Crop Phosphorus Removal

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


Photo: Soybean Field, Genevieve Metson, NRC

Why is crop phosphorus removal 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, phosphorus can contribute to aquatic pollution.

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, similar to fluctuations in oil pricing. 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, in addition to losses from industry, cities and homes (from human waste and detergents), and pastures or concentrated animal feeding operations (CAFOs), have contributed to algal blooms in lakes and coastal waters. Some of these algal blooms create harmful toxins affecting drinking water, food production (including shellfish), and recreational safety in waterbodies.[4] Even if the algal blooms are not toxic, they can 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 its essential role in agriculture vs. its potential as a pollutant, understanding where and how much phosphorus fertilizer is applied to cropland is important to inform management strategies that increase food security and water quality across the U.S. Information on phosphorus uptake and removal from crops, like the 2012 data presented here, is important to understand if phosphorus is being over- or under-applied based on crop needs.

How can I use this information?

The map, Crop Phosphorus Removal, is one of four EnviroAtlas maps that display phosphorus inputs and agricultural crop phosphorus demand in the conterminous U.S. Crop Phosphorus Removal and three other maps, Phosphorus Fertilizer Application, Phosphorus Application as Manure, and Net Agricultural Phosphorus Balance, 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 also 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?

Crop phosphorus removal in 2012 was estimated using county-level estimates of crop harvest. County-level data describing total crop phosphorus uptake (kg P/yr) in 2012 was acquired from IPNI; the data were compiled using 22 major crop yields and harvested acres from the USDA National Agricultural Statistics Service (NASS) summaries and U.S. Census of Agriculture data (see IPNI methodology for crops considered and removal rates used). 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 removal by dividing the total P crop 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 the county-specific per area P removal rates from IPNI to agricultural lands from NWALT (60m X 60m pixels) within the corresponding county. Finally, the ArcGIS Zonal Statistics tool was used to calculate mean kg/km^2/yr of P removed from each 12-digit HUC. This value was divided by 100 to convert to mean kg/ha/yr for each HUC. To correct for some pixels with unrealistically high P removal rates (most likely caused by little agricultural land in the county), we capped P removal at 9,000 kg of P per km^2, which is higher than potential removal of high estimates of corn yield (300 bushels/acre) and corn P removal.[5,6] For a more detailed description of data creation, see the layer's metadata or the publications below.

What are the limitations of these data?

EnviroAtlas uses the best data available, but there are still limitations associated with these data. To match the latest available fertilizer data (to create an agricultural balance layer where crop removal is subtracted from fertilizer and manure inputs), 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 only a subset of the 22 major U.S. crops and are annual in nature. As such the 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 and thus may represent an underestimate of total phosphorus removal in these areas of the country (particularly for diverse western cropland such as California's Central Valley or Oregon's Willamette Valley).

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. Links throughout the fact sheet contain additional information about phosphorus pollution risks and sustainability. To ask specific questions about this data layer, please contact the EnviroAtlas Team.

Acknowledgments

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

6. 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.

Falcone, J.A. 2015. U.S. conterminous wall-to-wall anthropogenic land use trends (NWALT), 1974–2012. U.S. Geological Survey Data Series 948, 33 p. plus 3 appendices as separate files.

Vaccari, D.A. 2009. Phosphorus: A looming crisis. *Scientific American* 300:54–59.