Quantitative P Index Development to Meet Numeric Water Quality Standards

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Abstract

The goal of a Phosphorus (P) index is to help producers improve water quality by reducing P load from individual agricultural fields. The sensitivity of the receiving waters should be reflected in the restrictiveness of a P index. Numeric water quality standards are becoming more common, linking P indices with these defined water quality goals is a necessary step. P indices were not originally developed to be quantitative predictors of phosphorus loss, but they are increasingly required to do so. The once clear line between a P index and a full hydrologic model has blurred as P indices become increasingly complex. Many P indices now incorporate sediment predictions from other models, such as RUSLE. Hydrologic models like Soil and Water Assessment Tool (SWAT) can accurately predict P loss for individual fields or entire watersheds. Models require a great deal of specialized knowledge, and are too complex for field managers to use. The goal of this research is to develop a vastly simplified interface for an existing hydrologic model (SWAT). This tool is an expansion of the Pasture Phosphorus Management (PPM) Calculator, a SWAT model based P index for the Lake Eucha/Spavinaw Basin, located in northeast Oklahoma and northwest Arkansas. The tool presented here, PPM+, is applicable to both pastures and cultivated land throughout Oklahoma, and allows a variety of field management options. This interface is under development and validation is underway. The purpose of this exhibition is to obtain feedback on the interface and incorporate that information to the final release.

Introduction

The Phosphorus (P) Index is an assessment tool for use by planners and land users to assess the risk for P leaving a site and traveling toward a water body (NRCS, 1994). A P Index is generally a qualitative tool which yields a categorical rating of P loss from a single site based on a number of field metrics and management options thought to influence phosphorus loss to nearby streams. This rating is used to determine allowable application of fertilizers and animal wastes.

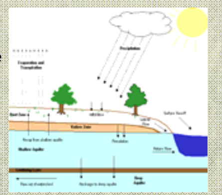
The PPM+ is an interface for an existing water quality model which predicts P loss, sediment, and runoff from a single field, effectively functioning as a P index. PPM+ allows Comprehensive Nutrient Management Plan (CNMP) developers to make predictions of actual P loads under differing managements and BMP scenarios. It is important to note that PPM+ is no more complex in application than a traditional P index.

P Index Evolution

P indices were not originally developed to be quantitative predictors of P loss (Lemunyon and Gilbert, 1993); nor were they intended to be used as a regulatory tool (NRCS, 1994). The role of P indices has been expanded to develop CNMPs to meet the Natural Resource Conservation Services (NRCS) standard for nutrient management (590). With the use of P indices as regulatory tools, the need for improved accuracy has increased. The flexible framework of the P index approach readily allows the incorporation of new science to improve predictions. The majority of P indexes now incorporate predictions from models such as the Revised Universal Soil Loss Equation (RUSLE) to better predict particulate P loss (Sharpley et al., 2003). The processes of P loss and transport are complex (Sharpley et al., 2002), the cost of additional accuracy is increased complexity. Some P indices have demonstrated a high correlation with measured P yields (Harmel et al., 2006; Eghball and Gilley, 2002; Sharpley et al., 2001), indicating that these indexes could be used to predict quantities of P loss. The ability of some P Indices to function as true P models has blurred the line between a P Index and a P model.

The SWAT Model

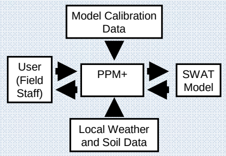
PPM+ is an interface for the Soil and Water Assessment Tool (SWAT) (Arnold et al., 1996). SWAT is a widely accepted model which has been used extensively by hydrologists and engineers since 1994 in the United States as well as a number of other countries around the world. SWAT's strength lies in the physical basis of the model, which gives it the ability to make accurate predications under a wide variety of conditions and Best Management Practices (BMPs). PPM+ only utilizes the "field" components of the SWAT model and does not use the channel routing and transformation routines that may be needed when applying the model at a watershed or basin scale. Models like SWAT have been used for many years to make predictions of P loss, but models have one primary weakness, they are complex. These models require a great deal of specialized knowledge, and data not readily available to P index users; farmers and conservation agents require a simpler tool (Veith et al., 2005).



SWAT Hydrologic Cycle

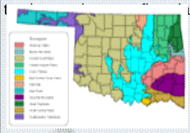
PPM+ - A Field Level Phosphorus Management Tool

Models like SWAT are generally too complex for use by conservationists and farmers, but they don't have to be. PPM+ was designed to be easy to use; the user does not see, nor directly interact with the SWAT model. An intelligent model interface takes relatively simple user data and generates the complex SWAT model inputs using internal database for weather, soils, and management. The SWAT model is executed in the background, after which PPM+ summarizes the output in a simple table that is easy to interpret. All the information entered by the user is listed in the output, along with monthly average precipitation, runoff, sediment, soluble and total P, and estimated annual Soil Test P (STP) increase.



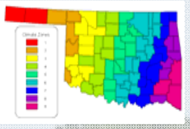
PPM+ Structure

PPM+ was developed for the state of Oklahoma, and includes databases describing weather, soils, and calibration parameters across the state. Oklahoma has tremendous differences in annual rainfall, ranging from 15 in/yr in the northwest panhandle to 55 in/yr in the mountains of the southeast. This tremendous difference must be accounted for in a statewide P management tool. Climatic and geologic diversity has given Oklahoma a wide variety of soil types, over 480 are currently represented in the interface. Hydrologic calibration parameter sets were developed for each Level III Ecoregion in Oklahoma by calibrating the SWAT model ...ta.



Oklahoma Ecoregions

Calibration Watersheds



Climate Zones

Meeting Numeric Water Quality Standards

P index thresholds (i.e. its restrictiveness) should be tied to local water quality objectives and/or standards. This is a difficult task if the P index is qualitative. With the increasing adoption of numeric water quality standards it is relative straightforward to calculate the maximum allowable P loss (lbs P/ac/yr) from agricultural lands within a basin required to meet the numeric standard (reductions from point sources and other nonpoint sources like urban should be considered). The maximum allowable P loss becomes the limit for a quantitative P index, ensuring that we are no more or less restrictive than required to meet the water quality standard. Qualitative P indices are unitless, but still typically contain thresholds that restrict the actions of the farmer. Often different restrictions are levied at category levels or thresholds, for example:

P Index value = 56 = high category = ½ recommended manure application allowed
P Index value = 85 = very high category = no manure application allowed

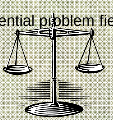
Setting P index thresholds that restricts field management has a direct impact on water quality, yet the effect is largely unknown. If we seek to strike a balance between economics and water quality, we must know the true water quality impacts of the decisions we make.

Qualitative

Indexed Risk (57 on a scale of 1-100)

Categorical (High, Medium, or Low)

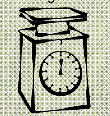
- Allows comparison of one field to another
- Useful to CNMP developers by providing guidance selecting management approaches
- Identify potential problem fields



Quantitative

Absolute P Load (2.7 lbs P/ac/yr)

- Provide P load and predict off-site impact
- Prioritize management practices based on water quality impacts
- Directly integrate nutrient management plans into watershed planning and the TMDL process



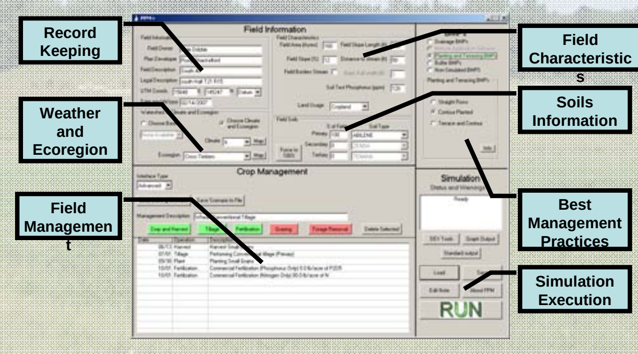
Improvements to PPM+

Previous versions of PPM+ (White et al., 2003) were only applicable to pasture systems in the Lake Eucha/Spavinaw Basin. The latest version is applicable to the entire State of Oklahoma, and includes common agricultural crops. The latest version is still under development, but has a significant number of improvements over previous versions.

- **Updated SWAT 2005 engine**
- **Expanded to cover the entire State of Oklahoma**
- **More flexible operation scheduling**
- **Handles row crops and small grains (simple and advanced options)**
- **Irrigated crops**
- **Rotational grazing and supplemental feed**
- **Hydrologic model calibration parameters by ecoregion**
- **Alum amended animal waste**
- **Predicts average annual STP change**
- **Cattle in streams impacts**
- **Riparian and grass buffers**
- **Pond effects**
- **Contour planting and terraces**
- **Multiple soils allowed within a single field**
- **Non-simulated BMPs tracked for record keeping**
- **Expanded validation and testing (in progress using data from Oklahoma and surrounding states)**

PPM+ User Interface

The PPM+ interface is shown below, and is near completion. The 2005 SWAT model used by PPM+ is being modified with updated P cycling routines. PPM+ will be extensively tested and validated before being released (Fall 2007). A beta version of the interface is available for inspection and testing on a nearby laptop. Feedback on the interface and model assumptions is welcome and encouraged, and will be used to revise the final interface.



Record Keeping – Important documentation that is not used in model predictions.
Weather and Ecoregions – Enter precipitation and ecoregion from map.
Field Management – Actual field operations including harvest, planting, tillage, fertilization, hay cutting, and grazing.
Field Characteristics – Field topographical parameters, STP and land use.
Soils Information – Fraction of field occupied by each soil type.
Best Management Practices – BMPs selection, inappropriate BMPs are disabled.
Simulation Execution – Save, load, execute and other functions for generating predictions.

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