GEOGRAPHIC INFORMATION SYSTEMS FOR NONPOINT POLLUTION RANKING OF WATERSHEDS

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Introduction and Objectives

As nonpoint pollution control programs develop the need to prioritize the critical contributing areas increases. Integrating geographic information system (GIS) technology with modeling capabilities provides a valuable approach to assist in identifying these critical areas and to rank the relative severity of each.

For many years GIS has been used to help assess varying resource-related issues. These activities are occurring at various scales, from a national GIS to analyze the multiple benefits of the 1985 Farm Bill (Maizel, 1990); to a state level program called MAPS for presenting perspectives on Montana's land and climate attributes (Nielsen et al., 1990); and to detailed county specific assessment programs such as VirGIS in Virginia (Shanholtz et al., 1990).

GIS's have been applied in a limited number of cases for statewide modeling of pollutant loadings such as sediment, animal manures, and agricultural chemicals. This Penn State study uses a GIS-based model to rank the nonpoint pollution potential of 104 watersheds in Pennsylvania. The initial goals were to: select important processes and parameters of watersheds that contribute to water quality degradation, acquire appropriate statewide data in a GIS format, develop a ranking model to use the data, and use the model to predict the relative potential for agricultural nonpoint pollution for the 104 watersheds.

The GIS-based ranking model provides an approach for other states and regions to consider for initial watershed screening. While the model is specifically tailored for agricultural pollution potential, the same approach can be used to incorporate other, nonagricultural uses. This screening does not produce precise values of pollutant generation or transport, but does indicate a relative comparison of pollution potential severity and a reasonable base for additional, in-depth studies.

Ranking Methodology

Agricultural Pollution Potential Index (APPI) that combines the individual indices of runoff, sediment production, animal loading, and chemical use was used to rank the 104 Pennsylvaniawatersheds. Figure 1 schematically illustrates the APPI (Petersen et al., 1991).

Runoff Index (RI). This index predicts the watershed's potential to produce surface runoff and uses the SCS Runoff Curve Number Method for predicting runoff volume. Precipitation, land use, and hydrologic soil group data are considered in the Curve Number method. Runoff is calculated for individual cells in the watershed, then summed and divided by the area of the watershed to calculate the runoff index.

Sediment Production Index (SPI). A modified version of the Universal Soil Loss Equation was used to calculate erosion for each cell. The erosion for all cells were summed for the watershed and this value multiplied by the sediment delivery ratio to determine the total sediment load.

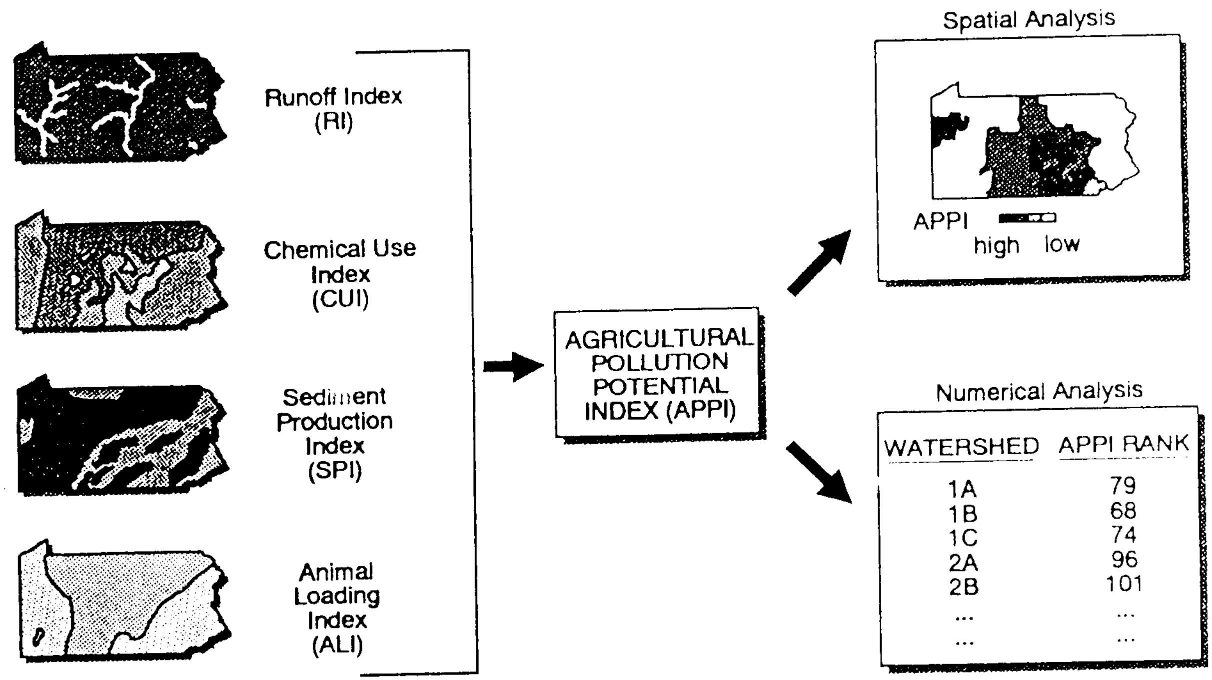

Figure 1. Agricultural Pollution Potential Index Schematic

Animal Loading Index (ALI). This index ranks the potential manure loading from livestock within a watershed. For each area, the nitrogen loadings were calculated using the number of livestock within the area and a loading factor for each animal type.

Chemical Use Index (CUI). This index ranks the potential for agricultural pollution from agricultural chemical applications. The potential loading of agricultural chemicals for each cell was rated as high, medium, low or not applicable based on the potential agricultural chemical application to each type of land use. Loading values were then summed for the watershed and divided by the total area to provide the chemical use index.

GIS Database

The Office for Remote Sensing of Earth Resources (ORSER) and the Land Analysis Laboratory at Penn State University developed the databases using the ERDAS and ARC/INFO software systems. For each data layer, existing map and data units were collected from various sources to produce parameter layers in the GIS. The seven data layers were scaled to 1:250,000 and subdivided into 100 m by 100 m (1 hectare) grid-cells.

The following briefly describes each data layer and the source of the information (Petersen et al., 1991). Similar data layers should be easily obtained or developed for other regions.

Watershed Boundaries. This layer was adapted from the State Water Plan of the Pennsylvania Bureau of Water Resources Management (BWRM). Watershed sizes were calculated using this data layer and verified against the standard size designated by BWRM. Similar watershed delineations should be available for other states and regions.

Land Use. This information was accessed from the U.S. Geological Survey (USGS) Land Use Data Analysis program. To further delineate agricultural land uses, we assigned agricultural lands with slopes ranging from 1-15% as cropland, while agricultural lands with slopes of 0-1% and greater than 15% we designated pasture.

Animal Density. The animal populations were obtained from the U.S. Census Bureau which provided the type and number of animals for each zip code. From this the nutrient loadings for various livestock types were calculated and the average manure nitrogen loading in each watershed determined.

Topography. This information was extracted from Digital Elevation Data (DEM) from the USGS. The percent slope for each grid cell was calculated using the elevation data in a 3 by 3 cell area surrounding the cell of interest.

Soils Data. The Soil Conservation Service's National Cartographic Center provided the State Soil Geographic Data Base (STATSGO) map. This soil geographic database is linked to a soil attribute record database called Soils-5. These combined databases provided soils information needed in the rankings.

Precipitation. The precipitation layer was developed in consultation with research scientists at ZedX, Inc., a commercial firm that markets specialized databases for agricultural decision making. The data layer combines two databases derived from the climatological station summaries published by the National Climatic Data Center in Asheville, North Carolina.

Rainfall-Runoff Factor. Scientists from ZedX, Inc. also helped produce this data layer. The 22-year annual average erosion index values (EI) for stations in Pennsylvania were spatially interpolated to create the data layer desired for this project (Russo and Bass, 1990).

Results

Figure 2 presents the rankings of watersheds considering only the agricultural lands including cropland, pasture, orchards, confined feeding ar-

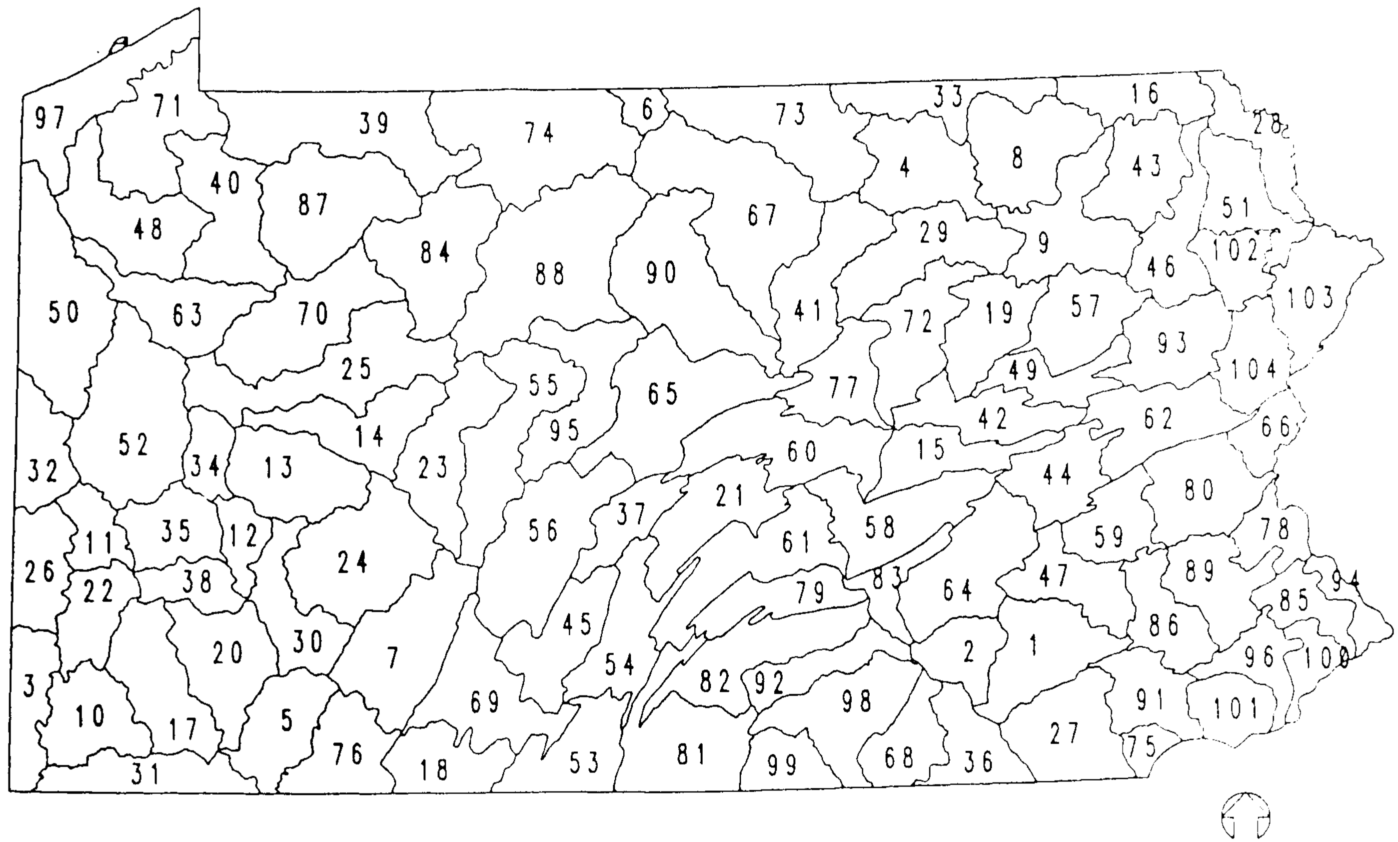

Figure 2. Ranking of Watersheds by Agricultural Pollution Potential Index Using Only Agricultural Lands

eas, farmsteads, etc. For the most part, the watersheds with the greatest agricultural pollution potential due solely to agricultural activities are located in the southwestern and northeastern section of Pennsylvania. These correspond to areas that have fairly steep topography and significant animal production on the agricultural land areas even though agricultural production is typically on less than 40% of the watershed. Typical agricultural pollution control practices will most likely be effective if targeted toward these high ranking watersheds. Therefore, further in-depth assessment and pollution control programs geared toward agricultural enterprises should most likely be focused toward the watersheds having the highest rankings.

Summary

Readily available databases can be incorporated into a GIS-modeling system to conduct a statewide or regional rankings of agricultural nonpoint pollution potential by watershed. The ranking model presented incorporated the potential pollutant generation from chemical use on agricultural lands and manure production from livestock. The model also assessed the relative potential for generated pollutants to be transported from land to stream systems. Because of the scale and availability of statewide data and the intent to perform an initial screening of critical watersheds, a simple model was used in this study. However, the approach offers a framework for further model development and sophistication as the data and scale of the study become more refined.

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