Net Agricultural Phosphorus Balance

This EnviroAtlas national map displays the mean crop phosphorus (P) balance between inorganic fertilizer and confined manure inputs and crop phosphorus removal from croplands (kg P/ha/yr) in the conterminous U.S. for 2012 summarized by 12-digit hydrologic unit (HUC). The data are based on International Plant Nutrition Institute (IPNI) compilations of county-level fertilizer sales data, confined manure production, and phosphorus content of major crops as well as cropland area from the U.S wall-to-wall anthropogenic land use trends (NWALT) land cover data for 2012.

Photo: EPA, Lexington, KY

Why is agricultural phosphorus balance important?

Phosphorus is an essential element of all living organisms, as a component of critical biomolecules for genetic material (DNA, RNA), energy transport (ATP) and membranes (phospholipids) within cells. As a result, it is necessary for plant growth along with nitrogen and other nutrients. In many ecosystems, including agricultural systems, phosphorus can be a limiting factor in plant growth and thus food production. In response to such limitations, farmers may apply additional phosphorus in the form of inorganic fertilizers, food and green waste composts, animal manures, or biosolids from human waste. However, when released from farms, cities, or industry, excess phosphorus can contribute to water pollution problems because algal growth is also limited by phosphorus availability in many freshwater and coastal ecosystems.

Since the domestic discovery of phosphorus deposits in the mid-1800s and following agricultural intensification after World War II, inorganic phosphorus fertilizer has become a key agricultural input in the U.S.[1] Phosphorus is mined from concentrated deposits of phosphate rock, primarily located in Morocco, China, and the U.S. (particularly in Florida).[2] As a mined non-renewable resource, inorganic phosphorus fertilizer is subject to potential price fluctuations associated with geopolitical scarcity. Increased use of fertilizer has increased crop yields, but also water quality problems associated with the addition of nutrients.[3]

Phosphorus in runoff and erosion from agricultural fields, pastures, and concentrated animal feeding operations, in addition to losses from industry and residences have contributed to algal blooms in lakes and coastal waters. Some algal blooms create harmful toxins affecting drinking water, food production (including shellfish), and recreational safety in waterbodies.[4,5] Algal blooms also cause hypoxia (low oxygen zones) that affect plants and animals in aquatic ecosystems and the industries that depend on them, such as fisheries in the Gulf of Mexico or Chesapeake Bay.

Because of the tension between the essential role of phosphorus in agriculture and its potential for overuse, understanding where and how much is applied to cropland is essential to maintain food security and increase water quality across the U.S. Better knowledge of the balance between phosphorus inputs and phosphorus uptake and removal from crops helps to target potential areas of excess phosphorus and pollution risk as well as cropland that may be in need of additional phosphorus to ensure high crop yields.

How can I use this information?

The map, Net Agricultural Phosphorus Balance, is one of four EnviroAtlas maps that display phosphorus inputs and agricultural crop phosphorus demand in the conterminous U.S. Net Agricultural Phosphorus Balance and three other maps, Phosphorus Fertilizer Application, Phosphorus Application as Manure, and Crop Phosphorus Removal, can be used alone or in conjunction with other data layers to help identify 12-digit HUCs where phosphorus is a significant pollutant (through over-application) or where there are opportunities for more efficient management or recycling to meet crop demands. These data can be used in models to examine the transport and cycling of phosphorus across terrestrial and aquatic ecosystems. Information on crop phosphorus demand and uptake is, or will be, needed for the 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?

Agricultural phosphorus balance in 2012 was estimated by subtracting crop phosphorus removal from inorganic phosphorus fertilizer application and phosphorus manure application (P fertilizer + P manure – P crop removal). County-level data describing total inorganic P fertilizer, confined manure, and total crop P uptake (kg P/yr) in 2012 were acquired from IPNI (see IPNI methodology for any of these phosphorus inputs and outputs). The land cover data used for this map, the 2012 U.S. national wall-to-wall land use trends (NWALT) data, were developed by the U.S. Geological Survey at a scale of 60m X 60m. These data were converted to per area rates (kg P/km^2/yr) of crop P input or removal by dividing the total P input or removal by the land area (km^2) of combined cultivated crop and hay/pasture (agricultural) lands within a county as determined from county-level summarization of the 2012 NWALT layer. We distributed county-specific per area P input and P removal rates to agricultural lands (60m X 60m pixels) within the corresponding county. Finally, the ArcGIS Zonal Statistics tool was used to calculate the mean P balance in kg/km^2/yr for each 12-digit HUC. This value was divided by 100 to convert to mean kg/ha/yr for each HUC. We capped P fertilizer application at 6000 kg P per km^2, manure at 10,000 kg P per km^2, and crop removal at 9000 kg P per km^2 to correct for some pixels with unrealistically high rates.[6-9]

What are the limitations of these data?

To match the latest available fertilizer data to create an agricultural balance layer, we used 60m resolution land use data that are not crop-specific. Finer scale and crop-specific land use could improve our understanding of phosphorus removal rates. The data presented here are based on fertilizer sales data and livestock populations as a proxy for P input application. Phosphorus removal considers only a subset of the 22 major U.S. crops. As a result, the application and removal rates are neither crop-specific, farm-specific, nor season-specific but rather a mean of overall annual cropland within a given county for 2012. Some crops, important regionally but not nationally, were not considered, which may represent an underestimate of total phosphorus removal in these areas of the country (particularly in the West). Data quality reporting may vary between states and counties. For example, fertilizer sold in one county in 2012 may have been applied in another county or during a later year, introducing additional error.

How can I access these data?

EnviroAtlas data can be viewed in the interactive map, accessed through web services, or downloaded.

Where can I get more information?

A selection of publications related to phosphorus application and ecosystem effects is listed below. For a more detailed description of data creation, see the layer's metadata or the publications below. To ask specific questions about this data layer, please contact the EnviroAtlas Team.

Acknowledgments

The data for Net Agricultural Phosphorus Balance were compiled by Genevieve Metson from the U.S. National Research Council. The data used to derive the map layer came from IPNI and NWALT. The fact sheet was written by Genevieve Metson (NRC), Jana Compton (EPA), and John Harrison (WSU Vancouver).

Selected Publications

1. Roberts, T.L., and D.W. Dibb. 2011. Fertilizer use in North America: Types and amounts in Lal, R. (Ed.), *Encyclopedia of Life Support Systems* (EOLSS), developed under the auspices of UNESCO. EOLSS Publishers, Oxford, U.K. 7 p.

2. Jasinski, S.M. 2013. Phosphate rock: USGS mineral commodity summaries: 2013. U.S. Geological Survey, Washington, D.C.

3. Cordell, D., and S. White. 2014. Life's bottleneck: Sustaining the world's phosphorus for a food secure future. *Annual Review of Environment and Resources* 39:161–188.

4. Anderson, D.M., P.M. Glibert, and J.M. Burkholder. 2002. Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries* 25:704–726.

5. Sharpley, A., H.P. Jarvie, A. Buda, L. May, B. Spears, and P. Kleinman. 2013. Phosphorus legacy: Overcoming the effects of past management practices to mitigate future water quality impairment. *Journal of Environmental Quality* 42(5):1308–1326.

6. U.S. Department of Agriculture Economic Research Service (ERS). 2015. Agricultural resource management survey on farm financial and crop production practices. Accessed June 2020.

7. MacDonald, J.M., M. Ribaudo, M. Livingston, J. Beckman, and W-Y. Huang. 2009. Manure use for fertilizer and for energy: Report to Congress. Administrative Publication No. AP-037, U.S. Department of Agriculture, Economic Research Service.

8. Murrell, T., and F. Childs. 2000. Redefining corn yield potential: Iowa. *Better Crops* 84:33–37.

9. Heckman, J.R., J.T. Sims, D.B. Beegle, F.J. Coale, S.J. Herbert, and T.W. Bruulsema. Phosphorus and potassium removal in corn: Eastern U.S. *Better Crops* 85:4–6.