Modeling the Effects of Conservation Tillage on Sediment and Nutrient Loading in the Maumee River

Kirk Zmijewski, Richard Becker
University of Toledo, Department of Environmental Sciences
kirk.zmijewski@rockets.utoledo.edu, www.eeescience.utoledo.edu

Abstract:

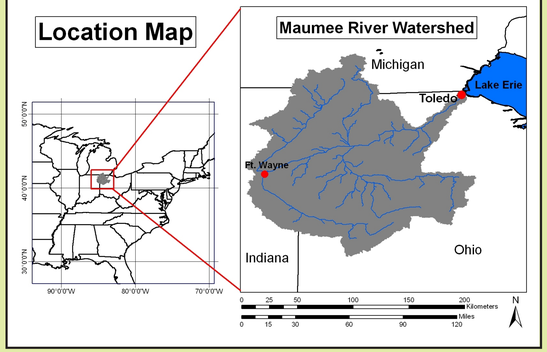
A hydrologic model of the Maumee River basin in NW Ohio was constructed to determine the relative effects of different drivers (weather, tillage practices, crop planting) on sediment and nutrient flow in the river.

The Maumee River watershed is the largest in the Great Lakes region, draining an area over 16,000 km^2. Though it only contributes a small percentage of the water into the Western Basin of Lake Erie, it contributes by far the largest volume of sediment. The area, previously known as the Great Black Swamp, was drained and clear cut for agricultural development in the 19th century. Today around 80% of the watershed is agricultural land usage. The rich organic soil contributes excessive sediment /nutrient loading within the western basin of Lake Erie, contributing to excessive algal blooms.

Conservation tillage was introduced in the 1980's as a means of reducing these sediment/nutrient loads. Recent years have seen reduced sediment yields within the Maumee River, however phosphate concentrations have risen after over the same time period. In addition, phosphate peaks are occurring during the late summer months where there were none before. These later summer inputs of phosphate may contribute to increased blooms of a potentially harmful alga, *Microcystis.*

Hydrological modeling was performed using ArcSWAT. A calibrated model was developed using 1992 land use practices, hydrograph sediment and nutrient data from the Waterville, OH, USGS gauging station. This model was then used to test the hypothesis that the implementation of conservation tillage could explain both the overall reduction in sediment and increase phosphate peaks in the later summer months. Scenarios were run for 1980-2009 using historical weather data, varying tillage, crop percentages and fertilizer application. It was found that historical weather patterns alone were sufficient to explain the increase in late summer phosphate peaks; weather and conservation tillage explained the overall reduction in sediment load; the area of corn row crops best explained the increase in phosphate. The finding that late summer storms are an important factor in late season phosphate delivery has implications for how the western basin responds to predicted climate change.

Location Map



Study Objectives:

-Phosphate peak in August in the Maumee River was noted to increase between 1975-2009
-Phosphate/Sediment Ratio has increased through time

Examine potential causes of sediment and phosphate peak shift in Aug-Sept.

1) Determine the effect of individual weather events on the sediment/phosphate shift
2) Determine the effect of conservation tillage on the sediment/phosphate shift
3) Determine the effectiveness of conservation tillage on reducing overall sediment/phosphate loads

Background:

Runoff from agriculture within the Maumee River watershed is the most significant source of sediment and nutrients within the western basin of Lake Erie.

Maumee River Basin

- The Maumee River is over 130 miles long, draining an area over 6000 sq. mi, the largest river system by area in the Great Lakes region.
- The EPA has designated a large portion of the Lower Maumee River as an Area of Concern due in part to high sediment and nutrient loads.

Conventional Tillage

Photo Credit: Arvil Rothwell

Effects of Tillage on Soils

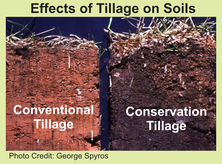


Photo Credit: George Spyros

No-Till (Conservation Tillage)

Photo Credit: USDA

Tillage Practices

- Conventional Tillage practices expose soils and nutrients from fertilizers to erosion. It also puts high demand on soil nutrients.
- Conservation Tillage was implemented in the early 1980s. By 1986, around 50% of agricultural land within the watershed used some form of conservation tillage.

Algal Bloom caused by Eutrophication

Photo Credit: NOAA

Effects of High Sediment Loads

- Excessive algal blooms are a major problem within the Western Basin. Excess nutrient loading increases bloom abundance. Due to reductions in point sources, blooms decreased during the 1980's but now have increased to some of the worst on record.
- *Microcystis* is a type of cyanobacteria that is potentially toxic; in a high sediment environment it gains a competitive advantage over other algal biota. *Microcystis* blooms impact local ecosystem and negatively affect the Lake Erie commercial fishing industry.

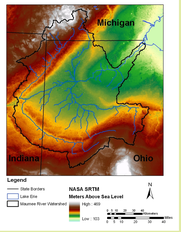
Methods:

A calibrated model was made using ArcSWAT (Soil and Water Assessment Tool) within a GIS environment.

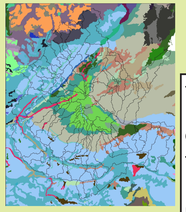
Six different scenarios were run from 1980-2009.

Models were run with historical and statistically averaged weather patterns to distinguish between trends in weather event intensity in

Shuttle Radar Topography Mission (SRTM) Data was used to determine hydrology and watershed extent



US STATSGO Soil Types used for model calibration



Model Scenarios

Historical Weather Data	Simulated Weather Data
Conventional Tillage	Conventional Tillage
10 yr Conventional, 20 yr Conservation Tillage	10 yr Conventional, 20 yr Conservation Tillage
30 yr Conservation Tillage	30 yr Conservation Tillage

-Tillage practices were modeled to determine if changing tillage practices reproduced the shift in sediment runoff.

Calibration:

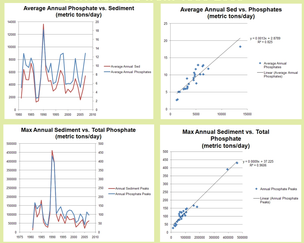
The model was calibrated vs. flow, sediment, and total phosphate measured at the Waterville, OH USGS gauging station.

Nash-Suttcliffe Efficiencies:
Flow: 0.69
Sediment: 0.37

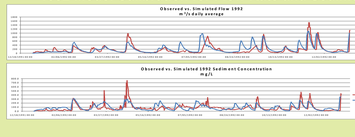
-Due to the inaccuracies of phosphate data obtained, sediment was used as a proxy to emulate sediment loads

-High correlations were seen in sediment/phosphate loads from 1980-2009

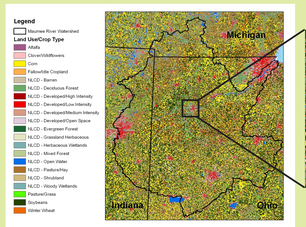
Average Annual Sediment and Phosphate correlations from 1980-2009



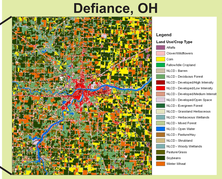
1992 Model Calibration for Flow Rate and Sediment



National Land Cover Dataset used to define land use types within watershed



Land Use Defiance, OH



NCDC Weather Stations used for model calibration

Results:

- Historical Weather Scenarios:

-Conventional Tillage:
-Late season phosphate shift from 1980-2007 IS reproduced

-Conventional 10 Year/Conservation 20 Year:

-Annual Overall Sediment Change: -1.0%

-30 Year Conservation Tillage

-Annual Overall Sediment Change: -5.9%

- Simulated (Statistically Averaged) Weather Scenarios:

-Conventional Tillage: *Late season phosphate shift not as apparent*

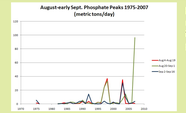
-Conventional 10 Year/Conservation 20 Year:

-Annual Overall Sediment Change: -1.4%

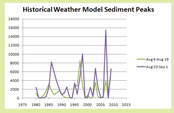
-30 Year Conservation Tillage:

-Annual Overall Sediment Change: -3.3%

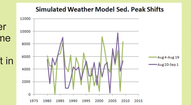
Historical weather data showing shift in August phosphate peaks



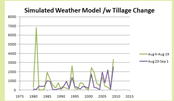
Historical weather model showing the same shift in peaks



Statistically simulated weather model for the same time period does not show the shift in peaks



Combined simulated weather and a change in tillage practices does not show the shift as strongly as weather alone



Conclusions:

-Overall suspended sediment loads have been reduced by conservation tillage by roughly 10% from 1980-2009

-Phosphate peaks have shifted in the late season where there were none before

-The ratio of phosphate/sediment has increased from 1980-2009

-The shift in these phosphates can be best explained by larger August storms

-A shift in tillage practices has caused some shift in phosphates, but it is not as evident as the change in weather patterns

Future/Ongoing Work:

- Use expanded calibration period to improve overall model quality
- Model fertilizer application for different crop areas within the watershed through time
- Model field specific tillage practices
- Model annual crop type planting using remotely sensed data

Acknowledgments:

Funding Provided By:

Office of Undergraduate Research (OUR-UT) Learning Collaborative, The University of Toledo

Data Provided By:

USDA, Heidelberg University, NRCS Natural Resources Conservation Service, NOAA, NASA, USGS science for a changing world