Oklahoma Clean Lakes & Watersheds Association

26th Annual Conference

Value of Informed Water Quality Management

Evaluating the Least Cost Selection of Agricultural Management Practices in the Fort Cobb Watershed

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Outline

- Introduction
- Problem Statement
- Objectives
- Study Area and Methodology
- Results
- Conclusion
- Future Research
- Acknowledgement

Introduction

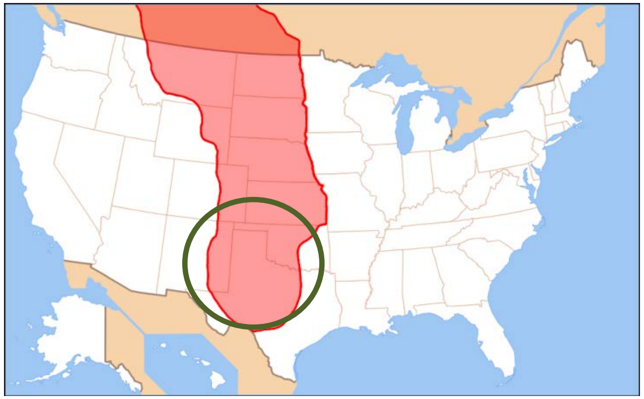
- Main cause of water quality impairment in the USA is due to human induced Non-Point Source Pollution

- Contamination of surface water and groundwater also puts drinking water resources at risk

Problem Statement

- Southern Great Plains of the United States
  - Stressing the landscape
  - Increasing uncertainty and risk in agricultural production
  - Impeding optimal agronomic management of crop, pasture, and grazing systems

(Garbrecht, et al., 2014)



Wishart, 2004

- Watersheds located in this region ⇨ issues of NPS pollution

- The Fort Cobb Reservoir and contributing streams are impaired water bodies ⇨ listed on Oklahoma 303(d) list as not meeting water quality standards
- Impaired by turbidity and phosphorus
- Too much sediment in water leads
  - taste and odor problems
  - reduced aquatic animal food
  - increased dredging cost.

Problem Statement

Source

- Upland areas (farms and fields) erosion
- Streams and waterways erosion
- Rill erosion and amount of upland sediment loading to and erosion in ephemeral channels

Management Practices

- Contour
- Conservation tillage
- Strip cropping

- Pond
- buffer strip
- small check dam

- Changing tillage systems
- Replacing cover crop with grass
- Avoiding overgrazing
- Conservation tillage
- grassed waterway

Objective

Evaluating the Least Cost Selection of Agricultural Management Practices in the Fort Cobb Watershed

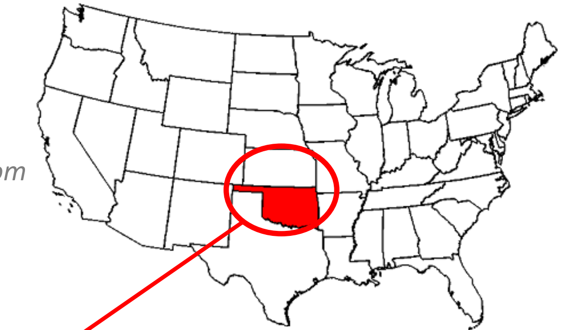
Specific objectives:

- Calibrate and validate a hydrological model
  - Surface runoff
  - Crop yield
  - Sediment load
- Generate different scenarios
- Evaluate economically and ecologically sound BMPs

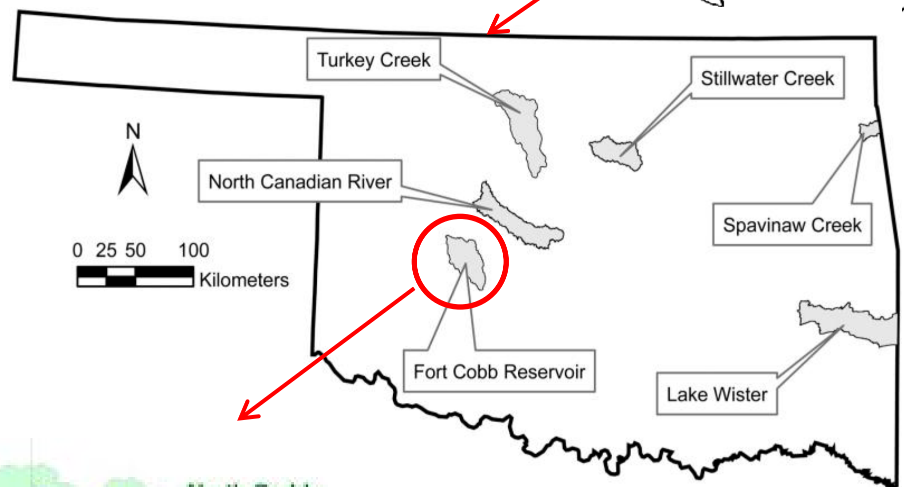
Study Area

Fort Cobb watershed

- located in west-central Oklahoma, United States
- rural agricultural catchment
- issues of NPS pollution (suspended solids, siltation, nutrients (N, P), and pesticides)
- Watershed area is 813 km^2



https://www.studyblue.com

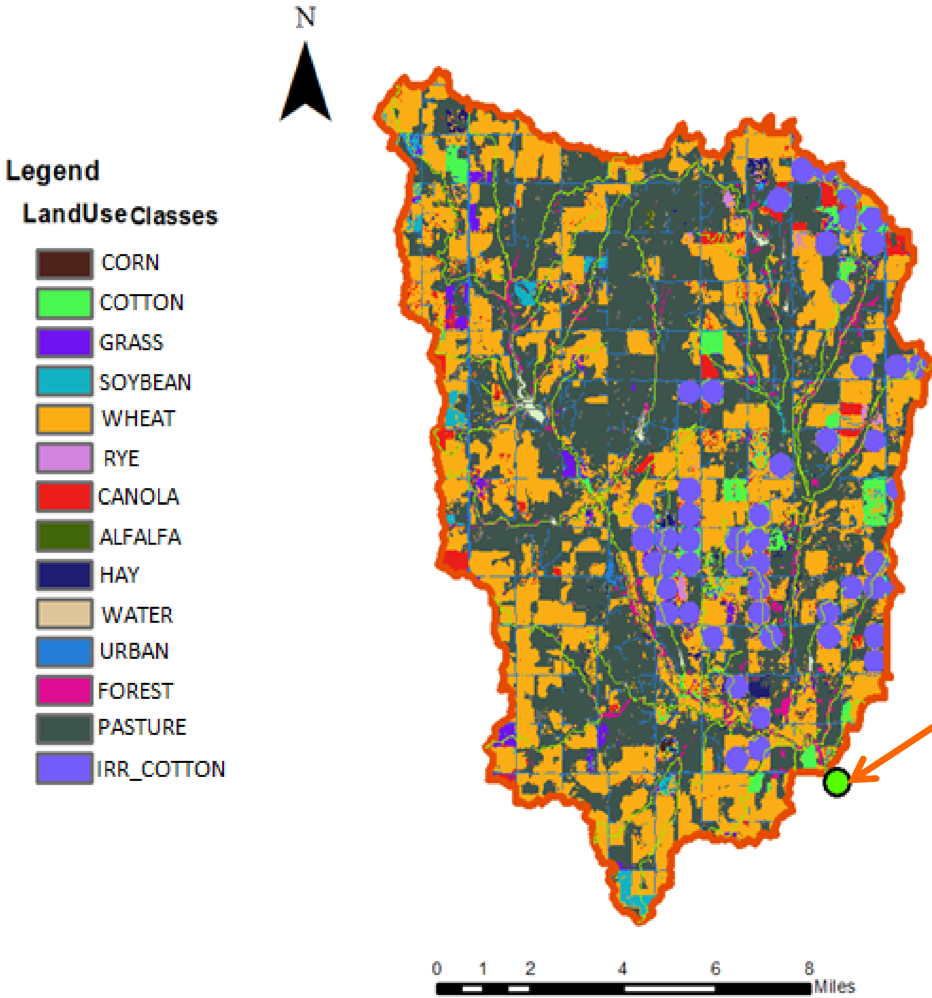


Storm, et al., 2009

Average annual basin values

Parameter	Historical
Precipitation (mm)	805.00
Max temperature (C)	22.2
Min temperature (C)	8.6

Study Area



Land Cover within the watershed

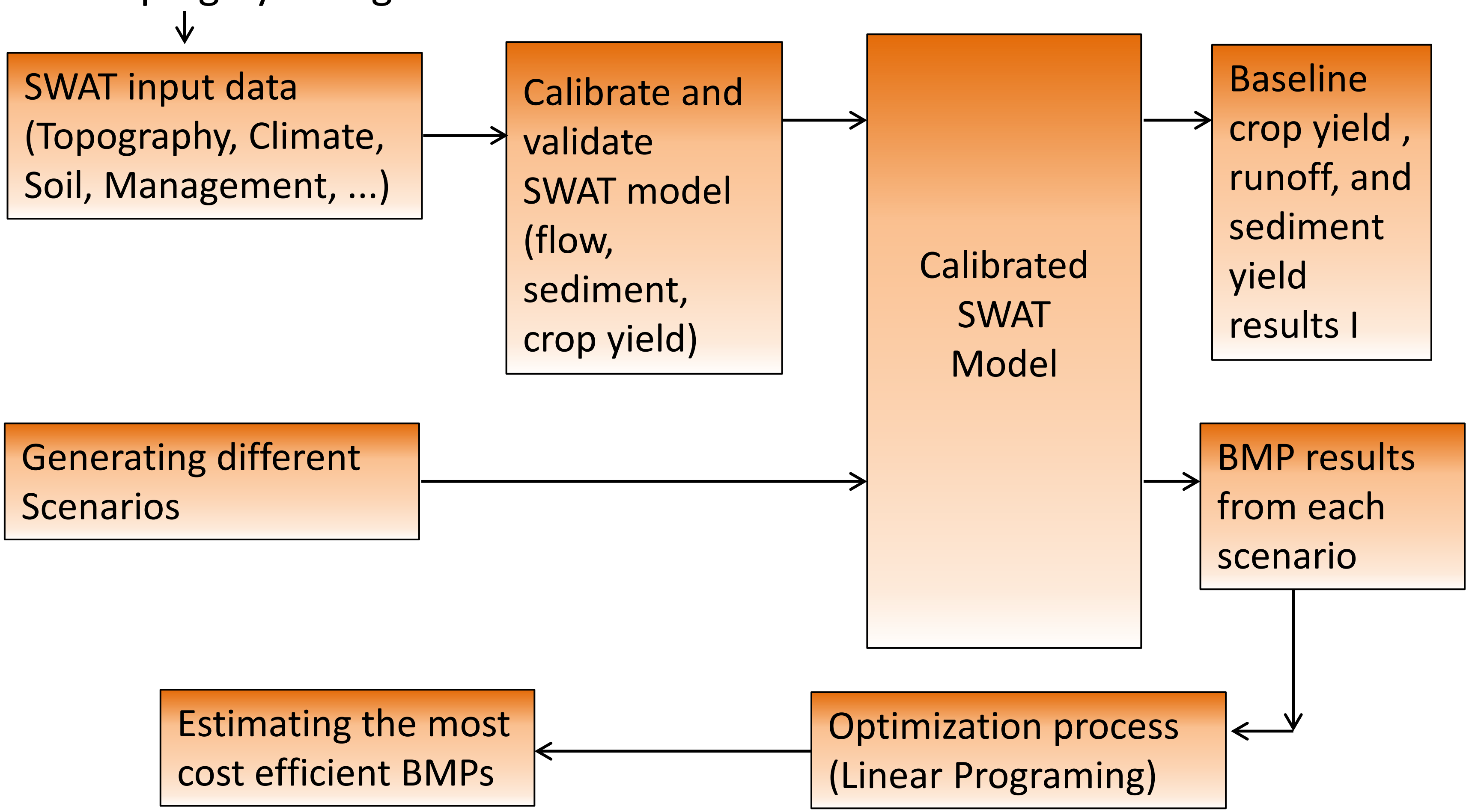
United States Department of Agriculture (USDA)
National Agricultural Statistics Service (NASS)

Land use	Percentage of cover
Pasture	43.7
Cotton	9.2
Wheat	34.45
Forest	1.8
Water	0.35
Planted	5.8
Urban	4.7

Methodology

Process of the project

Developing hydrological model:



Methodology

❑ SWAT model

- Soil and Water Assessment tool (SWAT) ➡ develop the hydrological model ➡ the amount of water and sediment yield, crop yield

Data	Data source
Elevation	10 m USGS Digital Elevation Model
Soil	Soil Survey Geographic Database- SSURGO soil data
Land use	US Department of Agriculture crop layer, national Agricultural Statistics Service (NASS)
Slope	Manually classified into 4 classes
Weather data (precipitation, temperature, wind speed, relative humidity, and solar radiation)	USGS weather stations, MESONET, airport values
Water bodies (ponds)	U.S. Army Corps of Engineers National Inventory of Dams (NID).

Methodology

❑ SWAT model

- **Contour** and **terraces** farming implementation in baseline scenario

https://www.slideshare.net/suryaveer/soil-erosion-and-soil-conservation

- Practice of plowing and/or planting across a slope ⇨ create a water break ⇨ reduces the formation of rills and gullies during times of heavy water run-off ⇨ reduces soil erosion

- Soil conservation practice applied to prevent rainfall runoff on sloping - land from accumulating and causing serious erosion

⇩

Require high capital investments

- Recommended in the western gently sloping part of the Oklahoma state

- One of the most cost efficient BMPs in farmlands

- They are already implemented in some parts in the watershed ⇨ **preventing reinvestment**

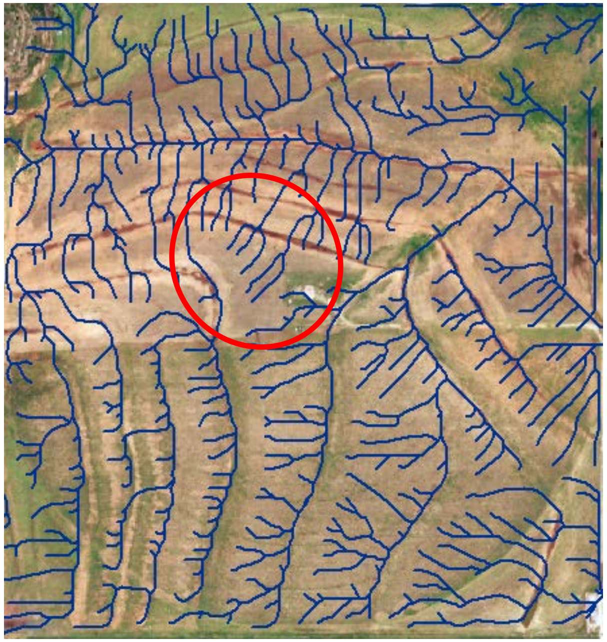
Methodology

❑ SWAT model

- Modeling **Contours** and **Terraces** that are already implemented in the watershed

Using 2 m Lidar

Drainage lines



- By writing a code in VB, CN and P-factor changed in HRUs where more than 65% of them were implemented by terraces and/or contour to see them in baseline scenario (Winchell et al., 2013)

Methodology

SWAT model calibration and validation

- Streamflow and sediment
  - Calibration: 1991–2000
  - Validation: 2001–2010
- Crop yield and monthly USGS observations of streamflow and suspended sediment concentration in Cobb Creek near Eakely gage (USGS 07325800)

- Statistical matrices:
  - coefficient of determination (R^2)
  - Nash-Sutcliffe efficiency (NS)
  - percentage bias (PB)

Methodology

- **Scenarios**
  - **Wheat, Cotton, Grain Sorghum**

    Conventional tillage

    No-till

    Contour + Conventional tillage

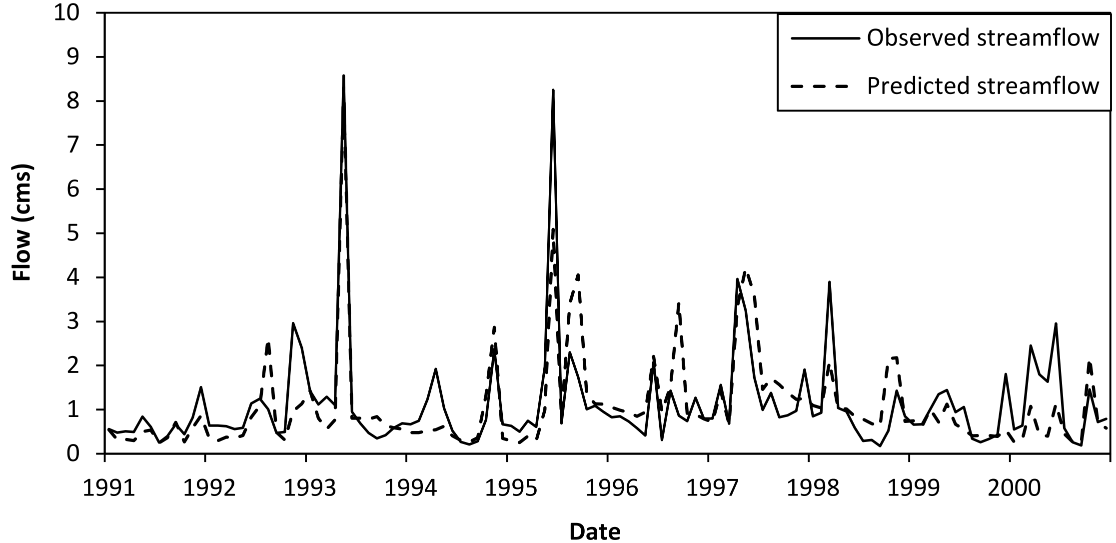
    Contour + No-till
  - **Pasture**

Results

SWAT model calibration and validation (USGS 07325800)

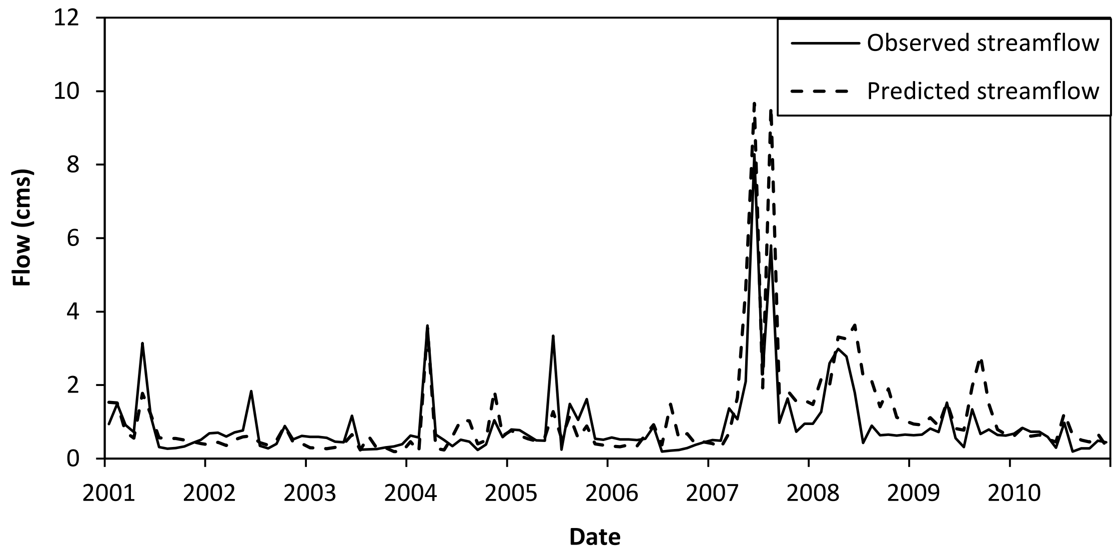
Calibration of streamflow

- Warm up time period: 1987-1990
- Calibration time period: 1991-2000
- R^2 = 0.64
- NS = 0.61
- PB = <1



Validation of streamflow

- Validation time period: 2001-2010
- R^2 = 0.79
- NS = 0.75
- PB = <1



Calibration of crop yield

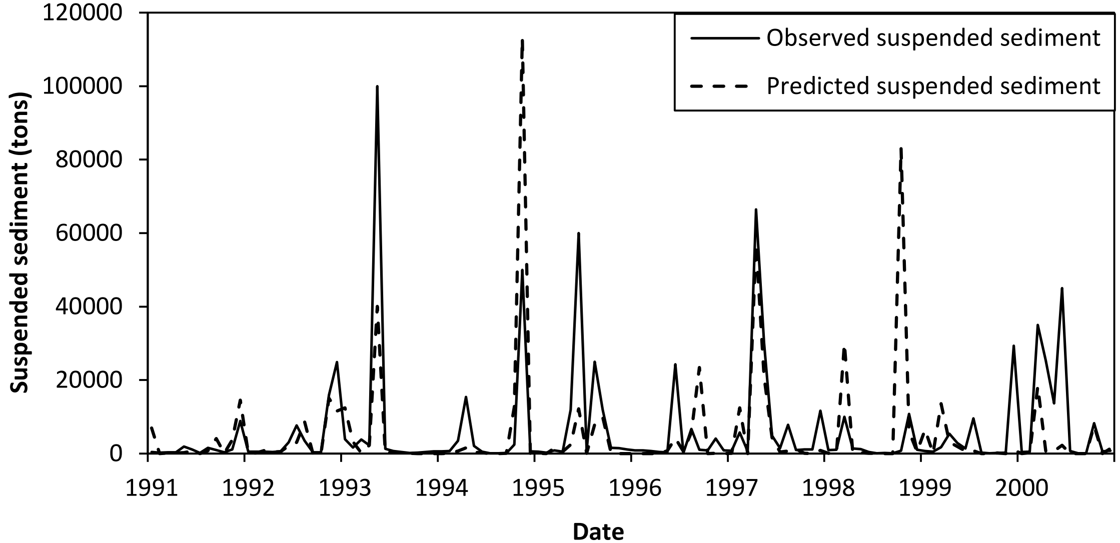
- County level (for Caddo, Custer, and Washita) NASS data for the years 2001 to 2015 (USDA, 2015)

Results

❑ SWAT model calibration and validation (USGS 07325800)

Calibration of sediment

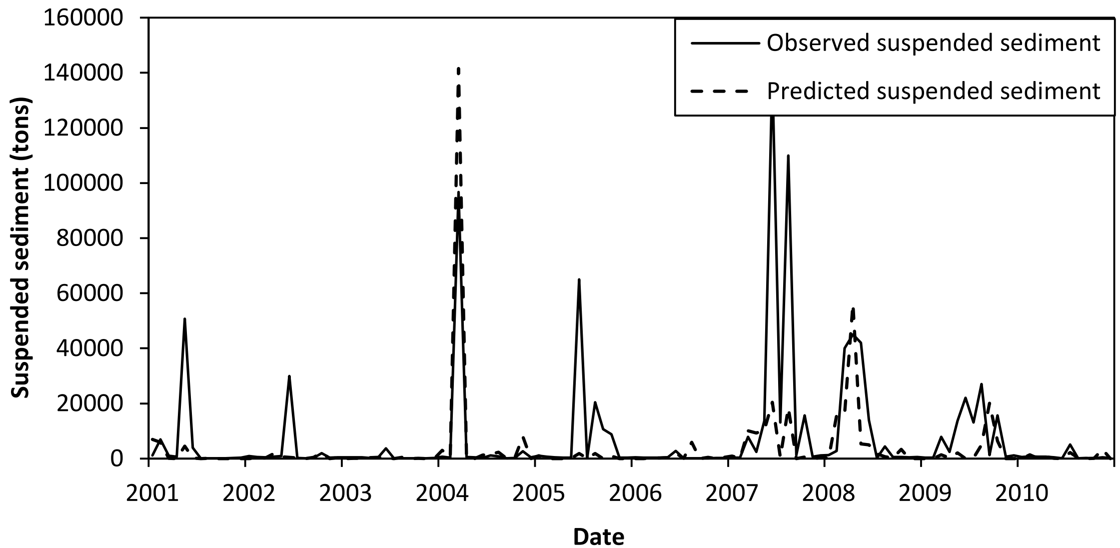
- Warm up time period: 1987-1990
- Calibration time period: 1991-2000
- R^2 = 0.35
- MNS = 0.37
- PB = <20



Validation of sediment

- Validation time period: 2001-2010
- R^2 = 0.38
- NS = 0.47
- PB = <40

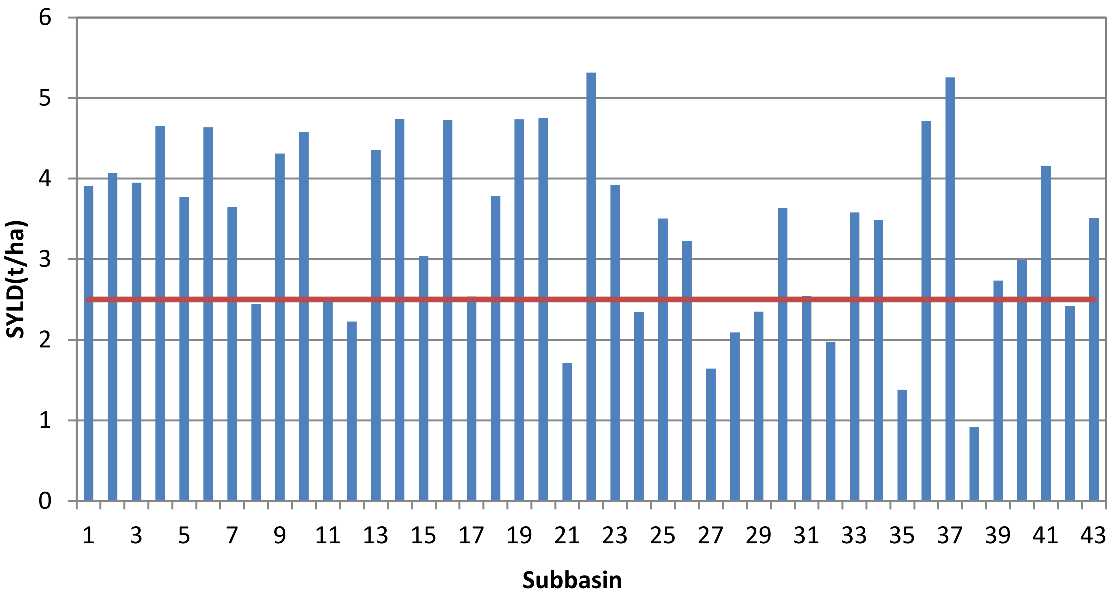
Since there were some gaps in observed sediment data, we were not able to adequately calibrate SWAT for sediment concentration.

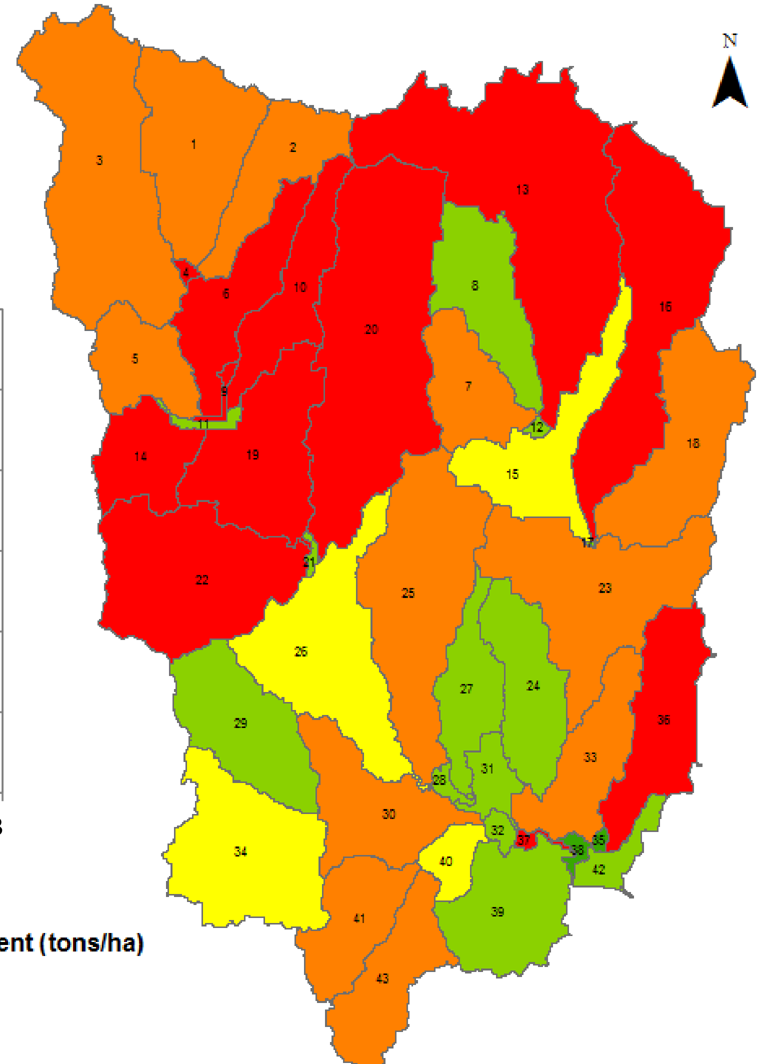


Results

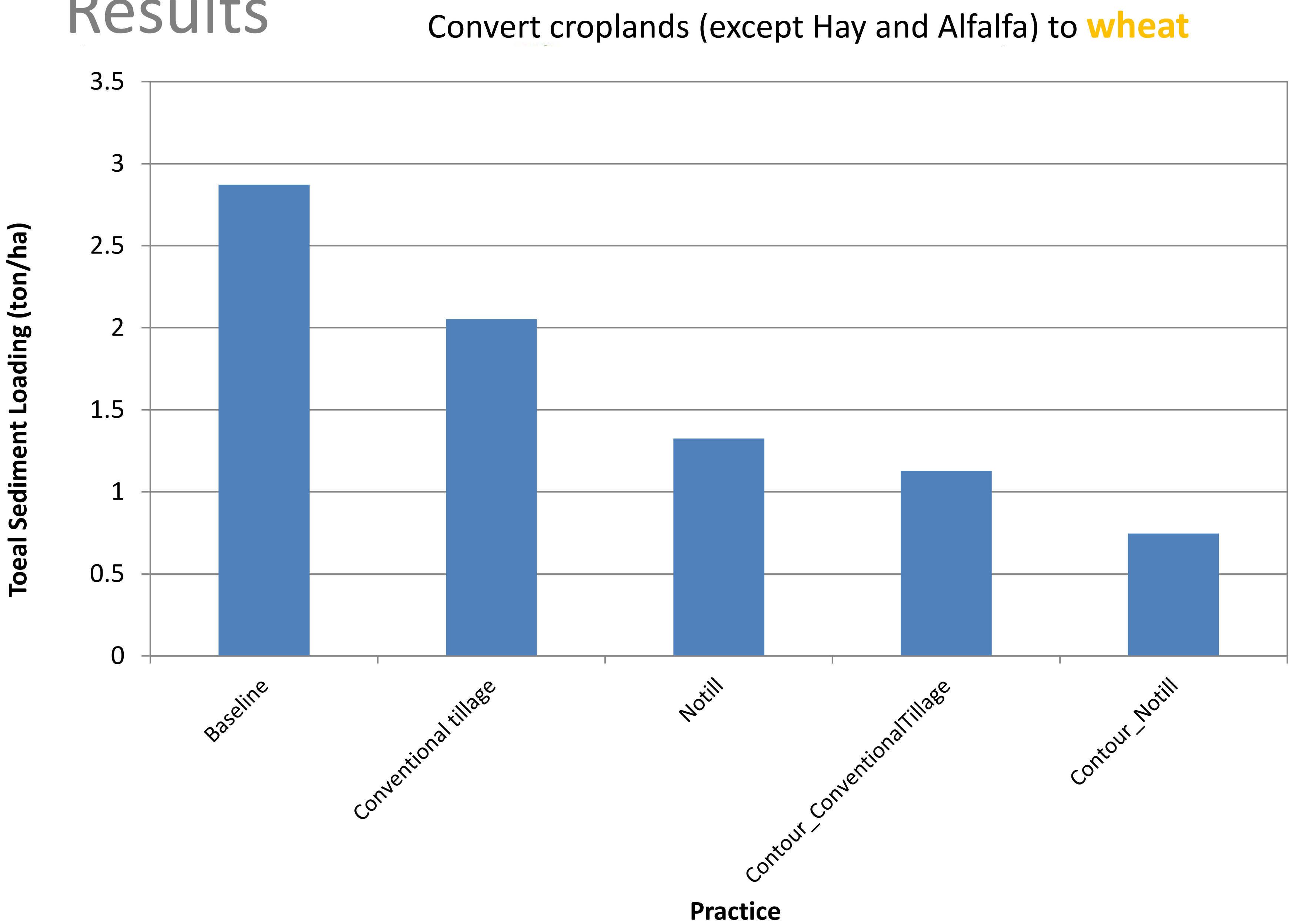
- Scenarios
- Baseline:

Sub-basin field sediment rate (ton/ha/yr)





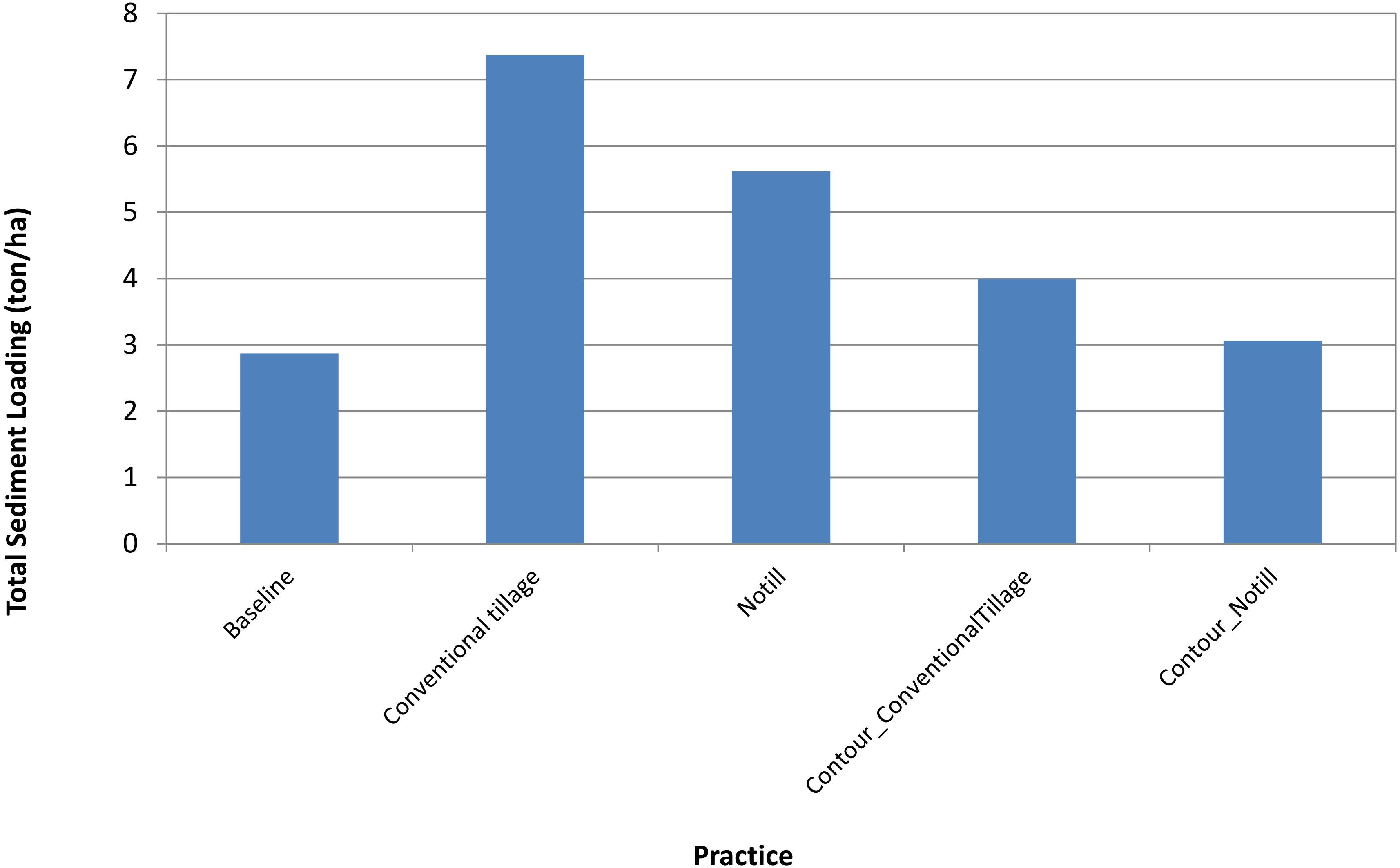
Results



Convert croplands (except Hay and Alfalfa) to wheat
Toeal Sediment Loading (ton/ha)
3.5
3
2.5
2
1.5
1
0.5
0
Baseline
Conventional tillage
Notill
Contour_ConventionalTillage
Contour_Notill
Practice

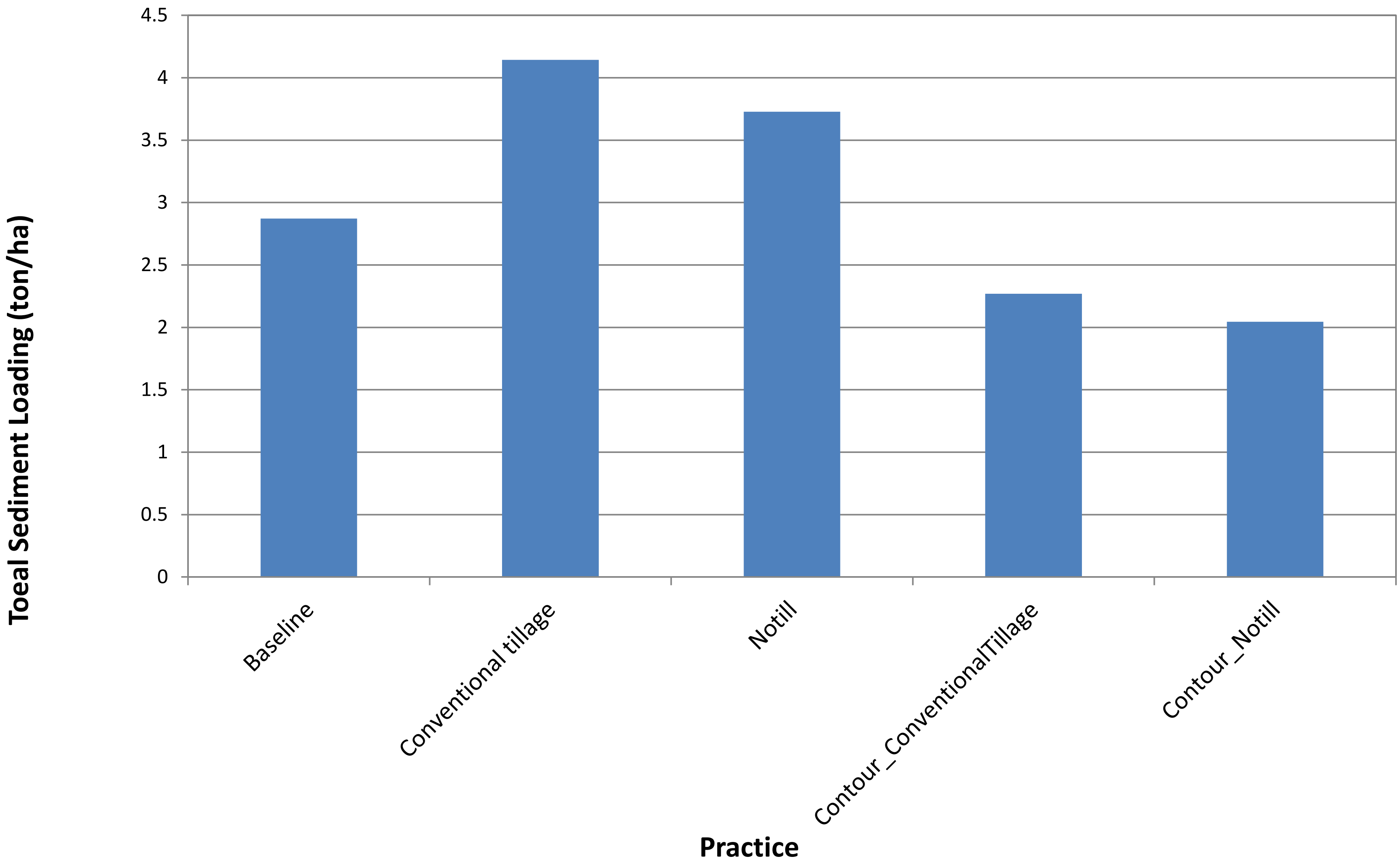
Results

Convert croplands (except Hay and Alfalfa) to **cotton**



Results

Convert croplands (except Hay and Alfalfa) to **grain sorghum**



Results

- Economic Analysis

Linear programming was used to identify the most cost-effective combination of management practices **maximizes revenue** of producers while insuring **sediment from the watershed does not exceed a specified target** (using GAMS)

SWAT → crop yield, surface runoff, and sediment loads

- Revenue
- Costs: Crop budget, sediment abatement

- The objective function: Net Farm Income in the Watershed,

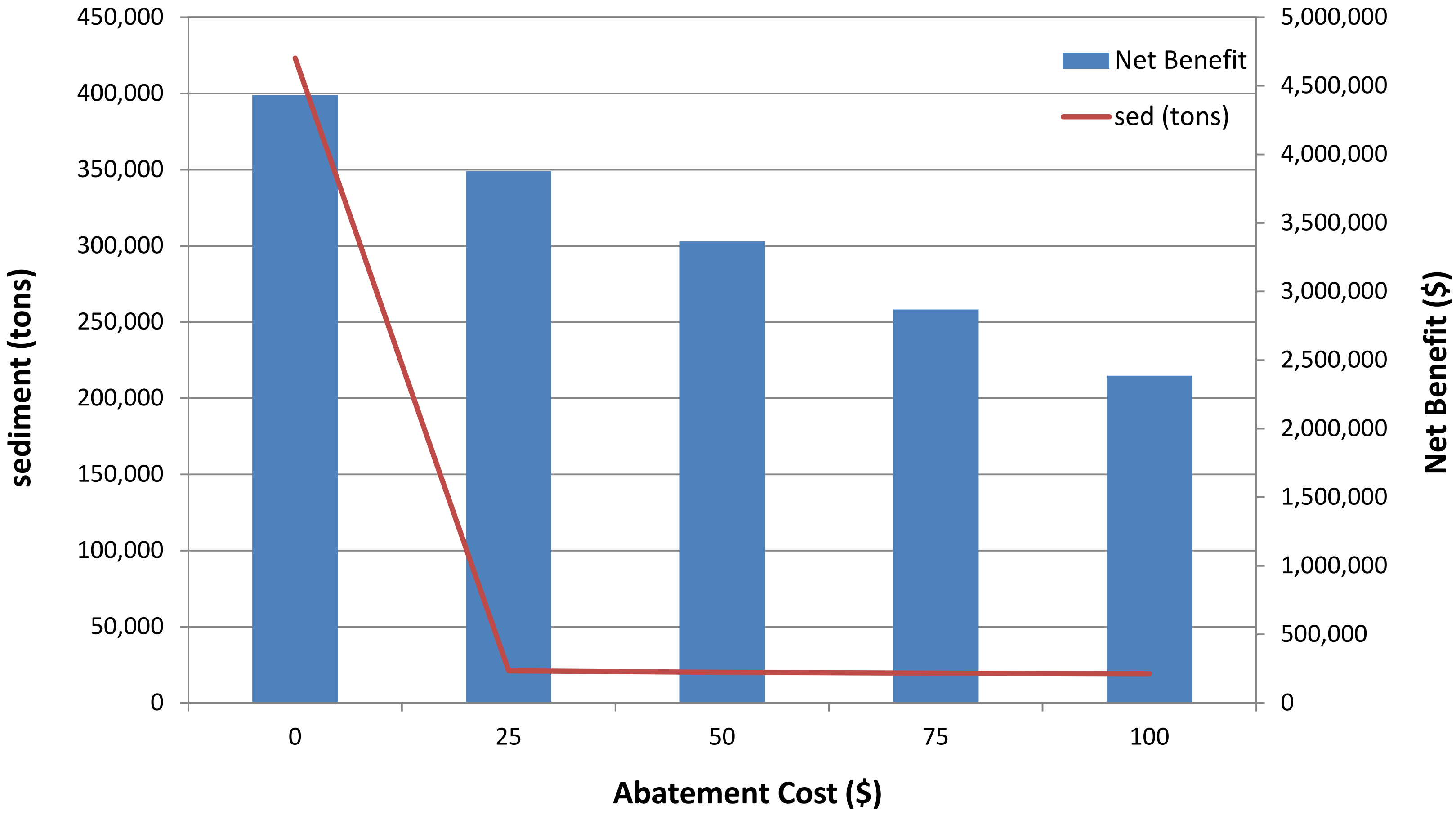
$$\textbf{Maximize } \Sigma_{hru}\, \Sigma_{bmp}\; NR_{bmp\ hru} * Ha_{bmp\ hru}$$

- Subject to:

$$\Sigma_{bmp}\, Ha_{bmp} < \text{Hectares in Hru}$$

$$\Sigma_{hru}\, \Sigma_{bmp}\; Sed_{bmp\ hru} * Ha_{bmp\ hru} \leq \text{Watershed Sed. Target}$$

Results



Net Benefit
sed (tons)
sediment (tons)
Net Benefit ($)
Abatement Cost ($)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
0
25
50
75
100

Results

- economic analysis

Estimated Sediment Loss Occurring after Market Solutions

Sediment yield from each crops hrus transported to main channel mt/ha (SYLD mt/ha)

abatement cost ($)	Slope Classes (%)	Cotton			Grain Sorghum			Wheat						Sediment reduction (%)
		Contour + No till	No till	Total	baseline	Conventional Tillage	Total	baseline	Contour + No till	Contour + Conventional Tillage	Conventional Tillage	No till	Total	
0	0-2		72.3	72.3	16.5	6.2	22.6	17.7			29.2		46.9	
	2-4		228.5	228.5	54.2	21.5	75.8	62.7			114.2		176.9	
	4-6		557.5	557.5	135.3	40.3	175.6	135.4			238.4		373.8	
	6-9999		1517.5	1517.5	258.2	90.4	348.6	369.4			646.8		1016.2	
	Total		2375.7	2375.7	464.2	158.4	622.6	585.2			1028.6		1613.8	
50	0-2	11.1	46.7	57.9	14.3	5.9	20.2	11.8	5.3	1.1	19.6	3.2	41.0	16.1
	2-4	28.8	140.2	168.9	40.4	17.1	57.5	27.2	22.4	8.8	53.2	26.0	137.7	24.3
	4-6	66.8	324.1	390.9	99.3	27.9	127.1	29.4	79.6	23.3	68.4	39.9	240.5	31.5
	6-9999	251.9	771.1	1023.0	161.5	54.8	216.4	67.5	255.2	33.3	195.9	73.7	625.7	35.3
	Total	358.6	1282.1	1640.7	315.6	105.6	421.1	135.9	362.5	66.5	337.1	142.9	1045.0	32.6
100	0-2	11.7	36.6	48.3	12.1	5.0	17.1	9.3	9.2	1.8	14.4	4.1	38.8	26.5
	2-4	42.1	85.0	127.1	30.7	12.2	42.8	11.3	47.6	11.6	23.9	21.7	116.1	40.5
	4-6	84.7	185.8	270.5	71.4	11.5	82.9	19.1	125.8	13.6	37.3	34.6	230.3	47.3
	6-9999	187.5	526.1	713.6	116.8	40.2	156.9	37.8	335.1	25.2	126.6	95.1	619.8	48.3
	Total	326.0	833.5	1159.5	230.9	68.8	299.8	77.4	517.7	52.1	202.2	155.6	1005.0	46.6

$100 abatement cost

40% sediment reduction

Crop	Area (ha)	Cover (%)
Pasture	4624	40.9
Wheat	3509	31
Cotton	1757	15.5
Grain Sorghum	468	4.1
Hay	114	1
Alfalfa	34.7	0.3
Other Crops	799	7.1
Total	11305.9	100

BMP	Area (ha)	(%)
Reduced-Tillage	7321.9	64.8
Contour + NoTill	2166.6	19.2
NoTill	1485.6	13.1
Contour + ReducedTillage	304.4	2.7
Total	11305.9	100.0

Future Research

- Ongoing research
    - Rotation for no-till wheat:
        - Wheat-cotton, wheat-grain sorghum, wheat-canola
    - Terrace repairs
- Suggesting the most cost efficient BMPs for reducing NPS pollution in each hru in the watershed

Acknowledgement

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Thank you for your attention