

Advances in Critical Loads Science and Application in the United States

Jennifer Phelan¹, Jason Lynch², Claire O'Dea³, Tonnie Cummings⁴, and Rick Haeuber²

¹ NADP-CLAD, University of Illinois, 2204 Griffith Drive, Champaign, Illinois, 61820, <http://nadp.sws.uiuc.edu/committees/clad>, phelan@illinois.edu

² U.S. EPA, 1200 Pennsylvania Avenue NW, Washington, DC, 20460

³ U.S. Forest Service, 1400 Independence Ave, SW, #1121, Washington, DC, 20250

⁴ U.S. National Park Service, Pacific West Region, 612 E. Reserve Street, Vancouver, Washington, 98661

Abstract

The objectives of this poster are to describe recent advances in critical loads science and application in the United States (U.S.), including critical load definitions, the National Critical Load Database (NCLD), and critical load maps. A series of critical load maps based on NCLD data are presented for the U.S. New critical load research, new and future products, and future directions for critical loads science and application are also outlined.

Key Words

critical load, deposition, exceedance

Introduction

The Critical Loads of Atmospheric Deposition (CLAD) Science Committee of the U.S. National Atmospheric Deposition Program (NADP) supports and advances the science and use of critical loads for assessing the effects of atmospheric deposition in the U.S. CLAD was officially formed in 2010, and its members consist of representatives from U.S. federal agencies, state agencies, universities, industry, non-governmental organizations, and consultants.

Products of CLAD include:

- Definitions of critical load terms (Critical Load Definitions)
- U.S. National Critical Load Database (NCLD)
- Critical load maps

This poster will describe recent efforts to advance the science and application of critical loads and exceedances in the U.S. and outline new critical load research products and future directions of CLAD.

Products

Critical Load Definitions

A standard set of definitions for critical load and critical-load related terms was developed by CLAD for use by its members and interested parties. For example, a critical load is, "A quantitative estimate of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt 1988). Other critical load terms defined or being considered by CLAD include: Empirical Critical Load; Steady-state Critical Load; Target Load; and Dynamic Critical Load.

National Critical Load Database (NCLD)

The NCLD consists of empirical and calculated critical loads data and information from many regional- and national-scale projects conducted and submitted to the NCLD by the research community (Lynch et al. 2015). This database serves as the source of data to examine the spatial extent of critical loads and their exceedance for the U.S. Critical loads represented in the NCLD include: Terrestrial Acidification; Aquatic Acidification; and Empirical Critical Loads of Nitrogen (N) for lichens, forest ecosystems, herbaceous species and shrubs, and mycorrhizal fungi.

Researchers are encouraged to submit new data to the NCLD to share and improve the estimation, calculation, refinement, mapping, and interpretation of critical loads for U.S. ecosystems.

Critical Load and Exceedance Maps

Three examples of critical load maps that represent the sensitivity of aquatic and forest ecosystems and lichens to deposition in the continental U.S. are presented in Figures 1 – 3. The critical loads are from the NCLD. Critical load exceedances were determined through comparisons of the critical loads with 3-year average total N and/or S deposition from the Total Deposition (TDEP) model. TDEP is a hybrid deposition model that provides estimates of total wet and dry deposition (2000 – 2013) based on a combination of measured and modelled data. Two time periods of deposition were selected to show temporal and spatial patterns of critical load exceedances (maps included in the poster). For Aquatic Acidification, the area of exceedance was found to decrease by 47% from 2000-02 to 2011-13, as large decreases in S deposition occurred over this time period, mainly in the eastern U.S. However, for both Forest Ecosystem and Lichen critical loads of N, the areas of exceedance have increased by 1.5 and 28%, respectively, likely because NH_3 deposition has increased throughout the U.S.

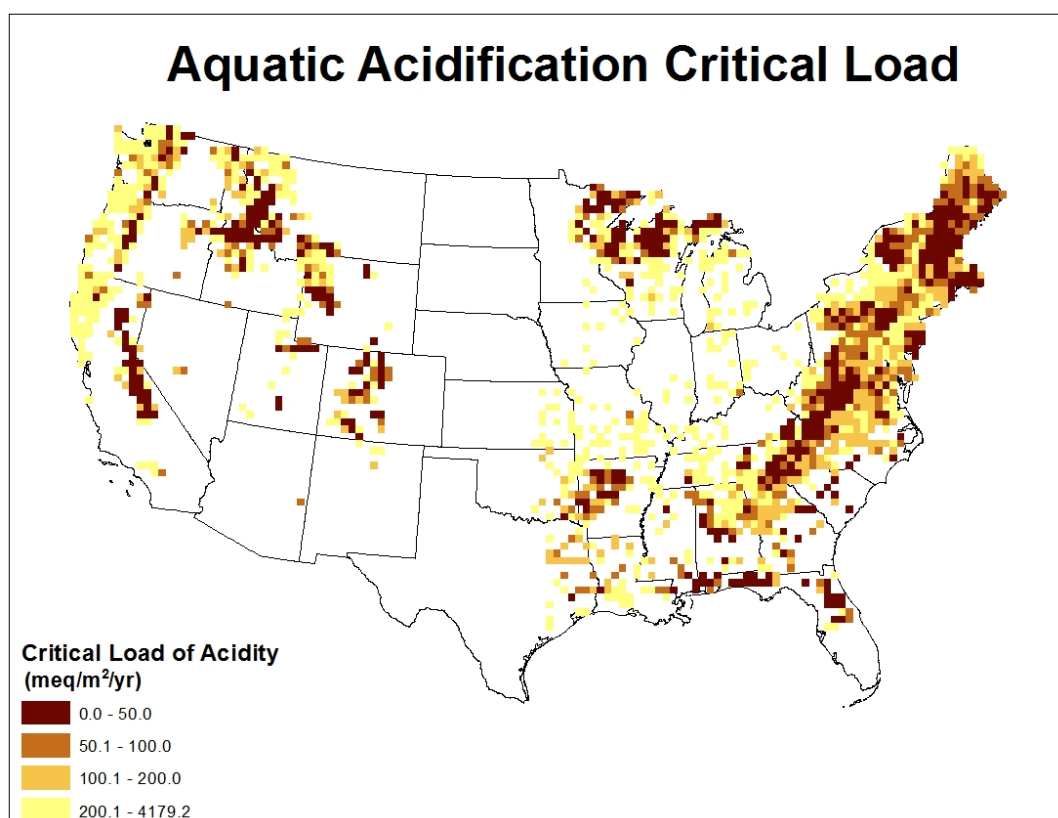


Figure 1. Aquatic critical loads of acidity in the continental U.S. Areas with critical load values are 36 km grids that contain at least one stream length or lake with a critical load value.

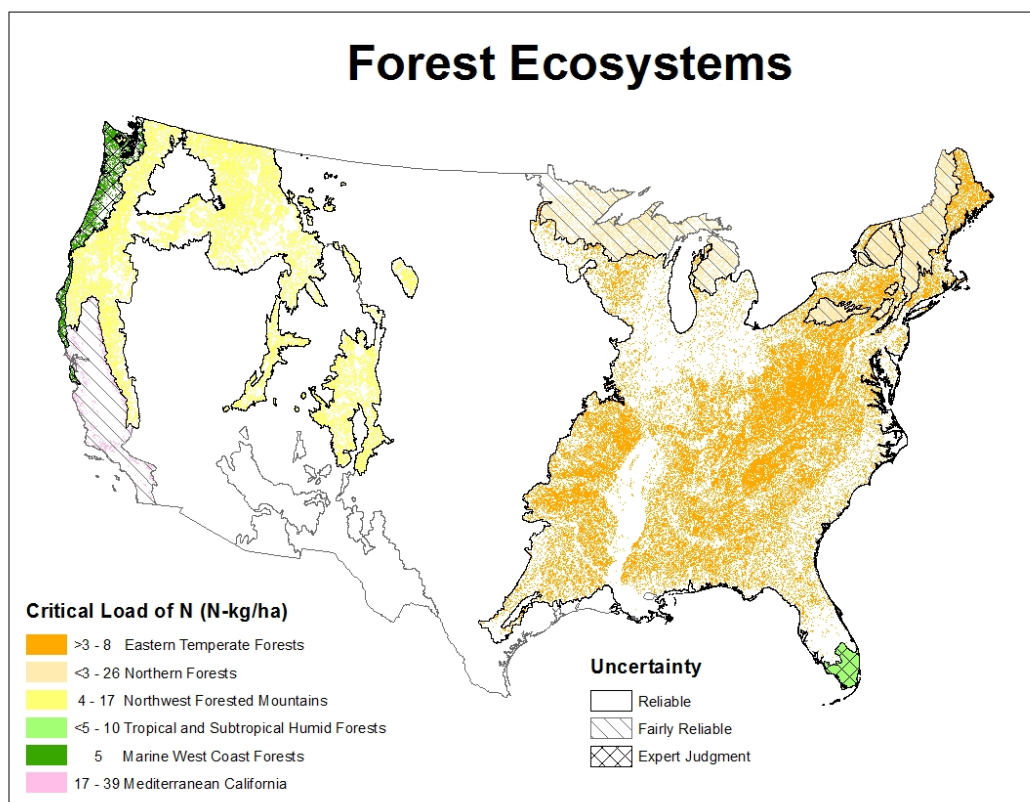


Figure 2. Forest Ecosystem critical loads of nitrogen (N) in the continental U.S. (based on Pardo et al., 2011). Areas with critical load values are forested land cover.

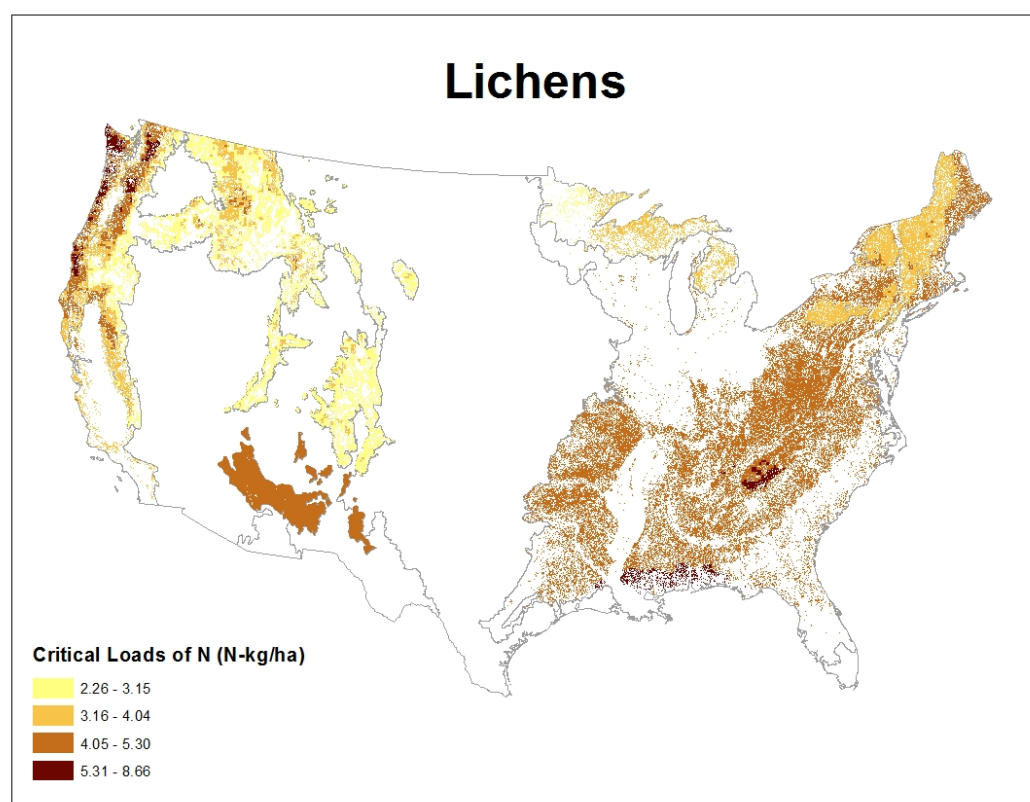


Figure 3. Lichen critical loads of nitrogen (N) in the continental U.S. (based on Geiser et al., 2010). Areas with critical load values are non-agriculture and non-urban land covers.

New Research Products and Future Directions

New Research to be Added to the NCLD

A variety of research that is relevant to critical loads is currently being conducted or was recently completed by members of CLAD and the science community. These studies evaluate(d) tree, herb, lichen and/or phytoplankton responses to atmospheric deposition and will be used to update terrestrial and aquatic acidification critical loads for the U.S.

New and Future Critical Load Products

New and future critical load products that are currently being or will be produced by CLAD members include: Air Quality – Ecosystem Services (AQES) Framework; U.S. EPA Critical Load Mapper Tool, U.S. Forest Service Handbook of Sensitive Species, and U.S. Forest Service Empirical Critical Load GIS Tool. The AQES is a tool to connect biological indicators impacted by air pollution to changes in ecosystem services with social value. The Critical Load Mapper Tool is an online GIS web tool to examine ecosystem sensitivity to N and S deposition for the continental U.S. The tool includes all NCLD critical loads and multiple deposition datasets ranging from 1850 to 2100. The Handbook of Sensitive Species is a three-volume technical report to identify species of lichen (vol. 1), trees (vol. 2), and herbs (vol. 3) that are sensitive to atmospheric deposition, and provides detailed descriptions of their ecology, geographic range, responses to deposition, and the ecosystem services they provide. The Empirical Critical Load GIS Tool is a tool for calculating and presenting empirical critical loads for forest ecosystems as a function of topographic and soil characteristics and climate conditions.

Future Directions for Critical Loads Research and Application

Two areas for future work include: 1. characterizing uncertainty of critical loads, and 2. critical load synthesis combining multiple critical loads within the same unit of area. Characterizing uncertainty will involve the development of a 5-point rating system to quantify uncertainty for all critical loads in the NCLD to facilitate meaningful evaluations, comparisons, and application of critical loads. The critical load synthesis will explore approaches for combining multiple critical loads within the same unit of area and evaluation of these approaches using case studies.

Conclusion

The development and use of critical loads of air pollutant deposition in the U.S. is gaining momentum, and recent research efforts in the U.S. have produced valuable data for calculating critical loads. The CLAD of NADP enables U.S. scientists, land managers, and environmental policymakers to enter into a productive and meaningful dialogue within the U.S. and with the international scientific community on methods for estimating, calculating, mapping, interpreting, and refining critical loads for the effects of acidification and excess nutrient N on terrestrial and aquatic ecosystems.

References

- Geiser LH, Jovan SE, Glavich DA and Porter M (2010). Lichen-based critical loads for atmospheric nitrogen deposition in Western Oregon and Washington Forests, USA. *Environmental Pollution* 158, 2412-2421.
- Lynch J, Pardo L and Huber C (2015). Detailed Documentation of the CLAD U.S. Critical Loads of Sulfur and Nitrogen, Access Database, version 2.5.
- Nilsson J and Grennfelt P-I (Eds) (1988). Critical loads for sulphur and nitrogen, vol. 15. Copenhagen, Denmark: Miljørapport: Nordic Council of Ministers.
- Pardo LH, Fenn M., Goodale CL, Geiser LH, Driscoll CT, Allen E, Baron J, Bobbink R, Bowman WD, Clark C, Emmett B, Gilliam FS, Greaver T, Hall SJ, Lilleskov EA, Liu L, Lynch J, Nadelhoffer K, Perakis S, Robin-Abbott MJ, Stoddard J, Weathers K and Dennis RL (2011). Effects of nitrogen deposition and empirical critical loads for nitrogen for ecological regions of the United States. *Ecological Applications* 21, 3049-3082.