7.7 Defining Soil Resource Management Areas Causing Watershed P Loss

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**Introduction:**

Considerable growth of crop and animal agriculture in the river bottoms of the West Kentucky Coal Field physiographic region has occurred. One of the big watersheds of the region, the Lower Green River (HUC 05110005), is rated ‘vulnerable’ to runoff ([www.epa.gov/iwi/hucs](http://www.epa.gov/iwi/hucs), 2001). Both surface and subsurface drainage are used in the area, and land managers utilize both natural and man-made channels to accelerate water removal from the more poorly drained areas. Results of a recent EPA 319 project conducted within McLean County (Henson, 2001) suggest that surface water phosphorus (P) levels in portions of three smaller watersheds (14 digit HUC’s) contributing to the Lower Green River are greater than the average observed in Kentucky’s surface waters (0.15 mg P/L; [http://water.nr.state.ky.us//ww/ramp/rmtests](http://water.nr.state.ky.us//ww/ramp/rmtests)).

These results have prompted questions from the region’s stakeholders (row-crop and broiler growers, rural non-farm landowners, local government, and local industry). What land uses, landforms and surface soil properties are associated with elevated water P concentrations? Anticipating oncoming regulation via the TMDL (total maximum daily load) approach, what can individual managers do to reduce P loading of surface waters? The area’s economy depends heavily on agriculture and river-bottom landscapes are an important base for economic activity. This project is an investment in the improvement/sustainability of soil resource management for improved water resource outcomes. Though the issue here is P, the chosen spatial approach, if successful, should be applicable to other pollutants moving from land to water resources.
The proposed research is premised on the rationale that “the solution needs to fit the scale (or dimension) of the problem”, and integrates several issues in P loading to surface waters. Those include soil P management, pathways of P transport, BMP development and watershed-scale assessment for identifying problem areas and targeting management (Sharpley and Tunney, 2000). First, land use, soil P, soil hydrology and the likelihood that the surface is at risk for generating runoff laden with P requires an analysis scale for which geographic information system (GIS) analysis is appropriate. The GIS analysis would define “critical source areas”, at high risk for P loss, based on a hierarchical classification system, which we would test with field study sites. Properly ground truthed, GIS analysis is the likely tool of choice in watershed-scale planning and the coming allocation of ‘watershed rights’ among different land areas/users.

Second, within the watershed, at the scale of individual fields, both the soil P level and the surface soil hydrology resulting from soil/crop management vary widely. Differing soil test interpretation philosophies and tillage systems result in differing levels of surface soil P. Conservation tillage systems, such as no-tillage, stratify more P at the soil surface. But the region lacks information on the relationship between these management choices and runoff P loss, and this at a time when the region is experiencing greater conservation tillage management.

The scope of the proposed research is to test the idea that Geographic Information System (GIS) analysis, perhaps in combination with local correlation and calibration of the relationships between surficial soil hydrologic and chemical properties, will define and locate “critical source areas” among landforms, soils and land uses found in the lower Green River.

Objectives:

The specific objectives of the research project fall under the main project objective, that being “the development and advancement of geospatial technologies in support of natural
resource management, land-use planning and decision making to improve environmental quality”. Specific objectives are: a) to use GIS to develop a hierarchical classification system that relates different layers of information (geology, topography, soils, and land use) to define and locate “critical source areas” for runoff P within the Lower Green River Watershed; b) to test whether the identified critical source areas exhibit expected differences in surface soil hydraulic properties, soil P levels, and soil management; and c) to calibrate the hierarchical classification system using a nested sampling approach.

**Background:**

Past GIS analysis of watersheds has found that nutrient losses are not spatially uniform. Steegen et al. (2001) found that sediment and P loss from two agricultural watersheds could be understood only if the spatial relationships between erosional and depositional areas were accounted for. Losses were greater where land uses resulting in sediment production were in close proximity to the outlet. McDowell et al. (2001) found that stream P concentrations during storm flow were driven by erosion from fields also high in soil test P, concluding that a better understanding of the spatial and temporal distribution of loss processes would improve BMP effectiveness. This supported an earlier GIS analysis by Endreny and Wood (1999), who found in simulations that only small parts of the watershed needed BMPs. These areas were somewhat variable (variable source areas), depending upon the precipitation event. Gburek and Sharpley (1998) had a similar conclusion, finding runoff production was in “limited but identifiable” parts (critical source areas, CSAs) of the watershed. Grove and Pena-Yewtukhiw (2005), working at field scale, demonstrated that topography and soil test P were most important to determining in-field areas with greater potential for eroded P transport.
Phosphorus input management varies in western Kentucky, including field areas in the Lower Green River watershed. Some growers utilize University of Kentucky recommendations, which follow a crop sufficiency philosophy. Others follow less conservative recommendations, usually based on a yield goal-soil maintenance philosophy (Fixen and Grove, 1990). When combined with variation due to irregular application of animal wastes in these fields, there is likely considerable variation in field-level soil P levels. Further, there is some diversity in rural land use (row cropping, pasture, forestry). The relationship between soil P and runoff water P is not well known for soils in the area, though other research suggests the relationship is positive and biphasic, more steeply inclining once a critical level of soil P loading is reached (Pote et al., 1999). Research on P sorption in Kentucky, reported by D’Angelo et al., 2001 and Vandiviere et al., 2003, suggests that the Belknap soil, important in the watershed, has low P affinity.

Surface soil management varies with land use, being least intensive in pastured and forested areas. Within row crop fields, tillage systems are changing. More growers are moving to no-tillage in their corn soybean rotation. Soybean leaves soils with fewer residues, and warmer, at corn planting. Chisel plowing with a number of secondary tillage trips still dominates area-wise, and losses in surface residues and soil structure associated with greater tillage intensity in this system are associated with greater particulate P loss in other studies (Bundy et al., 2001). No-tillage results in reduced inputs of labor, machinery and time during critical planting periods. Work done on well-drained row crop soils in Kentucky found little difference in runoff P loss between no-tillage and less intensive chisel plowing (Blevins et al., 1990; Seta et al., 1993).

**Procedures:**

Towards the first objective, we will conduct a GIS analysis of the McLean County portion of the Lower Green River watershed. As the transfer of soil P to surface waters is
mediated by the interaction of soil P level, soil hydraulic processes, and landscape attributes, so do each of these variates exhibit spatial characteristics due to distributions of soils, landscapes, and land uses. Spatial characteristics will be functionally and hierarchically classified into groups based on the characteristics that define source areas for runoff P. The functional hierarchical classification method developed will use, in the higher hierarchical classes, general characteristics of the watershed area (higher scale denominator information) related to macro processes (e.g. geology, relief, watershed hydrology), followed by more detailed characteristics of sub-watershed areas related to P suspension and movement (e.g. land use). The lower hierarchical classes will use even more detailed information, related to micro processes (e.g. soil series) (Elizalde, 2001).

The information will be characterized by variables selected assuming a functional relationship between them and the characteristics of a source area as regards runoff P (e.g. slope, row crop land use, soil map unit). Once source area criteria are established, subareas within each watershed will be put into one of three risk classes (low, medium, and high) for runoff P. Results of the hierarchical selection process will thereby define subareas in the watershed representative of three levels of risk as “critical source areas”. Proposed GIS data sources are the Quadrangle spatial Library (for county, land use [1:60,000 GIRAS], and digital elevation map layers), 7.5’ Geologic Quadrangle Maps (GQM - georeferenced, digital images), the digitized soil survey for McLean County (National Soil Survey, 1980), Digital Raster Graphics Maps of 7.5’ Topographic Quadrangles in Kentucky State Plane Coordinate System (DRGMAPS - NAD83 – georeferenced, for slope,), and USGS Hydrologic Maps (1:500,000 – for stream segmentation and hydrologic boundaries). We presume that we will use ARC/Info format. Data sources are available via the State of Kentucky’s Geospatial Data Library.
To meet the second and third objectives, we will select representative source areas, at each risk level, to test the classification system. Within the watershed, a sampling design for soil physical properties will be defined that fulfills the following needs: functional representation of the main geographical, soil type, land use, and management units; local representation of functional properties, transport coefficients, and surrogate or indicative variables; spatial variability structure of measured information as a basis for co-regionalization, quantitative basis for transferring findings from intensively sampled areas to less intensively sampled areas and independently validate the results. To accomplish that objective, the spatial sampling protocol will be based on a nested design. A transect is laid out across the watershed, covering the different source risk classes, and 12 nests will be laid out. Four nested sampling sites will be sited at each risk level. Within each of these 12 nests, 20 locations will be defined where soil surface hydraulic and physical properties will be measured. The sampling locations within the nests will be designed in a way that will support sound semivariogram and cross variogram information. In situ measurements will include water infiltration at and close to water saturation, air permeability, surface crust thickness, soil surface micro relief and dry bulk density. Soil structure, texture and P chemistry will be characterized in the laboratory. We will then relate soil surface physical and hydrologic properties and soil P chemistry to the hierarchical classification of risk as regards runoff P loss. We want to identify and provide to systems of soil decision-making essential information on spatial correlation structure, information that so far has often been ignored, but is essential for functional soil process and risk maps.

Mallants et al. (1997) and Wendroth et al. (2005) applied a scheme of alternating sampling distances in order to gain information on semivariance and cross variance structure for short and intermediate lag distances so as to define the spatially representative range for the
individual physical and chemical measurements. From this sampling scheme, we expect to derive a spatial relation between sampling labor-intensive variates and other, less intensive, surrogate variates. Based on these spatial relationships additional locations will be selected in the watershed. Associated soil physical and chemical properties and P loss risk will be predicted. At these locations, derived relationships will be validated. We expect this experimental procedure will test the suitability of the GIS based functional hierarchical system in adequately defining and delimiting source areas at low, medium and high (critical) risk for runoff P in McLean County portion of the Lower Green River Watershed.

**Expected Benefits:**

If the research is successful we should produce a functional hierarchical spatial classification system that both defines and delimits high risk, “critical source areas” for runoff-borne P that could be used by stakeholders (landowners, policymakers, regulators) interested in guiding and prioritizing implementation of practices designed to reduce P (and potentially other pollutants) impairment of surface waters in rural watersheds. Another major benefit will be in the mere experience of generating, testing and calibrating a GIS based functional hierarchical classification system to define other watershed-based environmental issues using a spatially sound sampling scheme to ground truth conditions in a rural Kentucky watershed. The research results have important implications regarding whether management of environmental problems might be done at the watershed scale, causing Kentucky’s land owners/managers to reduce environmental risk by delineating fields, or portions of fields, where the combination of soil properties and P management cause greater potential for runoff P loss, for BMP application. Further, such research results will assist them in determining the minimum data set required to document an area’s current and future runoff P risk status. This, then, could be the basis for
defining participation in future TMDL phosphorus credit trading schemes. A pilot program based on these ideas is just getting started in Lancaster County, Pennsylvania (Coale, pers. comm.).

Results of the research could be conveyed to stakeholders through several outlets. Watershed stakeholder field days, workshops for policymakers and regulators, and written summaries for all rural Kentuckians are all appropriate examples. Information on P runoff management and GIS classification system testing/calibration would be presented at field days. Workshops would show land owners/managers how to apply the classification system to other watersheds. A Soil Science News and Views article will be published following the second year of research to outline project progress. An Extension publication with recommendations based on the research will be published at the conclusion of the project. Finally, a decision support tool would be placed on the UK Precision Resource Management Website to help guide landowners and managers through the “critical source area” identification and delineation process.

**Deliverables:**

In addition to the extension components detailed above, it is anticipated that two or three scientific journal articles would result from this work, regardless of the acceptance or rejection of the scientific hypotheses. Several presentations at scientific meetings would also result. We would publish a “manual” on the GIS and related data required to determine the runoff P “risk level” for source areas within Kentucky’s rural watersheds.