Empirical critical loads for nitrogen for ecoregions of the US: current and future

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Outline

1. Background on critical loads
2. Empirical critical loads for lichens
3. A simple model for estimating lichens CLs
4. Refinement of empirical CL-other receptors
5. Next steps
Objectives

- synthesize current state of knowledge on effects of atmospheric N inputs on terrestrial and aquatic ecosystems in the U.S. → Empirical CL
- Audience: land managers, policymakers, researchers

USFS General Technical Report
http://treesearch.fs.fed.us/pubs/38109

Ecological Applications Pre-print
http://www.esajournals.org/toc/ecap/0/0
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**Critical load** of nitrogen is the level of deposition below which no harmful ecological effects occur for an ecosystem.
Empirical CL

- damage at observed N input
- N deposition set as CL
- extrapolated to similar ecosystems
- based on gradient studies, N additions, long-term observations
Exceedance of critical load

Exceedance =

Actual N deposition – Critical load

Communicates extent of risk to ecosystems
Critical load use in Europe

Models forecast widespread negative effects of nitrogen on ecosystems

Exceedance of nutrient critical loads in 2010 with current legislation emission scenario

- No exceedance
- < 200 eq.ha\(^{-1}\).yr\(^{-1}\)
- 200 - 400 eq.ha\(^{-1}\).yr\(^{-1}\)
- 400 - 700 eq.ha\(^{-1}\).yr\(^{-1}\)
- 700 - 1200 eq.ha\(^{-1}\).yr\(^{-1}\)
- > 1200 eq.ha\(^{-1}\).yr\(^{-1}\)
Biodiversity/changes in species composition

- Mycorrhizal fungi
- Lichens and bryophytes
- Vascular plants
  - Understory (herbs)
  - Overstory (trees)
- Aquatic micro-fauna & flora
Methods

- Data Sources:
- Literature review, reports, unpublished data
RESULTS:
Ranking of CL by receptor

- algae (diatoms) < lichens < mycorrhizal fungi < herbs + shrubs < trees/forests
Responses: Epiphytic lichen

- Increased in tissue N concentration

- Altered community composition: shifts away from oligotrophs to eutrophs

Most sensitive bioindicators in terrestrial ecosystems
Lichens CL

Empirical CL of N (kg ha\(^{-1}\) yr\(^{-1}\))

<table>
<thead>
<tr>
<th>Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 3</td>
<td>Tundra; Taiga</td>
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<tr>
<td>2.7 - 9.2</td>
<td>Marine West Coast Forests</td>
</tr>
<tr>
<td>3</td>
<td>North American Deserts</td>
</tr>
<tr>
<td>3.1 - 5.2</td>
<td>Northwestern Forested Mountains</td>
</tr>
<tr>
<td>3.1 - 10.2</td>
<td>Mediterranean California</td>
</tr>
<tr>
<td>4 - 6</td>
<td>Northern Forests</td>
</tr>
<tr>
<td>4 - 7</td>
<td>Temperate Sierras</td>
</tr>
<tr>
<td>4 - 8</td>
<td>Eastern Forests</td>
</tr>
</tbody>
</table>

Uncertainty

- Reliable
- Fairly Reliable
- Expert Judgement
Exceedance = Deposition-CL

Lichens

Exceedance of Critical Loads of N
- Below CL min
- At CL min
- Above CL min
- Above CL max

Uncertainty
- Reliable
- Fairly Reliable
- Expert Judgement
Relating Lichen condition to N deposition

- Based on shifts in community composition
- Simple model
  - N deposition
  - Precipitation volume
  - Air score

From: Geiser et al. 2010. Lichen-based critical loads for N deposition in W. Oregon and Washington

Env Poll *158*:2412-2421
Relating Lichen condition to N deposition

- Regressions:
  - Air score to total N dep +precip
  - Best Fit

**Air score =**

-0.0918 + -0.0024 * Precip (cm) + 0.1493 * Total N (kg ha-1 y-1)

From: Geiser et al. 2010. Lichen-based critical loads for N deposition in W. Oregon and Washington

*Env Poll* 158:2412-2421
<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Mean Annual Precip. (cm)</th>
<th>Air Score</th>
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<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
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<tr>
<td>Taiga*</td>
<td>20</td>
<td>80</td>
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<tr>
<td>Northern Forests*</td>
<td>100</td>
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<td>NW Forested Mtns.</td>
<td>30</td>
<td>203</td>
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<td>Marine W. Coast</td>
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<td>451</td>
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<td>East. Temperate Forests*</td>
<td>71</td>
<td>305</td>
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<tr>
<td>Mediterran. CA</td>
<td>41</td>
<td>127</td>
</tr>
<tr>
<td>Temperate Sierras*</td>
<td>30</td>
<td>178</td>
</tr>
</tbody>
</table>

*Extrapolated values
Next steps of empirical CL for lichens

- Improve extrapolated air scores
  - Northern and Eastern Forests, Temp. Sierras
  - Using existing FIA data

- Calculate CL at finer grid (finer precipitation data: 4km → 800m)
Importance of empirical models as a basis for dynamic modelling

- Factors that affect CL/response
  - Biotic
  - Abiotic
- Need to expand dataset
- Develop and improve dynamic N cycling models (including biodiversity)
Refinement of CLs

1. Fine-scale land-cover map
Refinement of CLs

1. Fine-scale land-cover map

2. Constrain range of CL biotic and abiotic factors
Refinement of CLs

1. Fine-scale land-cover map
2. Constrain range of CL biotic and abiotic factors
3. Input from resource managers on receptor and responses of concern
Responses: Ectomycorrhizal fungi

- Altered community structure and composition
- Decrease species richness
Responses: Herbaceous plants

- Altered community composition:
- Increases in nitrophilic species
- Increased invasives
- Decreased species richness (native species)
- Increased fire
Responses: Forests

- Increased nitrate leaching
- Increased foliar N concentration
- Increased SOM N, nitrification
- Decreased growth, root biomass, survivorship, health
Responses of concern

- Fire frequency: Joshua Tree
- Checkerspot butterfly (Weiss)
- Pitcher plant
Next steps

- Refine empirical CL model for lichens
- Refine empirical CL estimates to finer than ecoregion scale
- Provide input for potential dynamic modelling