Recommendations for PQUAL Sensitivity to Inputs

Guido Yactayo – UMCES
gyactayo@chesapeakebay.net

Background

- The HSPF uses the Agricultural Chemical Model (AGCHEM) and the Pervious Quality Model (PQUAL) modules for the simulation of nutrient export.

- AGCHEM simulates biological and chemical processes, while PQUAL simulates nutrient fluxes using a simpler coefficient-based method.

- Although AGCHEM is a robust module from academic and scientific standpoints, its high level of complexity represents a obstacle for comprehension management communities. The PQUAL module would be more straightforward for comprehension and decision implementation.

- The effect of changes in nutrient inputs on nutrient outflows from the land simulation of existing watershed models used in the Chesapeake Bay Watershed have been estimated. These input-output relationships are referred to in this analysis as sensitivity.

- The sensitivities obtained from the analysis of all models will be used to specify functional links between nutrient inputs and outputs and then implemented within the PQUAL module in the phase 6 version of the Chesapeake Bay Watershed model.

Objectives

- To estimate the effect of changes in nutrient inputs on nutrient outflows of existing watershed models (*The input-output relationship is referred to in this analysis as sensitivity*)
- To build, present and implement model sensitivities within the PQUAL module in the phase 6 version of the Chesapeake Bay Watershed model.

Phase 5.3.2 CBP Watershed Model

- The Chesapeake Bay Program Modeling Team has conducted a sensitivity analysis of the P532 AGCEHM simulation between all nutrient inputs and outputs

- This analysis incorporated input loadings and predicted yields information from fourteen different P532 scenarios, including simulations from 1985 to 2011

- Multi-variate regressions, slopes between nutrient export and input loading, and ratios between nutrient export and input loading were calculated to identify P532 landuse sensitivities.

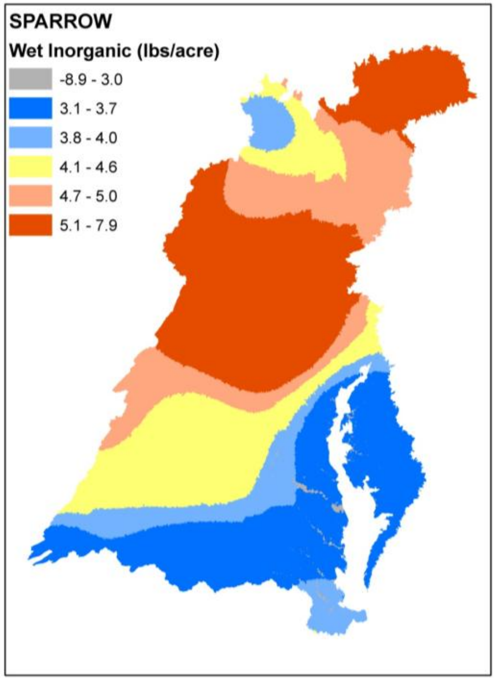
SPARROW model

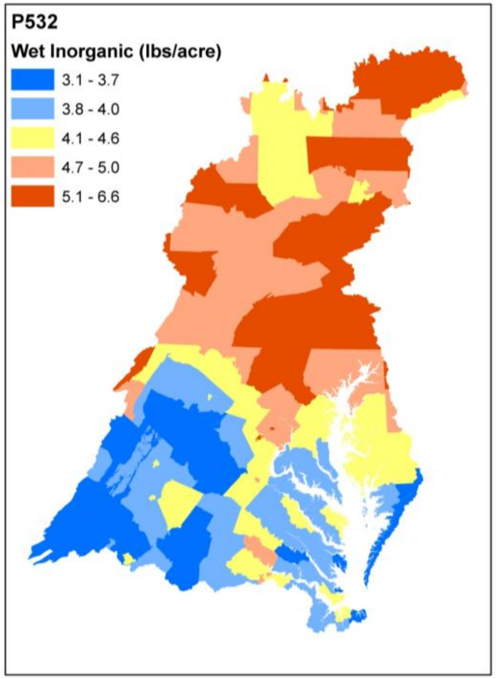
SPARROW is a spatially explicit, mass-balance watershed model that uses nonlinear regressions to quantify the relationship between observed nutrient fluxes in nontidal streams and inputs and factors that affect their overland and in-stream fate and transport.

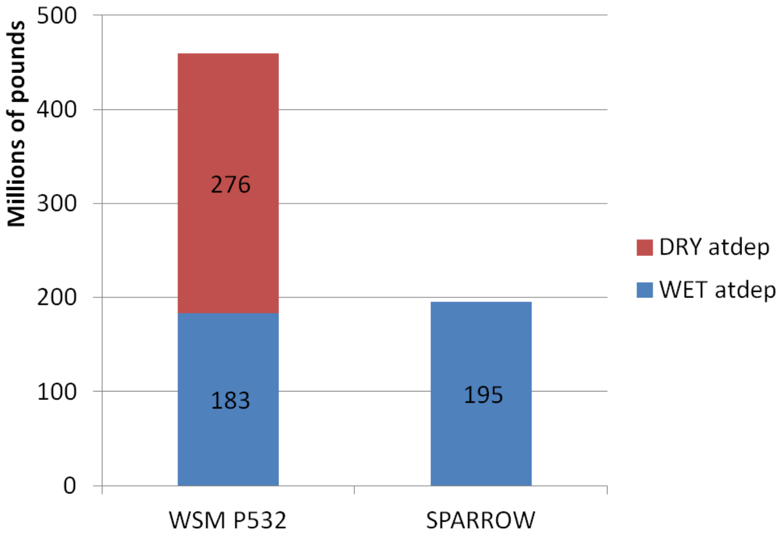
Spatially Referenced Regression on Watershed Attributes (SPARROW) Model has been used to provide empirical estimates of the source, fate, and transport of nutrients across the United States including the Chesapeake Bay Watershed.

Ator, S., J. Brakebill, and J. Blomquist. 2011. Sources, Fate, and Transport of Nitrogen and Phosphorus in the Chesapeake Bay Watershed: An Empirical Model. *USGS.* Available online at http://pubs.usgs.gov/sir/2011/5167/

Estimates of Atmospheric Deposition inputs for the year 2002

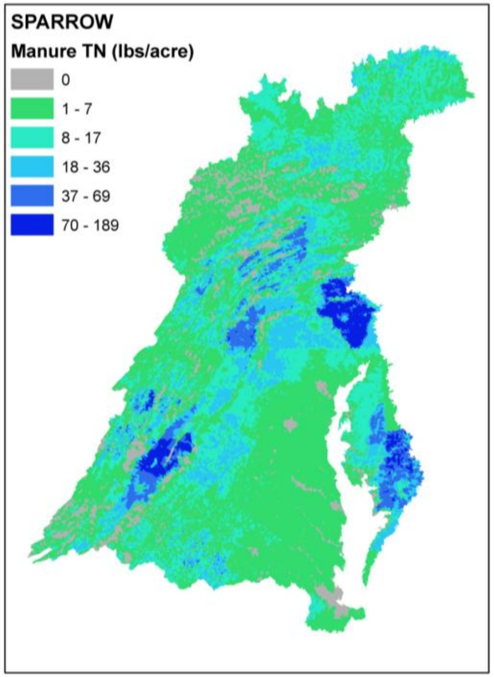


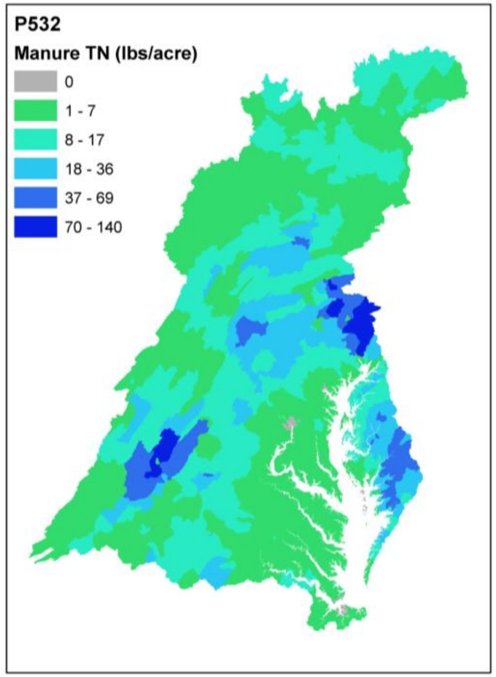


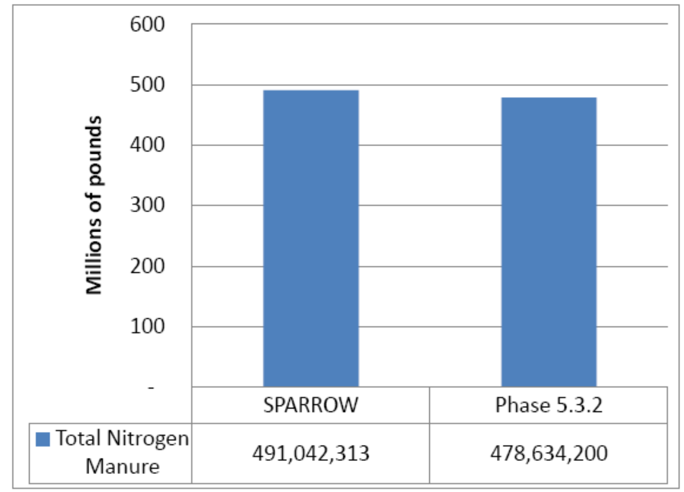


SPARROW input data set represents the average ***atmospheric (wet) deposition*** of inorganic nitrogen for the year 2002 compiled for every catchment of NHDPlus. Available online at http://water.usgs.gov/GIS/metadata/usgswrd/XML/nhd_atdep.xml

Estimates of Nitrogen input from Manure for the year 2002





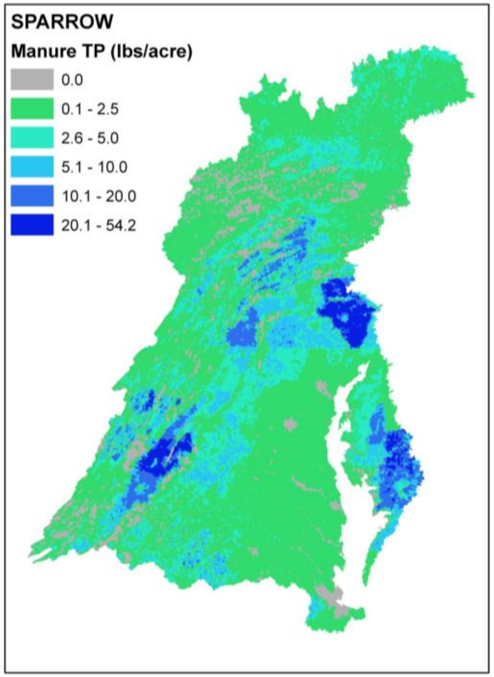


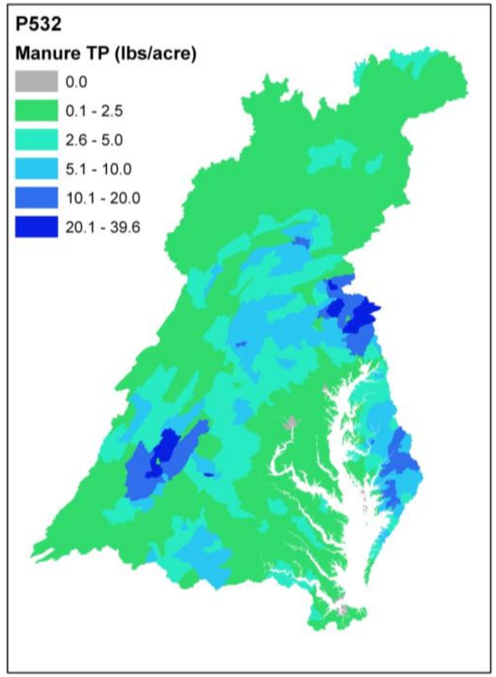
The nitrogen and phosphorus content of livestock wastes was estimated using Census of Agriculture.

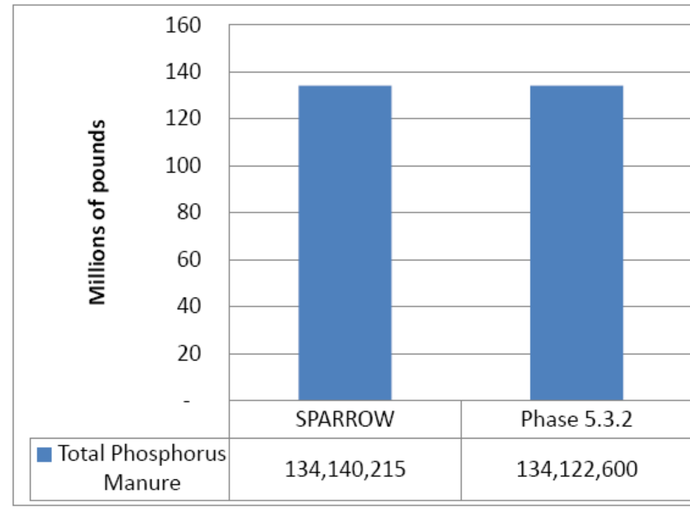
The procedures include: (1) estimating animal populations, (2) calculating nitrogen and phosphorus content of the animal manure, and (3) estimating the component of nitrogen and phosphorus from ***confined and unconfined livestock***.

SPARROW estimates of nitrogen input from manure ***do not account for loss through volatilization***. Thus, these estimates represent the total nitrogen content in manure as excreted by each livestock group. Available online at http://water.usgs.gov/GIS/metadata/usgswrd/XML/nhd_nutrients.xml

Estimates of Phosphorus input from Manure for the year 2002





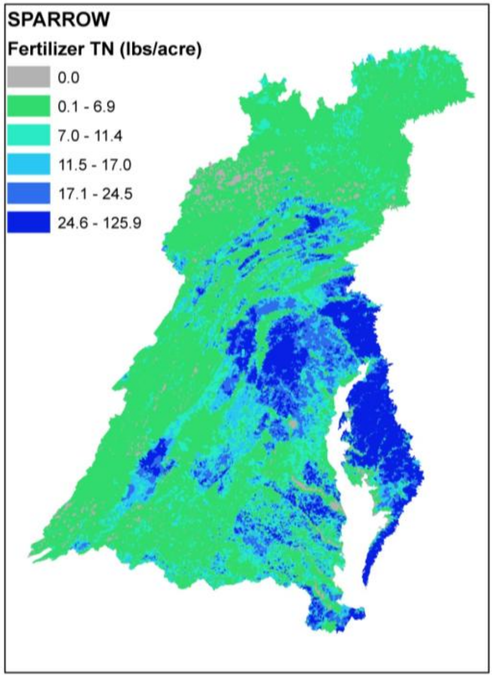


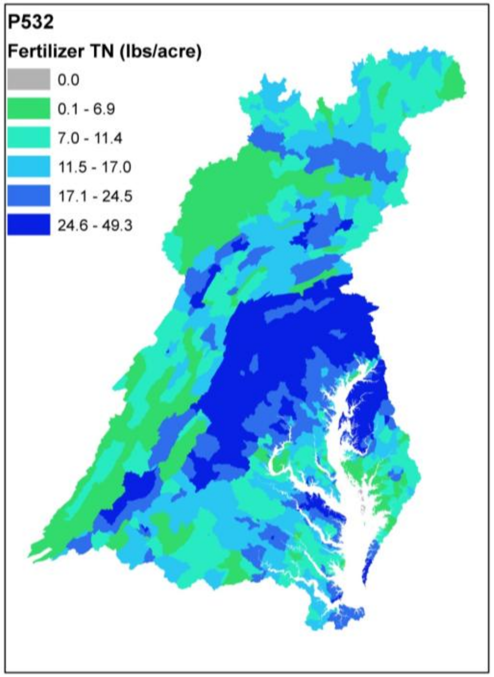
The nitrogen and phosphorus content of livestock wastes was estimated using Census of Agriculture.

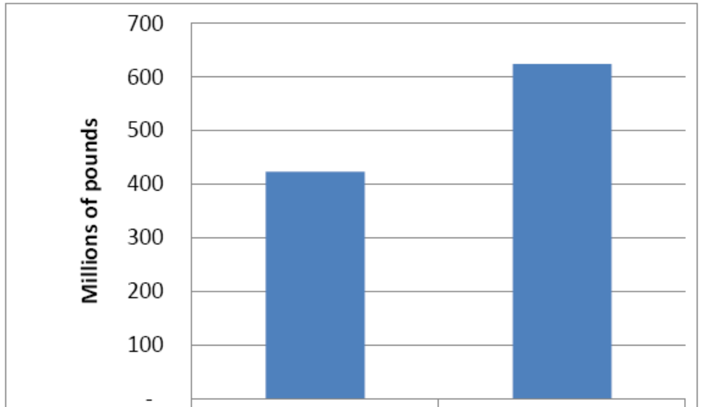
The procedures include: (1) estimating animal populations, (2) calculating nitrogen and phosphorus content of the animal manure, and (3) estimating the component of nitrogen and phosphorus from ***confined and unconfined livestock***.

SPARROW estimates of nitrogen input from manure ***do not account for loss through volatilization***. Thus, these estimates represent the total nitrogen content in manure as excreted by each livestock group. Available online at http://water.usgs.gov/GIS/metadata/usgswrd/XML/nhd_nutrients.xml

Estimates of Nitrogen input from Fertilizer for the year 2002





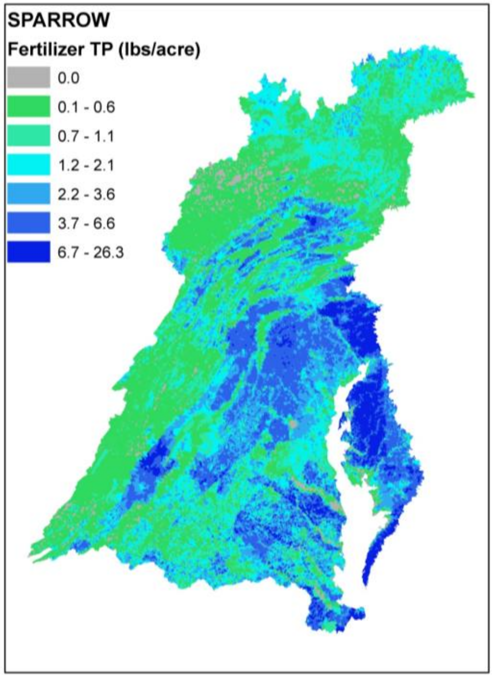


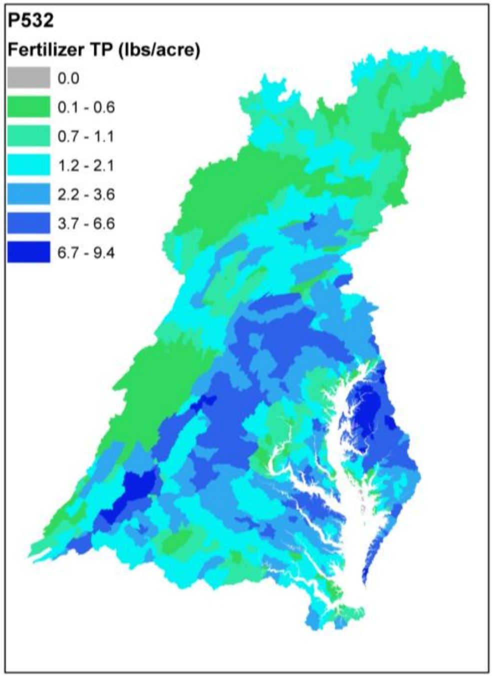
	SPARROW	Phase 5.3.2
Total Nitrogen Fertilizer	423,848,043	624,234,700

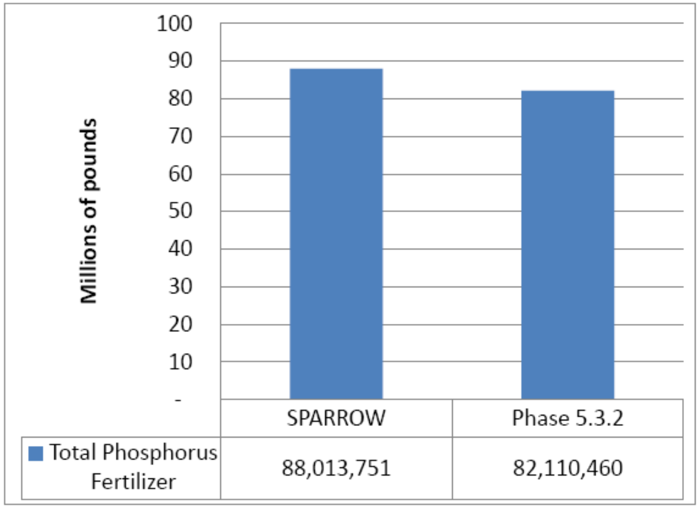
Estimates were calculated from the Association of American Plant Food Control Officials fertilizer sales data, Census of Agriculture fertilizer expenditures, and U.S. Census Bureau county population.

A national approach was used to estimate ***farm and nonfarm fertilizer*** inputs. Available online at http://water.usgs.gov/GIS/metadata/usgswrd/XML/nhd_nutrients.xml

Estimates of Phosphorus input from Fertilizer for the year 2002



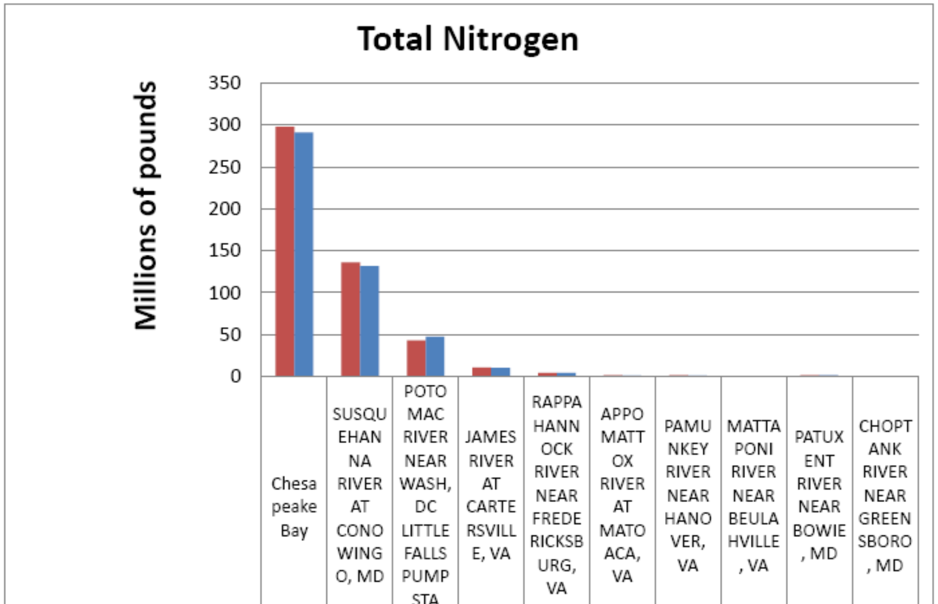




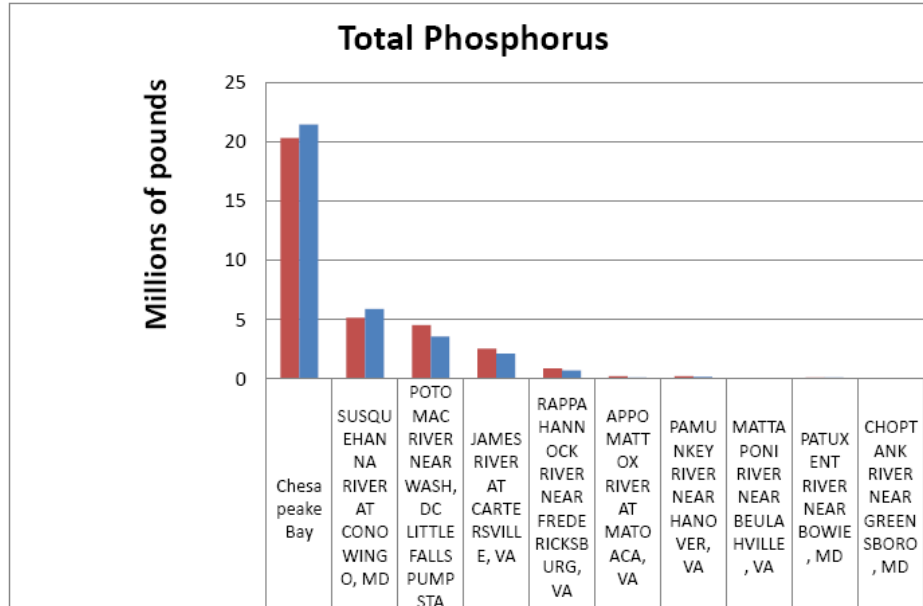
Estimates were calculated from the Association of American Plant Food Control Officials fertilizer sales data, Census of Agriculture fertilizer expenditures, and U.S. Census Bureau county population.

A national approach was used to estimate ***farm and nonfarm fertilizer*** inputs. Available online at http://water.usgs.gov/GIS/metadata/usgswrd/XML/nhd_nutrients.xml

Comparison between P532 and SPARROW outputs for 2002



	Chesapeake Bay	SUSQUEHANNA RIVER AT CONOWINGO, MD	POTOMAC RIVER NEAR WASH, DC LITTLE FALLS PUMP STA	JAMES RIVER AT CARTERSVILLE, VA	RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	APPOMATTOX RIVER AT MATOACA, VA	PAMUNKEY RIVER NEAR HANOVER, VA	MATTAPONI RIVER NEAR BEULAHVILLE, VA	PATUXENT RIVER NEAR BOWIE, MD	CHOPTANK RIVER NEAR GREENSBORO, MD
P532 2002 Scenario	297.9	136.2	43.0	11.0	4.5	1.5	1.4	0.8	1.4	0.4
SPARROW CBTN_v4 model	290.9	132.0	47.6	10.4	4.4	1.4	1.4	0.6	1.5	0.5



	Chesapeake Bay	SUSQUEHANNA RIVER AT CONOWINGO, MD	POTOMAC RIVER NEAR WASH, DC LITTLE FALLS PUMP STA	JAMES RIVER AT CARTERSVILLE, VA	RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA	APPOMATTOX RIVER AT MATOACA, VA	PAMUNKEY RIVER NEAR HANOVER, VA	MATTAPONI RIVER NEAR BEULAHVILLE, VA	PATUXENT RIVER NEAR BOWIE, MD	CHOPTANK RIVER NEAR GREENSBORO, MD
P532 2002 Scenario	20.33	5.18	4.55	2.57	0.90	0.22	0.23	0.08	0.11	0.03
SPARROW CBTN_v4 model	21.47	5.91	3.57	2.12	0.71	0.12	0.18	0.05	0.11	0.03

Despite differences in atmospheric and fertilizer input mass, spatial application rates and approach to assess water quality, the models showed almost the same output at 9 USGS stations

SPARROW Model Function

Sparrow estimated ***source-specific coefficients*** are interpreted as the proportion (fraction) of the applied or deposited nutrient mass transported to the tributaries.

- For example, Ator et al. (2011) estimated that approximately 24% of the total nitrogen from fertilizer was transported to the Chesapeake Bay tributaries in 2002 (a source-specific coefficient of 0.237).

- Similarly, less than 6 % of total nitrogen from manure and total phosphorus from both fertilizer and manure reached watershed streams. Source-specific coefficients were 0.058, 0.038, and 0.025, respectively.

The Agricultural Policy / Environmental eXtender (APEX) Model

- USGS-NRCS (2013) evaluated the impacts of conservation adoption on cropland in the Chesapeake Bay watershed. The APEX model was used to estimate field-level effects of the crop management and conservation practices. Concurrently, the SWAT model (Soil and Water Assessment Tool) was used to simulate non-point source loadings from land uses other than cropland and to route instream loads.

- The APEX model was developed to extend the Environmental Policy Integrated Climate (EPIC) model capabilities of simulating land management impacts for small-medium watersheds and heterogeneous farms. APEX simulates day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of water, soil, and nutrients.

The Agricultural Policy / Environmental eXtender (APEX) Model

- Very little information has been found to evaluate APEX and SWAT in the Chesapeake Bay region, and no spatial information or tabular detailed information has been publicly available for review.

- However, information from a study published by USGS-NRCS (2013), which included total inputs and outputs for four subregions of the Chesapeake Bay watershed, was used to calculate the ratio between predicted yields and input loads.

Functional Linear Concurrent Model (FLCM)

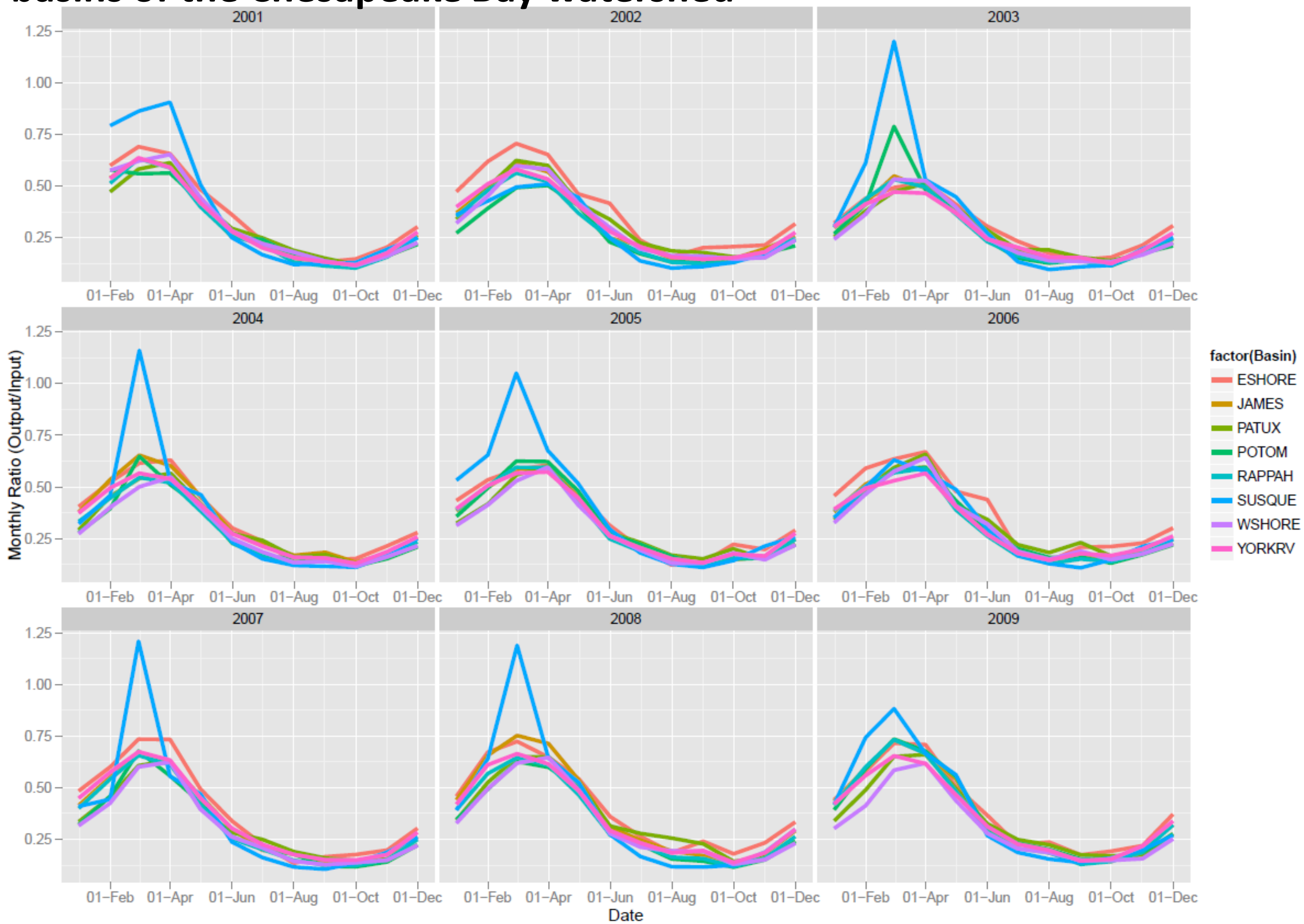
- FLCM employs a functional linear concurrent approach to predict loads in forested regions by using combinations of satellite-derived data such as vegetation and disturbance indexes (Figure 10), nitrogen atmospheric deposition, precipitation and physiographic and land cover parameters.

- The model was calibrated for the Chesapeake Bay region and the simulation period was from 2001 to 2009. Parameters and inputs vary by month, enabling predictions to be made on a monthly basis. Inputs and outputs are available for every major basin of the Chesapeake Bay watershed

- Functional links between nutrient inputs and outputs were also calculated using this model. The ratio between monthly yield and monthly input load was calculated for every major basin of the Chesapeake Bay watershed from 2001 to 2009

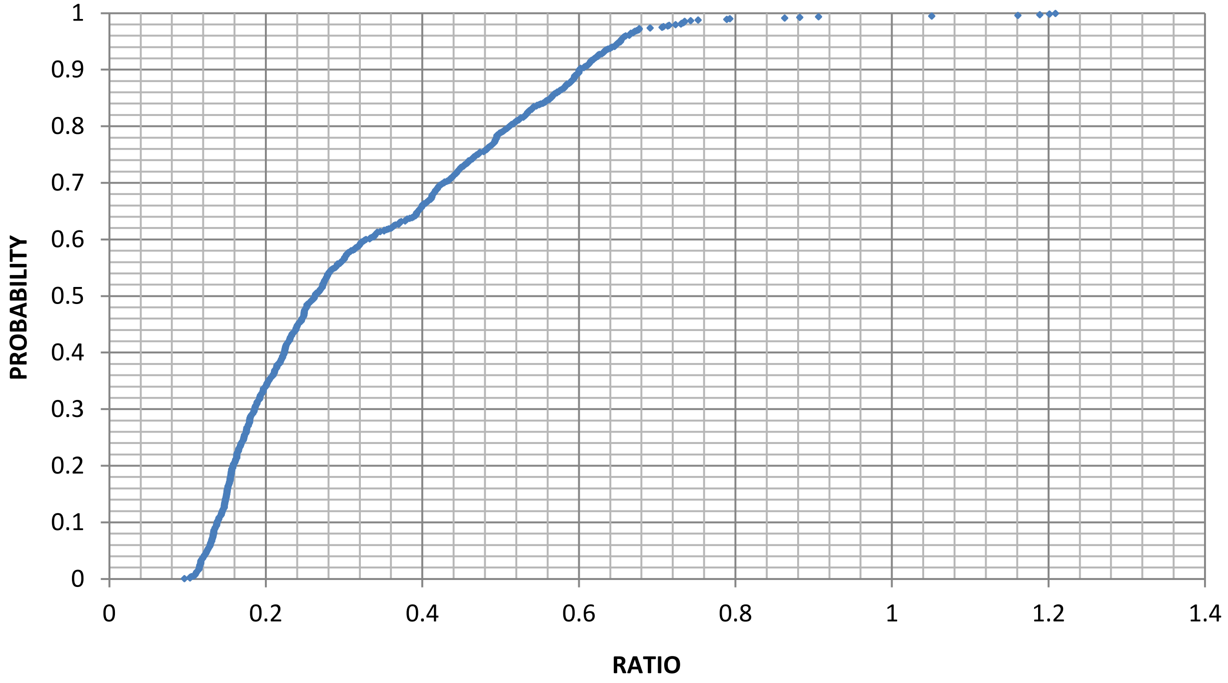
Functional Linear Concurrent Model (FLCM)

FLCM monthly total nitrogen ratio between monthly yield and input load for eight major basins of the Chesapeake Bay watershed



Functional Linear Concurrent Model (FLCM)

Cumulative distribution function of total nitrogen ratio between monthly yield and input load



Annual Phosphorus Loss Estimator (APLE) Model

- The APLE model is a Microsoft Excel spreadsheet model that runs on an annual time step. The model simulates sediment bound and dissolved P loss in surface runoff. It does not consider subsurface loss of P through leaching to groundwater or artificial drainage networks. It is intended to simulate edge-of-field P loss for uniform fields of several hectares in size, or smaller

- APLE was used to simulate phosphorus loss in every county of the Chesapeake Bay watershed and in five types of agricultural landuses from 1992 to 2005 (Mulkey, in prep). The landuses simulated were high-till with manure (hwm), high-till with manure nutrient management (nhi), low-till with manure (lwm), low-till with manure nutrient management (nlo), and pasture (pas).

- APLE model's phosphorus sensitivity to inputs was assessed by calculating the ratio between annual predicted yield and input loads for every county of the Chesapeake Bay watershed.

Annual Phosphorus Loss Estimator (APLE) Model

APLE median and average ratio between predicted yield and input loads

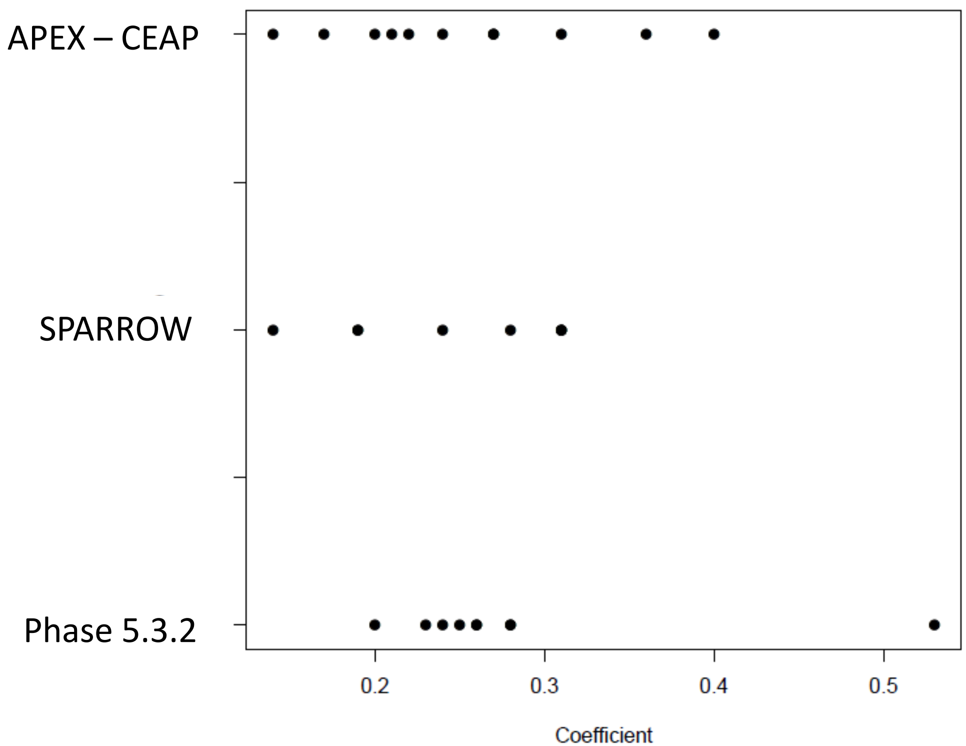
Landuse	Median Ratio	Average Ratio
high-till with manure (hwm)	0.247	0.448
high-till with manure nutrient management (nhi)	0.234	0.466
low-till with manure (lwm)	0.103	0.186
low-till with manure nutrient management (nlo)	0.097	0.191
pasture (pas)	0.081	0.155

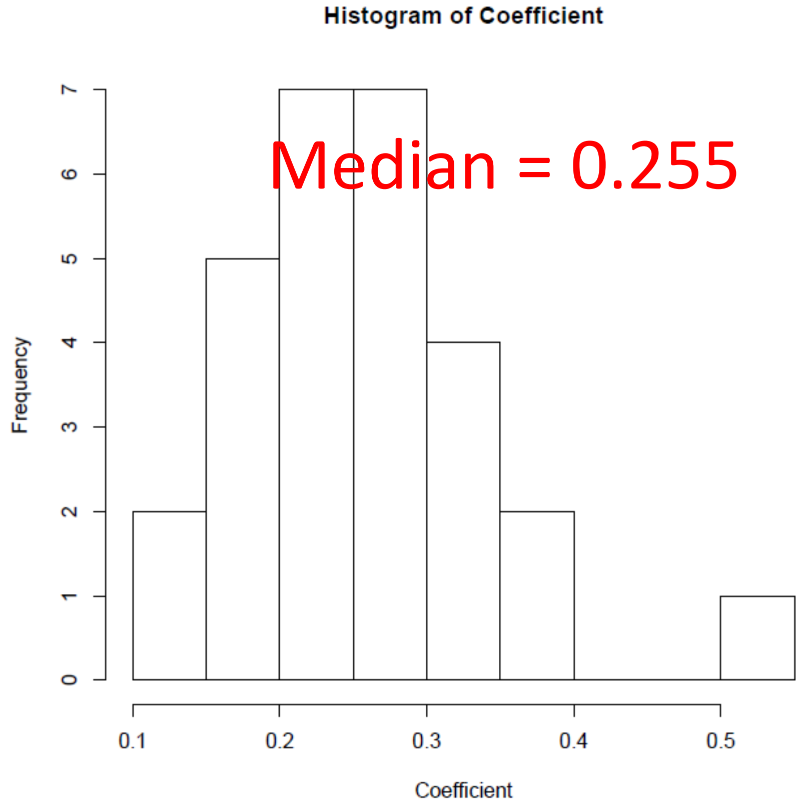
Annual Phosphorus Loss Estimator (APLE) Model

- The implementation of the APLE model will likely take one of two forms following further study. APLE may be used directly to estimate phosphorus losses from cropland as part of each scenario run. Though this model closely matches recent research, its implementation would preclude the use of multiple models for estimating phosphorus.

- Alternatively, multiple runs of APLE could be used to establish relationships between inputs and yield specific to each region's characteristics. This prediction could then be used with predictions from other models in an ensemble framework.

Fertilizer Nitrogen Sensitivities

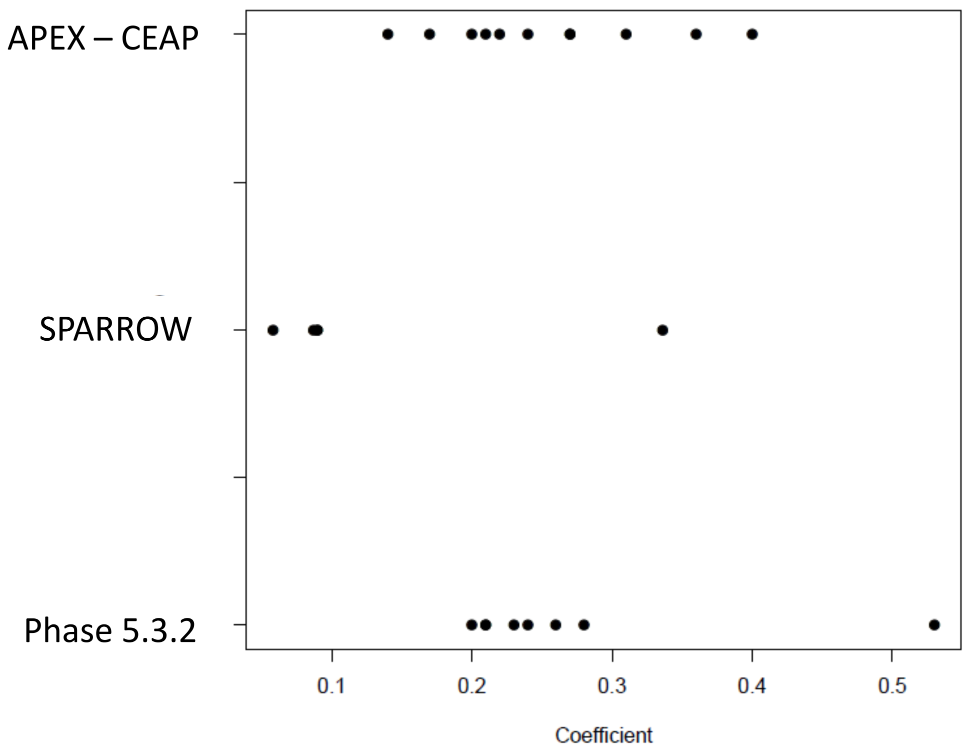


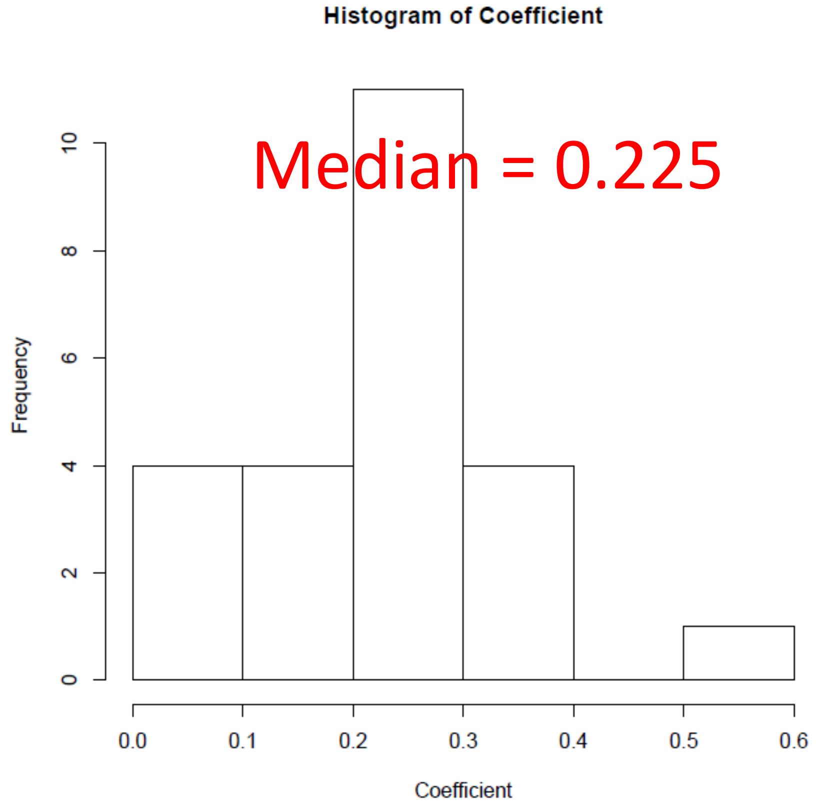


1. APEX – CEAP: Ratio between output and input (No-practice, 2006, and 2011 scenarios including all input sources in cropland areas)
2. SPARROW: source specific coefficient (Various studies in the Chesapeake bay and Northeastern and Mid-Atlantic regions) *
3. Phase 5.3.2: Ratio between input and output, slope of multivariate regression, and slope between output and input (14 scenarios / hwm, hom, lwm, alf, and hyw landuses)

* Preston and Brakebill (1999), Ator et al. (2011), Moore et al. (2011), and Preston et al. (2011).

Manure Nitrogen Sensitivities

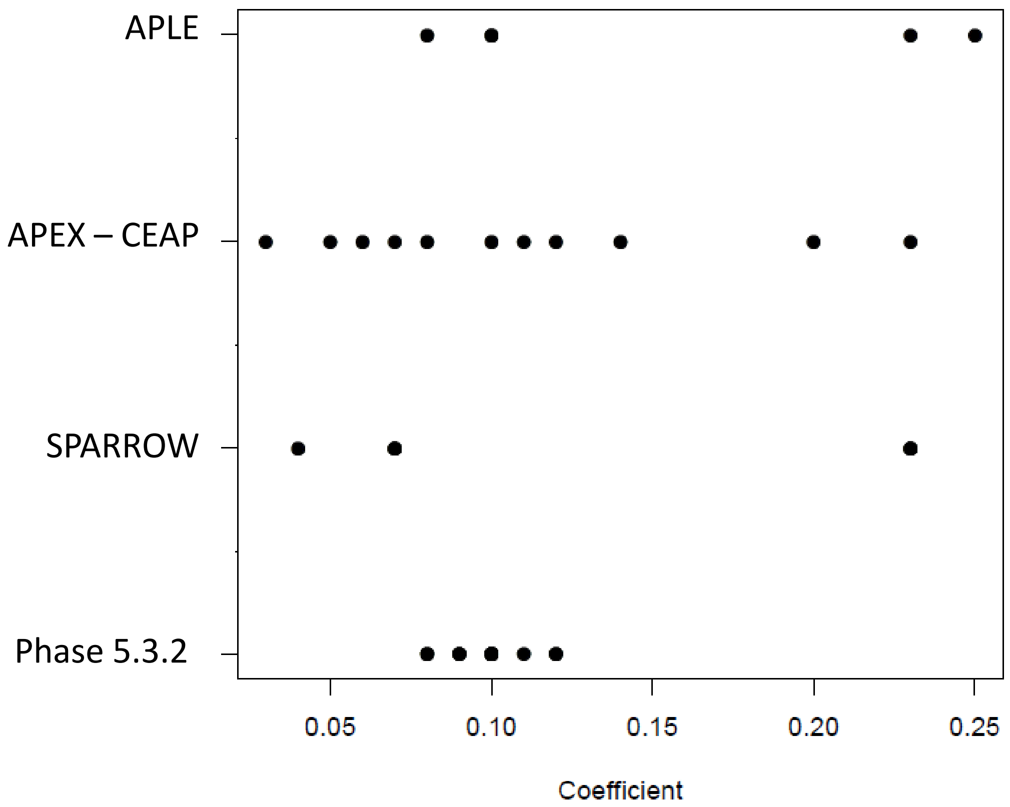


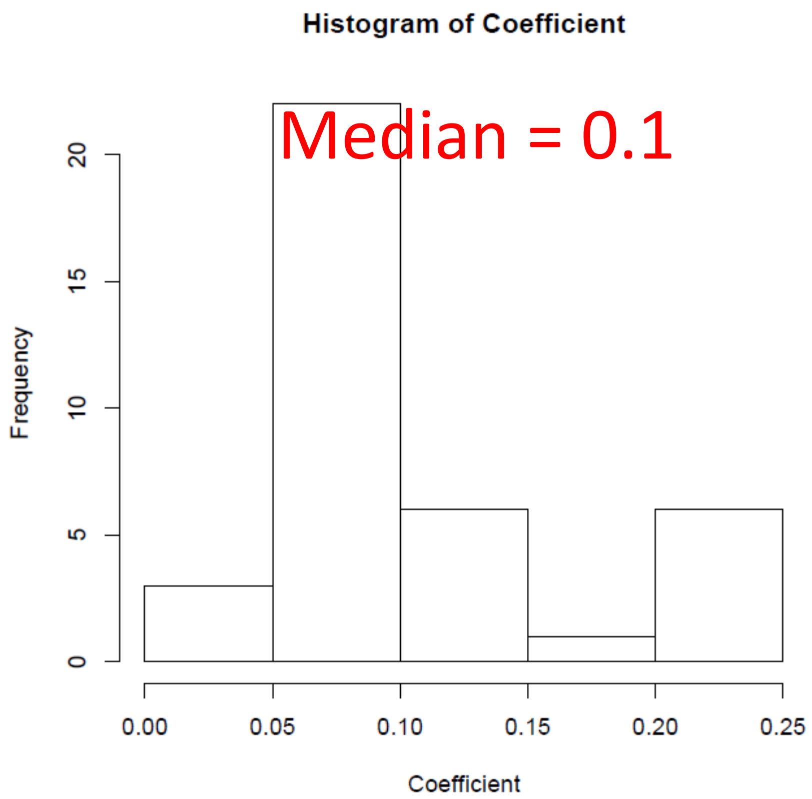


1. APEX – CEAP: Ratio between output and input (No-practice, 2006, and 2011 scenarios including all input sources in cropland areas)
2. SPARROW: source specific coefficient (Various studies in the Chesapeake bay and Northeastern and Mid-Atlantic regions) *
3. Phase 5.3.2: Ratio between input and output, slope of multivariate regression, and slope between output and input (14 scenarios / hwm, hom, lwm, alf, and hyw landuses)

* Preston and Brakebill (1999), Ator et al. (2011), Moore et al. (2011), and Preston et al. (2011).

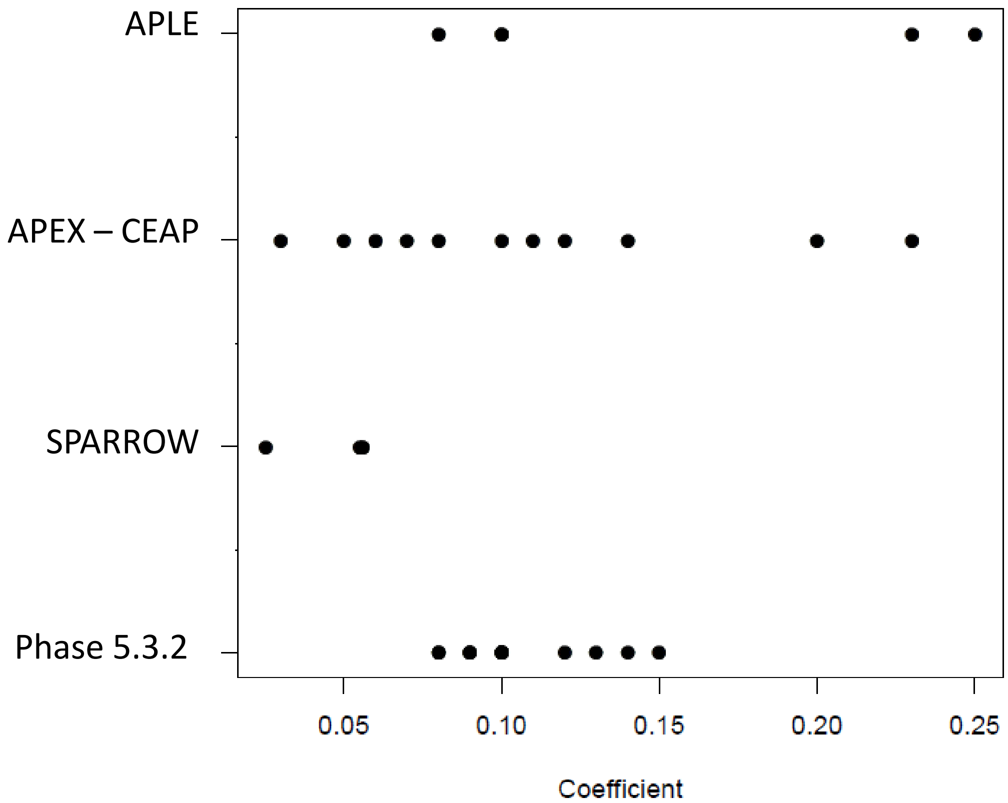
Fertilizer Phosphorus Sensitivities

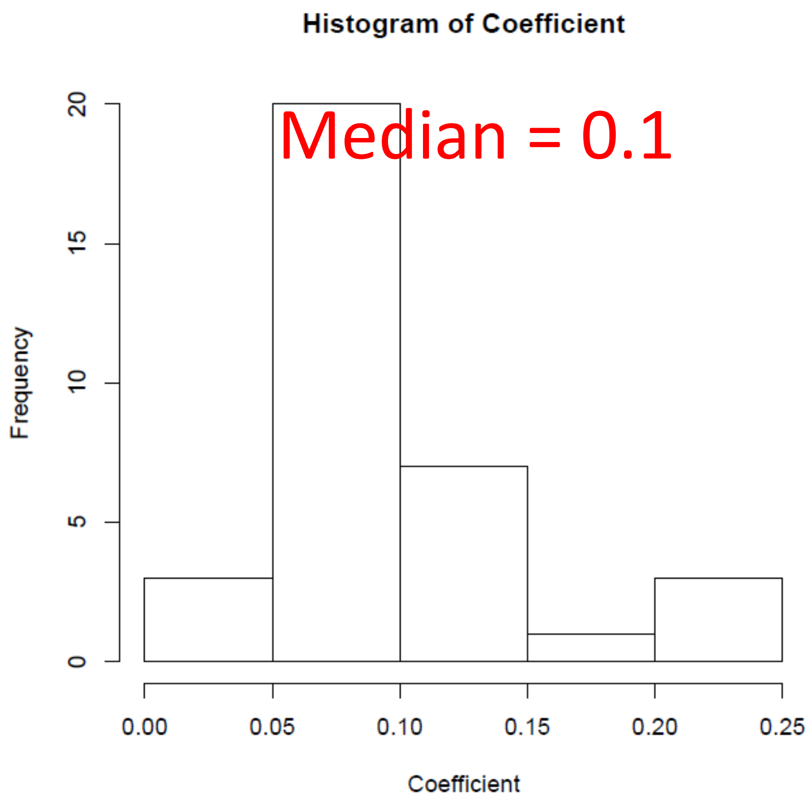




1. APLE: Ratio between annual predicted yield and input loads for every county of the Chesapeake Bay watershed
2. APEX – CEAP: Ratio between output and input (No-practice, 2006, and 2011 scenarios including all input sources in cropland areas)
3. SPARROW: source specific coefficient (Various studies in the Chesapeake bay and Northeastern and Mid-Atlantic regions)
4. Phase 5.3.2: Ratio between input and output, slope of multivariate regression, and slope between output and input (14 scenarios / hwm, hom, lwm, alf, and hyw landuses)

Manure Phosphorus Sensitivities





1. APLE: Ratio between annual predicted yield and input loads for every county of the Chesapeake Bay watershed
2. APEX – CEAP: Ratio between output and input (No-practice, 2006, and 2011 scenarios including all input sources in cropland areas)
3. SPARROW: source specific coefficient (Various studies in the Chesapeake bay and Northeastern and Mid-Atlantic regions)
4. Phase 5.3.2: Ratio between input and output, slope of multivariate regression, and slope between output and input (14 scenarios / hwm, hom, lwm, alf, and hyw landuses)

Recommendations

- We recommended to use a coefficient of 0.255 and 0.225 in PQUAL to calculate fertilizer and manure nitrogen losses, respectively.

- We recommended to use a coefficient of 0.1 in PQUAL to calculate both fertilizer and manure phosphorus losses.

Recommendations

- In forested regions, the P532 ratio between yield and input load was 0.29, whereas the FLCM median ratio was 0.26 and the average was 0.33. We recommend using a sensitivity value of 0.29 to calculate total nitrogen losses in forested regions.

- In grasslands, the P532 ratio between yield and input load was 0.07, whereas the APLE median ratio was 0.081 and the average was 0.155. We recommend using a sensitivity value of 0.081 to calculate total nitrogen losses in grasslands.

Links

- https://archive.chesapeakebay.net/Modeling/phase 5/Phase532/Sensitivity/