Hydrologic Impacts of Using Corn Stover for Bioenergy

Miae Ha, and Clyde Munster

Presenter: Miae Ha
Water Management and Hydrologic Science
Texas A&M University

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Presentation Overview

- Introduction
- Project objectives
- Methodology(study area, databases and model inputs, residue management, sensitivity, calibration)
- Results
- Conclusions
- Future work

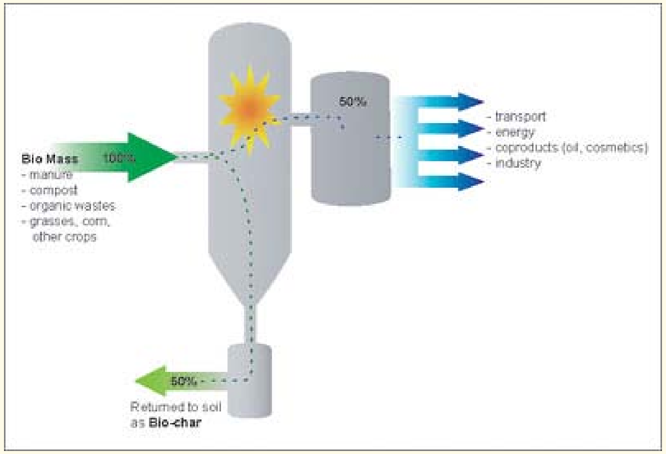
Introduction

- Northern Illinois – a major corn production state with several oil refineries
- What is pyrolysis?
- The mobile pyrolysis concept

  - consume corn stover feedstock at a rate of 40 tons/day
- Residue management
  - Santhi et al. (2006) – BMP practices in the West Fork Watershed of the Trinity River Basin in Texas to reduce sheet and rill erosion leaving adequate residue on the ground after harvest and prior to tillage for planting.

Pyrolysis

- Method to densify feedstocks for bioenergy
- Biomass ➔ combustion without O_2 ➔ Bio-oil
  ➔ Syngas
  ➔ Biochar
- Bio-oil ➔ Upgraded for transportation fuels
- Syngas ➔ Used for electric power
- Biochar ➔ Land application
  - 30% of feedstock ➔ biochar
  - Organic C to soil
  - Nutrients to soil

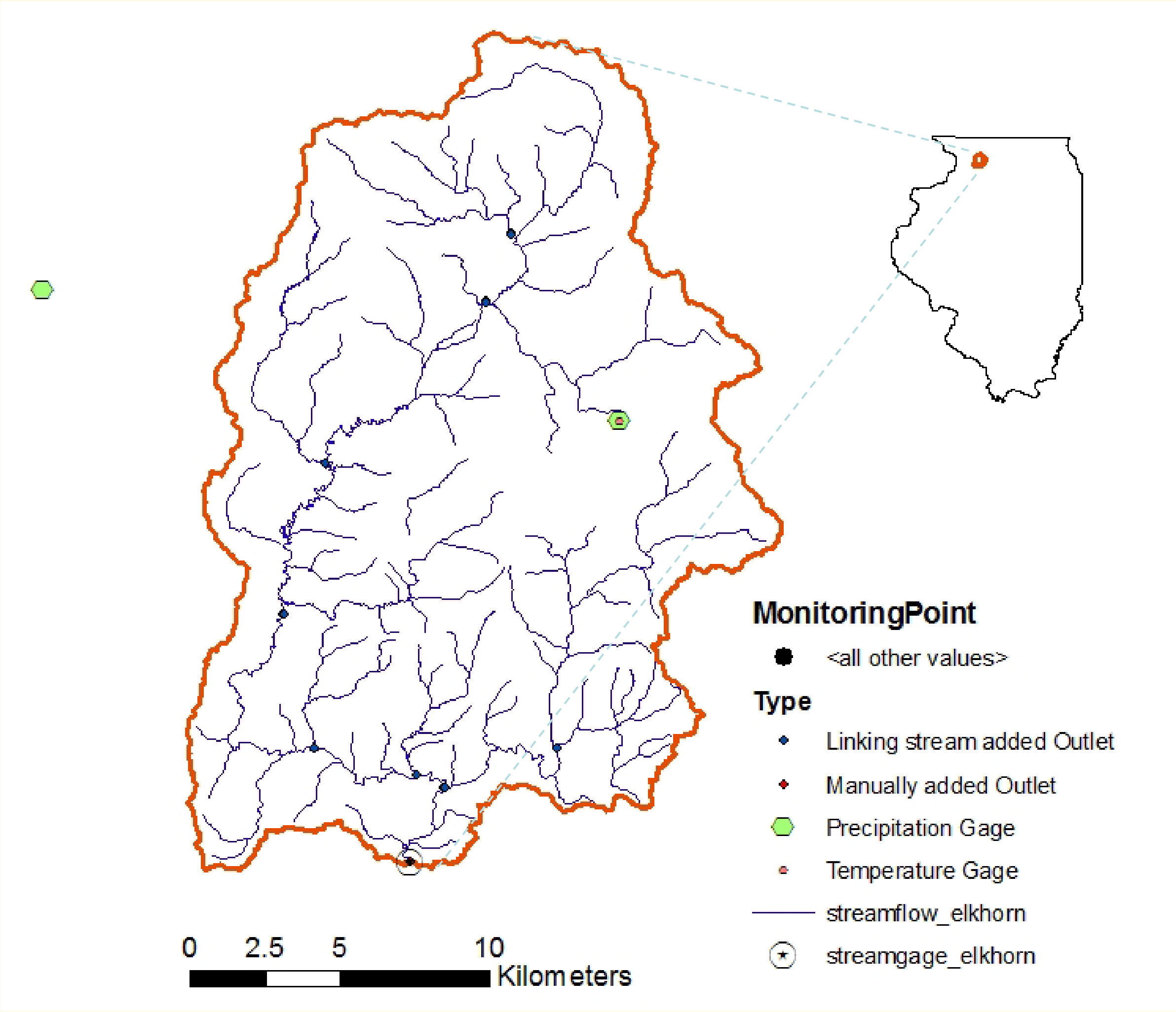


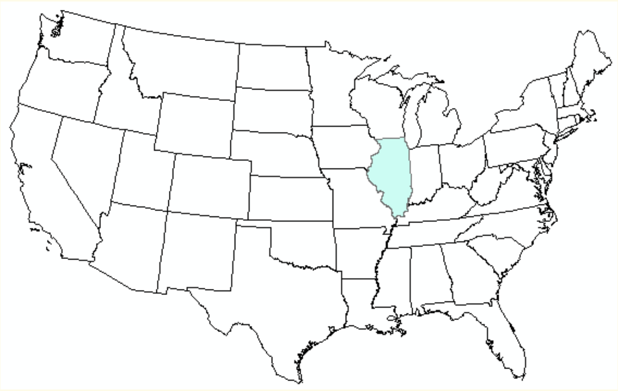
Objectives

- Determine the effects of corn stover removal on:
  - Runoff
  - Sediment transport
  - Crop production
- Compare two extreme residue management options:
  - 100% removal
  - 0% removal
- Use the Elkhorn Creek watershed near Penrose, IL, for this study

Study Area

- **Elkhorn Creek near Penrose, Illinois**

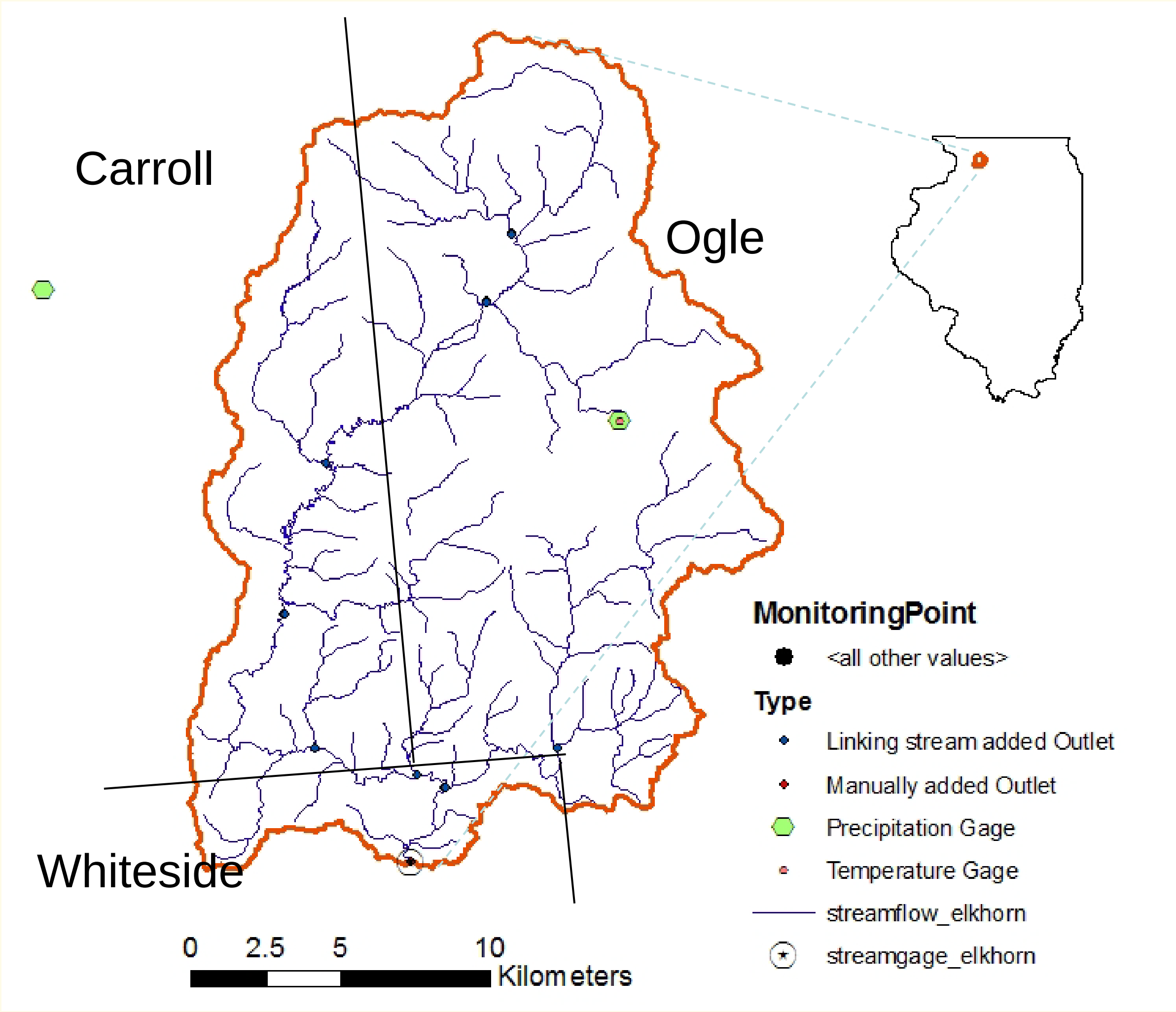


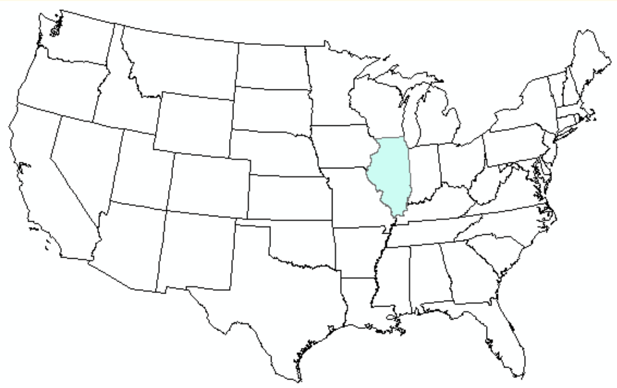


USGS gauging station
→**"05444000"**
→Lat. 41°54'10" / long. 89°41'46"

Study Area

- **Elkhorn Creek near Penrose, Illinois**





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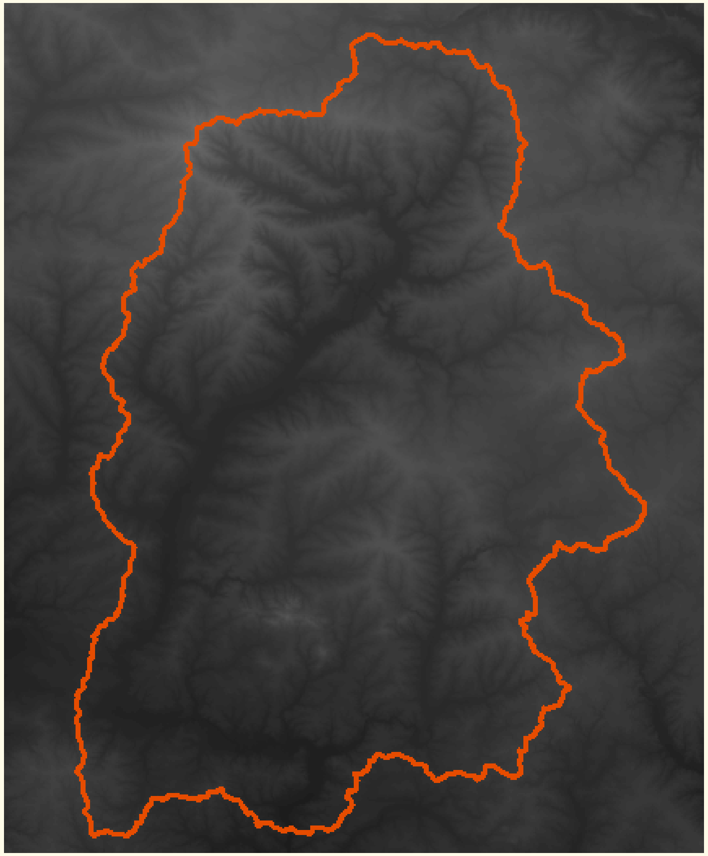
Databses and Model inputs – Topography

- **ArcSWAT 2005 – a basin-scale, continuous-time hydrology model that can produce simulation results on a daily, monthly, or annual basis.**

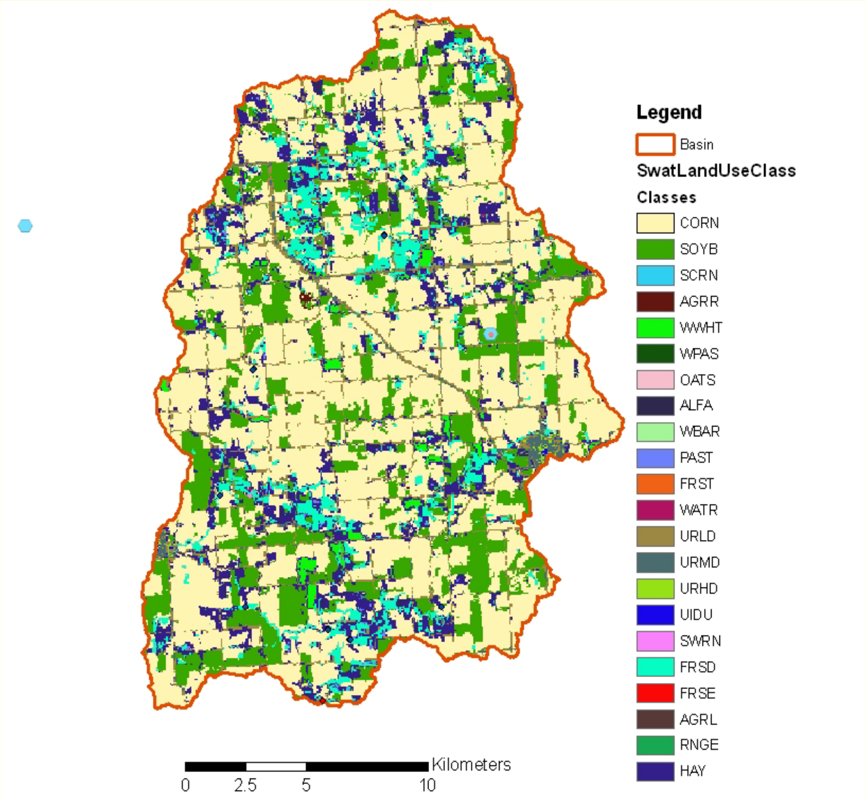
  - water quantity as well as water quality

- **Digital Elevation Model (DEM) National Hydrography Dataset (NHD) region 7 elevation, unit b Hydrologic Unit Code (HUC) "0709005" at Elkhorn creek near Penrose, IL.**



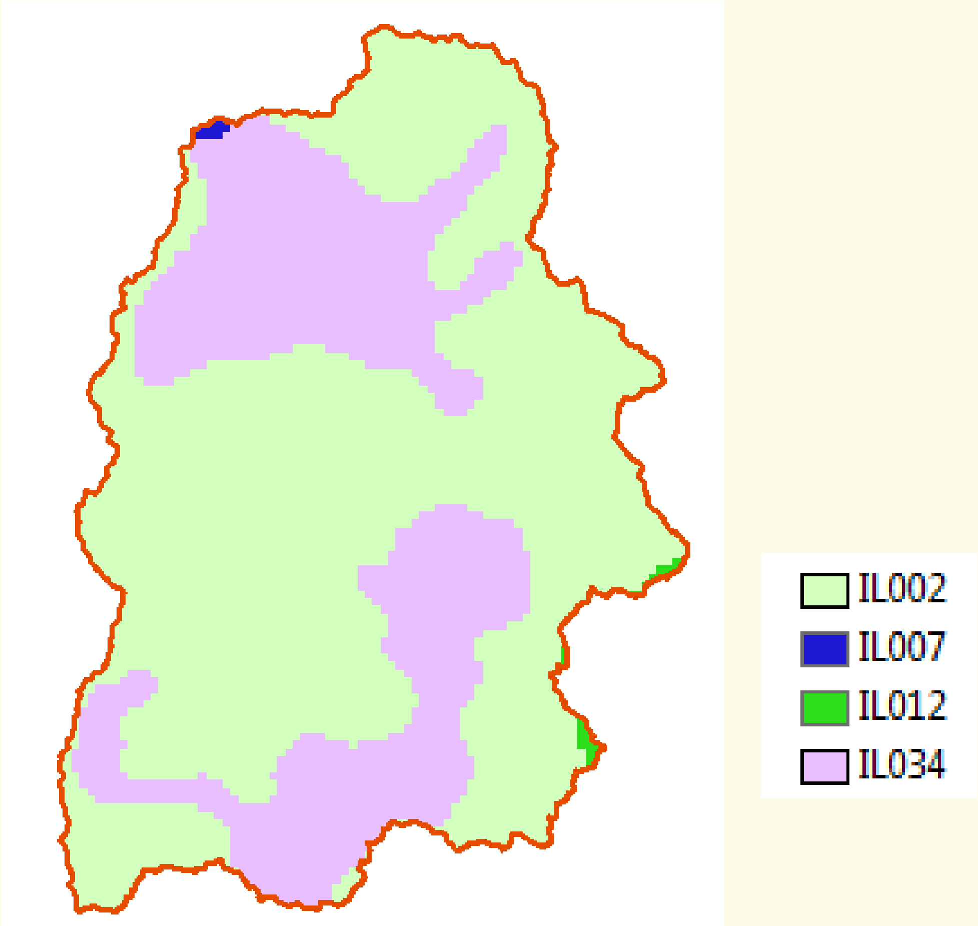
Databses and Model inputs – Landuse

- **2008 cropland data layer (CDL) by spatial analysis research section of National Agricultural Statistics Service (NASS)**
- **Corn (54.32%), soybean (18.59%), hay (11.33%), forest-deciduous (6.19%), and residential-low density (6.17%)**



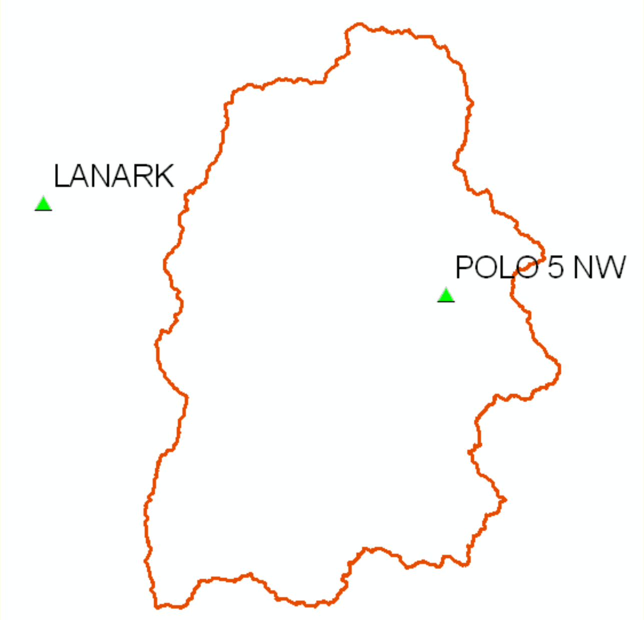
Databses and Model inputs – Soil

- **State Soil Geographic (STATSGO) by National Resources Conservation Service (NRCS)**
- **Primary soil series**
  - Ogle (66.9%) and
  Fayette (33%)
- **Hydrologic soil group (HSG) – "B" soil type.**



Databses and Model inputs – Weather

- Weather stations at Polo 5 NW (-89:36 N, 42:02 W) and Lanark (-89:50 N, 42:05 W) by National Climate Data Center (NCDC)
  - rainfall
  - air temperature
- Weather generator in SWAT
  – Wind speed, solar radiation, and relative humidity data

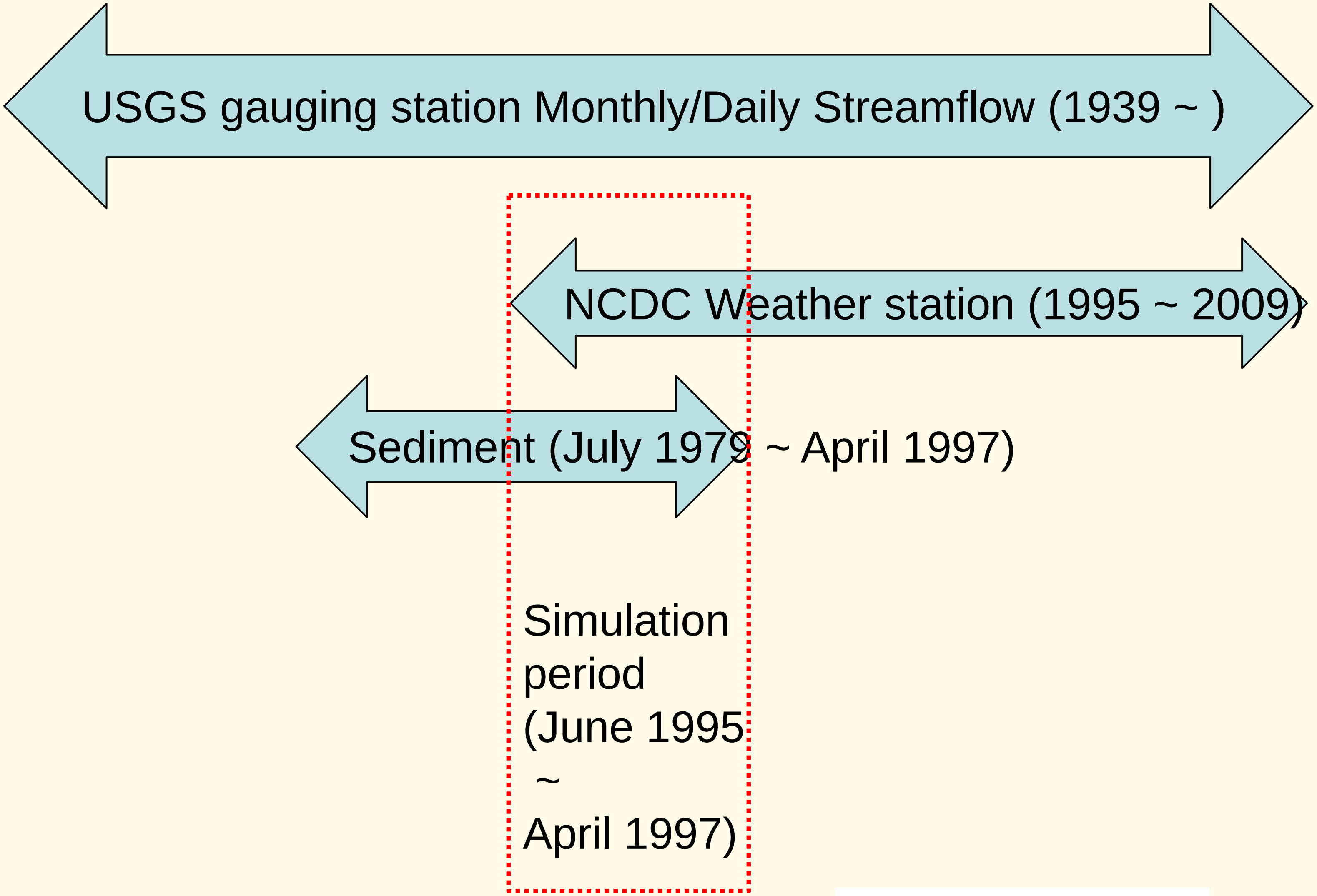


Name of station	Precipitation (PRCP)	Temperature (TMIN & TMAX)	Availability (year)
LANARK	O	-	2000-2009
POLO 5 NW	O	O	1996-2009

Databses and Model inputs – water quality samples

- **USGS gauging station “05444000”**
- **155 samples for sediment (mg/L)**
- **From July 11, 1979 to April 22, 1997**

SWAT simulation set-up



Residue Management

- **Management practice**
  - 0% residue left on the field
  - 100% residue left on the field
- **Heat unit (plants have heat requirements that can be quantified and linked to time to maturity)**
  - 0.15 for planting/beginning the growing season
  - 1.0 for harvest/kill for crops with no dry-down
  - 1.2 for harvest/kill for crops with dry-down

Drain Management

- Subsurface drain tiles are used extensively in Illinois.

  - Illinois drainage guidelines are available online at http://www.wq.uiuc.edu/dg/subsurface.htm

- The subsurface drainage in Illinois is typically installed three feet below the surface.

- SWAT parameters for subsurface tile drain

  - Depth to subsurface drain (DDRAIN) – 3 ft (914.4 mm)
  - Time to drain soil to field capacity (TDRAIN) – 24 hr
  - Drain tile lag time (GDRAIN) – 2 hr

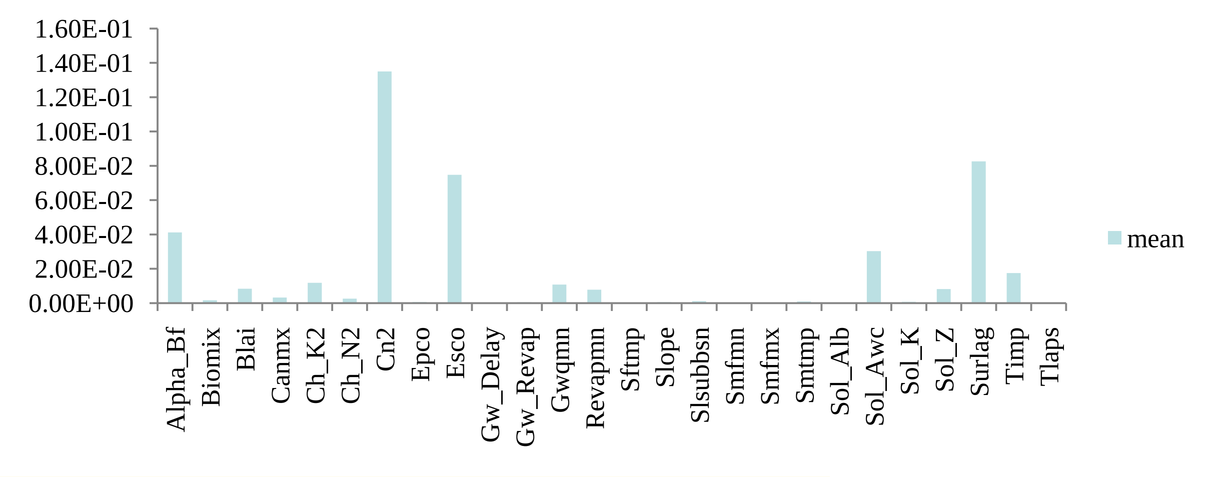
Baseflow simulation

- **Baseflow filter program** (Arnold et al.)
- http://swatmodel.tamu.edu/software/baseflow-filter-program

- Baseflow ranged from 0.56 and 0.71.
- Baseflow recession (ALPHA_BF) : 0.0197 (0.048)
- Ground water dealy (GW_DELAY) : 117 days (31d)

Sensitivity Analysis

- **SWAT 2005** – a combination of Latin Hypercube Sampling and One-At-a time sensitivity analysis (LHS-OAT method)
- Observed data – daily streamflow data from 1939 to 2010
- 26 parameters for flow analysis
- 4 hours for running 270 times using Quad core Intel Xeon Processor 2.2GHz workstation.
- Curve number (most important parameter)

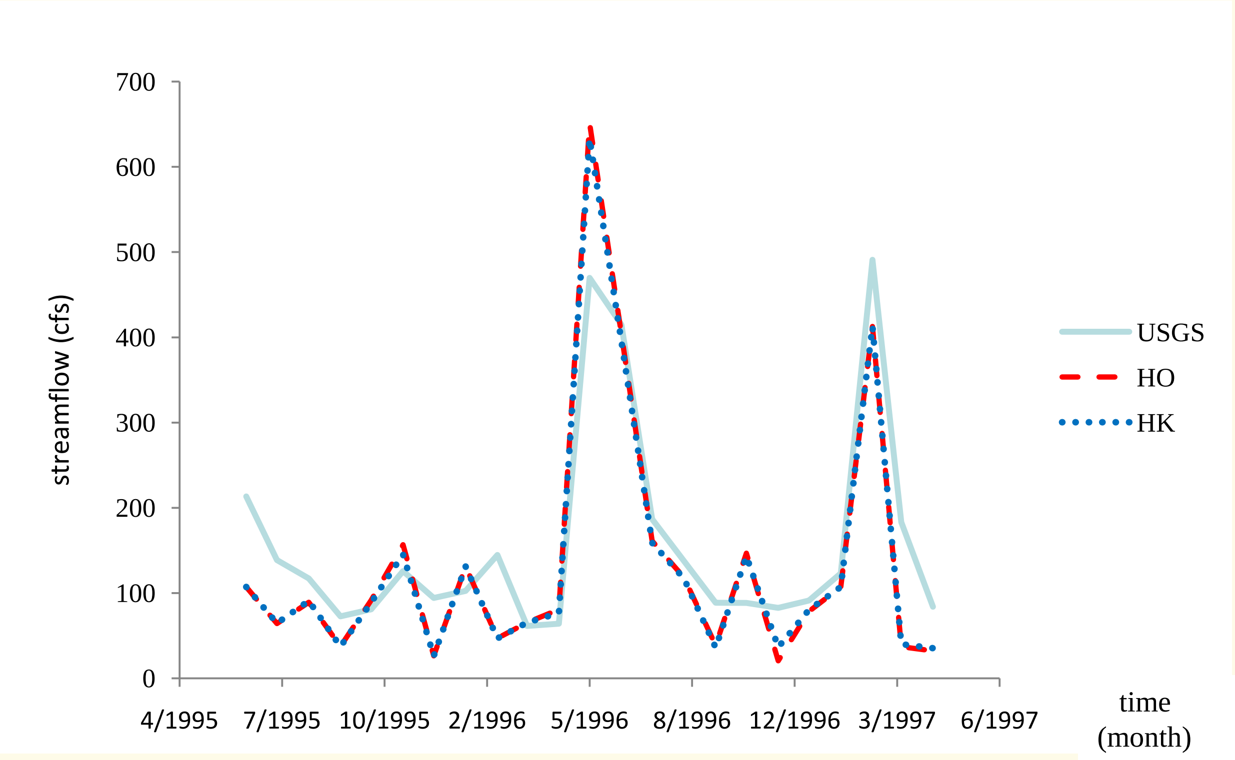


Calibration

Variable	Description	Calibrated	Default	Unit
CN2	Curve number	+20 %	Data	
ESCO	Soil evaporation Compensation coefficient	0.9		
ALPHA_BF	Base flow recession	0.0197	0.048	
GW_DELAY	Ground water delay	117	31	d
DDRAIN	Depth to subsurface drain	914.41		mm
TDRAIN	Time to drain soil to field capacity Drain tile lag time	24		hr
GDRAIN		2		Hr
USLE_C	Minimum value of USLE C factor for water erosion	0.50		
SPCON	Applicable to the land cover/plant Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing	0.0001	0.0001	
RSDCO	Residue decomposition coefficient	0.005	0.005	

Results

- **Calibrated and observed monthly average of streamflows**



- **Nash-Sutcliffe coefficient** = $1 - [\sum (Q_m - Q_p)^2] / [\sum (Q_m - Q_{avg})^2]$
  - Initial run = 0.35
  - Harvest and kill operation = 0.71
  - Harvest only operation = 0.68

Results

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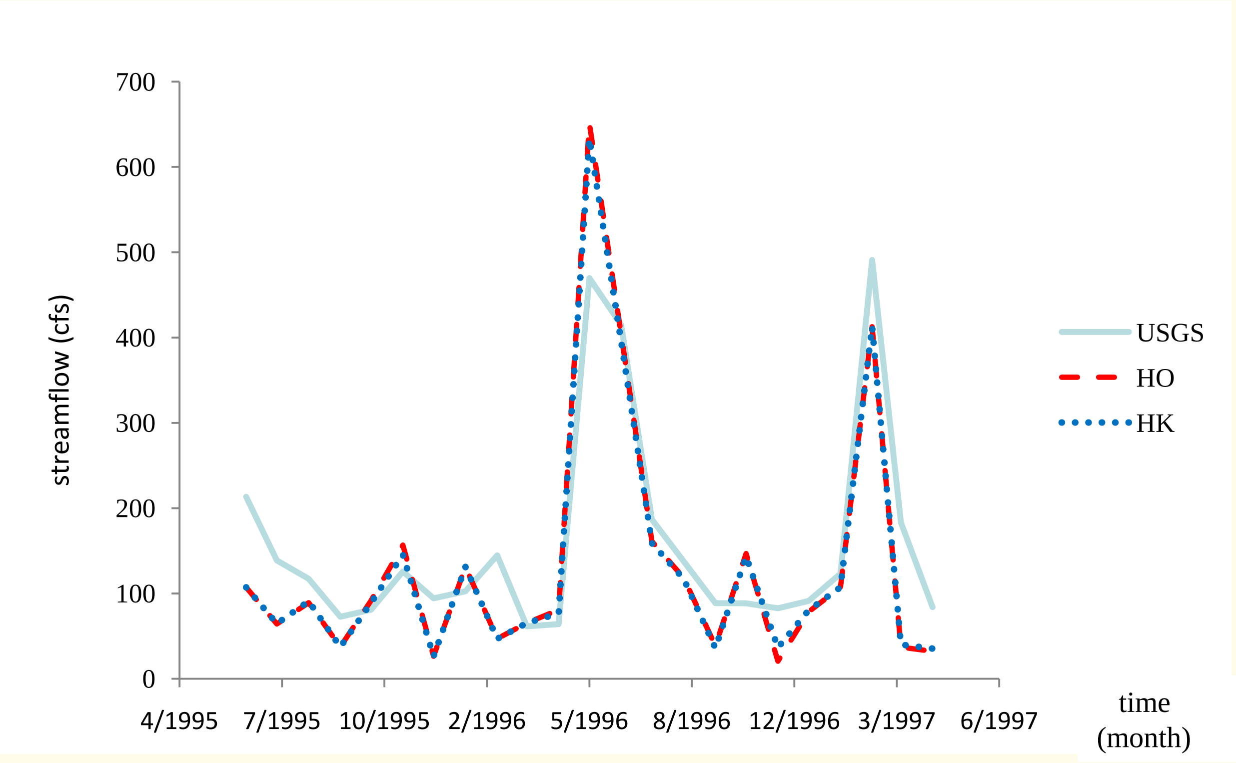

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  - Initial run = 0.35
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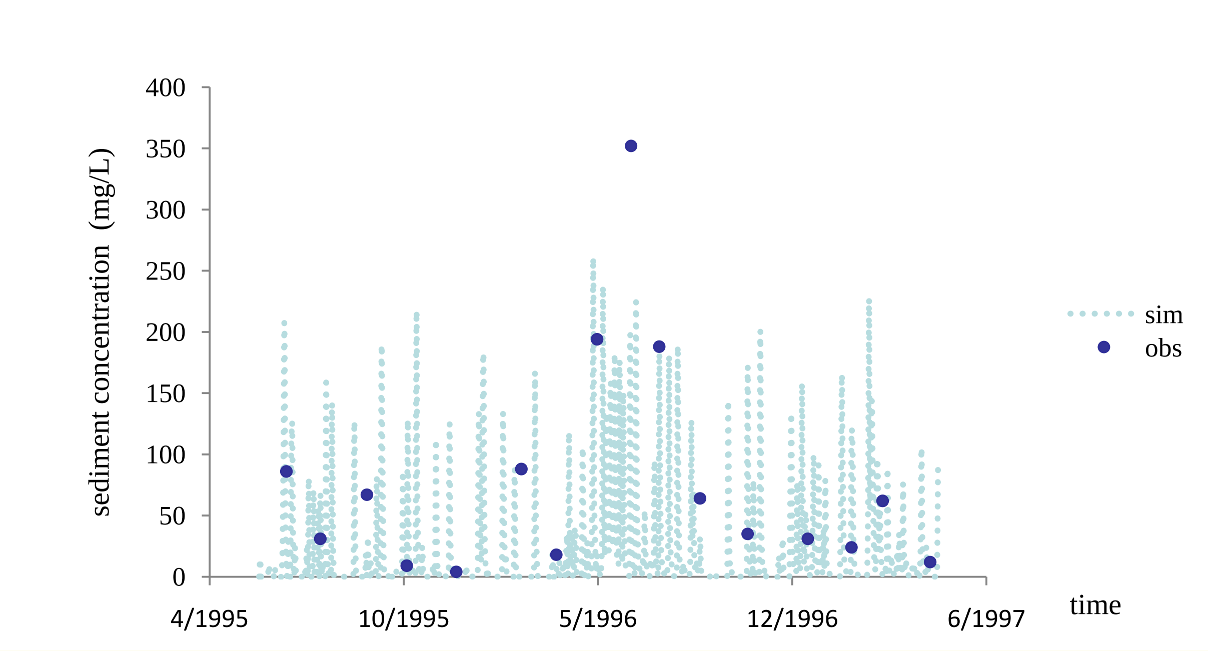
Between good and very good (Moriasi et al, 2007)

Results

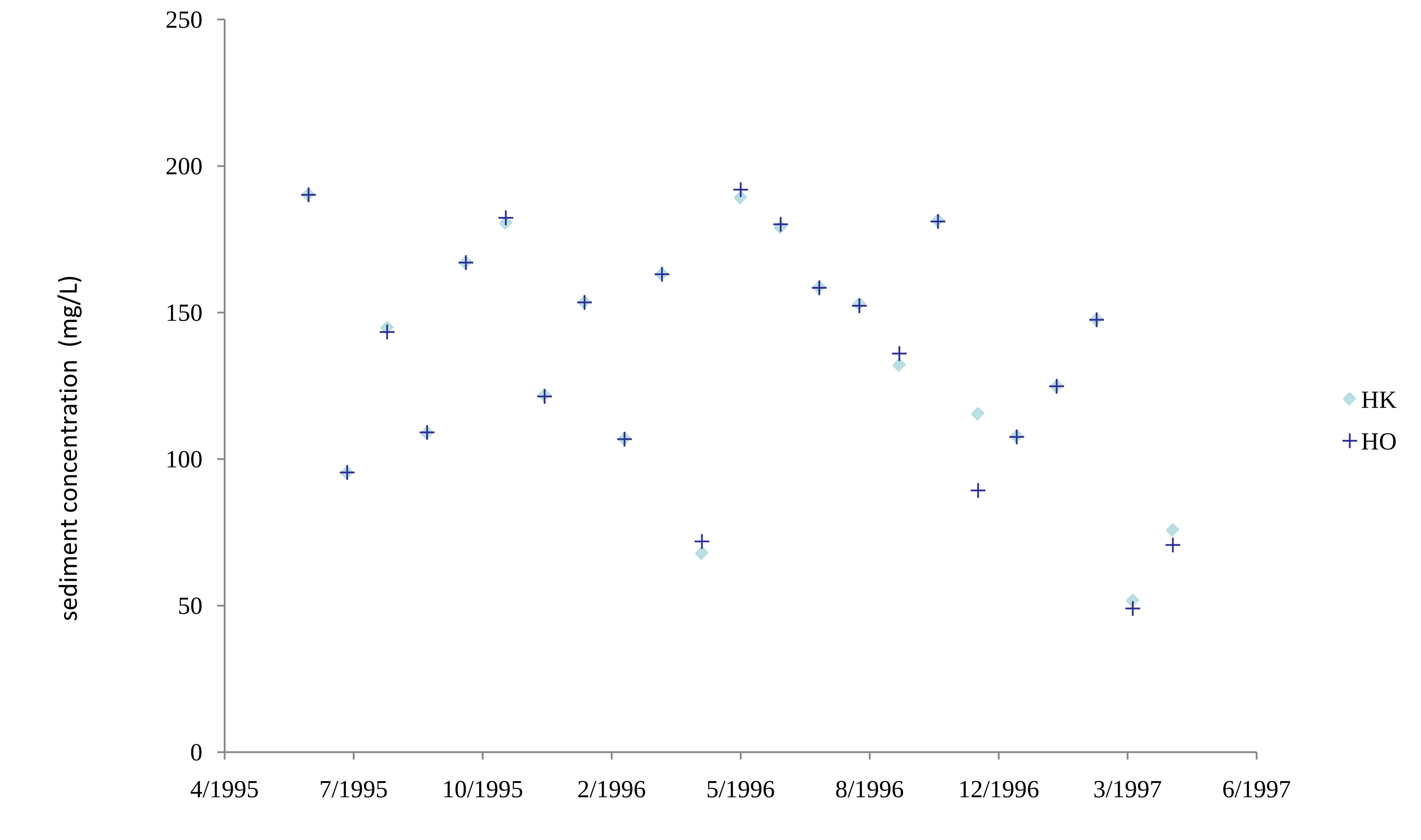
- **Simulated and observed daily average of sediment concentration (mg/L)**



- **Daily average of sediment concentration (mg/L)**
  - Simulated daily sediment concentration – 0 mg/L ~ 216 mg/L
  - Observed daily sediment concentration – 4 mg/L ~ 352 mg/L

Results

- **Simulated monthly average sediment concentrations (mg/L)**
  - **HK = 0% residue cover**
  - **HO = 100% (HO)**



Results – Corn yield

- Area weighted average yield = 7,372 lbs/ac (from NASS)
  - Harvested corn production (lbs/ac) for the county basis

County	Area (%)	bushel/ac	100% harvested(lbs/ac)
Carroll	14,550 ac (28.8%)	135	7,560
Ogle	32,485ac (64.3%)	130	7,280
Whiteside	3,486 (6.9%)	133	7,448

- Simulated corn yield (lbs/ac)
  - 0% residue left: 7,072 lbs/ac
  - 100% residue left: 8,671 lbs/ac

Conclusions - Calibration

- The Nash-Sutcliffe coefficient increased from 0.35 to:
  - 0.68 (100% residue)
  - 0.71 (0% residue)
- Primary SWAT variables used to improve simulations
  - curve number
  - soil evaporation compensation factor
  - available soil water capacity
  - baseflow fraction value

Conclusions

- Monthly streamflows for both management options were very similar
- Daily sediment concentrations
  - 4 mg/L to 352 mg/L for observed values
  - 0 mg/L to 261 mg/L for simulated values
- Corn yields
  - Actual area weighted average = 7,372 lb/ac
  - Simulated average = 7,072 lb/ac (0% residue)
  - Simulated average = 8,671 lb/ac (100% residue)

Future work

- Water Quality analysis
- Residue management (25%, 50%, 75%)
- Bio-char applications
  - Soil property changes
    - Water holding capacity
    - Plant available nutrients
    - Effects on corn production

Acknowledgments

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  - Dr. Munster
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Questions or Suggestions?

Thank you !