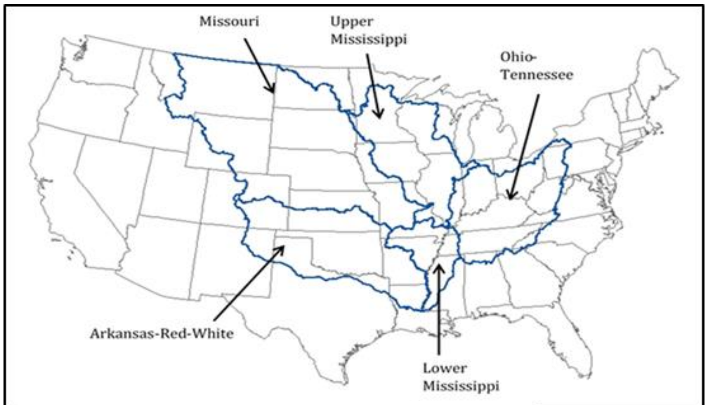
Subsurface Water Flow through Agricultural Tile Drainage Systems

This EnviroAtlas national map provides modeled estimates of sub-surface (lateral) flow at the outer edges of tile drained agricultural fields within each 12-digit hydrologic unit (HUC) in millimeters (mm) of water for 2002. Tile drainage is used in agriculture when a field is too wet to grow crops; pipes are placed under the soil to drain away excess water.



Limei Ran, USEPA, ORD/NERL/CED, RTPNC

Why is subsurface water flow through agricultural tile drainage systems important?

Agriculture can affect the quantity and quality of water in streams and waterbodies. Tile drainage can reduce runoff and sediment and improve conditions for crops, but it can also carry pollutants to streams and groundwater and change the hydrology of watersheds.

Tile drainage provides many benefits to farmers. It increases water storage in the soil, leads to greater crop productivity, prevents the buildup of salts, allows farmers to plant earlier and plant a greater variety of crops, makes it easier to use machinery in fields, and makes harvesting more efficient.[1,2] Tile drainage reduces the flow of water over the surface of a field, which can reduce the amount of sediment, phosphorus (P) and other pollutants in runoff compared to surface drainage.[1,3]

However, nutrients and other pollutants can still be carried in water flowing through tile drainage. Tile drainage can increase the transport of nitrogen (N) to ground and surface waters.[1] Well water contaminated with high levels of nitrate can cause an illness in infants called methemoglobinemia or blue-baby syndrome. Phosphorus can also be transported through tile drainage.[1,2] Water in tile drainage can quickly carry nutrients and pollutants to surface waters.[4]

Nitrogen and phosphorus are both nutrients that are critical to the existence of life on earth, but excess nutrients in fresh and near-coastal waters can result in algal blooms. Algal blooms can interfere with fishing and recreation and make drinking water difficult to treat; they can produce toxins that can make people sick and cause fish kills. The decay of particularly large blooms can reduce oxygen levels (known as hypoxia) in offshore waters to a point that is too low for many species to survive, creating “dead zones.”

Tile drainage can also change the hydrology of a watershed.[1,3] It can change the pattern of flow regimes for streams. Even though tile drainage decreases surface runoff, it can increase total flows to streams, increase erosion, change the stream channel’s shape, and contribute to flooding.[1,2,3] These changes can affect aquatic species and their habitats.

How can I use this information?

This map can be used to identify potential sources of water pollution and to understand hydrologic changes associated with agriculture. They can be viewed with layers describing water demand to suggest where tile drainage might pose a risk to water supply. While the model output is based on 2001/2002 data that may not represent current conditions, the information about the movement of water at the edge of agricultural fields can be used as a baseline to compare with current and future projections.

How was the data for this map created?

These data were created using the Fertilizer Emissions Scenario Tool for CMAQ (FEST-C). FEST-C combines Meteorology data for 2002 produced by the Weather Research Forecast model v3.4 and wet and dry atmospheric deposition to agricultural soils estimated by bidirectional CMAQ5.2[5] with field-level biogeochemistry and edge-of-field water movement simulated by the Environmental Policy Integrated Climate (EPIC) model. Simulations were performed for more than 100,000 rectangular grid cells (12km on a side) that form a continuous modeling layer across the conterminous U.S. These EPIC simulations are representative of regional, rather than local-scale conditions and assume conservation tillage on representative soils for specific crops at the HUC-8 (subbasin) scale. Irrigated and rain fed management simulations were performed for each of 22 major commercial crops. The results were then aggregated across all agricultural land in a

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simulation grid cell.[6] In order to pair land use with the meteorological and emission scenarios, the agricultural area in each grid cell was estimated using National Land Cover Database (NLCD) 2001 and US Department of Agriculture (USDA) 2002 Census of Agriculture county-level data. The gridded data are summarized by 12-digit HUC. For detailed information on how this data was generated, see the metadata.

What are the limitations of these data?

EnviroAtlas uses the best data available, but there are still limitations associated with these data. These data layers contain substantial uncertainties; they are based on models and large national geospatial databases. This map reflects assumptions about soil, weather, crop variety, and crop-specific management conditions in each 12-digit hydrologic unit. Early simulation design and performance evaluation for 2002 yield, fertilizer use, and predicted plant and harvest dates are reported in Cooter et al.[6] These simulations represent nutrient applications that roughly follow regional nutrient management practices on the most prevalent agricultural soils as identified in the National Resources Inventory at the HUC-8 level. The use of average grid cell slope could result in the over-estimation of horizontal water and nutrient losses by the model for some crop/soil combinations, particularly for tile drainage systems. Regional-scale studies of edge-of-field N and P losses are not generally available. Comparison of some of these 2002 EPIC nutrient export results for the Upper Mississippi River Basin, which lies within the larger Mississippi/Atchafalaya River Basin, to other published modeling studies are presented in Cooter et al.[7] Further comparison of model estimates of crop yield, fertilizer application amounts and timing, crop planting and harvest dates, and irrigation water use agree with USDA and US Geological Survey (USGS) estimates that rely heavily on site-specific survey information representing long-term average conditions in terms of overall spatial pattern and magnitude.[8,9]

How can I access these data?

EnviroAtlas data can be viewed in the interactive map, accessed through web services, or downloaded. The NLCD 2001 can be downloaded from the MRLC and the Census of Agriculture can be downloaded from the USDA's website.

Where can I get more information?

A selection of publications related to subsurface flow and dissolved nutrients is listed below. To ask specific questions about this data layer, please contact the EnviroAtlas Team.

Acknowledgments

The data for this map were generated by Ellen Cooter (FEST-C) and Jesse Bash (CMAQ), Computational Exposure Division, US EPA; Limei Ran, Dongmei Yang, UNC Institute of the Environment; and Verel Benson, Benson Consulting (FEST-C). Ellen Cooter, Computational Exposure Division (CED), Atmospheric Model Analysis and Application Branch, US EPA, and Megan Culler, EPA Student Services Contractor created this fact sheet.

Selected Publications

1. Blann, K.L., J.L. Anderson, G.R. Sands, and B. Vondracek. 2009. Effects of agricultural drainage on aquatic ecosystems: A review. *Critical Reviews in Environmental Science and Technology* 39:909–1001.

2. King, K.W., M.R. Williams, M.L. Macrae, N.R. Fausey, J. Frankenberger, D.R. Smith, P. Kleinman, and L.C. Brown. 2015. Phosphorus transport in agricultural subsurface drainage: A review. *Journal of Environment Quality* 44:467.

3. King, K.W., N.R. Fausey, and M.R. Williams. 2014. Effect of subsurface drainage on streamflow in an agricultural headwater watershed. *Journal of Hydrology* 519:438–445.

4. Robertson, E.M., and D.A. Saad. 2013. SPARROW Models used to understand nutrient sources in the Mississippi-Atchafalaya River Basin. *Journal of Environmental Quality* 42:1422–1440.

5. Appel, K.W., K.M. Foley, J.O. Bash, R.W. Pinder, R.L. Dennis, D.J. Allen, and K. Pickering. 2011. A multi-resolution assessment of the Community Multiscale Air Quality (CMAQ) model v4.7 wet deposition estimates for 2002–2006. *Geoscientific Model Development* 4:357–371.

6. Cooter, E., J. Bash, V. Benson, and L. Ran. 2012. Linking agricultural crop management and air quality models for regional to national-scale nitrogen assessments. *Biogeosciences* 9:4023–4035.

7. Cooter, E.J., L. Ran, D. Yuan, and V. Benson. 2017. Exploring a United States maize cellulose biofuel scenario using an integrated energy and agricultural markets solution approach. *Annals of Agricultural and Crop Sciences* 2(2):1031.

8. Brakebill, J.W., and J.M. Gronberg. 2017. County-level estimates of nitrogen and phosphorus from commercial fertilizer for the conterminous United States, 1987–2012: U.S. Geological Survey data release.

9. Yuan, Y., R. Wang, E. Cooter, L. Ran, P. Daggupati, D. Yang, R. Srinivasan, and A. Jalowska. 2018. Integrating multimedia models to assess nitrogen losses from the Mississippi basin to the Gulf of Mexico. *Biogeosciences* 15:7059–7076.