Improved physical representation of vegetative filter strip in SWAT

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AGRICULTURAL & BIOLOGICAL ENGINEERING

Vegetative Filter Strip (VFS)

- Conservation practice installed at the edge of agricultural fields to reduce losses of pollutants from agricultural areas into receiving waterbodies.

Vegetative Filter Strip (VFS)

- Highly popular due to various Natural Resources Conservation Service (NRCS) initiatives and subsidies provided by federal and state conservation programs
- How to quantify the effectiveness of VFS
- Potential areas for perennial bioenergy crops – energy crops in conservation areas – as filter crop in VFS area
- Can we use SWAT?

SWAT- VFS: Regression based model by White and Arnold 2009

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Development of a simplistic vegetative filter strip model for sediment and nutrient retention at the field scale†

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Abstract:

Vegetative filter strips (VFSs) are a commonly used conservation measure to remove pollutants from agricultural runoff. The effectiveness of VFSs has been widely studied at the plot scale, yet researchers generally agree that field scale implementations are far less effective. The purpose of this research was to develop a field scale VFS submodel for the Soil and Water Assessment Tool (SWAT). A model for the retention of sediments and nutrients in VFSs was developed from experimental observations derived from 22 publications. A runoff retention model was developed from Vegetative Filter Strip MODel (VFSMOD) simulations. This model was adapted to operate at the field scale by considering the effects of flow concentration generally absent from plot scale experiments. Flow concentration through 10 hypothetical VFSs was evaluated using high resolution (2 m) topographical data and multipath flow accumulation. Significant flow concentration was predicted at all sites, on average 10% of the VFS received half of the field runoff. As implemented in SWAT, the VFS model contains two sections, a large section receiving relatively modest flow densities and a smaller section treating more concentrated flow. This field scale model

SWAT- VFS: Regression based model by White and Arnold 2009

Runoff reduction $R_R(\%) = 75.8 - 10.8\ln(R_L) + 25.9\log(Ksat)$

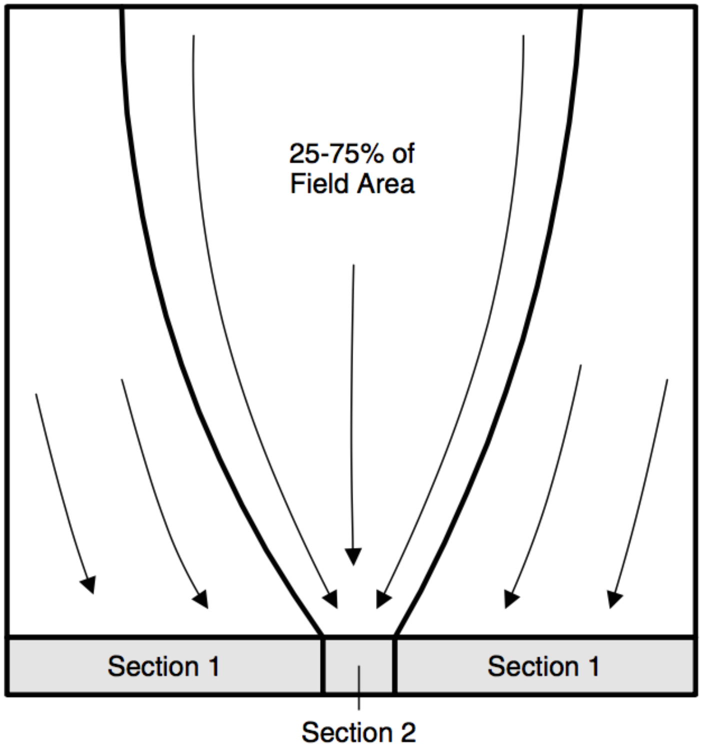
Sediment reduction $S_R(\%) = 79.0 - 1.04S_L + 0.213R_R$

Organic N reduction $OrgN_R(\%) = 0.036S_R^{1.69}$

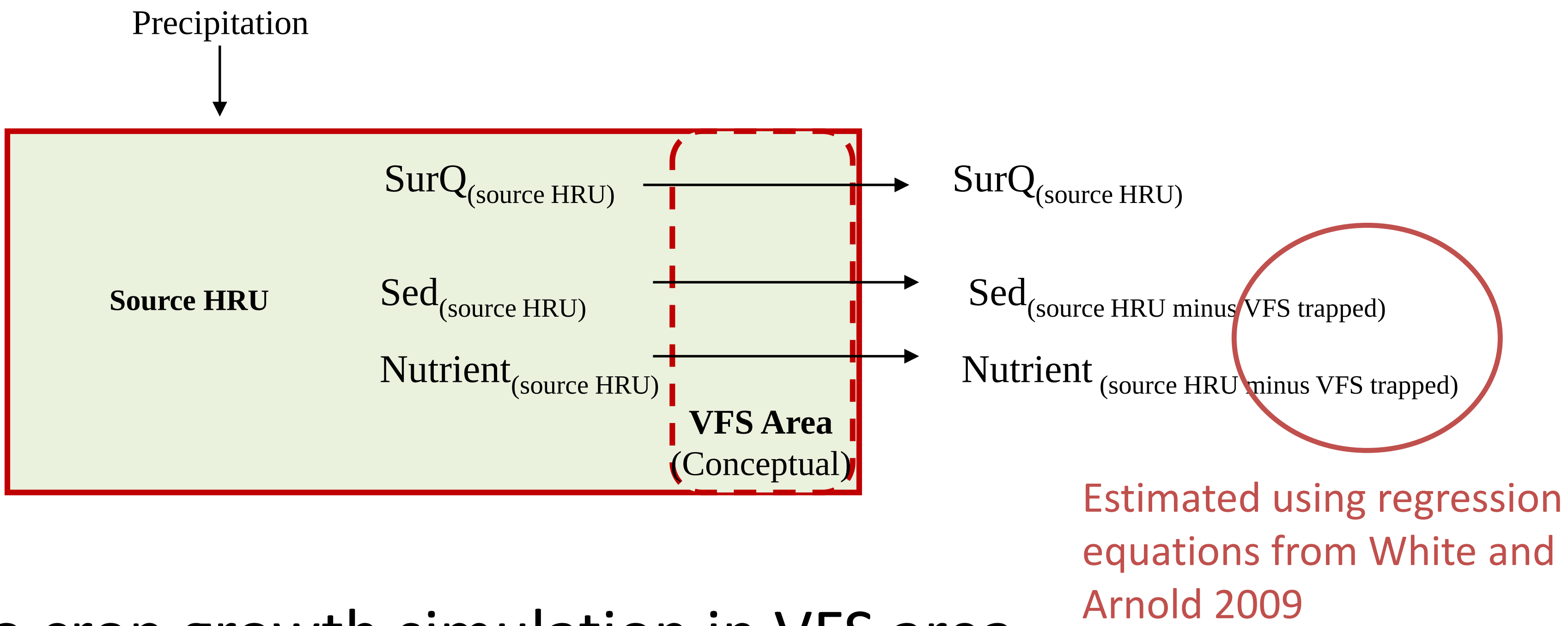
Nitrate N reduction $NN_R(\%) = 39.4 + 0.584R_R$

Adsorbed P reduction $AP_R(\%) = 0.9S_R$

Dissolved P reduction $DP_R(\%) = 29.3 + 0.51R_R$



SWAT- VFS areas are conceptual

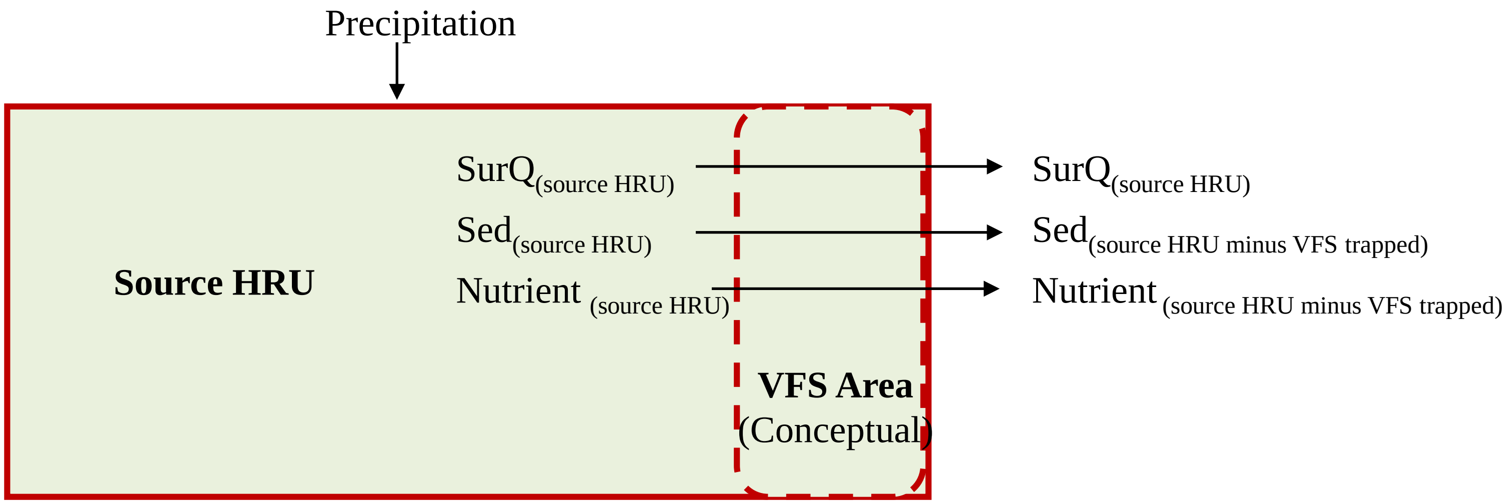


- No crop growth simulation in VFS area
- Hydrology routing in VFS area is not considered
- Sediment and nutrients trapped in VFS area is not accounted

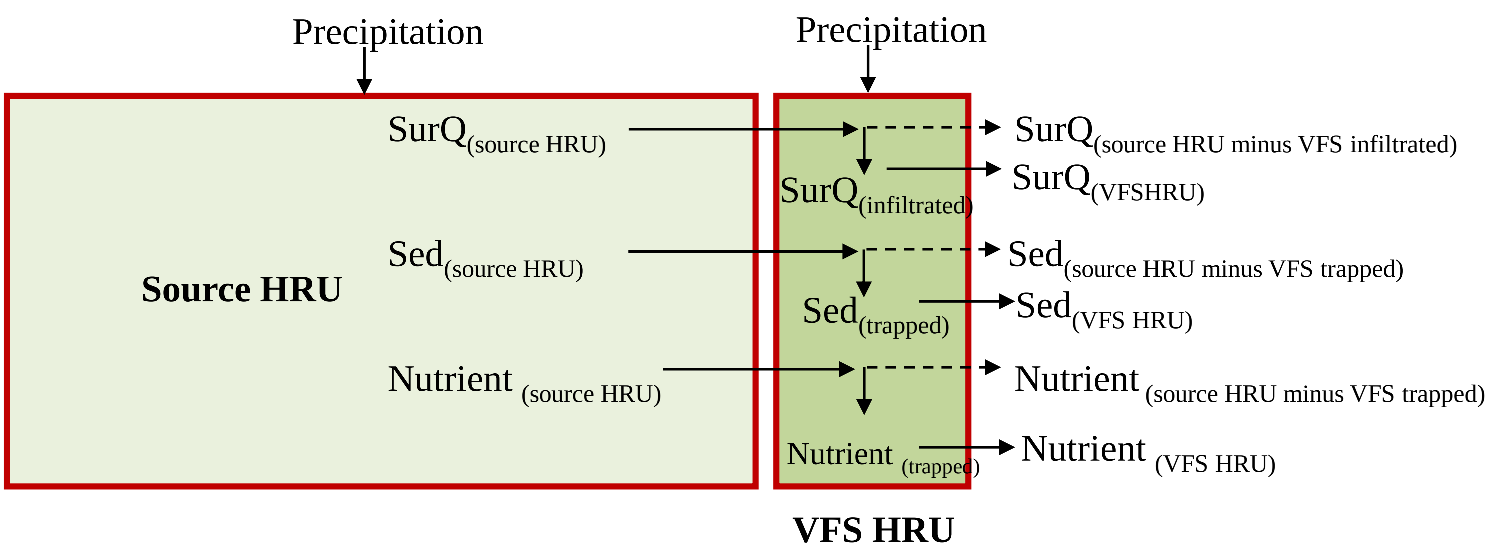
Research Objectives

- Improve the SWAT model representation of VFS algorithm to represent crop growth in filter strip
- Simulate routing of water, sediment and nutrients from source area through VFS area, and water infiltration in VFS area
- Validate the model improvement with field measured data

SWAT- VFS Enhancement



Biomass yield



Sample SWAT input files

000010001.ops - Notepad

File Edit Format View Help

```
|.ops file watershed HRU:1 Subbasin:1 HRU:1 Luse:CORN Soil: 407691 Slope 0-9999 1/8/2015 12:00:00 AM ArcSWAT 2012.10
  5 15      2007   4     1       10.00        0.10000   00.01                                2
```

VFS parameters

VFS HRU number

000010000.sub - Notepad

File Edit Format View Help

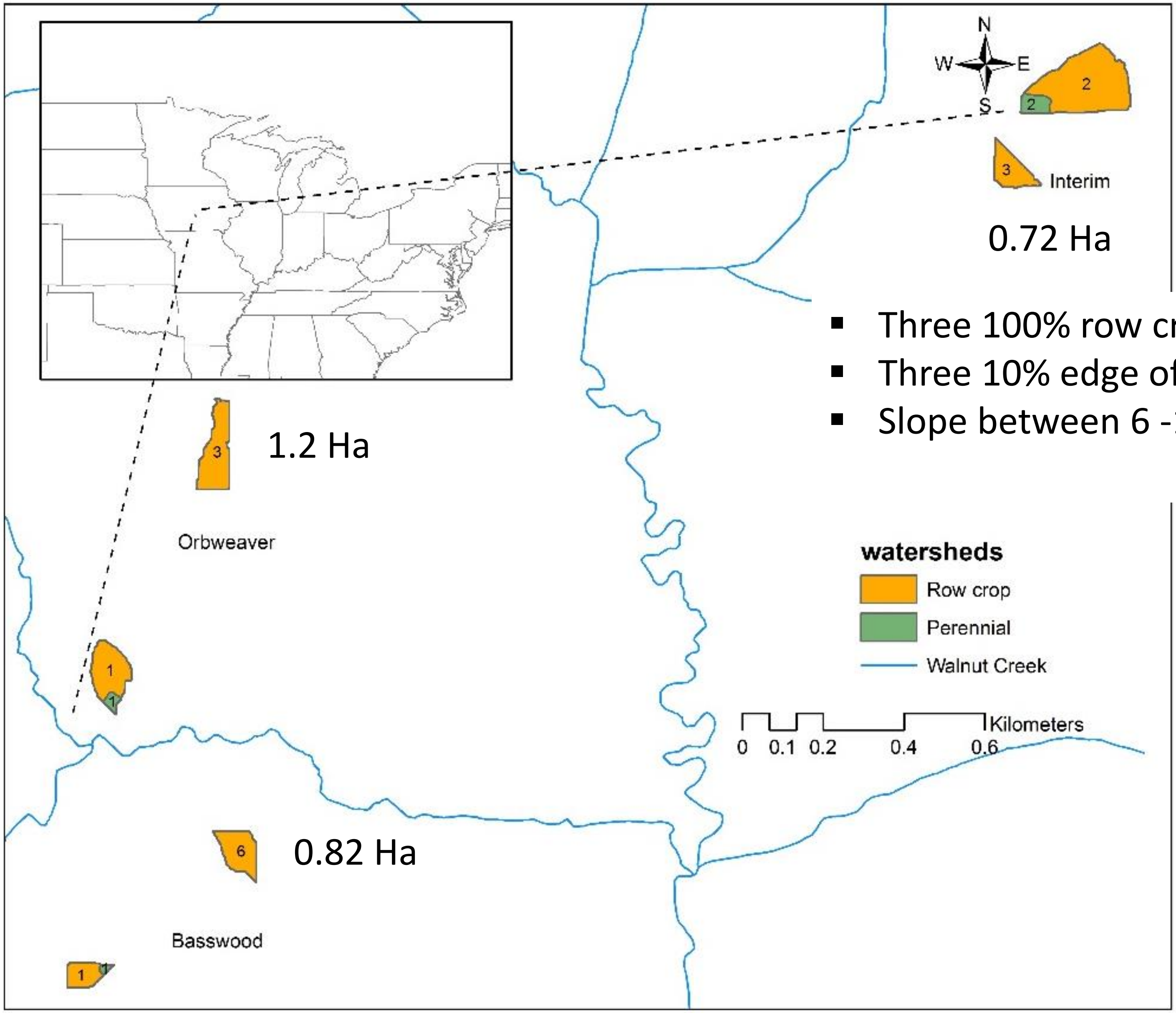
```
   0.000    0.000    0.000    0.000    0.000    0.000
| TMPINC: Climate change monthly temperature adjustment (January - June)
   0.000    0.000    0.000    0.000    0.000    0.000
| TMPINC: Climate change monthly temperature adjustment (July - December)
   0.000    0.000    0.000    0.000    0.000    0.000
| RADINC: Climate change monthly radiation adjustment (January - June)
   0.000    0.000    0.000    0.000    0.000    0.000
| RADINC: Climate change monthly radiation adjustment (July - December)
   0.000    0.000    0.000    0.000    0.000    0.000
| HUMINC: Climate change monthly humidity adjustment (January - June)
   0.000    0.000    0.000    0.000    0.000    0.000
| HUMINC: Climate change monthly humidity adjustment (July - December)
   0.000    0.000    0.000    0.000    0.000    0.000
| HRU data
             2     | HRUTOT : Total number of HRUs modeled in subbasin

HRU: Depressional Storage/Pothole

Floodplain

HRU: Riparian

HRU: General
000010001.hru000010001.mgt000010001.sol000010001.chm 000010001.gw000010001.ops000010001.sep
000010002.hru000010002.mgt000010002.sol000010002.chm 000010002.gw             000010002.sep
```

VFS HRU files

Additional Model Improvements

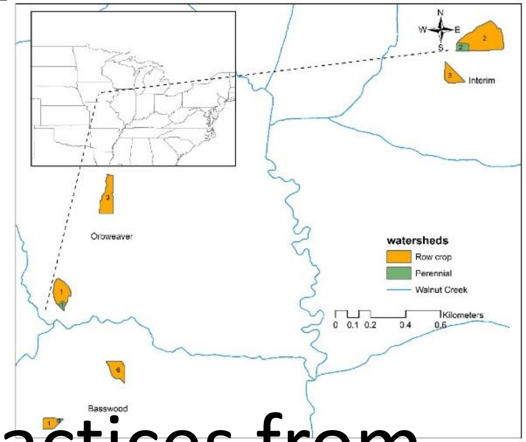
- Hydraulic conductivity estimated from soil texture
- VFS algorithm active if there is any flow contribution from source HRU
- Bug fix in runoff reduction equation

Validation using paired watershed data



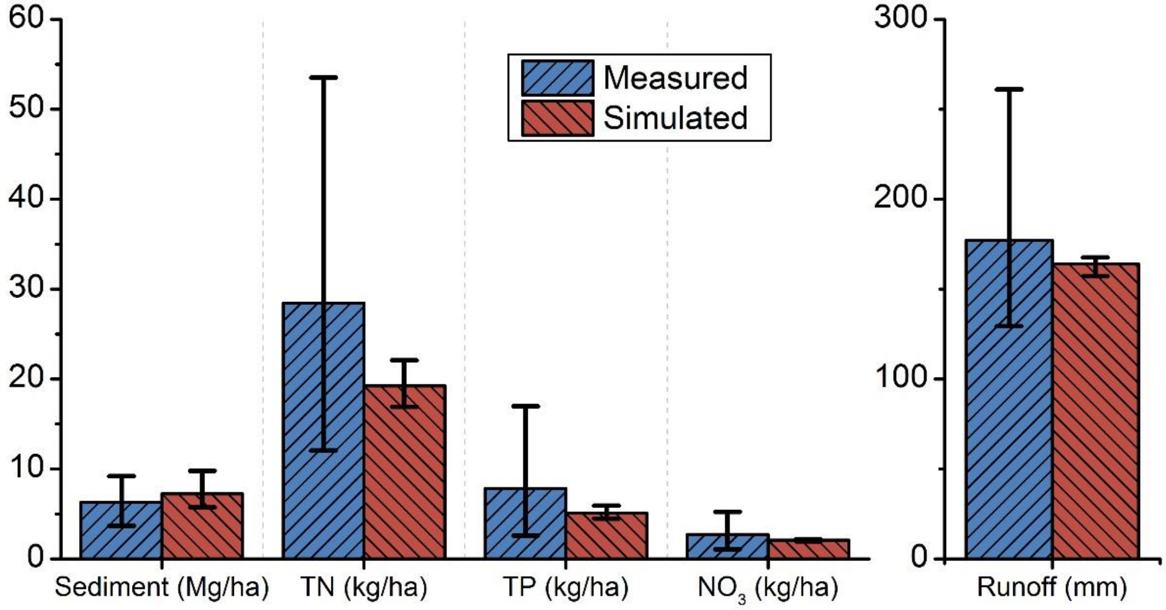
- Three 100% row crop control watershed
- Three 10% edge of watershed VFS
- Slope between 6 -10.5%

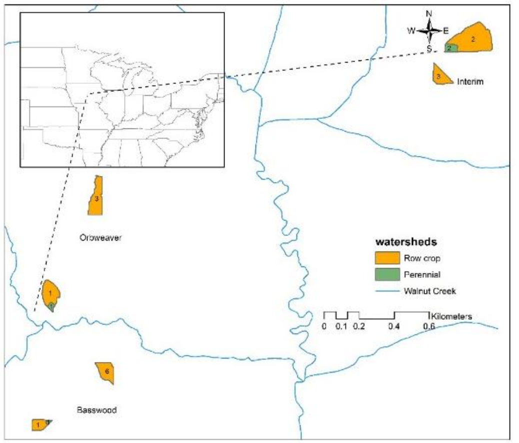
One HRU models for control watersheds



- Soil data from SSURGO database
- Weather data from NCDC
- Crop rotation and management practices from field data
- Model setup for 11 years, with 4 years warm up and 7 year for evaluation
- Manually calibrated for runoff and water quality

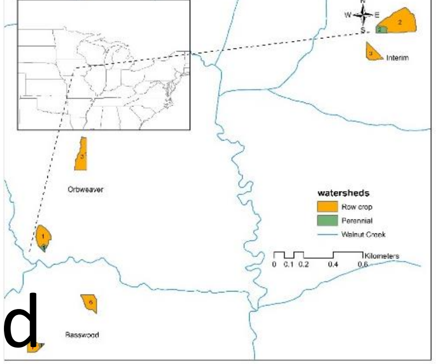
Control watersheds SWAT evaluation





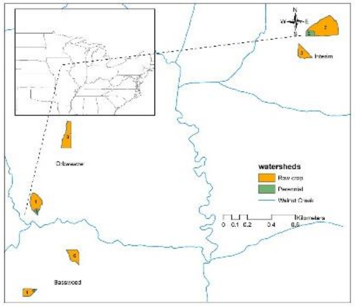
	Basswood6	Interim2	Weaver3
Area (Ha)	0.82	0.72	1.20
Correlation Coeff (R)	0.84	0.79	0.76
Coeff of Determination (R^2)	0.71	0.63	0.58
Nash-Sutcliffe eff (NS)	0.66	0.62	0.58

VFS watershed simulation



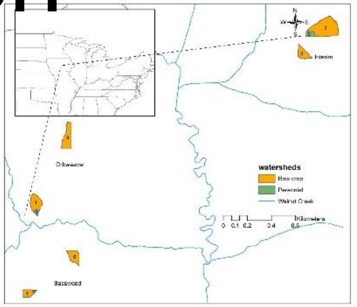
- Model parameters from control watershed simulation transferred to VFS watersheds
- Three scenarios developed:
  - Scenario 1: No VFS
  - Scenario 2: VFS using current framework
  - Scenario 3: VFS using new framework
- Scenario 3 considered unfertilized Indian grass as perennial filter grass

SWAT- VFS Enhancement - validation



	Field measured	
	Control no VFS watershed	VFS watersheds
Runoff (mm)	177.2	69.6
Sediment (Mg/ha)	6.3	0.4
TN (kg/ha)	28.4	3.3
TP (kg/ha)	7.8	0.8
NO3 (kg/ha)	2.7	0.8

SWAT- VFS Enhancement - validation

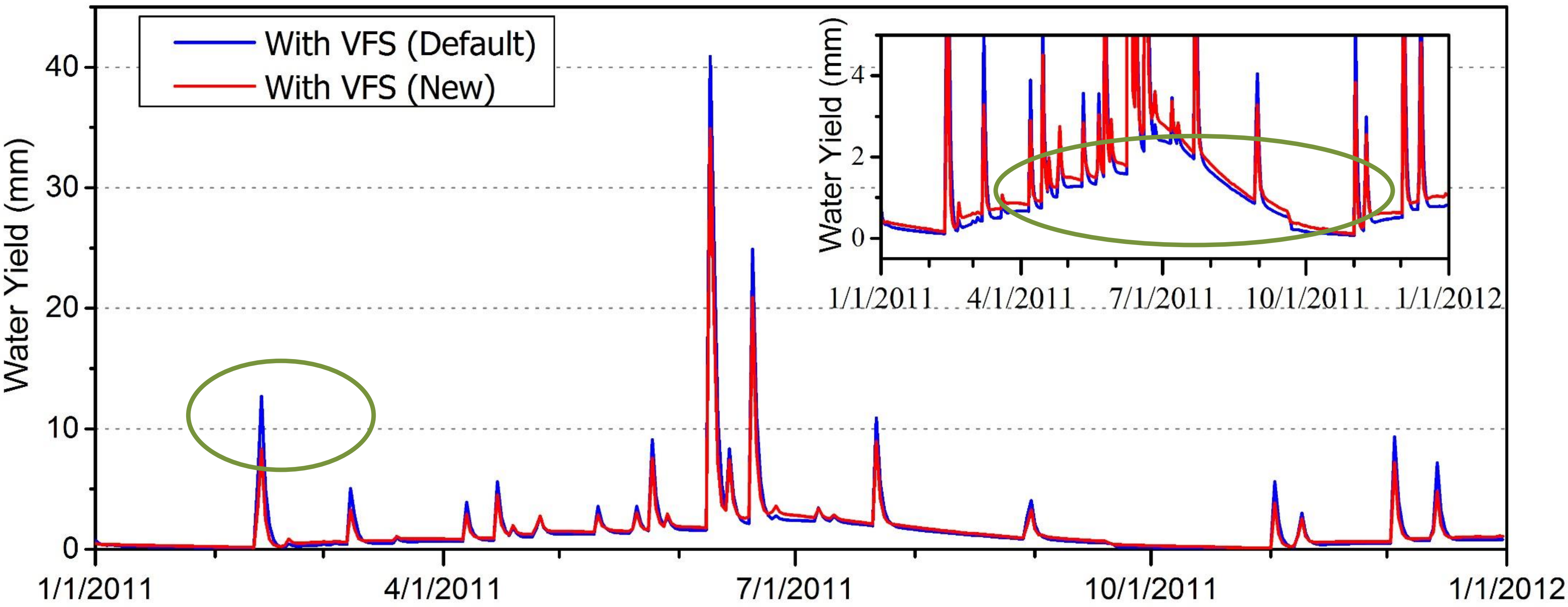


	Field measured		SWAT simulation		
	Control no VFS watershed	VFS watersheds	No VFS	With VFS (Default)	With VFS (New)
Runoff (mm)	177.2	69.6	149.9	149.9	89.2
Sediment (Mg/ha)	6.3	0.4	5.4	2.0	0.6
TN (kg/ha)	28.4	3.3	16.5	8.3	4.6
TP (kg/ha)	7.8	0.8	4.4	1.9	0.8
NO3 (kg/ha)	2.7	0.8	3.0	1.5	1.0

Better physical representation of processes with new representation

	Units	No VFS	With VFS (Default)	With VFS (New)		
				Source area	VFS area	Combined
Area	ha	0.53	0.53	0.478	0.052	0.53
Surface Q	mm	246.7	246.7	126.3	516.5	164.6
Groundwater Q	mm	191.3	191.3	190.3	994.0	269.1
Water Yield	mm	473.2	473.2	353.0	1595.3	474.8
Sediment yield	Mg/ha	10.8	3.6	1.3	0.2	1.2
Denitrification	kg/ha	0	0	0	36.7	3.6
Org N loading	kg/ha	27.42	13.24	8.26	0.16	7.47
N surface Q	kg/ha	7.11	4.04	2.56	6.53	2.95
Corn Yield	Mg	4.8	4.8	4.4	-	4.4
Grass Yield	Mg	-	-	-	0.33	0.33

Increased base flow and reduced peak



Conclusions

- SWAT-VFS framework improved with spatially explicit VFS HRUs
- Measured data from paired watershed studies from central Iowa used to verify model improvements
- Model improvements significantly improved the hydrology and water quality representation of VFS in SWAT
- Improvements enables evaluation potential management practices in VFS area, such as fertilizer application, biomass production and its impacts of hydrology and water quality