Improved physical representation of vegetative filter strip in SWAT

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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?
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 was then compared to SWAT, a modified conservative function. This model is designed to improve SWAT's vegetation model.
SWAT- VFS: Regression based model by White and Arnold 2009

Runoff reduction \[ R_R(\%) = 75.8 \times 10.8\ln(R_L) + 25.9\log(K_{sat}) \]

Sediment reduction \[ S_R(\%) = 79.0 \times 1.04S_L + 0.213R_R \]

Organic N reduction \[ \text{Org}N_R(\%) = 0.036S_R^{1.69} \]

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

Estimated using regression equations from White and Arnold 2009
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

Precipitation

Source HRU
- SurQ_{(source HRU)}
- Sed_{(source HRU)}
- Nutrient_{(source HRU)}

VFS Area
- SurQ_{(source HRU)}
- Sed_{(source HRU minus VFS trapped)}
- Nutrient_{(source HRU minus VFS trapped)}

Biomass yield

Precipitation

Source HRU
- SurQ_{(source HRU)}
- Sed_{(source HRU)}
- Nutrient_{(source HRU)}

VFS HRU
- SurQ_{(infiltrated)}
- Sed_{(trapped)}
- Nutrient_{(trapped)}
- SurQ_{(VFS HRU)}
- Sed_{(VFS HRU)}
- Nutrient_{(VFS HRU)}
Sample SWAT input files

VFS parameters

VFS HRU number

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

<table>
<thead>
<tr>
<th></th>
<th>Basswood6</th>
<th>Interim2</th>
<th>Weaver3</th>
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<tbody>
<tr>
<td>Area (Ha)</td>
<td>0.82</td>
<td>0.72</td>
<td>1.20</td>
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<tr>
<td>Correlation Coeff (R)</td>
<td>0.84</td>
<td>0.79</td>
<td>0.76</td>
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<tr>
<td>Coeff of Determination ($R^2$)</td>
<td>0.71</td>
<td>0.63</td>
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<tr>
<td>Nash-Sutcliffe eff (NS)</td>
<td>0.66</td>
<td>0.62</td>
<td>0.58</td>
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</table>
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

<table>
<thead>
<tr>
<th></th>
<th>Field measured</th>
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<tbody>
<tr>
<td></td>
<td>Control no VFS watershed</td>
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<tr>
<td>Runoff (mm)</td>
<td>177.2</td>
</tr>
<tr>
<td>Sediment (Mg/ha)</td>
<td>6.3</td>
</tr>
<tr>
<td>TN (kg/ha)</td>
<td>28.4</td>
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<tr>
<td>TP (kg/ha)</td>
<td>7.8</td>
</tr>
<tr>
<td>NO3 (kg/ha)</td>
<td>2.7</td>
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<tr>
<td></td>
<td>Field measured</td>
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<td>----------------------</td>
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</table>
Better physical representation of processes with new representation

<table>
<thead>
<tr>
<th>Units</th>
<th>No VFS</th>
<th>With VFS (Default)</th>
<th>Source area</th>
<th>VFS area</th>
<th>Combined</th>
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<tbody>
<tr>
<td>Area</td>
<td>ha</td>
<td>0.53</td>
<td>0.478</td>
<td>0.052</td>
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<td>Surface Q</td>
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<td>Groundwater Q</td>
<td>mm</td>
<td>191.3</td>
<td>190.3</td>
<td>994.0</td>
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<td>Water Yield</td>
<td>mm</td>
<td>473.2</td>
<td>353.0</td>
<td>1595.3</td>
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<tr>
<td>Sediment yield</td>
<td>Mg/ha</td>
<td>10.8</td>
<td>1.3</td>
<td>0.2</td>
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<tr>
<td>Denitrification</td>
<td>kg/ha</td>
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<td>0</td>
<td>36.7</td>
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<td>Org N loading</td>
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<td>8.26</td>
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<td>N surface Q</td>
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<td>Corn Yield</td>
<td>Mg</td>
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<td>4.4</td>
<td>-</td>
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<tr>
<td>Grass Yield</td>
<td>Mg</td>
<td>-</td>
<td>-</td>
<td>0.33</td>
<td>0.33</td>
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</table>
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