SWAT Bioenergy Applications for the U.S. Corn Belt region:

Assessment of large-scale bioenergy cropping scenarios for the Upper Mississippi and Ohio-Tennessee River Basins

Dr. Yiannis Panagopoulos, Researcher (Presenter)
Center for Agricultural and Rural Development, Dept. of Economics, Iowa State University, USA
Center for Hydrology and Informatics, Dept. of Civil Eng. National Technical University of Athens, GR

Dr. Philip W. Gassman, Associate Scientist
Dr. Catherine Kling, Professor
Center for Agricultural and Rural Development, Dept. of Economics, Iowa State University, USA

Dr. Cibin Raj, Researcher
Dr. Indrajeet Chaubey, Professor
Department of Agricultural and Biological Engineering, Purdue University, USA

Dr. Jeffrey Arnold, Agricultural Engineer
USDA-ARS, Grassland, Soil and Water Research Laboratory (GSWRL), Temple, TX, USA

Swat Conference
14-16 October 2015
Purdue University, IN USA

Study Regions (UMRB & OTRB)

Primary source regions of nutrients to the Gulf of Mexico

UMRB

Area: 492,000 km^2
Crops: 50%
<5% Slopes: 75%
Prec: 900 mm/y

Loads at Grafton IL
(447,000 km^2)

Flow: 3500 m^3/s
NO_3-N: 360,000 t/y
TN: 500,000 t/y
TP: 30,000 t/y

OTRB

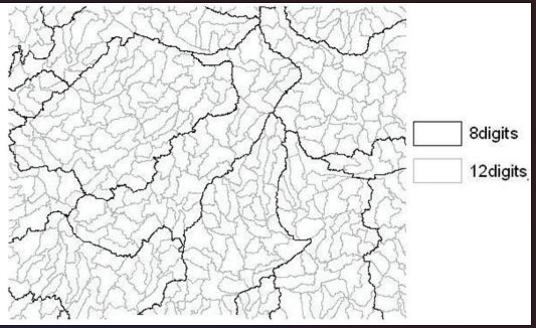
Area: 528,000 km^2
Crops: 20%
<5% Slopes: 35%
Prec: 1200 mm/y

Loads at Metropolis IL
(526,000 km^2)

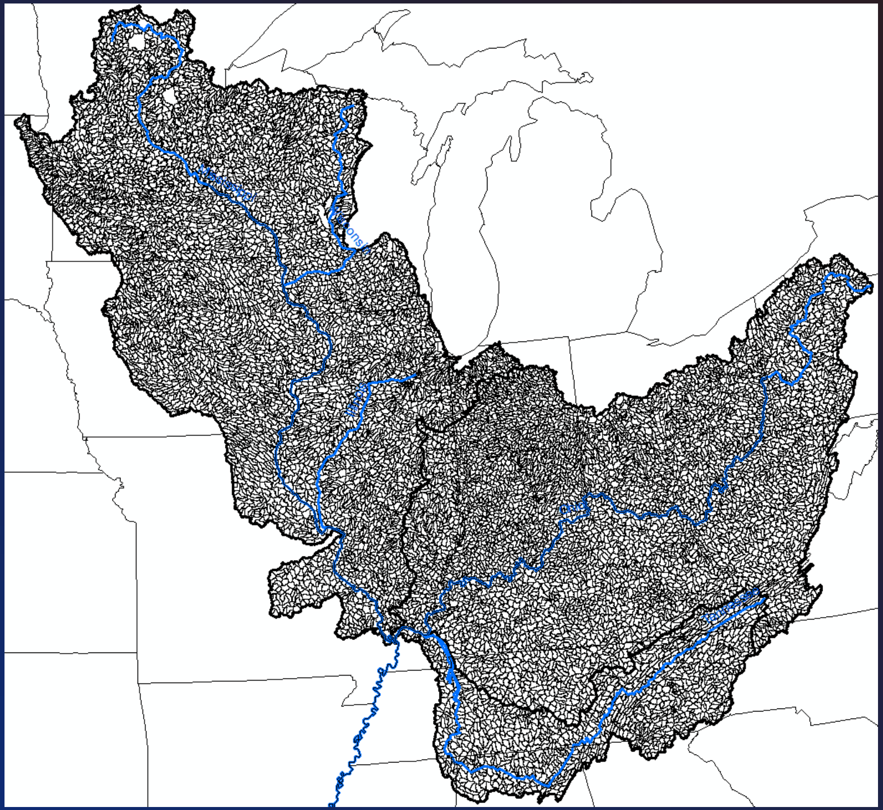
Flow: 8400 m^3/s
NO_3-N : 330,000 t/y
TN: 500,000 t/y
TP: 48,000 t/y

Corn Belt modelling with SWAT

- A “12-digit watershed” scale modelling system
- A major refinement, which can improve:
  - Input data accuracy (precipitation – management)
  - Water and pollutant routing
  - Scenarios targeting

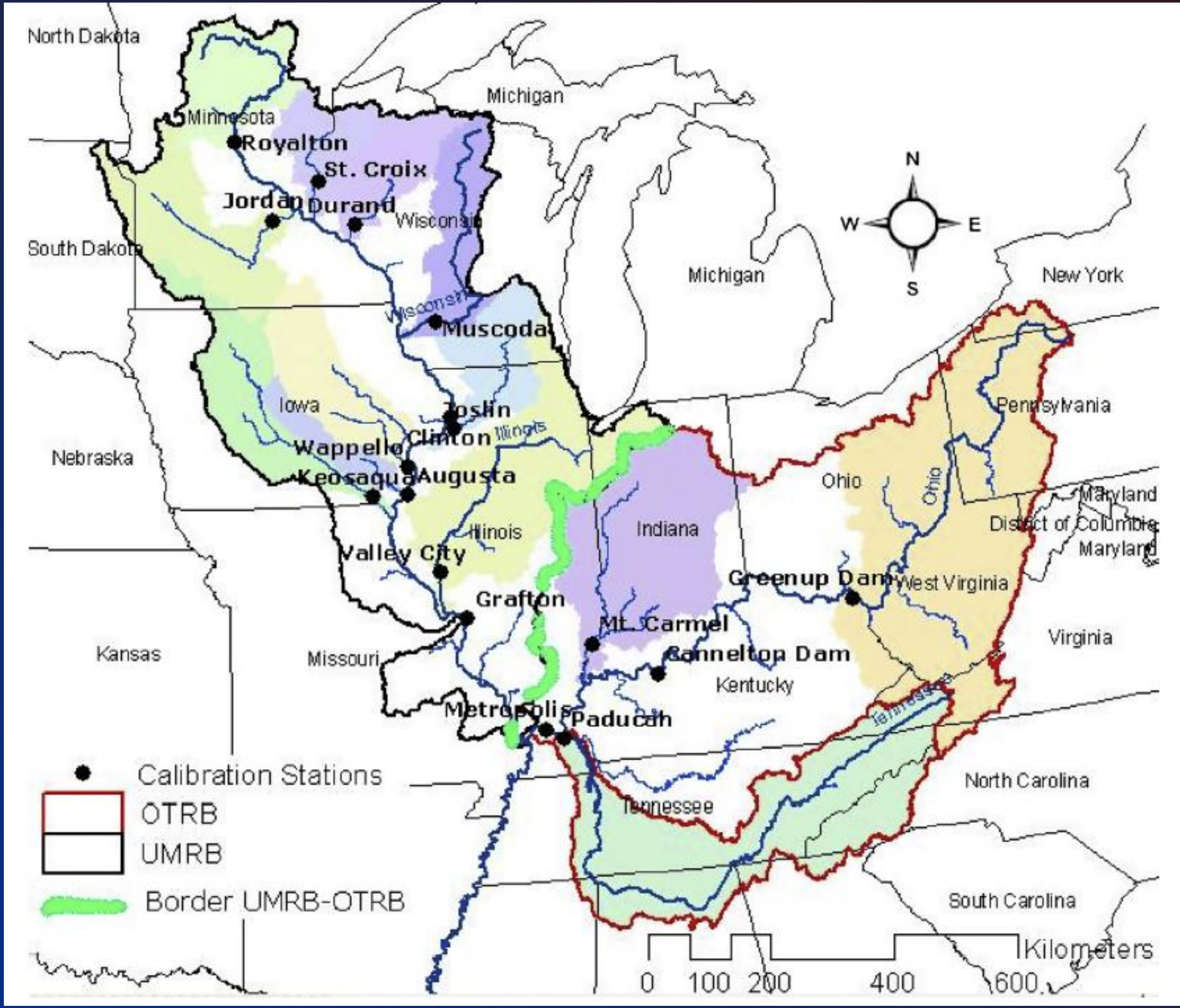


- UMRB: 5729 12digits
- OTRB: 6350 12digits
- Average 12digit area: ~ 85 km^2
- Average 8digit area: ~ 4000 km^2
- A 50 times finer discretization



Calibration approach

- Individual UMRB and OTRB projects created in ArcSWAT 2012
- Hydrologically independent watersheds within UMRB and OTRB
- SWAT-CUP for flows, manual calibration for water quality



Model setup, calibration and validation

Journal of Hydrology 524 (2015) 348–366

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

A refined regional modeling approach for the Corn Belt – Experiences and recommendations for large-scale integrated modeling

Yiannis Panagopoulos [a,*], Philip W. Gassman [a], Manoj K. Jha [b], Catherine L. Kling [a], Todd Campbell [a], Raghavan Srinivasan [c], Michael White [d], Jeffrey G. Arnold [d]

[a] Center for Agricultural and Rural Development, Iowa State University, Ames, IA 50011-1070, USA
[b] Civil Engr. Dept., North Carolina A&T State University, 1601 E. Market St., Greensboro, NC 27410, USA
[c] Spatial Sciences Laboratory, Texas A&M Univ., College Station, TX 77845, USA
[d] USDA-ARS, Grassland, Soil and Water Research Laboratory, Temple, TX 76502, USA

A R T I C L E I N F O

Article history:
Received 7 July 2014
Received in revised form 12 January 2015
Accepted 20 February 2015
Available online 7 March 2015
This manuscript was handled by Laurent Charlet, Editor-in-Chief, with the assistance of Nicolas Gratiot, Associate Editor

Keywords:
Corn Belt
Large-scale calibration
Nonpoint source pollution
Refined modeling
SWAT

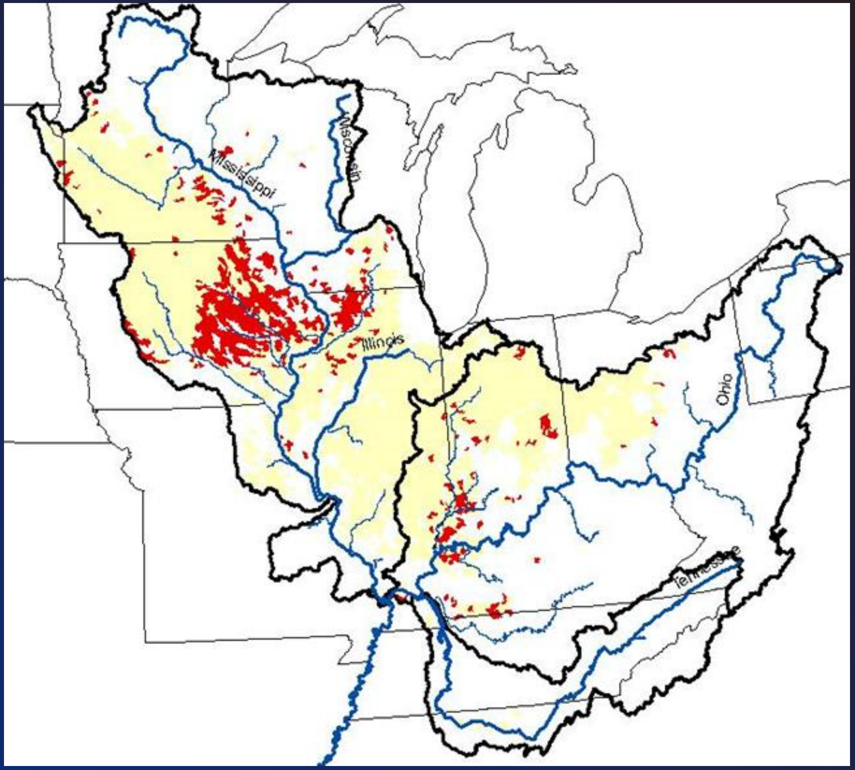
S U M M A R Y

Nonpoint source pollution from agriculture is the main source of nitrogen and phosphorus in the stream systems of the Corn Belt region in the Midwestern US. This region is comprised of two large river basins, the intensely row-cropped Upper Mississippi River Basin (UMRB) and Ohio-Tennessee River Basin (OTRB), which are considered the key contributing areas for the Northern Gulf of Mexico hypoxic zone according to the US Environmental Protection Agency. Thus, in this area it is of utmost importance to ensure that intensive agriculture for food, feed and biofuel production can coexist with a healthy water environment. To address these objectives within a river basin management context, an integrated modeling system has been constructed with the hydrologic Soil and Water Assessment Tool (SWAT) model, capable of estimating river basin responses to alternative cropping and/or management strategies. To improve modeling performance compared to previous studies and provide a spatially detailed basis for scenario development, this SWAT Corn Belt application incorporates a greatly refined subwatershed structure based on 12-digit hydrologic units or 'subwatersheds' as defined by the US Geological Service. The model setup, calibration and validation are time-demanding and challenging tasks for these large systems, given the scale intensive data requirements, and the need to ensure the reliability of flow and pollutant load predictions at multiple locations. Thus, the objectives of this study are both to com-

Biofuel scenarios and marginal lands

- Baseline: C-S and C-C in 30% of the Corn Belt area (330,000 km^2)
- Scenarios:
  - Corn Stover Removal
  - Perennials (Switchgrass/Miscanthus)
- Where:
  - To all cropland or
  - To environmentally marginal land or
  - To environmentally non-marginal land
- Marginal land:
  - Slopes > 2% and
  - Annual erosion rate > 2t/ha (baseline)

Red: Marginal cropland (15%)
Yellow: Non-marginal cropland (85%)



Biofuel management scenarios in the Corn Belt

Baseline: C-S and C-C in 30% of the Corn Belt area (330,000 km^2)

Scenarios:

1	20% corn stover removal from the entire cropland
2	50% corn stover removal from the entire cropland
3	20% corn stover removal from the environmentally non-marginal cropland
4	50% corn stover removal from the environmentally non-marginal cropland
5	Switchgrass in all cropland
6	Miscanthus in all cropland
7	Switchgrass in environmentally non-marginal cropland
8	Miscanthus in environmentally non-marginal cropland
9	Switchgrass in environmentally marginal cropland
10	Miscanthus in environmentally marginal cropland

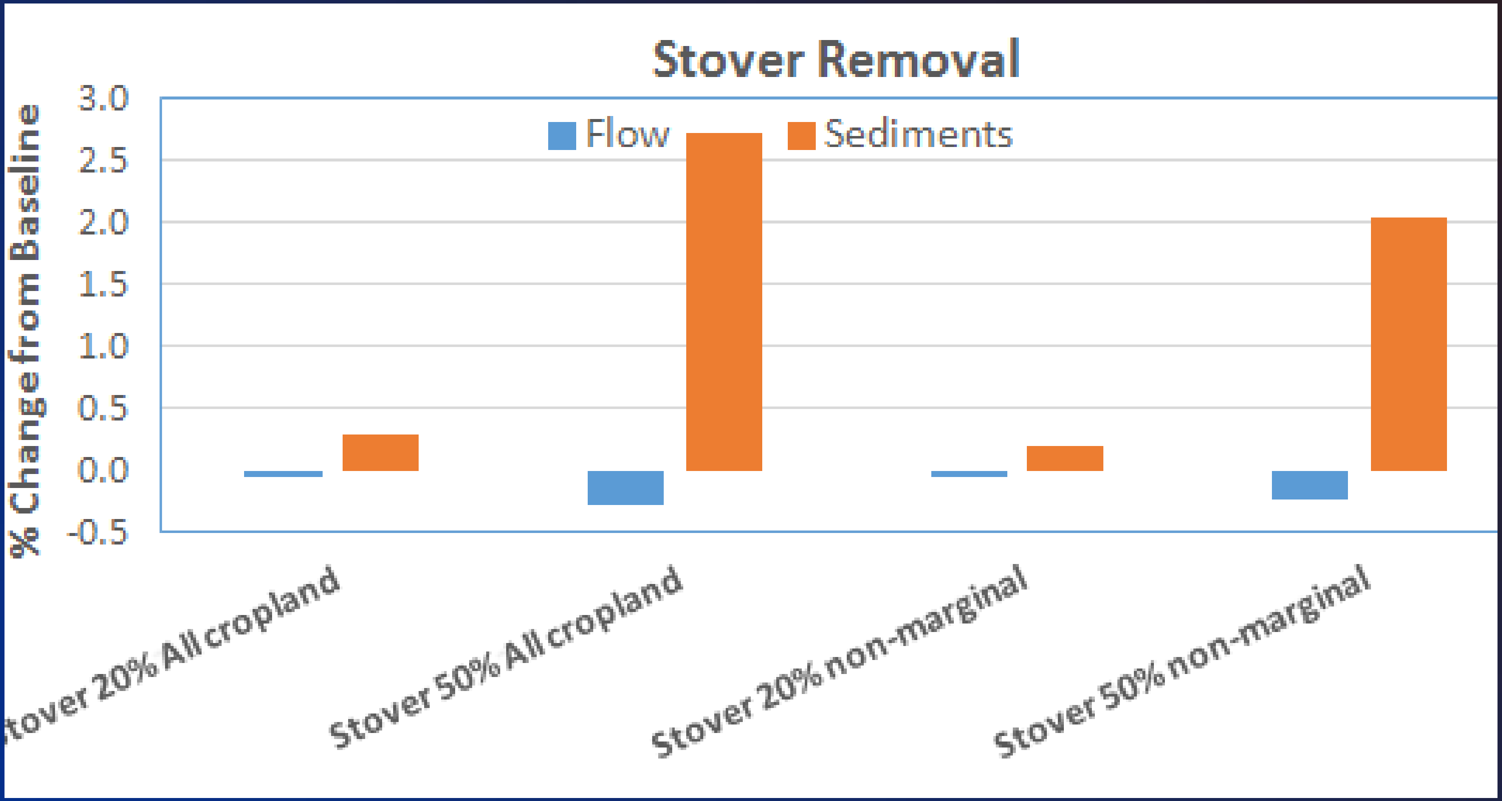
Results presentation

- For the entire Corn Belt Region (entering Mississippi downstream)
- Mean annual basis
- River flows (as % change from the baseline)
- Sediments and Nutrients (as % change from the baseline)
- Crop grain yields and/or bio-yields (t/ha)

Baseline (1981-2000):

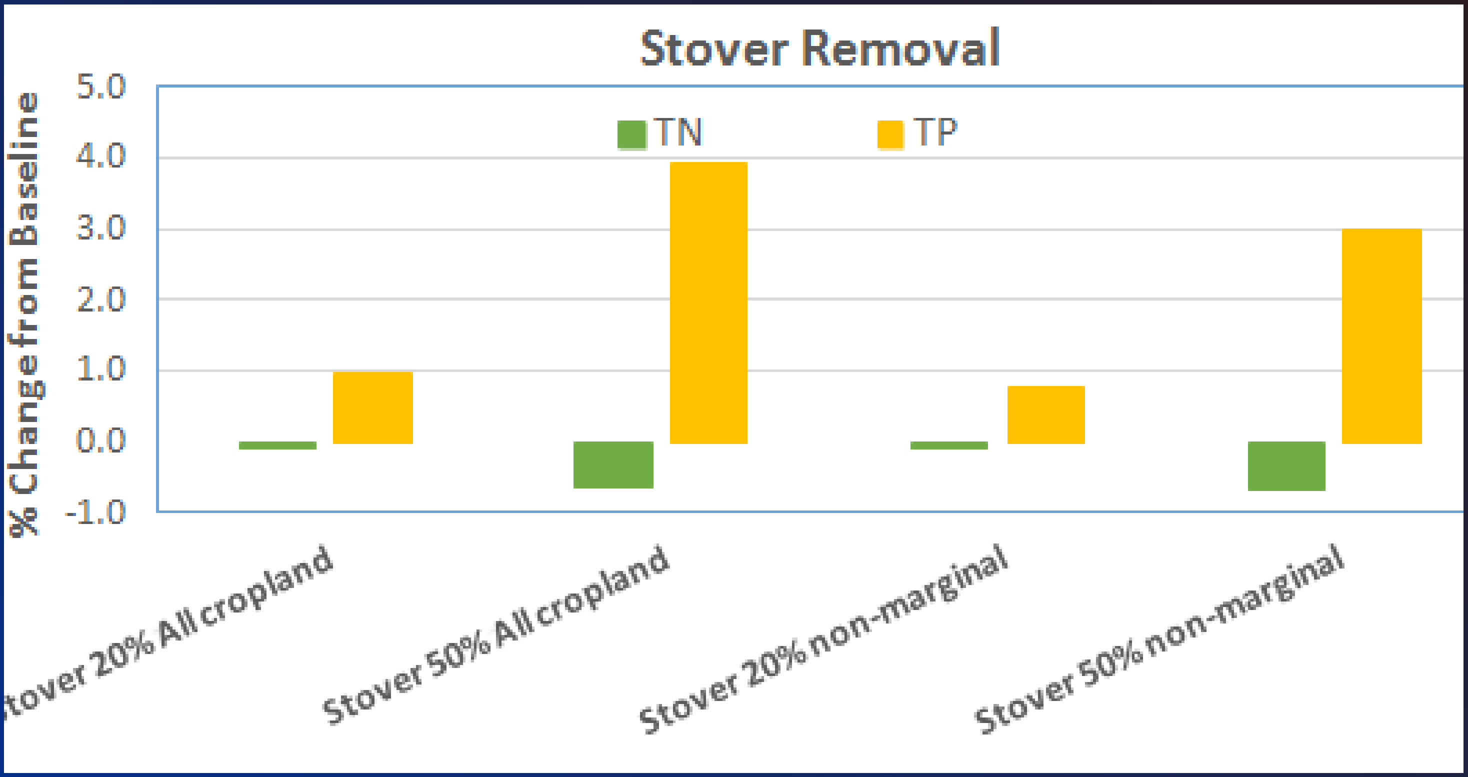
- Mean annual flow: 10,734 m^3/s
- Mean annual sediments: 75.260,000 t
- Mean annual TN: 909,500 t
- Mean annual TP: 79,343 t

Results
Corn Stover (flow and sediments)



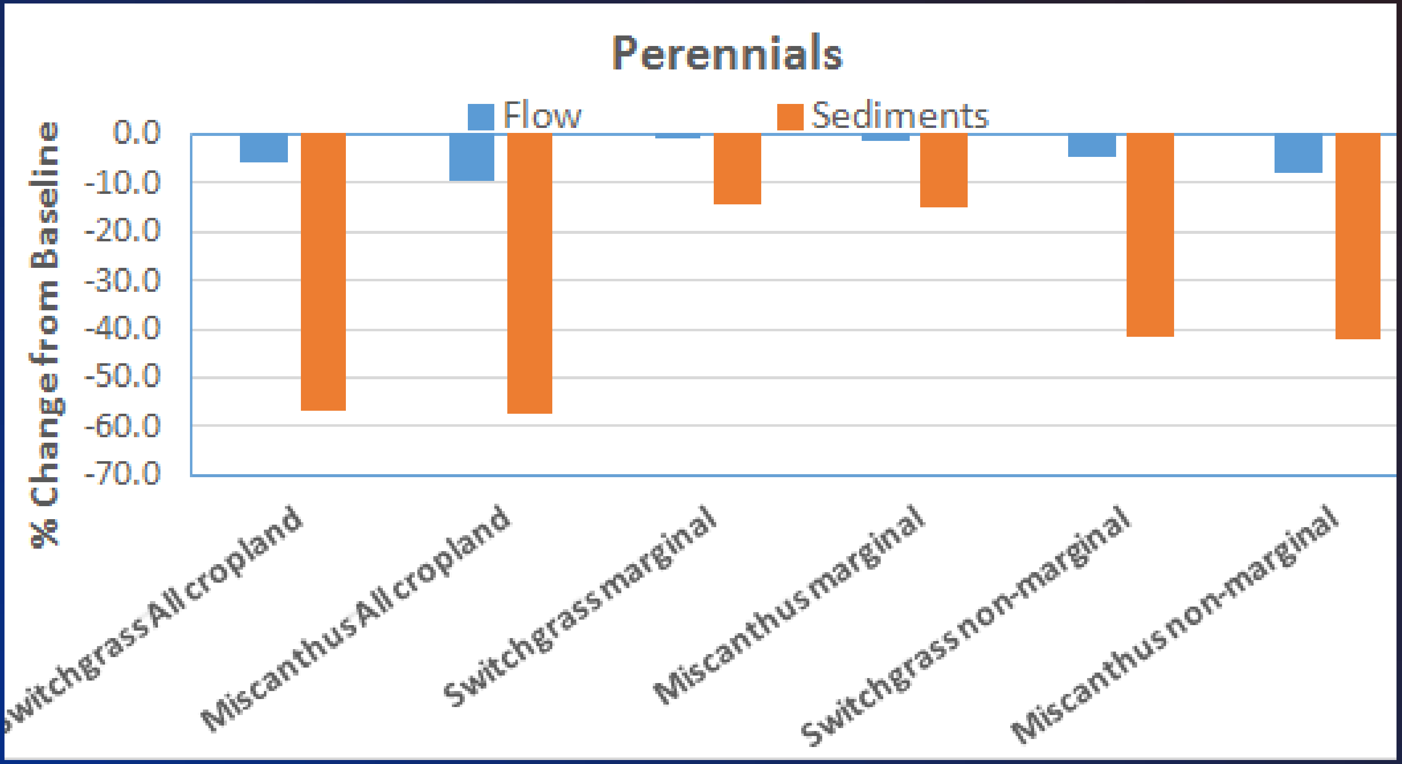
Marginal: 15% of cropland, Non-marginal: 85% of cropland

Results
Corn Stover (nutrients)



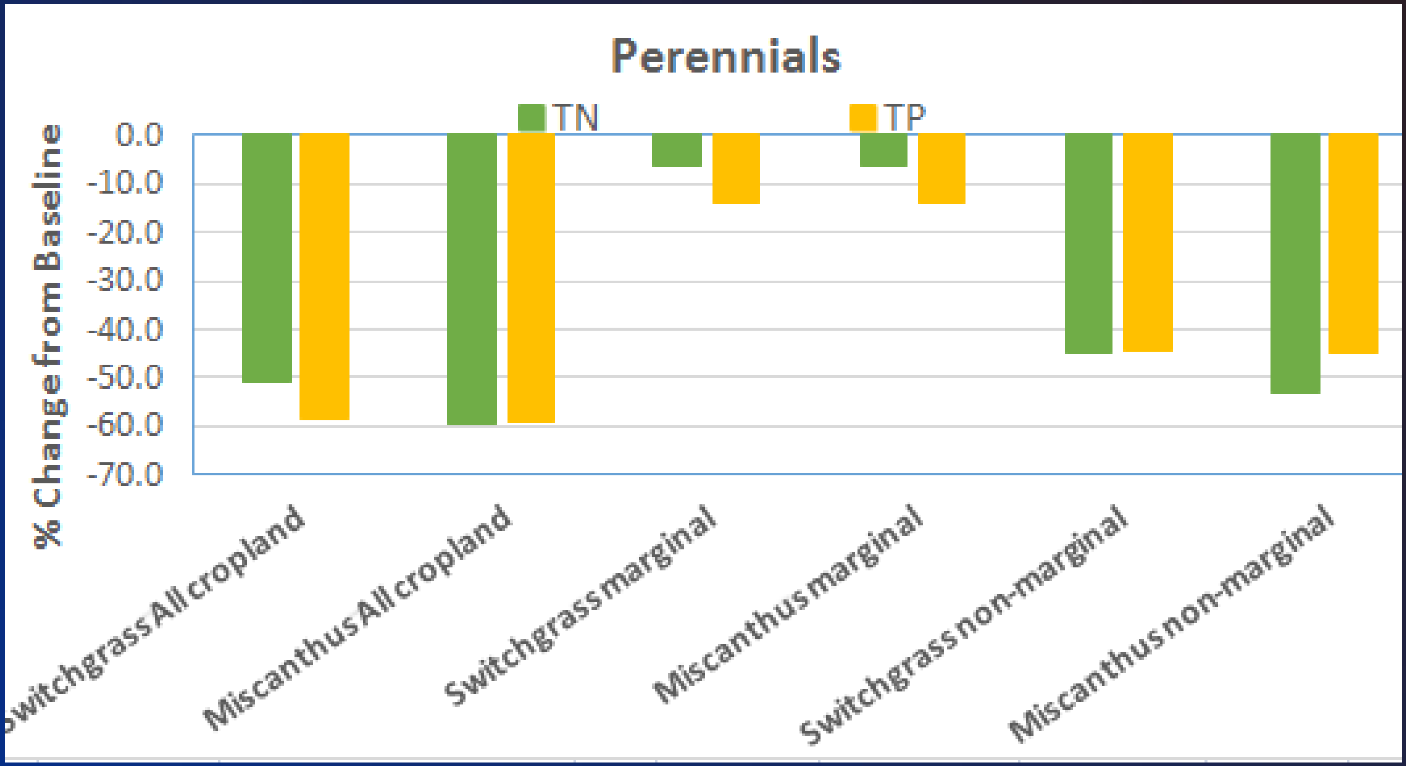
Marginal: 15% of cropland, Non-marginal: 85% of cropland

Results
Perennials (flow and sediments)



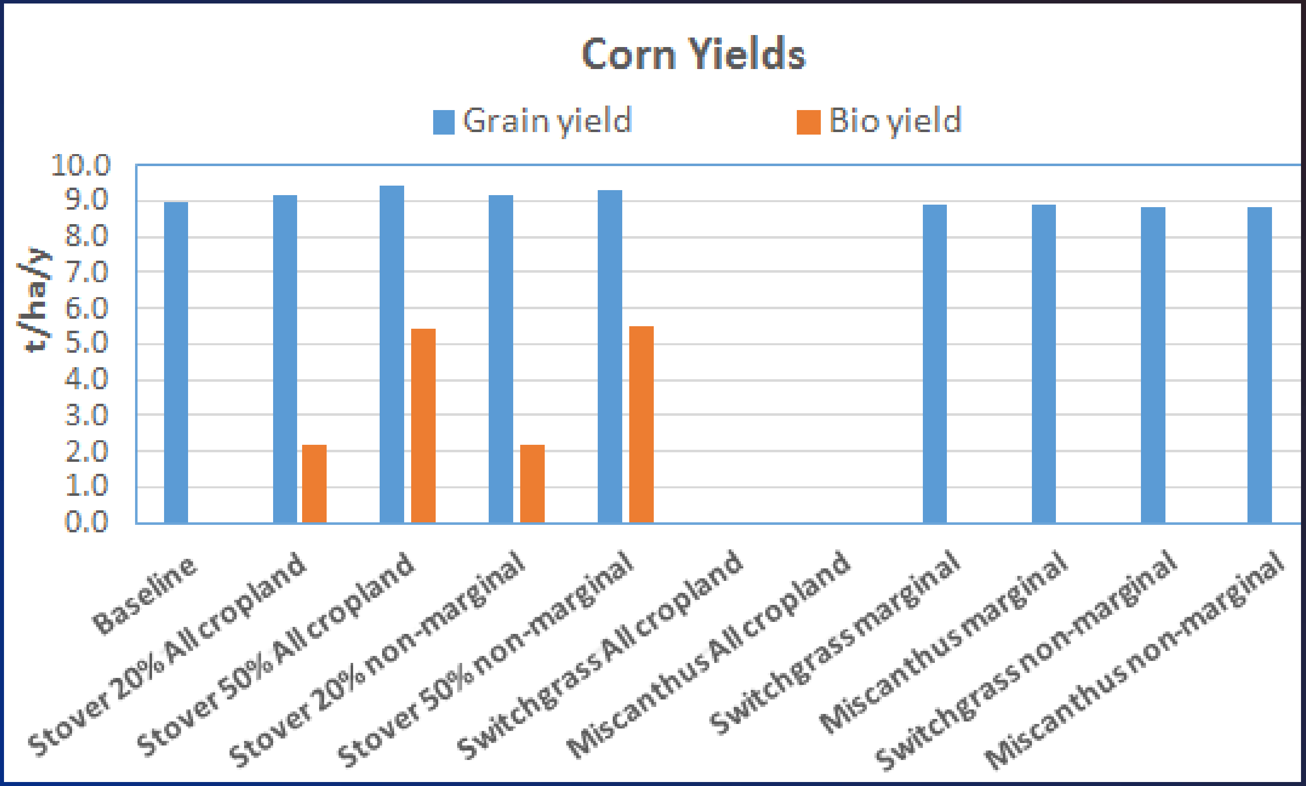
Marginal: 15% of cropland, Non-marginal: 85% of cropland

Results
Perennials (nutrients)



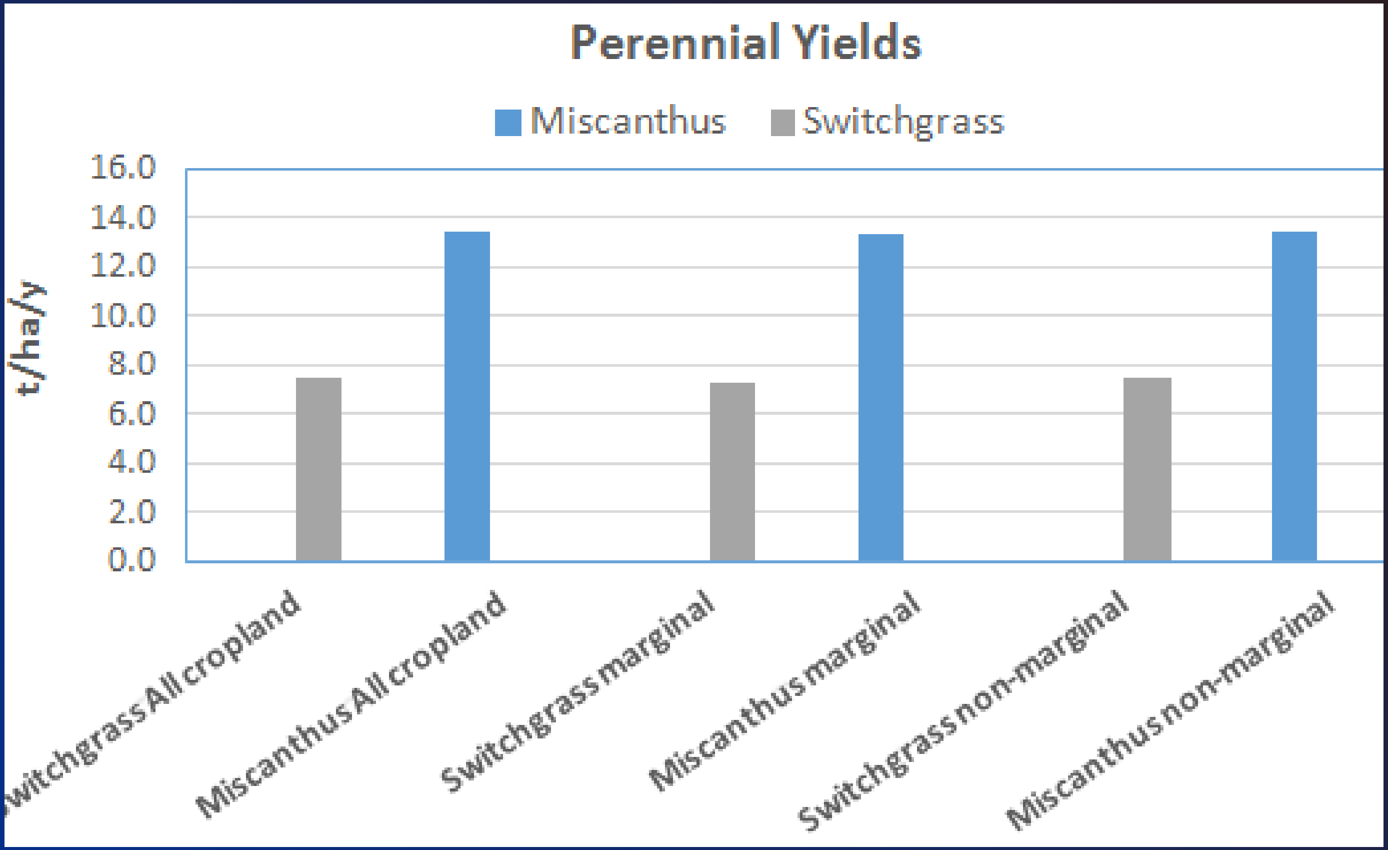
Marginal: 15% of cropland, Non-marginal: 85% of cropland

Results
Corn Stover (grain and bio-yields)



Marginal: 15% of cropland, Non-marginal: 85% of cropland

Results
Perennial yields



Marginal: 15% of cropland, Non-marginal: 85% of cropland

Conclusions

- Stover removal does not result in significant water quality alterations
- Switchgrass and miscanthus are equivalent and very effective in reducing water pollution (achieve the 45% reduction target for the hypoxic zone when entirely implemented)
- Both reduce sediments and P at a higher rate in sloping and most erosive land (marginal land)
- To significantly reduce N, they should be implemented in lowland areas as well (reduce subsurface flow and leaching of soluble N forms transported by tiles)
- SWAT perennial yields probably underestimated
- SWAT yields need extensive calibration – limited spatial variability and sensitivity to climate and geomorphologic differences

A reasonable plan for addressing cost-effectively the food-energy-water nexus at the large scale

1. Stover removal in concentrated lowland areas with high productivity
2. Perennials growth in environmentally marginal land but also in selected lowland tile-drained areas with the highest N pollution
3. Progressively add more areas based on economic factors