0%	0%	0%	0%	0%	0%	0%	0%	85%	85%	85%	85%	85%	85%	100%	100%	100%
White Ash	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	24%	24%	24%	24%	100%	100%	100%	100%
Green Ash	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	3%	3%	3%	100%	100%	100%	100%
Butternut	0%	0%	0%	0%	0%	0%	38%	38%	38%	38%	38%	38%	100%	100%	100%	100%	100%	100%
Black Spruce	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Red Pine	0%	0%	99%	99%	99%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
White Pine	0%	0%	0%	0%	9%	9%	9%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Bigtooth Aspen	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Quaking Aspen	0%	0%	0%	0%	101%	101%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
White Oak	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	24%	24%	24%	24%	100%	100%	100%	100%
Red Oak	0%	0%	2%	2%	2%	2%	2%	2%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Northern White Cedar	0%	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Eastern Hemlock	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	6%	6%	6%	6%	6%	6%	100%	100%
American Elm	0%	0%	0%	0%	0%	0%	5%	5%	5%	5%	5%	5%	100%	100%	100%	100%	100%	100%

Downloaded 2020-03-22 from N-CLAS | N Deposition: Mean Total Deposition (2013-2015)

- Percent area in exceedance of the CL of N for the Driftless Area Ecoregion for varying levels of N deposition
- This table shows the area that would be exceeded at each N deposition level, if it were to occur, and does not reflect actual, current deposition values.

Results: outreach

- This project was conducted with considerable input from stakeholders during frequent conference calls and in-person workshops
- The tool can be accessed via the National Atmospheric Deposition Program website in order to increase the breadth of the potential user group
- Demonstrations to stakeholder groups are continuing

Implications and applications in the Northern Forest region

- This project provides resource managers and policy makers access to current best science in the form of a simple tool for assessing the interactions of climate and N deposition on the Northern Forest in order to achieve specific economic, social, and ecological objectives for sustainable forest management over the long term

- The enhanced GIS-based management tool includes information on climate and N deposition and provides:
  - improved interface to allow for maximum user flexibility--it allows users to determine forest health risks for a selected area for their management scenarios
  - geospatial, graphical, and tabular output. Both figures and tables can be downloaded as jpegs or as csv (excel compatible files).

Future directions

- We continue to do outreach to demonstrate how to use N-CLAS to stakeholders (resource managers)
- We continue to modify and improve N-CLAS to enhance the user interface, improve ease of use, and incorporate changes requested by stakeholders
- We hope to expand N-CLAS to the national scale and to incorporate recent work that would allow us to project changes in rate of tree growth and probability of survival due to N deposition

List of products

Peer-reviewed publications

Robin-Abbott, Molly J.; Pardo, Linda H. 2017. How climatic conditions, site, and soil characteristics affect tree growth and critical loads of nitrogen for northeastern tree species. Gen. Tech. Rep. NRS-172. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 143 p.
https://www.fs.usda.gov/treesearch/pubs/55007

Pardo, Linda H.; Coombs, Jason A.; Robin-Abbott, Molly J.; Pontius, Jennifer H.; D'Amato, Anthony W. 2019 Tree species at risk from nitrogen deposition in the northeastern United States: A geospatial analysis of effects of multiple stressors using exceedance of critical loads. Forest Ecology and Management 454 (2019) 117528.
https://doi.org/10.1016/j.foreco.2019.117528

GIS-based management tool

This tool provides high resolution, spatially explicit critical load and exceedance mapping to inform sustainable forest management. N-CLAS
http://nadp.slh.wisc.edu/committees/clad/links.aspx

Leveraged grants

- We received special funds from the Northern Research Station which allowed us to make significant progress on the project until the NSRC funds were made available.
- In addition, we had a summer intern in 2017 who lead the development of the user interface and assisted with stakeholder interactions.
- In 2018, we received funds from the US Forest Service National Air Program to enhance the user interface of N-CLAS and begin to expand N-CLAS to the national scale

List of products: Stakeholder Workshops

- *WMNF presentation, Campton, NH, 19 Sep 2016*
  - **Nitrogen Critical Loads Assessment by Site (N-CLAS) incorporating site and climate** Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow
- *NADP Workshops Santa Fe, NM October 2016*
  - **N-CLAS (Nitrogen Critical Load Assessment by Site): High resolution, spatially explicit critical load and exceedance mapping tool to inform policy and sustainable forest management** 31 October 2016. Stakeholder Workshop Organizer
- *VMC workshop, Burlington, VT, 2 Dec 2016*
  - **Nitrogen Critical Loads Assessment by Site (N-CLAS) incorporating site and climate** Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow
- *Deposition FARM team, 8 February 2017*
  - **N-CLAS intro: using a GIS tool for assessing effects of nitrogen deposition** Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow
- *UVM McIntire-Stennis Research Group, 7 March 2017*
  - **N-CLAS intro: using a GIS tool for assessing effects of nitrogen deposition** Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow
- *National Air Program Meeting, Juneau, AK, 18 May 2017*
  - **Getting the most out of N-CLAS—**
    a GIS tool to aid N deposition and climate change assessments Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow
- *NADP Workshops San Diego, CA October 2017*
  - **N-CLAS (Nitrogen Critical Load Assessment by Site): High resolution, spatially explicit critical load and exceedance mapping tool to inform policy and sustainable forest management** 31 October 2017. Stakeholder Workshop Organizer

List of products: Stakeholder Workshops

continued

- *NADP Workshops Milwaukee, WI April 2018*
  - **N-CLAS (Nitrogen Critical Load Assessment by Site): Demo and stakeholder feedback session** Stakeholder Workshop Organizer
- *Stakeholder workshop, Washington, DC, June 2018*
  - **Assessment of stakeholder needs and output visualization feedback.** Input from USFS, EPA, National Park Service, Fish and Wildlife Service
- *Deposition FARM team, 8 August 2018*
  - **N-CLAS updates: : statistical histogram outputs and interpretation** Linda H. Pardo,
- *NADP Workshops Albany, NY November 2018*
  - **Stakeholder needs evaluation and feedback sessions** Stakeholder Workshop Organizer
- *National Air Program Meeting, Tempe, AZ, December 2018*
  - **USFS Air Program feedback session—tailoring N-CLAS outputs for USFS applications** Linda H. Pardo

List of products: Presentations

- *ECANUSA talk*
  - **Assessing spatial patterns of the effects of nitrogen deposition on forests using a GIS management tool for critical loads and exceedance**. Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow. 30 Sep 2016
- *ECANUSA poster*
  - **Comparison of critical loads of nitrogen and exceedance for forested Class I areas of the Northeastern U.S.** Molly Robin-Abbott, Linda H. Pardo, Jason Coombs, Jennifer Pontius. 30 Sep 2016
- *NADP talk*
  - **Assessing spatial patterns of the effects of nitrogen deposition on forests using a GIS management tool for critical loads and exceedance** Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow. 2 November 2016, Santa Fe, NM
- *NADP Poster*
  - **A spatial analysis of species at risk from N deposition in Class I Areas in the Northeast and upper Midwest** Molly Robin-Abbott, Linda H. Pardo, Jason Coombs, Jennifer Pontius. ~2 November 2016. Santa Fe, NM
- *VMC talk*
  - **Identifying species at risk from nitrogen deposition in forests in the northeastern U.S.: a geospatial analysis of effects of multiple stressors using exceedance of critical loads** Linda H. Pardo, Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs, Keith H. Nislow. 2 December 2016, Burlington, VT
- *VMC poster*
  - **A spatial analysis of species at risk from N deposition in Class I Areas in the Northeast and upper Midwest (v2** *this is a different poster from above***)** Molly Robin-Abbott, Linda H. Pardo, Jason Coombs, Jennifer Pontius. ~2 December 2016. Burlington, VT
- *ESA poster (co-author; presenter)*
  - **Geospatial analysis of tree species at risk from nitrogen deposition in the northeastern U.S.** Molly J. Robin-Abbott, Linda H. Pardo, Jason A. Coombs, Jennifer H. Pontius, Anthony W. D'Amato. 15 August 2019, Louisville, KY. Also presented at:
    - National Atmospheric Deposition Program Meeting, Boulder, CO, 6 November 2019
    - FEMC Meeting, 13 December 2019