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Using Remote Sensing Data to Update a Dynamic Regional-Scale Water Quality Model

R. A. Smith (1), A. Nolin (2), J. Brakebill (3), E. Sproles (2), and M. Macauley (4)

(1) WRD, US Geological Survey, Reston, VA, United States (rsmith1@usgs.gov), (2) College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, United States (nolina@science.oregonstate.edu), (3) US Geological Survey, Baltimore, MD, United States (jwbrakeb@usgs.gov), (4) Resources for the Future, Washington, DC, United States (Macauley@rff.org)

Regional scale SPARROW models, used by the US Geological Survey, relate watershed characteristics to in stream water quality. SPARROW models are widely used to identify and quantify the sources of contaminants in watersheds and to predict their flux and concentration at specified locations downstream. Conventional SPARROW models are steady-state models and describe the average relationship between sources and stream conditions based on long-term water quality monitoring data and spatially referenced explanatory information. However, many watershed management issues stem from intra- and inter-annual changes in contaminant sources, hydrologic forcing, or other environmental conditions, which cause a temporary imbalance between inputs and stream water quality. Dynamic behavior of the system relating to changes in watershed storage and processing then becomes important.

Here, we describe a dynamically calibrated SPARROW model of total nitrogen flux in the Potomac River Basin based on seasonal water quality and watershed input data for 80 monitoring stations over the period 2000 to 2008. One challenge in dynamic modeling of reactive nitrogen is obtaining spatially detailed and sufficiently frequent input data on the phenology of agricultural production and terrestrial vegetation. We use the Enhanced Vegetation Index (EVI) and gross primary productivity data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Terra satellite to parameterize seasonal uptake and release of nitrogen. The spatial reference frame of the model is a 16,000-reach, 1:100,000-scale stream network, and the computational time step is seasonal. Precipitation and temperature data are from the PRISM gridded data set, augmented with snow frequency derived from MODIS. The model formulation allows for separate storage compartments for nonpoint sources including fertilized cropland, pasture, urban land, and atmospheric deposition. Removal of nitrogen from watershed storage to stream channels and to "permanent" sinks (deep groundwater and the atmosphere) occur as parallel first-order processes.

We use the model to explore an important issue in nutrient management in the Potomac and other basins: the long-term response of total nitrogen flux to changing climate. We model the nitrogen flux response to projected seasonal and inter-annual changes in temperature and precipitation, but under current seasonal nitrogen inputs, as indicated by MODIS measures of productivity. Under these constant inter-annual inputs, changing temperature and precipitation are predicted to lead to flux changes as temporary basin stores of nitrogen either grow or shrink due to changing relative rates of nitrogen removal to the atmosphere and release to streams.