Predicting presence of nutrients and pesticides in base flow of first order streams in the Mid-Atlantic Coastal Plain

Anne C. Neale and Ann M. Pitchford,USEPA/ORD/NERL/ESD/LEB

EPA Science Forum 2004
Healthy Communities and Ecosystems

Introduction

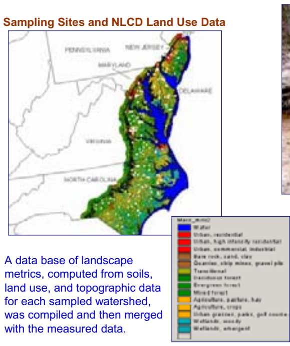
Excess nutrients and pesticides in the environment can cause a variety of ecological and human-health effects. When nutrients are unused by plants, or pesticides remain after use on their intended target, these compounds can be transported to streams, either directly through overland flow or through percolation through the soil, eventually contributing to ground-water discharge, sometimes termed "base flow," in a stream. Elevated concentrations of pesticides or nutrients can make water unfit for human consumption and can cause adverse effects on aquatic organisms (Briggs, 1992).

The Landscape Indicators for Pesticides Study in Mid-Atlantic Coastal Streams (LIPS-MACS) is a collaborative research effort between the U.S. Environmental Protection Agency's Office of Research and Development and the U.S. Geological Survey's National Water Quality Assessment Program. One of the objectives of the study was to develop models to relate land use, geology, and other geographic variables to water quality and aquatic ecology in small streams of the Mid-Atlantic Coastal Plain. Once models are developed and tested, they can be used to predict pesticides and nutrients for all similar watersheds in the region. These models will enable managers to compare watersheds and make preliminary decisions about where to allocate resources for additional monitoring, TMDL development, or remediation.

Methods

A base network of 174 small (typically first-order) streams was selected across within a gradient of hydrogeologic and land-use settings, from a population of 10,144 first-order watersheds within the region. Water samples were collected from all 174 streams and analyzed for selected pesticides, pesticide metabolites, nutrients, and major ions. Benthic-community and habitat assessments were also conducted at each stream.

Sampling Sites and NLCD Land Use Data



A data base of landscape metrics, computed from soils, land use, and topographic data for each sampled watershed, was compiled and then merged with the measured data.

The first step in our data analysis approach was to the reduce the number of independent variables by using a principal component analysis (PCA), thereby also eliminating the problems associated with collinearity common to landscape indicator modeling.

We then used a binary logistic regression to analyze the relationship between presence of pesticides and nutrients at various levels (dependent variables) and our suite of landscape metrics (independent variables), sampling date, and latitude. A binary logistic regression will predict the probability of a concentration of a given nutrient or herbicide exceeding some criteria. This predicted probability can then be calculated for all first-order watersheds in the region.

List of Landscape Metrics Compiled

Pagt	Percentage of all agricultural use
Pfor	Percentage of forest
Purb	Percentage of urban
Pwetl	Percentage of wetland
Agtsl3	Total agricultural land use on steep slopes (greater than 3%)
Rddens	Road density (km of road/km2 of watershed area)
Stxrd	Number of road/stream crossings per km of stream
Stprd	Length of roads in close proximity to streams
Ragt0	Percentage of land next to stream that is agriculture; 0 denotes stream cell only
Rfor0	Percentage of land next to stream that is forest
Rurb0	Percentage of land next to stream that is urban
Rwetl0	Percentage of land next to stream that is wetland
Elevmean	Mean elevation in watershed
Elevrange	Difference in highest and lowest elevations in watershed
Plancurve	Related to slope curvature and estimated rate of modeled sedimentation change
Slpmean	Average slope of watershed
Awc	Weighted mean soil available water capacity from STATSGO using relative proportions of the soil map unit components and their associated horizon thicknesses, expressed in inches of water per inch of soil, as a surrogate for porosity (NRCS, 1994)
Bd	Weighted mean soil bulk density from STATSGO using relative proportions of the soil map unit components and their associated horizon thicknesses, expressed in megagrams per cubic meter (NRCS, 1994)
Clay	Weighted mean soil percent clay fraction from STATSGO using relative proportions of the soil map unit components and their associated horizon thicknesses, expressed as percent of whole soil (NRCS, 1994)
Fastdrained	Sum of soil hydrogroups A and B
Moisture	Soil moisture content
Om	Weighted mean soil organic matter content from STATSGO using relative proportions of the soil map unit components and their associated horizon thicknesses, expressed as percent of whole soil (NRCS, 1994)
Perm	Weighted mean soil permeability value from State Soil Geographic Data Base (STATSGO) using relative proportions of the soil map unit components and their associated horizon thicknesses, expressed in inches per hour (NRCS, 1994)
Sand	Weighted mean soil percent sand fraction from STATSGO using relative proportions of the soil map unit components and their associated horizon thicknesses, expressed as percent of whole soil (NRCS, 1994)
Wtdep	Weighted mean depth to apparent water table from STATSGO using relative proportions of the soil map unit components,expressed in feet (NRCS, 1994)

Results – Principal Components

The first seven orthogonal components explained 82% of the variability within the independent variables.
The first principal component (PC 1) explains 28% of the variability and is representative of a high to low relief gradient. PC 2 is representative of urban land use. The third PC is indicative of soil texture (percent clay and percent sand) and permeability and explains 14% of the variability. PC 4 represents amount of agriculture in the watershed and in the riparian buffer. PC 5 accounts for 9 % of the variability and indicates areas with a high percentage of wetland area both in the entire watershed and in the riparian buffer and with soils of higher organic matter. PC 6 and 7 explain only a small amount of the variability (4% each). PC 6 suggests areas with higher wetland percentages in the riparian buffer only and soils with higher bulk density. PC 7 is positively associated with organic matter and bulk density of the soils as well as elevation.

Principal Components Coefficients

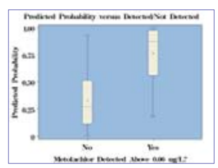
	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Variable							
moisture	**-0.76598**		0.46932				
plancurve	**0.78167**						
wtdep	**0.80486**						
om	-0.38087				0.55379	-0.36620	0.47528
bd			0.54827			0.41532	0.49799
awc	-0.57991		-0.53079		0.32361		
fastdrained	0.65478		0.41358				-0.38987
Elevrange	**0.82960**						
perm	0.32370		**0.84148**				
clay	-0.32943		**-0.72419**		-0.31811	0.32709	
sand	0.32061		**0.88232**				
Pfor	0.36468	-0.61664		-0.50007			
Pwetl	-0.47645			-0.37552	0.58560		
Purb	0.36319	**0.80974**					
Pagt	-0.49811			**0.76768**			
Agtsl3	0.45752			0.60308			
Slpmean	**0.81218**						
Elevmean	0.64442						0.45228
Rddens	0.43402	**0.81081**					
Stprd		**0.79017**					
Ragt0	-0.59171			0.64121			
Rurb0		**0.80915**					
Rwetl0				-0.40178	0.60180	0.45214	
Rfor0	0.56761	-0.43208			-0.33611		
Stxrd		**0.80608**					
Variance explained (%)							
	28	16	14	9	7	4	4

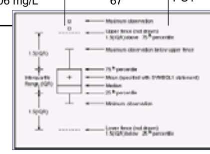
Note: Only those coefficients with an absolute value > 0.3 are listed in the table; those with a coefficient > 0.7 are listed in bold type.

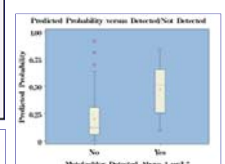
Results – Logistic Regression

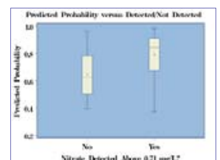
The logistic regression results for metolachlor, an herbicide, nitrate plus nitrite as total nitrogen, and total phosphorus are presented below. We were able to predict presence of metolachlor at levels above 0.06 µg/L with an 87% concordance and at levels above 1 µg/L with an 86% concordance. Nitrate plus nitrite was predicted at levels above 0.71 mg/L (ecoregional nutrient criteria) with a concordance of 78% and at levels above 1.5 mg/L with a concordance of 72%. Presence of total phosphorus at levels above 0.06 mg/L were predicted with a concordance of 67 %.

Parameter	Criteria Value	Percent Concordant	Significant Principal Components	Hosmer and Lemeshow Goodness of Fit Test (p-value)
Metolachlor	0.06 µg/L	87	PC 1, PC4, PC7, Sampling Date	0.47
Metolachlor	1 µg/L	86	PC 1, PC4, PC7, Latitude	0.67
Total Nitrogen (nitrate + nitrite)	0.71 mg/L	78	PC2, PC3, PC4	0.31
Total Nitrogen (nitrate + nitrite)	1.5 mg/L	72	PC3, PC4	0.41
Total Phosphorus	0.06 mg/L	67	PC1	0.41



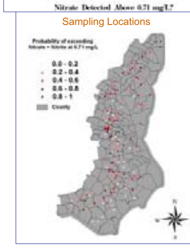




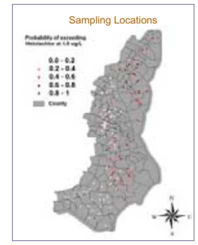


Sampling Locations

Sampling Locations

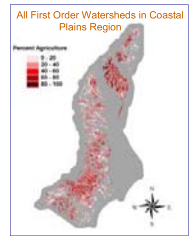


Sampling Locations



Sampling Locations

All First Order Watersheds in Coastal Plains Region



Conclusion and Next Steps

We were able to fairly accurately predict presence or absence of nutrients and pesticides at different concentrations. We are in the process of calculating soils and landscape metrics for the full 10,144 first-order watersheds in the region. When this data set is complete, we will be able to apply these models and predict presence of pesticides and nutrients at selected levels for most of our sample population of first-order watersheds. These models will enable managers to compare watersheds and make preliminary decisions about where to allocate resources for additional monitoring or remediation. We will also be conducting a similar study in the upper mid-western region (corn belt) of the country. This study will be begin collecting field data in August of this year.

Acknowledgements

We wish to thank Scott W. Ator and Judith M. Denver of the USGS, Donald Ebert and Maliha Nash of the U.S. EPA, and Rick Van Remortel of Lockheed Engineering and Sciences Company.