

SWAT Bioenergy Applications for the U.S. Corn Belt region:
**Assessment of large-scale scenarios for the Upper
Mississippi and Ohio-Tennessee River Basins**

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Study Regions (UMRB & OTRB)

Primary source regions of nutrients to the Gulf of Mexico

UMRB

Area: 492,000 km²

Crops: 50%

<5% Slopes: 75%

Prec: 900 mm/y

Loads at Grafton IL
(447,000 km²)

Flow: 3500 m³/s

NO₃-N: 360,000 t/y

TN: 500,000 t/y

TP: 30,000 t/y



OTRB

Area: 528,000 km²

Crops: 20%

<5% Slopes: 35%

Prec: 1200 mm/y

Loads at Metropolis IL
(526,000 km²)

Flow: 8400 m³/s

NO₃-N : 330,000 t/y

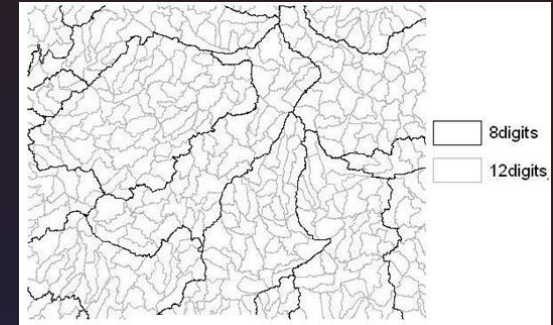
TN: 500,000 t/y

TP: 48,000 t/y

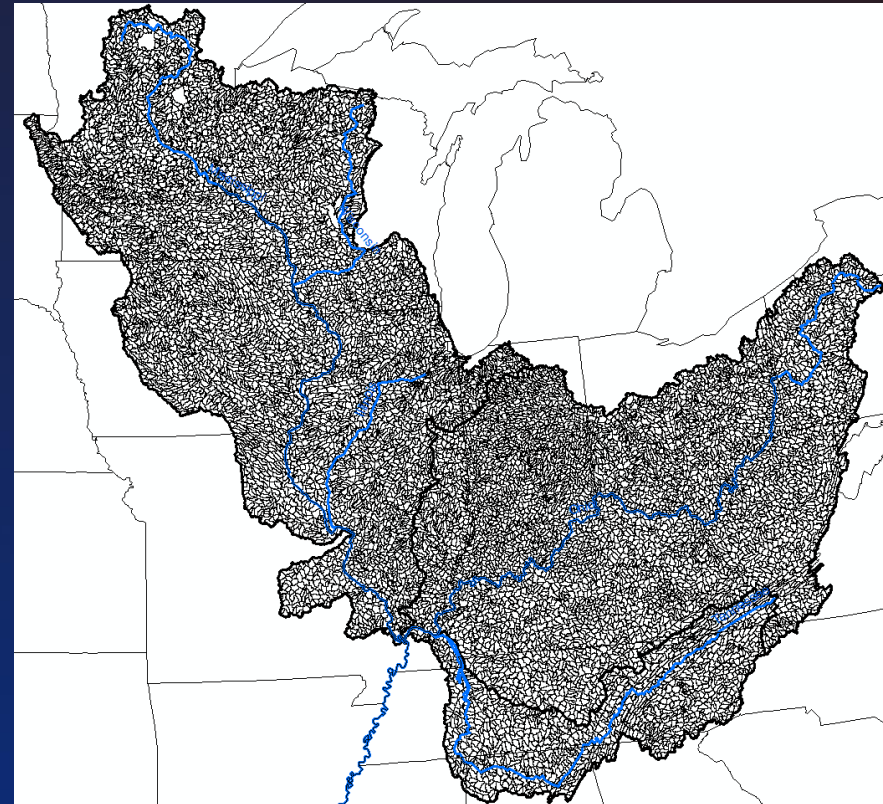


Corn Belt modelling with SWAT

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

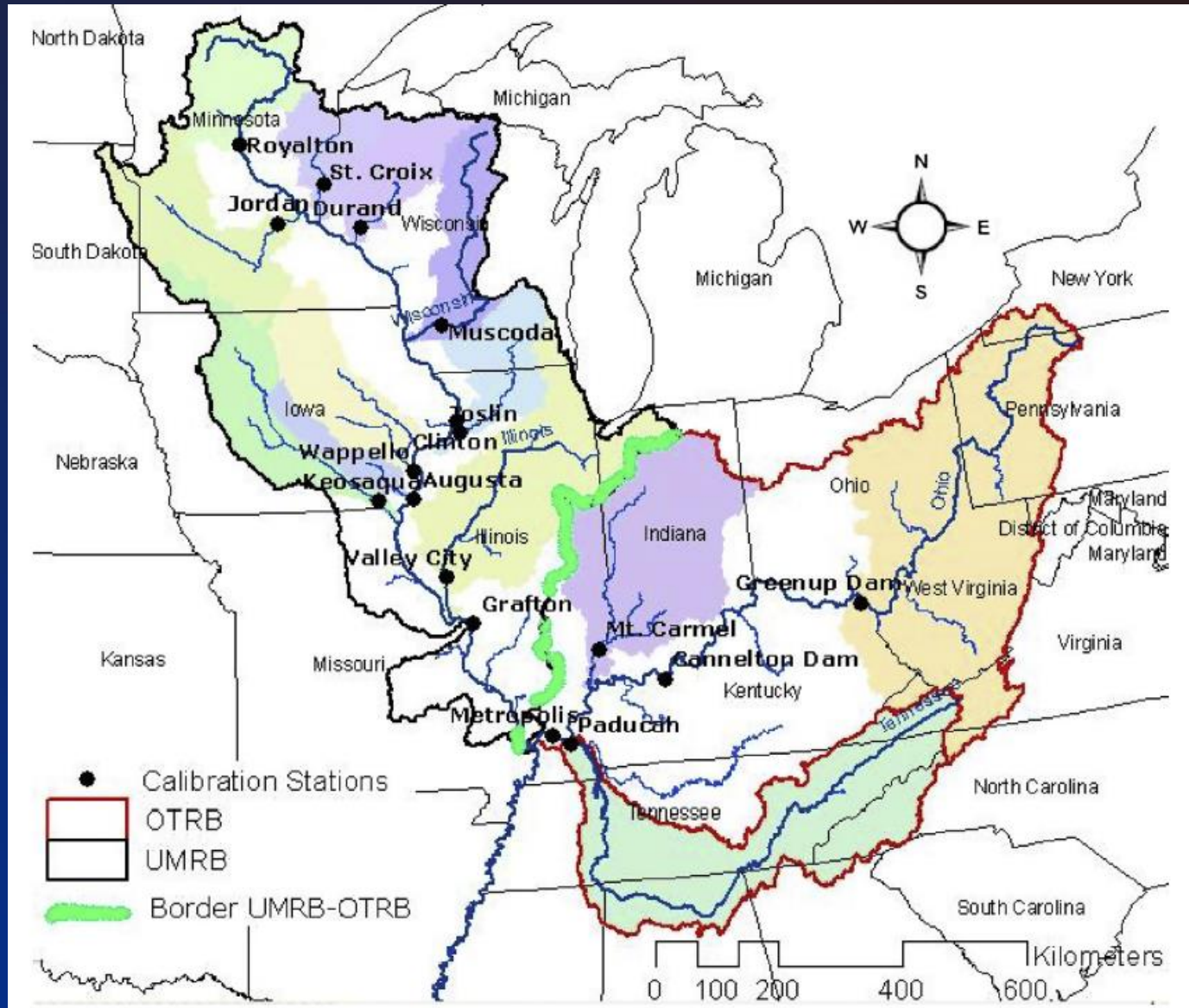


- UMRB: 5729 12digits
- OTRB: 6350 12digits
- Average 12digit area: $\sim 85 \text{ km}^2$
- Average 8digit area: $\sim 4000 \text{ km}^2$
- A 50 times finer discretization



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

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



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SUMMARY

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 km²)

- Scenarios:

- Corn Stover Removal
- Perennials (Switchgrass/Miscanthus)

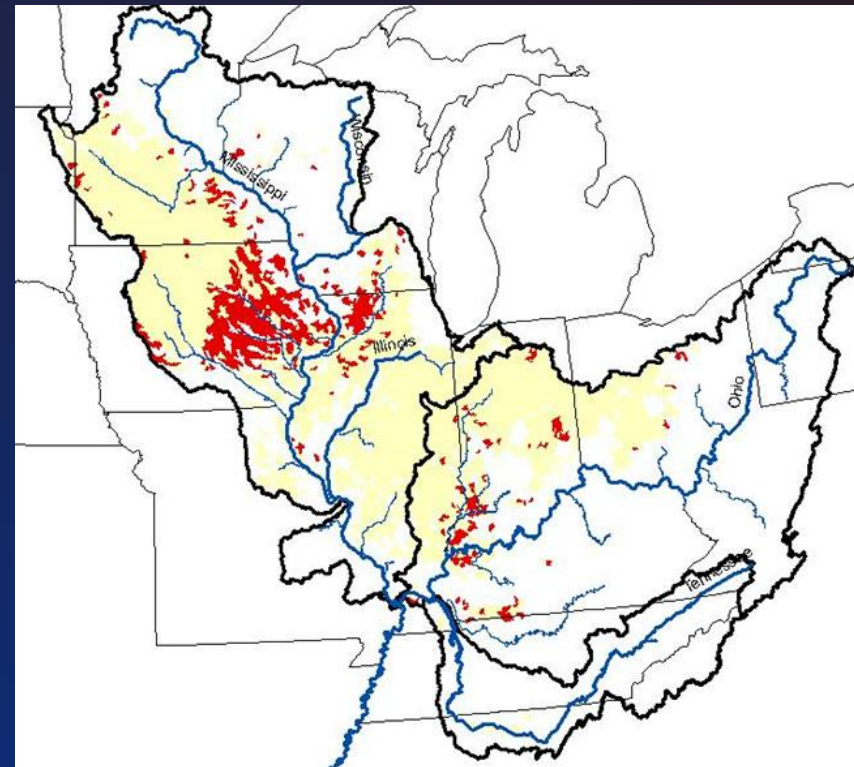
- Where:

- 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 km²)

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

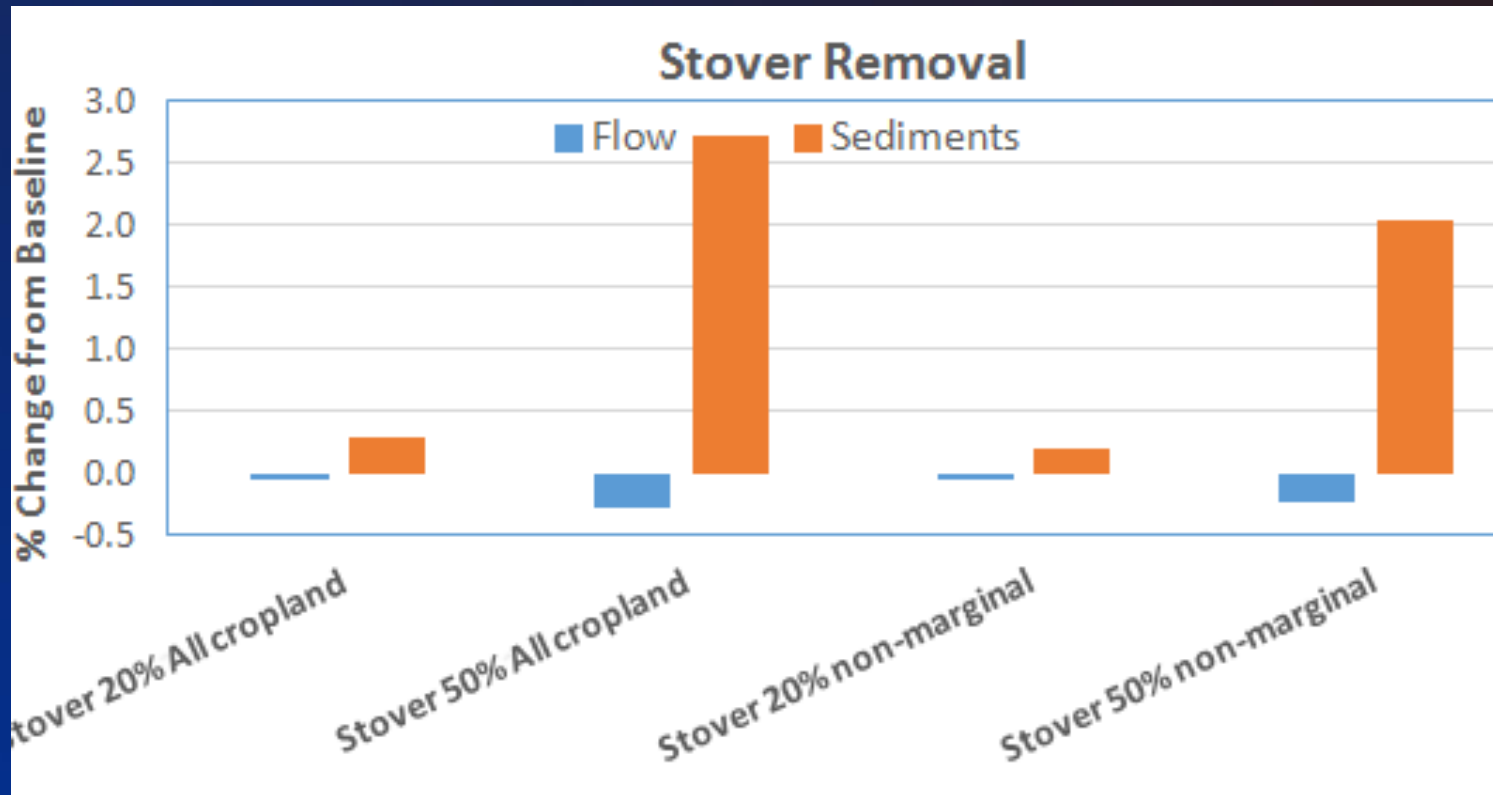
- For the entire Corn Belt Region (entering Mississippi downstream)
- Mean annual basis
- River flows (as % change from the baseline)
- Sediments and Nutrients (as % change from the baseline)
- Crop grain yields and/or bio-yields (t/ha)

Baseline (1981-2000):

- Mean annual flow: 10,734 m³/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)

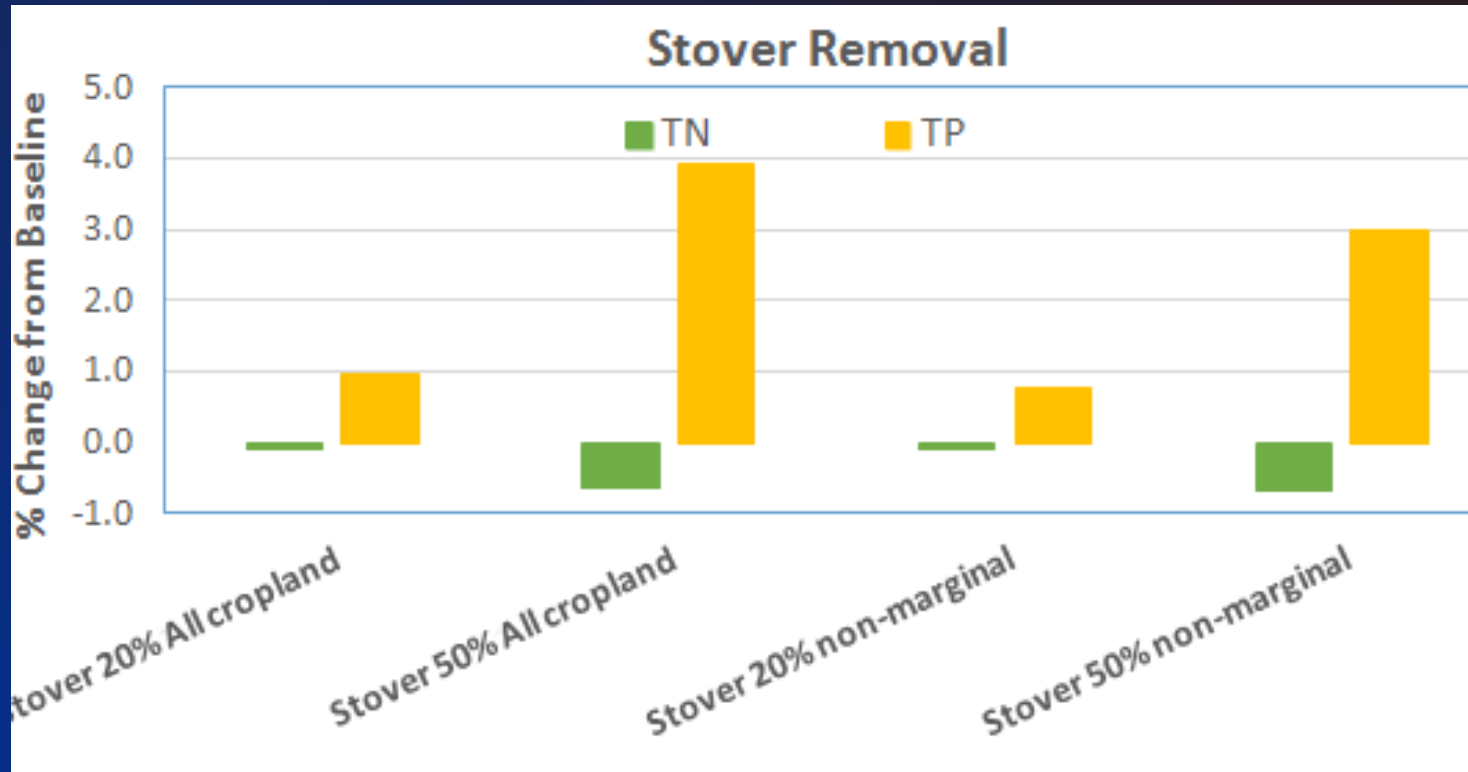


Marginal: 15% of cropland, Non-marginal: 85% of cropland



Results

Corn Stover (nutrients)

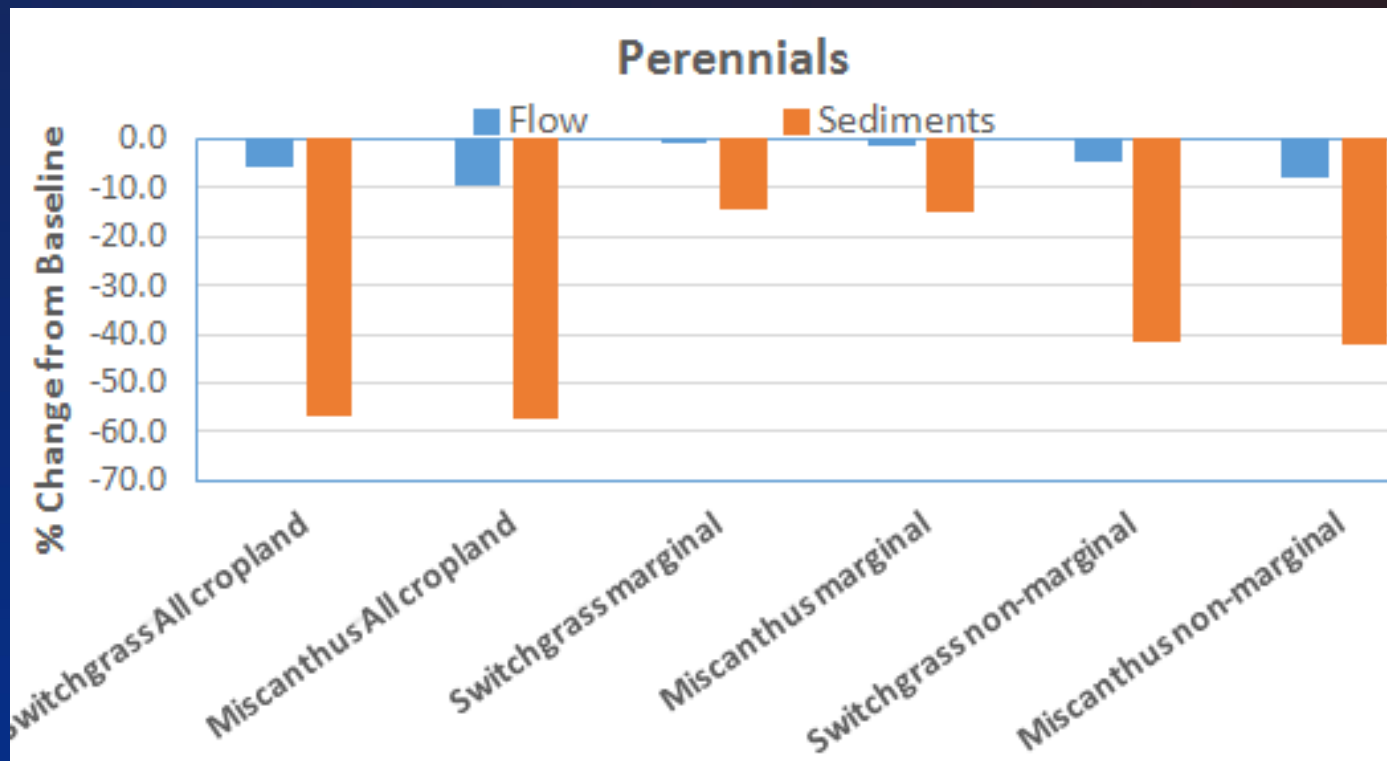


Marginal: 15% of cropland, Non-marginal: 85% of cropland



Results

Perennials (flow and sediments)

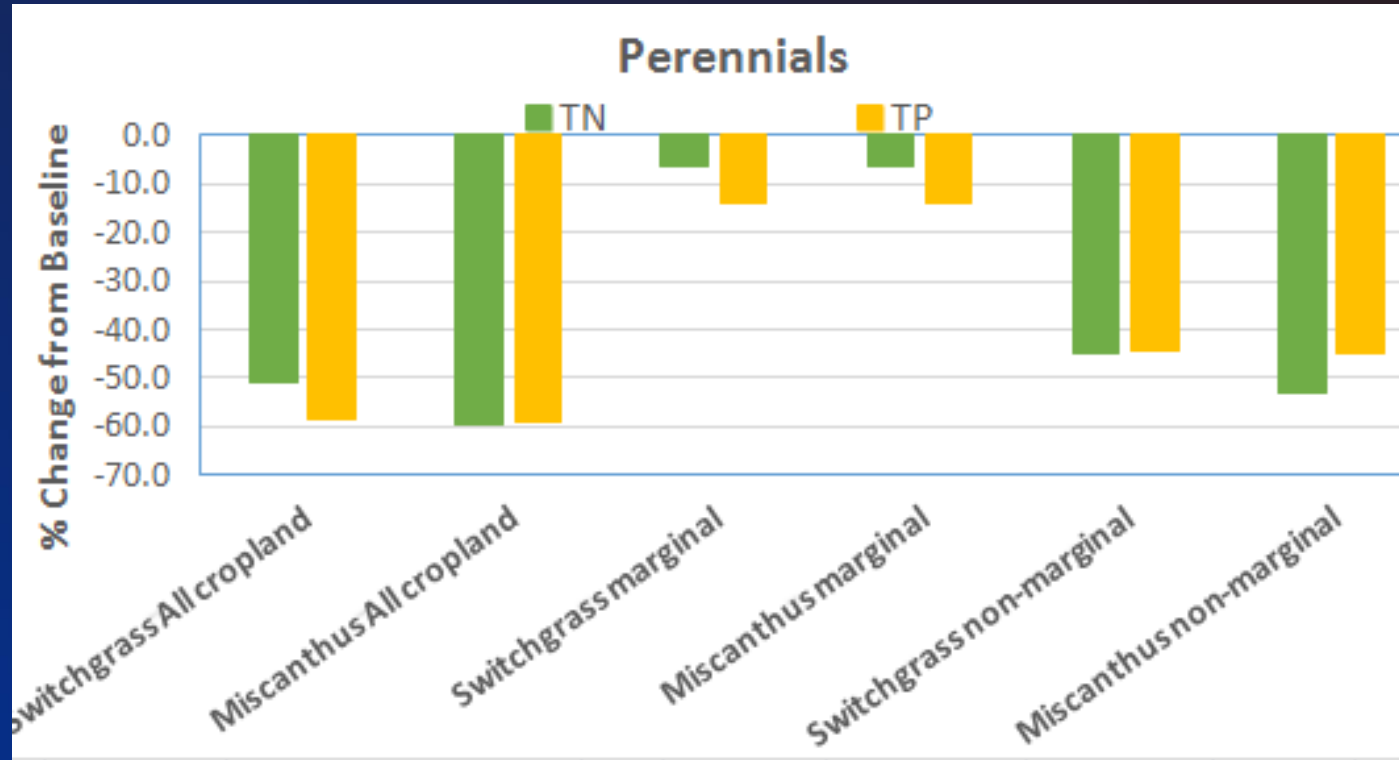


Marginal: 15% of cropland, Non-marginal: 85% of cropland



Results

Perennials (nutrients)

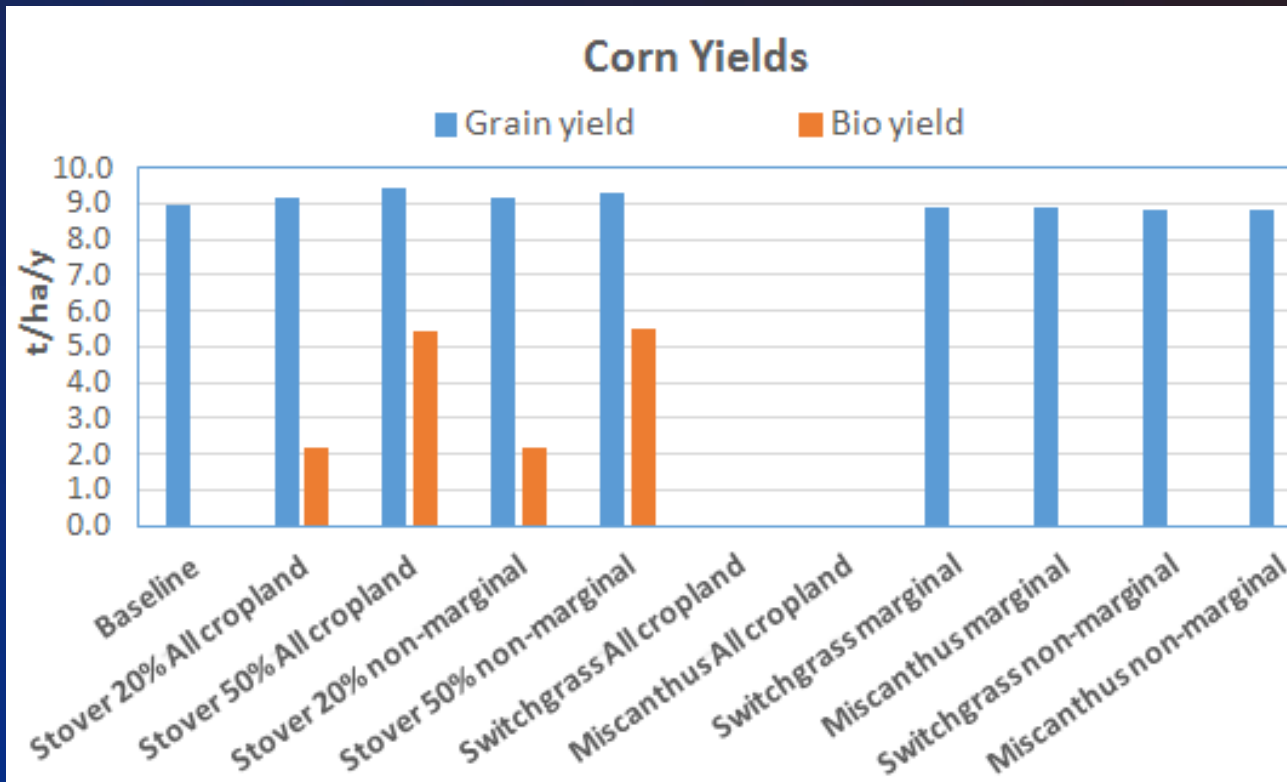


Marginal: 15% of cropland, Non-marginal: 85% of cropland



Results

Corn Stover (grain and bio-yields)

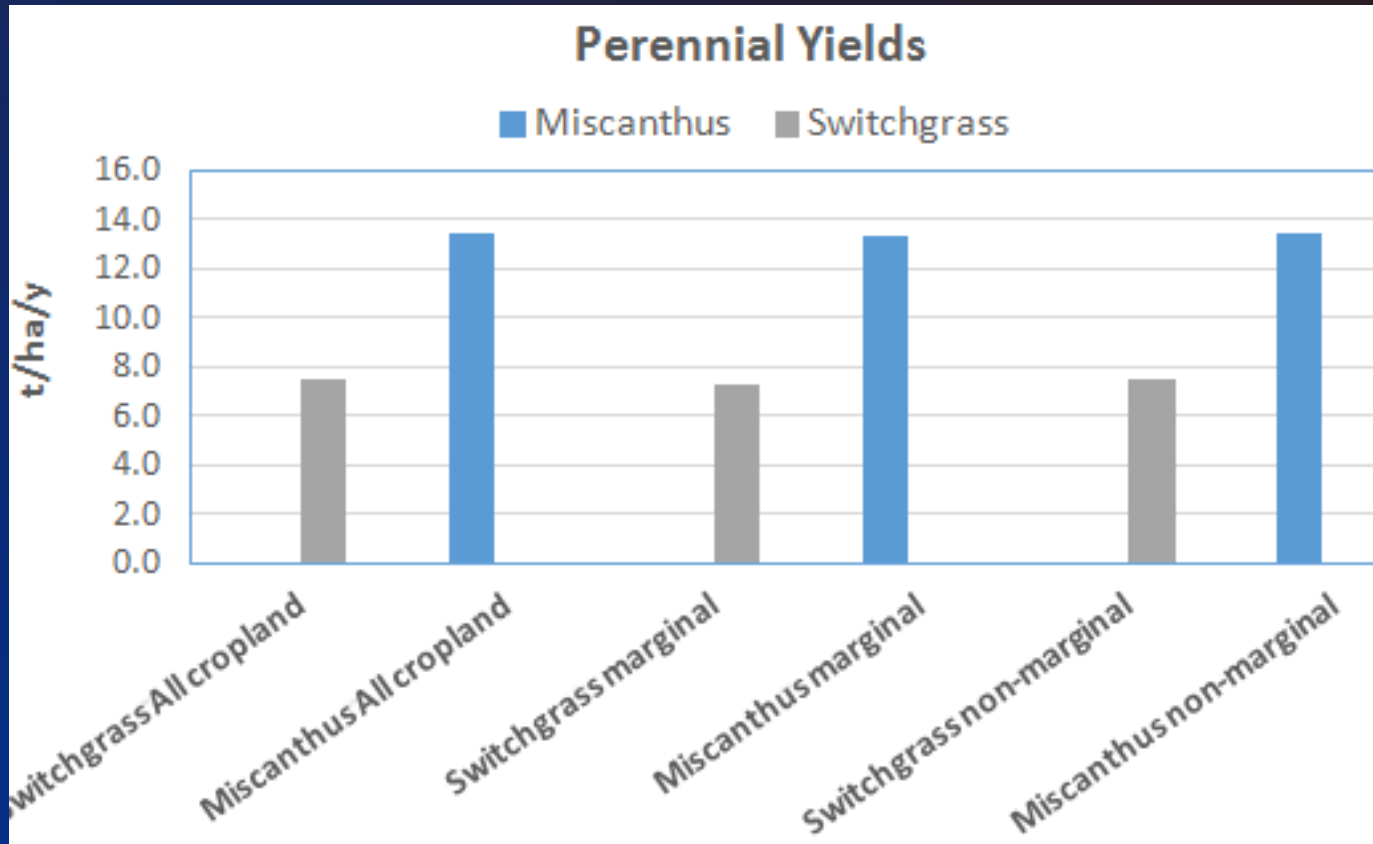


Marginal: 15% of cropland, Non-marginal: 85% of cropland



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 target for the hypoxic zone when entirely implemented)
- Both reduce sediments and P at a higher rate in sloping and most erosive 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

A viable plan

A general viable solution for the Corn Belt (food, biofuels, water quality, cost) may include the combined implementation of:

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