# Water Quality Impacts of Agricultural BMPs in a Suburban Watershed in New Jersey

Zeyuan Qiu
Lizhong Wang

Department of Chemistry and Environmental Science
New Jersey Institute of Technology
Newark, NJ

NJIT New Jersey's Science & Technology University

# Outline

- Introduction
- Study area
- Materials and methods
- Results and discussions
- Conclusions

# Watershed restoration

- Water quality degradation
  - Point & nonpoint sources
  - Major causes: nutrients and sediment
- Pollutant load reductions for impaired water bodies
  - EPA's total maximum daily loads (TMDLs) program (1972 Clean Water Act)
- Watershed approach to water quality management

# Water quality management in suburban watersheds

- More attention to stormwater runoff and related pollution caused by rapid urban development
- Agriculture still is a primary cause of the water pollution.
- Expensive and difficult to achieve additional pollutant load reductions from the urban stormwater runoff through implementing urban stormwater BMPs
- Cost effective strategies for TMDL control
  - Encouraging farmers to implement the agricultural BMPs
  - Cost-sharing through subsidies and penalties
  - Pollutant load trading

# Agricultural best management practices (BMPs)*

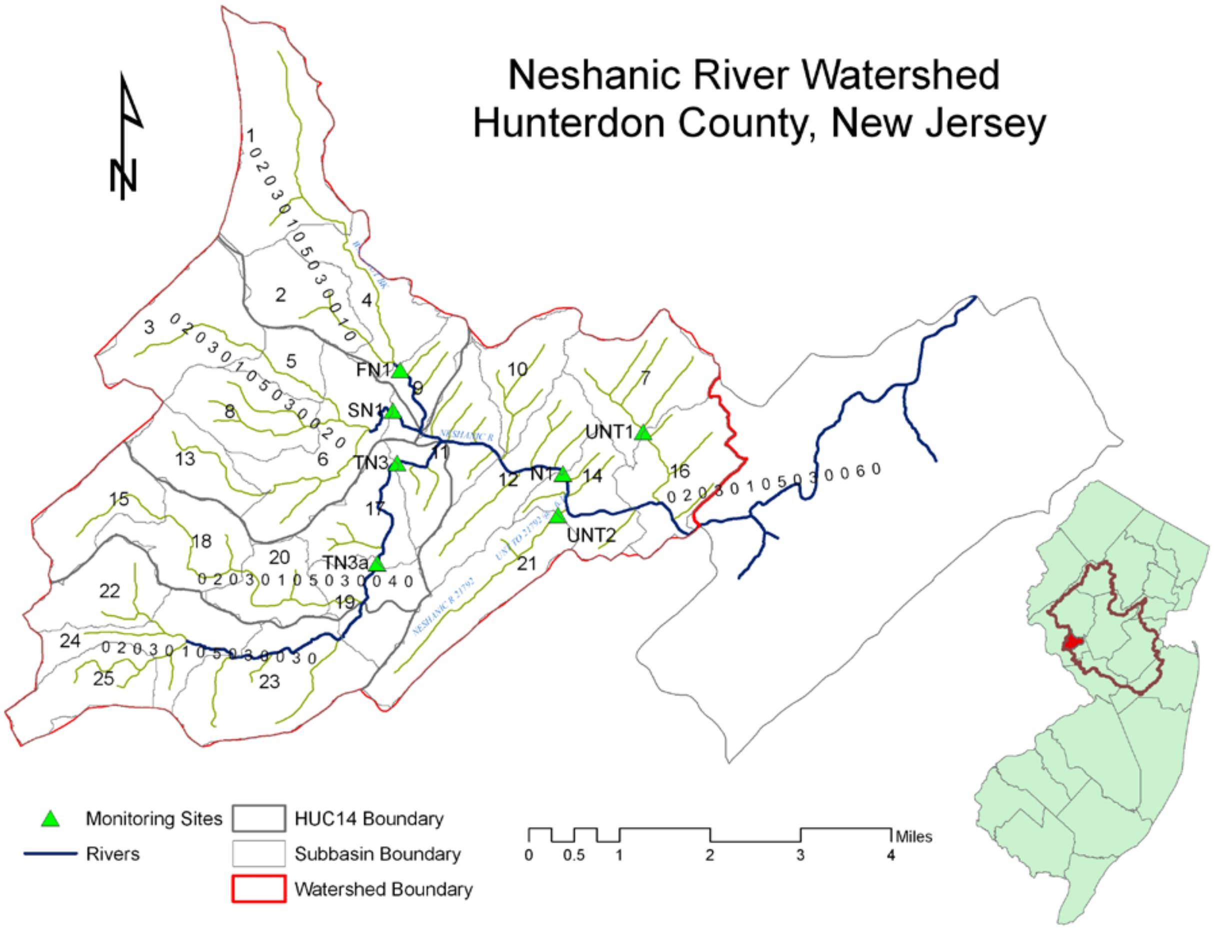
- Changes in the mode of cultivation
  - Reduction of fertilizers
  - Few changes in farm practices
  - Reduction of manure use
  - Adoption of new tillage practices
- Changes in land use
  - Change of crop types
  - Construction of buffer strips and wetlands
  - Conversion of arable land to grassland
- Land reclamation works as measures for environmental prevention and promotion of agricultural efficiency

* Zanou et al. (2003)

# Developing viable agro-environmental policies in suburban watersheds

- Assessing the water quality impacts of agriculture is the key.
- Evaluating water quantity and quality processes with watershed-scale hydrological and water quality models
- Soil and Water Assessment Tool (SWAT)
  - Physically based
  - Daily time step over a long time period
  - Field scale BMPs
  - Water quality at sub-watershed and watershed scale
  - Widely applied to estimate water quality impacts of BMPs in many agricultural watersheds
  - Still limited applications in suburban watersheds

# Study area




- 31 mi$^2$, a part of the Raritan River Basin
- The Neshanic River is a tributary to the South Branch of the Raritan River which drains to the Atlantic Ocean.

# The Neshanic River watershed

- Impaired aquatic life, and nonpoint source pollution in bacteria, phosphorus, and total suspended solids (NJDEP 2008)
- One of the worst water bodies in terms of overall water quality in the Raritan River Basin (Reiser 2004)
- Experiencing rapid suburbanization during the last two decades
  - Urban lands from 17.4% in 1986 to 30.7% in 2002
  - Agricultural lands from 55% in 1986 to about 40% in 2002
  - Other land uses were relatively steady
- One of the priority watersheds to implement agricultural BMPs to improve water quality (NJWSA 2002)
  - Relatively poor water quality
  - High percentage of agricultural lands

# Land uses and area distribution in 2002

| Land use | SWAT Code | Area (ha) | Area (acre) | Percentage of Watershed |
|---|---|---|---|---|
| Residential-High Density | URHD | 37.643 | 93.0177 | 0.48 |
| Residential-Medium Density | URMD | 83.8012 | 207.0769 | 1.06 |
| Residential-Med/Low Density | URML | 152.4431 | 376.6946 | 1.93 |
| Residential-Low Density | URLD | 1939.1447 | 4791.7235 | 24.56 |
| Commercial | UCOM | 111.338 | 275.1218 | 1.41 |
| Institutional | UINS | 184.2726 | 455.3468 | 2.33 |
| Transportation | UTRN | 65.2198 | 161.1615 | 0.83 |
| Agricultural Land-Generic | AGRL | 140.756 | 347.8151 | 1.78 |
| Corn | CORN | 739.1015 | 1826.3569 | 9.36 |
| Soybean | SOYB | 733.9184 | 1813.549 | 9.3 |
| Rye | RYE | 137.514 | 339.804 | 1.74 |
| Hay | HAY | 301.3341 | 744.6116 | 3.82 |
| Timothy | TIMO | 662.955 | 1638.195 | 8.4 |
| Pasture | PAST | 358.3089 | 885.3992 | 4.54 |
| Orchard | ORCD | 45.0575 | 111.3394 | 0.57 |
| Forest-Deciduous | FRSD | 1207.2375 | 2983.1443 | 15.29 |
| Forest-Evergreen | FRSE | 83.3509 | 205.9643 | 1.06 |
| Forest-Mixed | FRST | 365.7434 | 903.7703 | 4.63 |
| Wetlands-Forested | WETF | 439.5385 | 1086.1217 | 5.57 |
| Wetlands-Non-Forested | WETN | 2.6616 | 6.577 | 0.03 |
| Wetlands-Mixed | WETL | 82.2502 | 203.2445 | 1.04 |
| Water | WATR | 21.8233 | 53.9265 | 0.28 |

# Neshanic river watershed restoration plan


## Project Team

- Administrative Agency
  - Division of Watershed Management at NJDEP
- Lead Agency
  - New Jersey Institute of Technology
- Supporting Agencies
  - Rutgers Cooperative Extension
  - North Jersey Resource Conservation & Development Council
  - New Jersey Water Supply Authority
  - South Branch Watershed Association
  - Hunterdon County Soil Conservation District
  - Natural Resource Conservation Service
  - 4 Municipalities in the watershed

NJIT New Jersey's Science & Technology University THE EDGE IN KNOWLEDGE



http://ims.njit.edu/neshanicNew/index.html

# Project tasks

- Characterization and assessment
  - Water Quality Monitoring
  - Stream Visual Assessment
  - Stormwater Infrastructure Inventory
- BMP evaluation
  - Agricultural BMPs
  - Stormwater BMPs
- Watershed modeling
  - Soil and Water Assessment Tool (SWAT)
  - Cost-effective economic model
- Watershed restoration plan
- Public outreach

# Evaluating agricultural BMPs with SWAT

- Input data to ArcSWAT
  - 10-meter DEM
  - 1:24K stream network
  - 2002 land use/cover (NJDEP data & project inventories during 2007-2008)
  - SSURGO digital soil data (compiled from NRCS)
  - Streamflow and water quality monitoring data (NJDEP/USGS)
  - Weather data at the Flemington weather station (NOAA)
- 21 types of land uses/covers
- 53 types of soils
- Delineation: 25 subbasins and 625 HRUs

# Evaluating agricultural BMPs with SWAT (cont.)

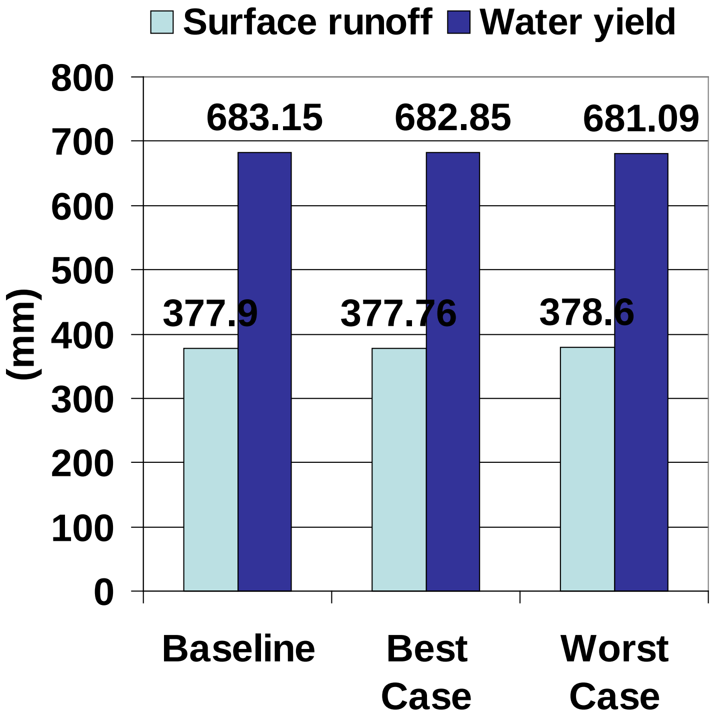
- Sensitivity analysis
  - Top-ranked SWAT parameters that affect the stream flows for further auto-calibration
- Calibration
  - Daily stream flows observed during 2001-2002 at the USGS Reaville stream flow gage station on the Neshanic River (N1 in watershed map)
- Simulating water quality impacts under three land use management scenarios during 1993-2004.
  - Baseline scenario: minimum tillage (chisel plow and disk plow); modest fertilizer applications
  - Best case: no-tillage practices for crops such as corn, soybean and ryes; others remain the same as in the baseline situation
  - Worst case: moldboard plow in addition to chisel and disk plows; more phosphorus fertilizer applications to lawns, crops and hays

# Sensitivity analysis & calibration

- Top 10 sensitive flow parameters
  - Alpha_BF, CN2, GWQMIN, ESCO, Sol_Awc, Canmx, Sol_Z, Timp, Blai and Ch_K2
- Calibration
  - Nash-Sutcliffe coefficient measures the goodness-of-fit on the [0, 1] interval.
  - The closer the coefficient is to 1, the better the fit.
  - The coefficient was improved from -0.64 for the initial model to 0.48 for the calibrated model.
- Simulated crop yields:106.8, 32.5, 40.2 bushels per acre for corn, soybean and rye; 2.89 and 2.59 tons per acre for hay and timothy.
- Comparable to NASS statistics in Hunterdon County: 98.7, 31.8 and 35.5 bushels per acre for corn, soybean and rye; 3.09 and 1.8 tons per acre for hay and timothy.

# Watershed annual average surface runoff and water yields

- Surface runoff and water yield slightly increase as tillage intensity increases, but their differences are not significant.



# Watershed annual average losses from HRUs to streams

- Soil loss increases as the intensity of tillage practices increases.
- No-till is not necessary the best practice for improving water quality.
  - Compared to the minimum tillage in the baseline scenario, no-till in the best case scenario decreases the TN loss to the streams by 3 percent, but increases the TP loss by 26 percent.
  - Primarily from the increase of losses in the soluble phosphorus, which are 0.17 and 0.248 kg/ha in the baseline and the best case scenarios, respectively.

| Scenario | Soil Loss (t/ha) | N App. (kg/ha) | TN Loss (kg/ha) | P App. (kg/ha) | TP Loss (kg/ha) |
|---|---|---|---|---|---|
| Baseline | 0.103 | 109.543 | 10.169 | 13.075 | 0.296 |
| Best Case | 0.098 (-4.85%) | 109.543 (0) | 9.869 (-2.95%) | 13.075 (0) | 0.373 (+26.01%) |
| Worst Case | 0.153 (+48.54%) | 115.246 (+5.21%) | 10.923 (+7.41%) | 51.031 (+290.29%) | 0.566 (+91.22%) |

# Watershed annual average losses from HRUs to streams (cont.)

- Worst case scenario:
  - 7.41 and 91 percent increases in the TN and TP losses
  - N and P application increase 5.21 and 290 percent.
  - Primarily from the fertilizer application in residential, commercial and industrial lawns.

| Scenario | Soil Loss (t/ha) | N App. (kg/ha) | TN Loss (kg/ha) | P App. (kg/ha) | TP Loss (kg/ha) |
|---|---|---|---|---|---|
| Baseline | 0.103 | 109.543 | 10.169 | 13.075 | 0.296 |
| Best Case | 0.098 (-4.85%) | 109.543 (0) | 9.869 (-2.95%) | 13.075 (0) | 0.373 (+26.01%) |
| Worst Case | 0.153 (+48.54%) | 115.246 (+5.21%) | 10.923 (+7.41%) | 51.031 (+290.29%) | 0.566 (+91.22%) |

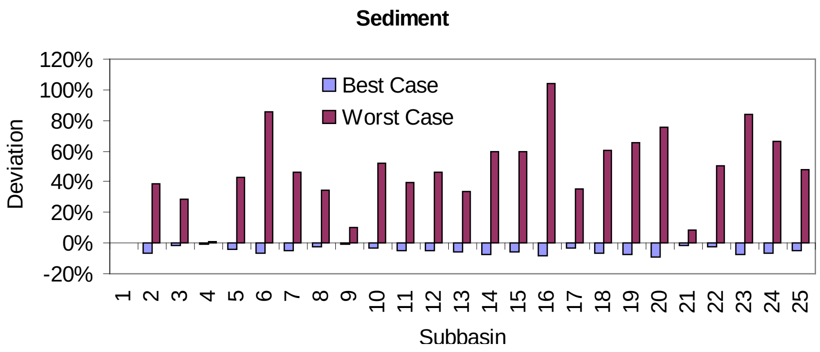
# Average annual loads at watershed outlet

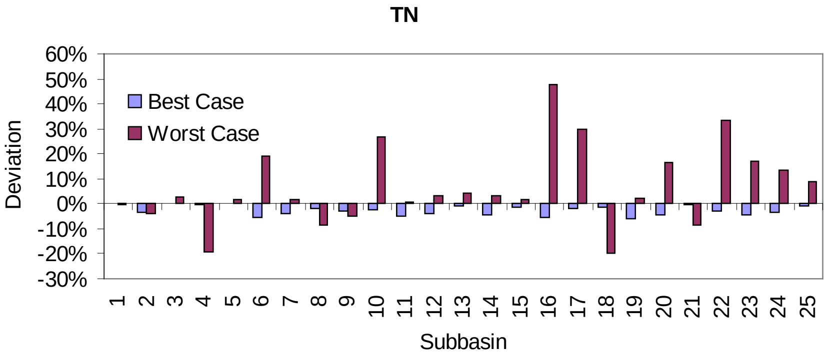
- Loading pattern among those three scenarios mirrors the pattern in soil loss, TN and TP losses discussed above.
- In-stream bio-chemical process seems decrease the impacts of soil and TP losses, but aggregate the impact of the TN loss.

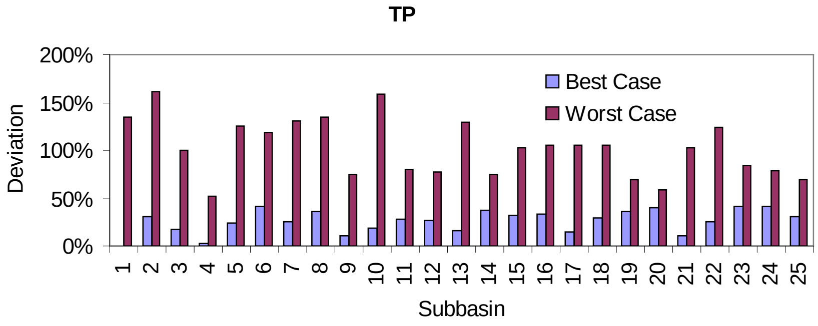
| Scenario | Sediment | TN | TP |
|---|---|---|---|
| Baseline | 708.90 | 150.07 | 15.59 |
| Best Case | 680.10 (-4.06%) | 147.72 (-1.56%) | 15.72 (+0.82%) |
| Worst Case | 1001.00 (+41.20%) | 165.78 (+10.47%) | 17.48 (+12.11%) |

# Losses from subbasins into streams

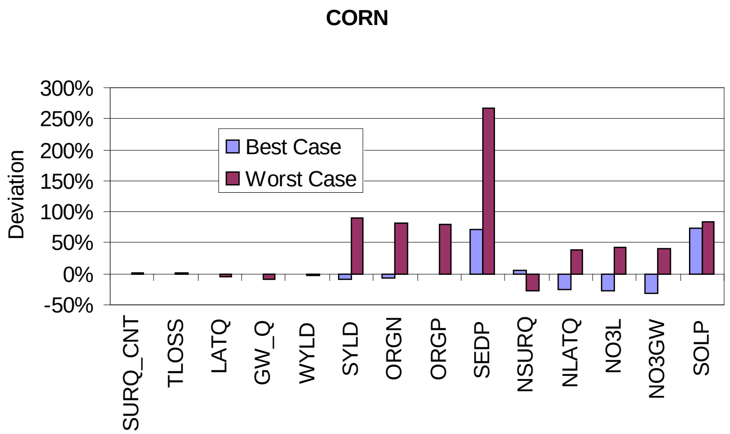
- Percentage changes show the similar patterns as their losses at the watershed scale, they do vary substantially by subbasins.
- The subbasins with higher percentage of croplands tend to experience higher soil, TN and TP losses.

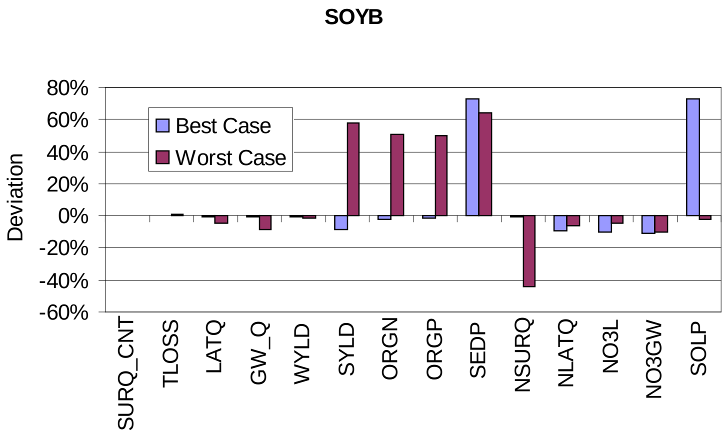


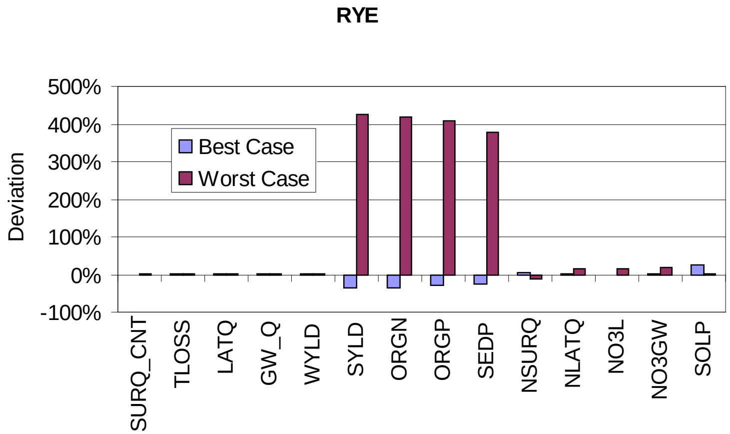



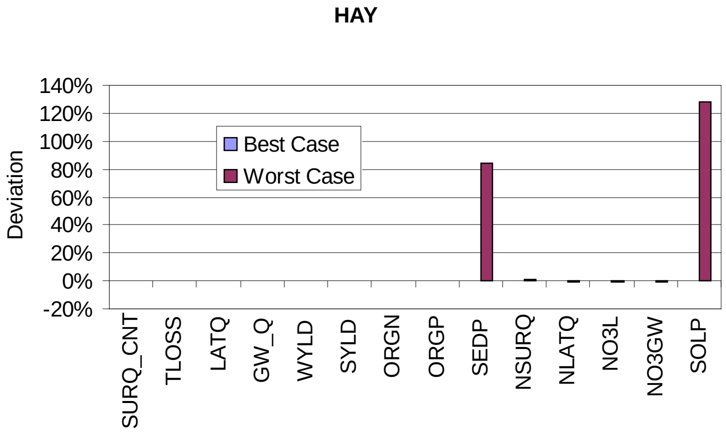



# Losses from land uses/covers into streams



# Conclusions

- Mixed results in term of water quality improvement when switching from minimum-till to no-till. No-till practices result in a lower TN loss, but a higher TP loss.
- Mismanagement as represented by the worst case scenario could result in significant water quality degradation.
- Application of SWAT in a suburban setting could be more complicated than in a agricultural setting.
- Future research will consider the aggregate impacts of agricultural, lawn and wildlife and stormwater BMPs on both water quantity and quality.