Cultivated Biological Nitrogen Fixation

This EnviroAtlas national map estimates the rate of cultivated biological nitrogen fixation (C-BNF in kg N/ha/yr) by legumes (e.g., soybeans and alfalfa) 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 surveys of legume harvest and relationships of harvest yields with C-BNF rates. The mean rate of C-BNF is for the 12-digit HUC, not for agricultural lands within the HUC.

Why is biological nitrogen fixation important?

Nitrogen (N) is a fundamental building block for life. Though N is abundant on earth, much of it is in the form of an atmospheric 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, availability of reactive N limited plant productivity in many ecosystems, thus limiting food production.

Prior to the early 1900s, cultivated biological nitrogen fixation (C-BNF) was important for sustainable agricultural production.[1] The expanded use of nitrogen fertilizers created by fossil fuel combustion, beginning at the turn of the 20th century, has steadily decreased the overall reliance on C-BNF as a nitrogen source to many agricultural systems. Nevertheless, C-BNF remains a significant source of N for agricultural production in the United States and around the world.

C-BNF and other practices associated with food production and energy consumption have increased annual reactive N inputs to terrestrial ecosystems three-to-fivefold above pre-European levels in the conterminous US.[2] Though human-created nitrogen inputs, such as C-BNF, 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 effects on climate.

Information on C-BNF can help inform policy decisions related to agriculture and the mitigation of nitrogen pollution. By identifying hotspots of C-BNF at local, regional, and national scales, management efforts to enhance legume production and reduce the impacts of nitrogen pollution can be optimized. Spatial information allows for regional assessments of C-BNF rates. It also helps with decisions on cost-benefit trade-offs associated with various nitrogen sources.

Enviroatlas provides a measure of C-BNF to facilitate comparisons of nitrogen input across hydrologic units of varying size. More information on inputs of reactive N to the U.S. can be found in data fact sheets describing nitrogen fertilizer application, biological nitrogen fixation in natural and semi-natural ecosystems, and nitrogen inputs from manure produced on confined animal feeding operations.

How can I use this information?

The map, Cultivated Biological Nitrogen Fixation, is one of a group of EnviroAtlas maps that display reactive N inputs to the conterminous US. These data could be used either alone or in conjunction with other data layers to help identify areas where nitrogen is a significant pollutant source. These data could also be used in models that examine the transport and cycling of nitrogen across terrestrial and aquatic ecosystems. Information on C-BNF is or will be needed for development of nutrient reduction strategies, nutrient credit exchanges, and payments for ecosystem services.

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How were the data for this map created?

Nitrogen inputs from C-BNF were calculated with a model relating harvest yields of various leguminous crops with BNF rates.[1] We accessed county-level data on annual harvest yields for soybeans, alfalfa, peanuts, beans, and peas for 2006 from the USDA Census of Agriculture. We estimated the yield of the non-alfalfa leguminous component of hay as 32% of the yield of total non-alfalfa hay. This was based on the average fraction of total non-alfalfa hay made up by an assortment of clover species for the period 1924–1964, the period for which national level data on clover and non-alfalfa hay overlapped. C-BNF was modeled as a function of harvest yield, which assumes that yields reflect differences in soil properties, water availability, temperature, and other local and regional factors that can influence root nodulation and rate of N fixation.[1] We distributed county-specific C-BNF rates to agricultural lands (30 x 30m pixels) within the corresponding county. Following this distribution, we used the spatial analyst tool in ArcMap 10.0 (ESRI, Inc., Redlands, CA) to calculate a mean rate of C-BNF for individual 12-digit HUCs (22 March 2011 version). For a more detailed description, see the layer's metadata or the publications below.

What are the limitations of these data?

All national data layers such as NLCD and county-level legume crop yield data are, by their nature, imperfect. Nitrogen inputs generated from processing these datasets cannot be taken as absolute truth but as the best available data. National data layers continue to improve and periodic updates to EnviroAtlas will reflect those improvements. Correcting or improving these data sets is beyond the purview of the EnviroAtlas project.

We are using the best data available, but we want users to understand the limitations associated with these data. The quality of the yield data varies from state to state and county to county. The differences 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 use the data to inform further investigation. Accuracy information for source data can be found on the 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 the Multi-Resolution Land Characteristics Consortium (MRLC). County scale harvest data can be accessed from the USDA Census of Agriculture.

Where can I get more information?

Information on nitrogen cycling, nitrogen fertilizer in the U.S., and the health and environmental impacts of nitrogen can be found in the publications listed below. The data used to derive C-BNF rates came from the USDA Census of Agriculture. For additional information on how the data were created, access the metadata for the data layer from the drop down menu on the interactive map table of contents and click again on metadata at the bottom of the metadata summary page for more details. To ask specific questions about this data layer, please contact the EnviroAtlas Team.

Acknowledgments

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Selected Publications

1. Peoples, M.B., J. Brockwell, D.F. Herridge, I.J. Rochester, B.J. Alves, S. Urquiaga, R.M. Boddey, F.D. Dakora, S. Bhattarai, S.L. Maskey, C. Sampet, B. Rerkasem, D.F. Khan, H. Hauggaard-Nielsen, and E.S. Jensen. 2009. The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. *Symbiosis* 48: 1–17.

2. 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.

3. 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.

4. 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.