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THE POTENTIAL FOR USING A P LOSS MODEL TO IMPROVE THE ACCURACY OF THE KENTUCKY PHOSPHORUS INDEX

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Introduction: The phosphorus (P) Index is an assessment tool developed to identify fields which are most vulnerable to P loss by accounting for the major source and transport factors controlling P movement in the environment. The Kentucky P Index was developed over 10 years ago, and since its inception, a significant amount of research investigating the factors governing P loss at the field scale has been published. The KY P Index, however, has not been updated to stay current with the literature. A recent analysis by Bolster (2011) showed that several limitations exist with the Index, including how each factor in the Index is weighted, the lack of terms to account for planned P application rates, and the use of land cover and field slope as surrogates for erosion rather than erosion rates as derived from RUSLE. Furthermore, a recent comparison between measured P runoff collected from sites in North Carolina and Georgia and estimates of P risk obtained with 12 southern P Indices showed that the KY P Index provided some of the poorest estimates of P loss risk of all the P Indices tested. These studies highlight the need to update and revise the KY P Index to better reflect the current state of the science.

Ideally, measured edge-of-field P loss data should be used to update and refine a P index. However, such data are lacking in many states and this is particularly true for Kentucky. When sufficient data are unavailable, an alternative approach to updating and improving a P Index is to use estimates of P loss generated from a validated P loss model to help guide index revision. In the current study, this approach to P Index revision is evaluated using the Pennsylvania P Index, which is one of the more well-developed P indices in the U.S. and has served as a template in the development of other P indices, with the goal of demonstrating that this approach should be considered for updating and revising the KY P Index.

Methods: P loss data were generated for a wide range of field and land management conditions using the Annual P Loss Estimator (APLE) P loss model (Vadas et al. 2009). The P loss data were then fit with the PA P Index by using least squares regression to adjust the weights on each factor in the index to obtain the best fit to the model-generated data. Estimates of P loss risk were then calculated for a variety of fields across a range of physiographic and climatic regions in the U.S. using the existing and modified versions of the PA P Index and compared with measured edge-of-field P loss data. Correlations between the measured P loss data set and values of the original and modified PA P Indices were evaluated.

Results: Fitting the PA P Index to the APLE-generated data resulted in a noticeable reduction in the amount of scatter between P Index values and model-generated P loss when compared with the original Index. The weights obtained by fitting the APLE-generated P loss data were significantly different from the weights of the original PA P Index. More importantly, the relative magnitudes of the weights for the modified Index were drastically different from the original Index. For instance, in the original PA P Index, weights for runoff, sediment loss, applied manure, and applied fertilizer are all set to one and the weight for STP is 0.2. The weights for the modified version of the PA P Index, however, varied by a factor of over 20. The biggest difference in the relative magnitudes of the weights is in how particulate P loss is weighted. With the original Index, P loss from runoff and erosion are equally weighted. The fitted weight for the erosion component of the modified Index, however, was an order-of-magnitude greater than the fitted weight for dissolved runoff P loss from STP.

Using the weights obtained from fitting the APLE-generated data noticeably increased the correlation between P index predictions and the measured P loss data set. For instance, using the modified P index increased r^2 from 0.19 to 0.36 for the untransformed data and from 0.52 to 0.65 for the log-transformed data. Moreover, the root mean square error, mean absolute error, and mean absolute percent error were all significantly lower for the modified PA P index compared with the original PA P index.

Summary: The significant improvement in the modified version of the PA P index using the fitted weights demonstrates the critical role that proper weighting plays on P index accuracy. In the current KY P Index, index weights were based on the professional judgment of the technical specialists who developed the 590 Standard for KY (NRCS 2001). In this study a simple method for obtaining index weights that are consistent with a validated P loss model is demonstrated using the PA P Index as an example. An additional advantage to this approach is that the resulting P Index is capable of generating actual estimates of P loss (i.e. loads) rather than a relative risk rating. This is an important consideration given the recent emphasis by USEPA for states to develop numeric water quality standards for lakes and streams. Given that USDA-NRCS is requiring that each state evaluate the accuracy of their P index, the method demonstrated in this study should be considered when making needed revisions to the KY P Index.

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ADDITIVE STATE SPACE MODEL – A PROMISING APPROACH TO WATER-QUALITY-RELATED TREATMENT EXPERIMENTS IN HETEROGENEOUS LANDSCAPES

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Inherent soil spatial variability complicates understanding of hydrological, soil and plant-related processes in agriculturally used ecosystems. This variability is often times considered as a severe obstacle especially when treatments have to be imposed in an area of interest that is known to be affected by underlying spatial trends. In those cases, randomization and blocking of treatments does not necessarily result in the expected compensation of soil variability or spatial trends of soil properties across the landscape. The objective of this contribution is to introduce an experimental approach to study field-scale solute leaching behavior as affected by rainfall amount, intensity and application time delay in a variable landscape of Kentucky. The experimental approach is also applied to a nitrogen fertilizer experiment in a farmer's field that is known for its considerable spatial variability causing the crop response to vary across the landscape. In this case, a unique fertilizer-yield-response function would be inappropriate. In both field studies, treatments were not randomly arranged but laid out in a systematic sine-oidal design. The concept of this design is based on the fact that the scale of treatment application differs from that of underlying field variability. An additive state-space model approach has been adapted from economic time series modeling. It decomposes small-scale variability caused in our studies by treatments of either rainfall scenarios in one case or fertilizer application rate in the other case. The large-scale component manifests the underlying trend caused by different factors that remain unknown or are known to some extent. In case of the leaching experiment, different rainfall characteristics were varied in the experiment across different scales. The new additive state-space approach was able to separate small-scale from large-scale variation components, the latter being in our case the influence of rainfall amount and intensity. Once the different scales of variation were identified, the large-scale behavior was described in an autoregressive model. In case of the leaching experiment, the auxiliary variables were amount and intensity of rainfall application, and in case of the nitrogen treatment study, landscape topography, such as elevation, and soil clay content were most helpful to explain the

varying response of the crop yield to nitrogen applied across the field. In the presentation, both experiments will be presented in detail and their major outcomes, followed by a description of the statistical analysis. The results of this contribution are relevant for all those who study hydrologic, vadose zone and crop processes at the field- and landscape-scale. This study shows how to impose treatment experiments in a non-random but systematic design in variable landscapes in order to improve water and environmental quality, efficiency of nitrogen fertilizers, and management of water resources and field crops. At the same time, inherent soil variability does no longer have to be considered as an obstacle, but as an opportunity.

DEVELOPMENT AND APPLICATION OF NUMERIC INTERPRETATIONS OF KENTUCKY'S NARRATIVE WATER QUALITY STANDARDS FOR NUTRIENTS

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Excess nutrients are a significant cause of water quality impairments to surface waters in Kentucky. Excess nutrients can affect water quality and uses of lakes and streams through stimulation of plant and algal growth which can result in low or widely fluctuating dissolved oxygen, pH, altered habitat for aquatic life, reduced biological integrity of aquatic communities, taste and odor problems in drinking water systems, and aesthetically undesirable accumulations of algae. These potential problems from nutrient-related causes are addressed in various sections of Kentucky's water quality criteria. In the course of surface water quality monitoring, field observations, measurements and biological surveys identify cases where these criteria are exceeded, resulting in an assessment that the waterbody is not supporting aquatic life or recreational uses.

Waterbody impairments from nutrient-related causes are addressed by water resource management programs such as the Total Maximum Daily Load (TMDL) and Nonpoint Source Pollution programs, through TMDL calculations and watershed-based plans. Both programs have a goal of returning the waterbody to meeting water quality standards and fully supporting the uses. These programs require quantifiable target concentrations for the pollutant in order to develop allowable loads and calculate the needed load reductions. Since many of the water quality criteria related to nutrients are narrative and not numeric, these narrative criteria must be translated into numeric interpretations. The Kentucky Division of Water (DOW) has recently outlined a process for developing numeric interpretations for TMDL analysis and watershed-based plans involving nutrients. While there are important differences in the function of targets for these two purposes, the general process is similar. Multiple sources of information are drawn upon to derive one or more targets that are appropriate for the watershed characteristics and the specific nature of the observed impairment(s). The first category of information comprises empirical data from similar streams that show the relationship between nutrient indicators and indicators of impairment, preferably pointing to a concentration or range above which impairment is likely to occur. The second category of information employs summary statistics describing the range of concentrations observed in similar streams that have been observed to fully support the use (i.e., "reference sites"). The third category of information consists of literature values such as classification schemes, models, or other published guidelines that are relevant to the specific impairments identified and which have been derived from comparable watersheds. Multiple candidate targets produced from these three categories are weighed and a final target is selected.

This general approach to developing numeric interpretations has been used to provide initial target concentrations for a TMDL model under development for nutrients in Floyds Fork (Jefferson, Oldham, Shelby, Bullitt, and nearby counties). For this watershed, stream size was judged to be an important factor potentially influencing the response of aquatic life and benthic algae to nutrient loadings. Targets were selected (total phosphorus and total nitrogen) for three stream-size classes. Targets take two forms: a conservative target where the model can allow an exceedence of the target every three years and a maximum target that should not be exceeded in the water quality model. Follow-up monitoring in 2012 will be conducted to validate or refine these targets before finalizing the allowable loads.

Floyds Fork TMDL Draft total nitrogen and total phosphorus targets*

Size category	**TP target 3 yr ex**	**TP target max**	**TN target 3 yr ex**	**TN target max**
Headwater (<5 sq mi)	0.09	0.12	0.70	1.0
Wadeable (5-100 sq mi)	0.15	0.25	1.1	1.6
Transitional/Boatable (>100 sq mi)	0.20	0.66	2.2	2.4

*In headwater sections of the watershed, the target is to be applied as an annual geometric mean. In wadeable and transitional/boatable sections, the target is to be applied as a growing season (April-October) geometric mean. In all sections, the lower target is not to be exceeded more than once in every three years, and the maximum is never to be exceeded, each of these as an annual or growing season geometric mean.

Numeric interpretations also are being developed by DOW in support of watershed based plans (WBPs). Targets serve multiple functions in WBPs. First, a set of screening benchmarks is helpful in the process of reviewing early phase monitoring data in order to identify priority sub-watersheds for the more focused monitoring needed to estimate pollutant loads. Second, after review and possible refinement, the targets for select indicators can serve as analytical endpoints for determining load reductions. Finally, targets can be used for post-implementation success monitoring as an indicator of when to re-examine recovery of the uses. Benchmarks have been developed for two WBPs to date (January 2012) with more in review. Pending input and feedback from the WBP developers, these benchmarks will serve as target concentrations for developing load reductions in the plans.

Watershed-Based Plan Benchmark Recommendations

Triplett Creek, Rowan County		Lower Howards Creek, Clark County	
Total P	0.02 mg/L	Total P	0.25 mg/L
TKN	0.50 mg/L	TKN	0.50 mg/L
Nitrate-Nitrite-N	0.40 mg/L	Nitrate-Nitrite-N	2.0 mg/L
Total N	0.65 mg/L	Total N	2.5 mg/L

ARSENIC REMOVAL IN REACTOR SYSTEMS

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The potential application of a biochemical process for achieving near complete removal of arsenic in the wastewater stream was investigated in one-stage and two stage reactor systems. The process involved the coupling of biological oxidation of As (III) to As (V), and the subsequent adsorption of As (V) by Activated Alumina (AA). The chemoautotrophic *Thiomonas arsenivorans* strain b6 was used for the oxidation of As (III) to As (V). The one-stage reactor process was operated under two influent As (III) concentrations (60 mg/L and 100 mg/L) and a constant hydraulic retention time (HRT) of 1.0 day for 12, and 6 days, respectively. The pattern of arsenic removal was very similar under both operating conditions. The two-stage reactor system was operated under a very high influent As (III) concentration of 500 mg/L and HRT of 1 day. A near complete removal of arsenic was achieved at 10 days in the two stage reactor process. However, the overall performance of both reactor systems may have been limited due to various operating parameters and interference from several chemical species competing for the same adsorption site on AA.

NOTES

TRENDS IN WATER QUALITY ISSUES FOR APPALACHIAN MINING

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Water quality issues continue to impact coal mining operations in Appalachia as operators attempt to obtain permits for pollutant discharge or hollow fills. Diverse groups have assessed the long-term impacts of mining and reclamation efforts on water quality. This presentation examines recent research reports and ongoing studies of cumulative hydrologic impact of surface mining in Appalachia. Interpretation of these studies may inform decisions by regulatory authorities including the U. S. Army Corps of Engineers, the U. S. Environmental Protection Agency, and the Kentucky Division of Water as they evaluate requests for permits.

Well-publicized studies, such as those by Gregory Pond and others, have raised questions about the long-term impact of Appalachian mining on aquatic life in mountain streams. Recent studies published in 2011 suggest additional evidence of the impacts of mining. These new studies include those by Melissa M. Ahern, et al., 2011, The association between mountaintop mining and birth defects among live births in central Appalachia, 1996-2003, Environmental Research 111, 838 – 846; and Ty Lindberg, et al., 2011, Cumulative impacts of mountaintop mining on an Appalachian watershed, PNAS, see www.pnas.org/cgi/doi/10.1073/pnas.1112381108. These are not the only sources of new information, however, because both operators and regulators continue to conduct field studies to gather data used in cumulative hydrologic impact assessments (CHIA). Comparing the results of these additional studies suggests that the impact of mining and related activities varies among watersheds.

These water quality issues inform critical decisions on water discharge permits issued under Section 402 of the Clean Water Act and dredge and fill permits issued under Section 404 of the Clean Water Act. In connection with evaluation of these permits, EPA and the Corps entered into a Memorandum of Understanding to conduct “Enhanced Surface Coal Mining Pending Permit Coordination Procedures” (“Enhanced Coordination Procedures”). The EPA also issued a Detailed Guidance: Improving EPA Review of Appalachian Surface Coal Mining Operations Under the Clean Water Act, National Environmental Policy Act and the Environmental Justice Executive Order (“Detailed Guidance”).

Several groups independently filed suit against EPA to challenge EPA's oversight of coal-related water permits under the Enhanced Coordination Procedures and the Detailed Guidance. The different suits were consolidated into one now pending in the U.S. District Court, Washington, D.C. In October 2011 the U. S. District Court struck down policies and procedures adopted by the EPA Corps regarding dredge and fill permits required under the Clean Water Act. National Mining Association v. Lisa Jackson, No. 10-CV-1220 (D. D.C. Oct. 6, 2011). The court ruled that the EPA had "exceeded the statutory authority conferred upon it by the Clean Water Act" and that the agencies had ignored the proper "notice and comment rulemaking requirements" of the Administrative Procedures Act. These consolidated cases will yield at least one more major decision regarding EPA's guidelines for review and requirements for water discharge permits for coal mining operations (the Detailed Guidance).

It is important to note that the issue before the court was not whether the policies and procedures were warranted by the facts about the environmental impacts of mining, and the court did not suggest that similar policies and procedures, if adopted according to statutes and procedural rules, would not be upheld. Therefore, it is critical to future regulatory decisions, whether in rulemaking or in individual permit decisions, that the breadth and complexity of water quality data be fully evaluated.