EnviroAtlas

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Fact Sheet

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Natural Biological Nitrogen Fixation

This EnviroAtlas national map displays the rate of biological nitrogen (N) fixation (BNF) in natural and semi-natural ecosystems within each 12-digit hydrologic unit (HUC) in the conterminous United States (excluding Hawaii and Alaska) for the year 2006. These data are based on the modeled relationship of BNF with actual evapotranspiration (AET) in natural and semi-natural ecosystems. The mean rate of BNF is for the 12-digit HUC, not for natural and semi-natural lands within the HUC.

Why is biological nitrogen fixation important?

Nitrogen (N) is a fundamental building block for life. Though nitrogen is abundant on Earth, much of it is in the form of nitrogen gas (N_2), which is not usable by most organisms. Reactive N, however, can be used by all organisms, though it is much less abundant than N_2. Reactive N is created naturally through lightning strikes and by specialized bacteria that convert (or fix) N_2 gas into reactive N. Before the 20th century, the availability of reactive N limited plant productivity in many ecosystems and it was also a major limitation for food crop production.

Prior to European settlement, biological nitrogen fixation (BNF) was the only way (other than atmospheric deposition) that nitrogen entered ecosystems in North America. Since settlement, and particularly in the past century, advances in technology associated with food production and energy consumption have increased annual inputs of reactive N to terrestrial ecosystems and reduced the overall importance of natural and semi-natural BNF as a nitrogen source.[1] Currently, annual inputs of N from natural and semi-natural BNF in the conterminous United States are likely half of BNF inputs prior to European settlement. At the same time, annual reactive N inputs to terrestrial ecosystems in the conterminous U.S. are three to five times greater than pre-European settlement levels.[1]

Information on natural rates of nitrogen inputs to terrestrial ecosystems in the U.S. is critical for setting baselines for N management. Nitrogen management is important because, although human-created nitrogen inputs are critical for maintaining a sufficient food supply, inefficient nitrogen use in agriculture and society has led to countless human health and environmental problems. These problems include increased mortality and morbidity from air pollution, contamination of drinking water supplies, increased

frequency and severity of harmful algal blooms, hypoxia in freshwater and coastal marine ecosystems, and negative effects on climate.

Information on BNF can help inform policy decisions to combat nitrogen pollution. By quantifying background rates of N inputs at local, regional, and national scales, management efforts can optimize reductions of human-created N inputs. Spatial information allows for regional assessments of BNF rates, and it could help with setting nitrogen loading criteria.

EnviroAtlas provides a measure of BNF in natural and semi-natural ecosystems to facilitate comparisons of background N inputs across watersheds of varying size. More information on inputs of reactive N to the U.S. can be found in EnviroAtlas data fact sheets describing map layers for nitrogen fertilizer application, cultivated biological nitrogen fixation, and nitrogen inputs from manure produced on confined animal feeding operations.

How can I use this information?

The map, Natural Biological Nitrogen Fixation, is one of four EnviroAtlas maps that display reactive N inputs to the conterminous US. These data can be used either alone or in conjunction with other data layers to help identify areas where background N inputs are naturally high or low. These data can be used in models that examine the transport and cycling of nitrogen across terrestrial and aquatic ecosystems. The information can be used for nutrient reduction strategies, credit exchanges, and payments for ecosystem services.

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How were the data for this map created?

Biological nitrogen fixation in natural and semi-natural ecosystems was estimated using a correlation with actual evapotranspiration (AET). This correlation is based on a global meta-analysis of BNF in natural and semi-natural ecosystems.[2] AET estimates for 2006 were calculated using a regression equation describing the correlation of AET with climate and land use/land cover variables in the conterminous U.S.[3] Data describing annual average minimum and maximum daily temperatures and total precipitation at the 2.5 arcmin (~4 km) scale for 2006 were acquired from the PRISM climate dataset. The National Land Cover Database (NLCD) for 2006 was acquired from the USGS at the scale of 30 x 30 m. BNF in natural and semi-natural ecosystems within individual 12-digit HUCs was modeled with an equation describing the statistical relationship between BNF (kg N ha^{-1} yr^{-1}) and actual evapotranspiration (AET; cm yr^{-1}) and scaled to the proportion of undeveloped and non-agricultural land in the 12-digit HUC. HUC boundaries were taken from the NHDPlusV2 Watershed Boundary Dataset (WBD Snapshot).

What are the limitations of these data?

All national data layers such as NLCD and modeled AET data are, by their nature, imperfect. Nitrogen inputs generated from processing these datasets should not be taken as absolute truth but as an estimate using the best available data. National data layers continue to improve and periodic updates to the Atlas will reflect those improvements. Correcting or improving these data sets is beyond the purview of this Atlas project.

The quality of the yield data varies from state to state and county to county; evidence of this variability can be seen by comparing adjacent areas with similar land use/land cover in two different counties or states. The NLCD estimates land cover based on a classification of satellite imagery; the process of classifying imagery into land cover types is not 100% accurate. The user should be aware that the mapped data can be used to inform further investigation. Accuracy information for PRISM and NLCD source data can be found on their respective websites.

How can I access these data?

EnviroAtlas data can be viewed in the interactive map, accessed through web services, or downloaded. Data describing national land cover can be downloaded from Multi-Resolution Land Characteristics Consortium (MRLC). Climate data can be accessed from the PRISM climate dataset.

Where can I get more information?

Information on nitrogen cycling, BNF in the U.S., and health and environmental impacts of nitrogen can be found in the publications listed below. For additional information on how the data were created, access the metadata for the data layer from the layer list drop down menu on the interactive map. To ask specific questions about this data layer, please contact the EnviroAtlas Team.

Acknowledgments

EnviroAtlas is a collaborative effort led by EPA. The data for BNF were generated by Daniel Sobota from the Oak Ridge Institute for Science and Education (ORISE). Climate data came from PRISM. The fact sheet was written by Daniel Sobota, ORISE, and Jana Compton, EPA.

Selected Publications

1. Sobota, D.J., J.E. Compton, and J.A. Harrison. 2013. Reactive nitrogen inputs to US lands and waterways: How certain are we about sources and fluxes? *Frontiers in Ecology and the Environment* 11:82–90.

2. Cleveland, C.C., A.R. Townsend, D.S. Schimel, H. Fisher, R.W. Howarth, L.O. Hedin, S.S. Perakis, E.F. Latty, J.C. Von Fischer, A. Elseroad, and M.F. Wasson. 1999. Global patterns of terrestrial biological nitrogen (N_2) fixation in natural ecosystems. *Global Biogeochemical Cycles* 13:623–645.

3. Sanford, W.E., and D.L. Selnick. 2013. Estimation of evapotranspiration across the conterminous United States using regression with climate and land-cover data. *Journal of the American Water Resources Association* 49:217–230.

4. Compton, J.E., J.A. Harrison, R.L. Dennis, T.L. Greaver, B.H. Hill, S.J. Jordan, H. Walker, and H.V. Campbell. 2011. Ecosystem services altered by human changes in the nitrogen cycle: a new perspective for US decision making. *Ecology Letters* 14:804–815.

5. Houlton, B.Z., E.W. Boyer, A. Finzi, J. Galloway, A. Leach, D. Liptzin, J. Melillo, T.S. Rosenstock, D.J. Sobota, and A.R. Townsend. 2012. Intentional vs. unintentional nitrogen use in the United States: Trends, efficiency, and implications. *Biogeochemistry* 114:11–23.