Simulating establishment period of perennial bioenergy grasses in the SWAT model

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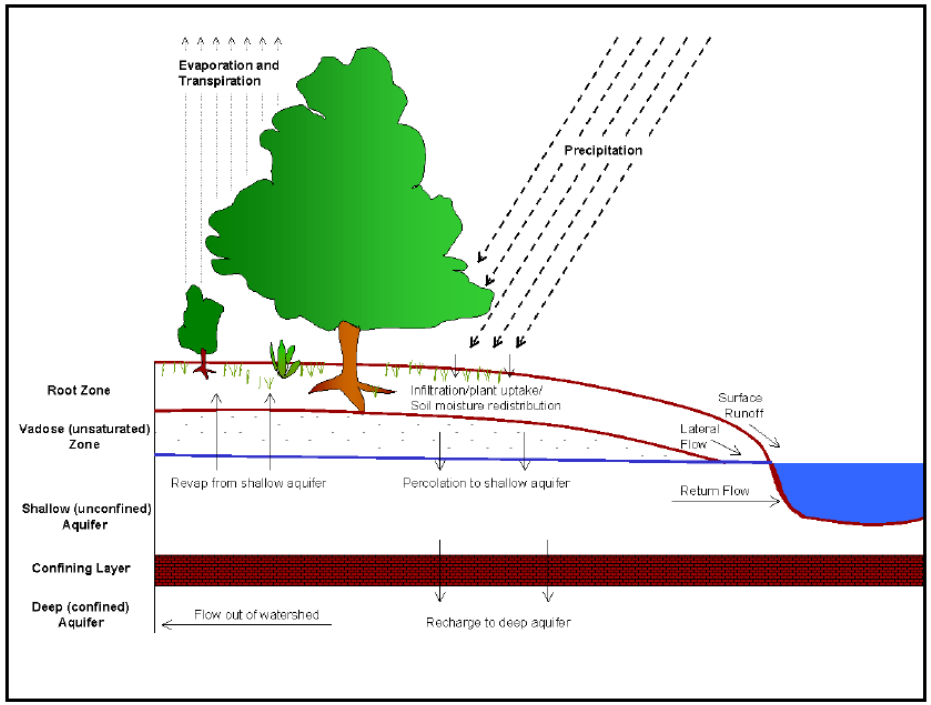
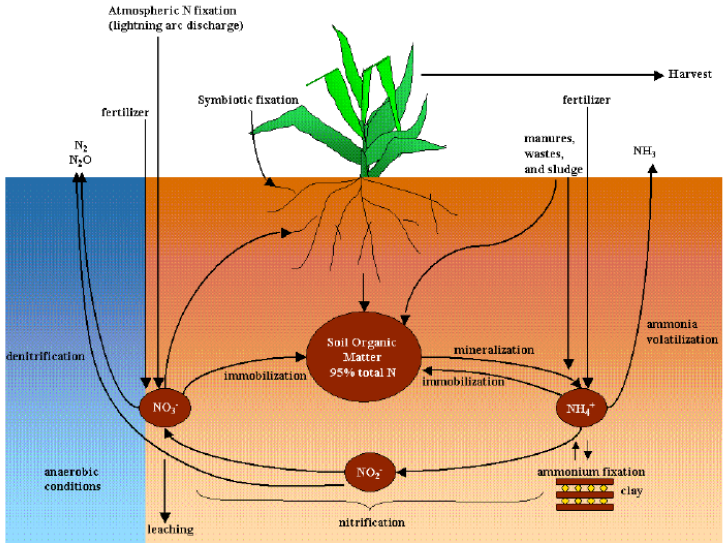
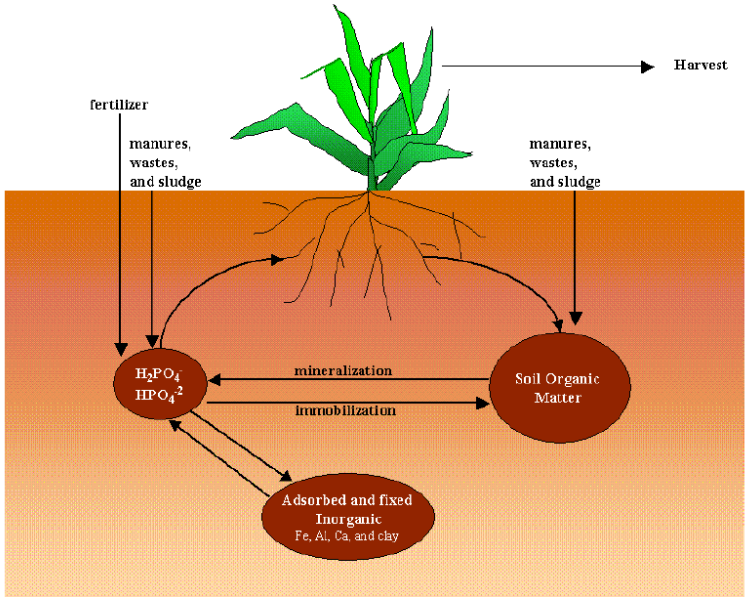
Crop growth representation is important for Ecohydrological analysis



Hydrological cycle



Nitrogen cycle



Phosphorus cycle

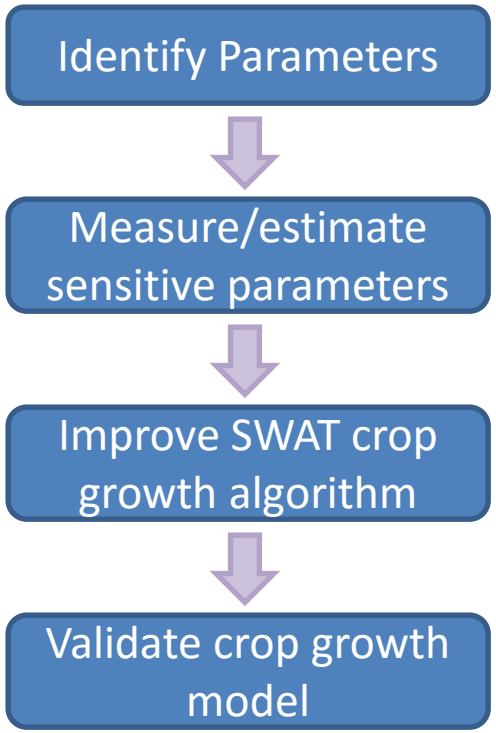
Miscanthus, switchgrass and crop residue as biofeedstock

Switchgrass (~10 Mg/ha) *Miscanthus (~25 Mg/ha)*

Miscanthus

Modeling bioenergy crops in SWAT

- SWAT requires about 25 crop growth parameters
- *Miscanthus* and upland switchgrass are not in the default crop database of SWAT



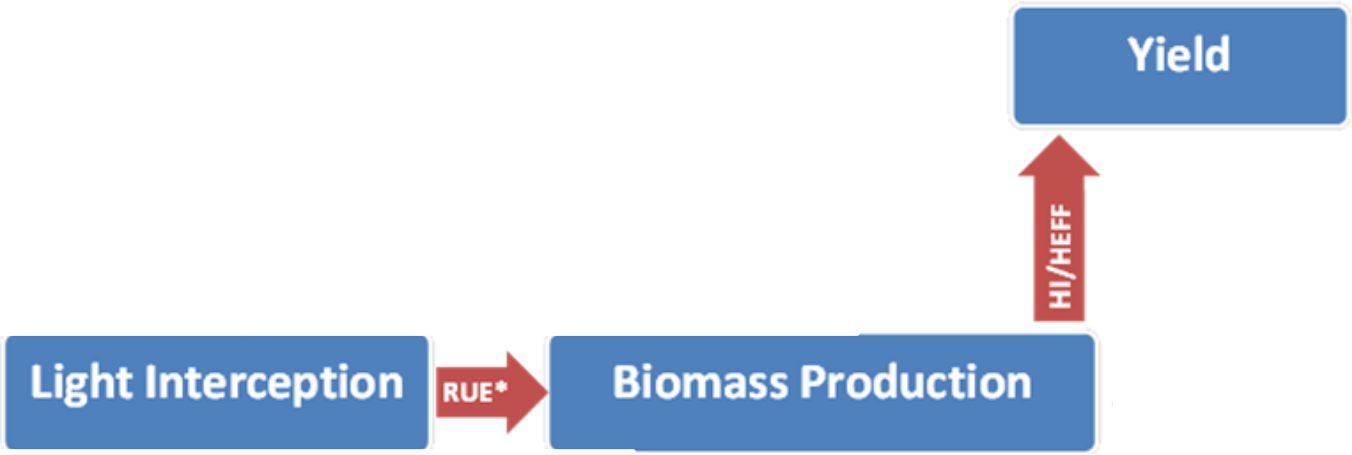
Crop growth representation in the model
Sensitivity analysis

Data collected from research plots
Biomass, leaf area index, crop height, harvest efficiency

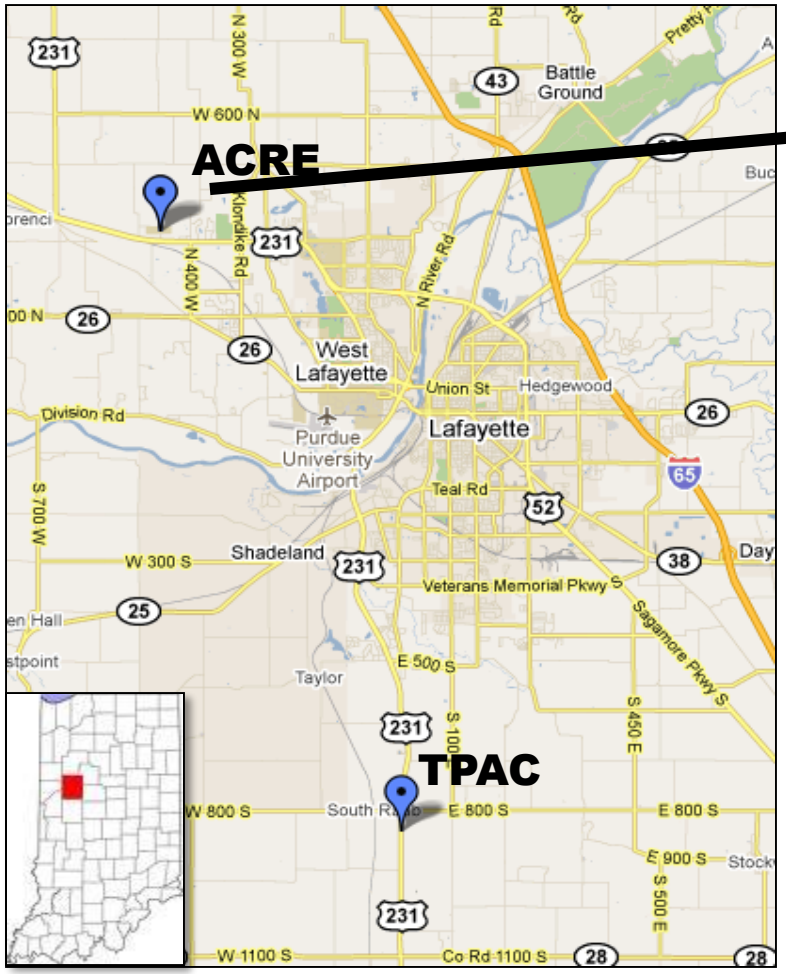
Check SWAT simulation of perennial grasses and modify if required

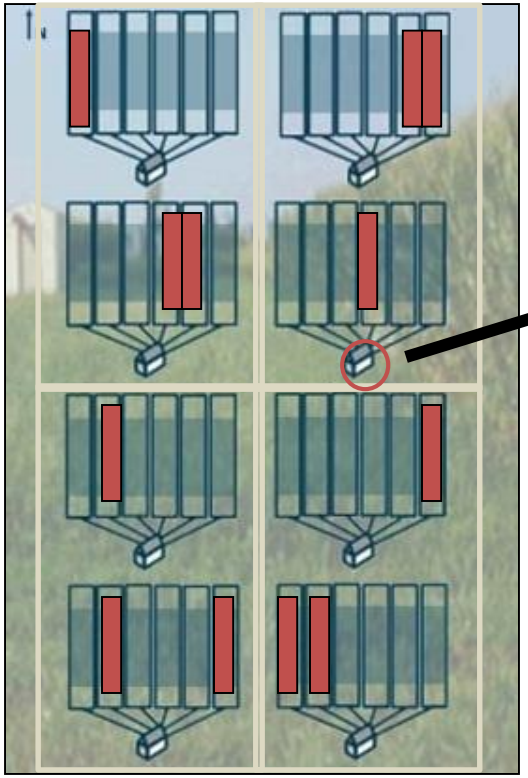
Validate energy crop simulations of SWAT with measured data

Crop growth in SWAT



Data Collection: Purdue Research Stations





Purdue Water Quality Field Station

Switchgrass – Shawnee (2007)

Miscanthus x giganteus (2008)

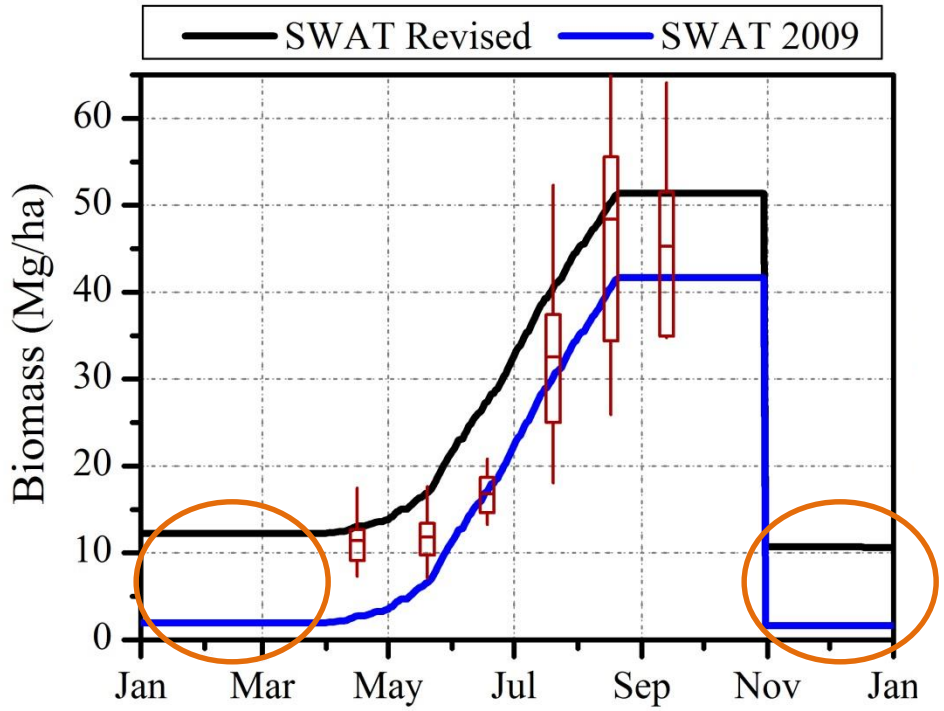
Data Collection WQFS and TPAC

- Emergence dates (daily observations)
- Daily temperature (^{o}C)
- Daily solar radiation (x0.5 determined PAR)
- Total biomass (Monthly destructive sampling)
  - Top growth, stem base, rhizome, root
- Leaf Area Index (Decagon AccuPAR LP-80)
- Canopy height measurement (m)
- Tissue Nitrogen or phosphorus
- Annual yield: Biomass removed at harvest (g/m^2)
- Field residue after harvest (g/m^2)
- Root distribution to 60 cm (percent)

Crop Growth Algorithm Improvement

- Plant nutrient uptake in stress periods
- Harvest operation representation – Harvest Index (HI) adjustments with water and nutrient stress
- Dormancy period representation and dead root allocation in harvest operation
- LAI after the crop maturity – senescence representation

Better growth and nutrient uptake representation by revised SWAT



- Nutrients stored in below ground biomass not considered
- About 100 kg N/ha & 30 kg P/ha stored

- Affect nutrient uptake process
- water quality estimations impacted

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BIOENERGY

GCB Bioenergy (2014), doi: 10.1111/gcbb.12210

Perennial rhizomatous grasses as bioenergy feedstock in SWAT: parameter development and model improvement

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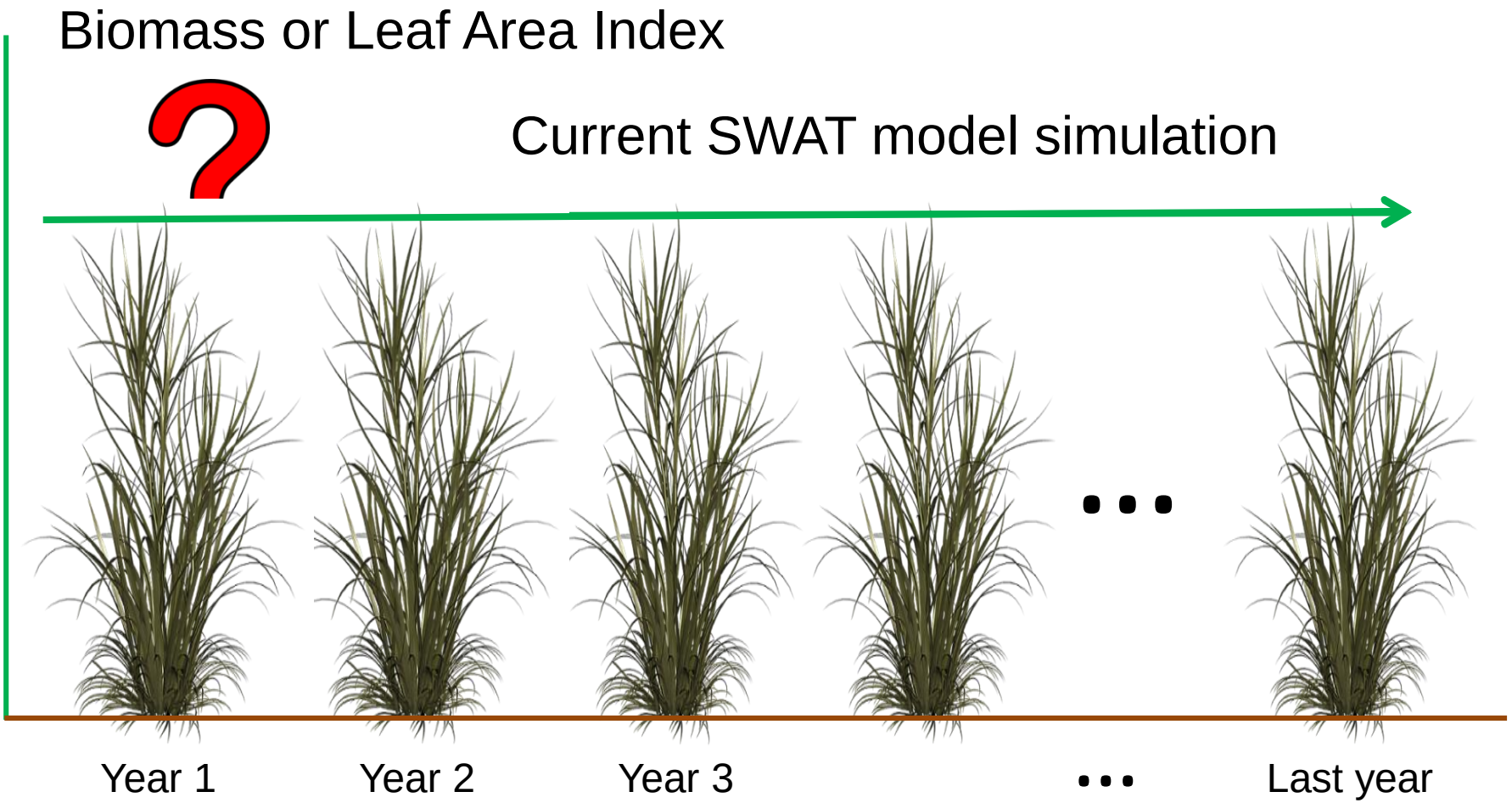
Abstract

The Soil and Water Assessment Tool (SWAT) is increasingly used to quantify hydrologic and water quality impacts of bioenergy production, but crop-growth parameters for candidate perennial rhizomatous grasses

- Model improvements are now incorporated in the official SWAT model: Version 612 (http://swat.tamu.edu/software/swat-model/)
- http://swat.tamu.edu/conferences/2015/material/june-25/d4/raj/

Establishment period of perennial bioenergy grasses

Perennial grasses is building their biomass during the establishment period



Establishment period

Post-Establishment period

Picture source: https://auntiedogmasgardenspot.wordpress.com/2013/07/02/switchgrass-panicum-virgatum-plant-care-guide/

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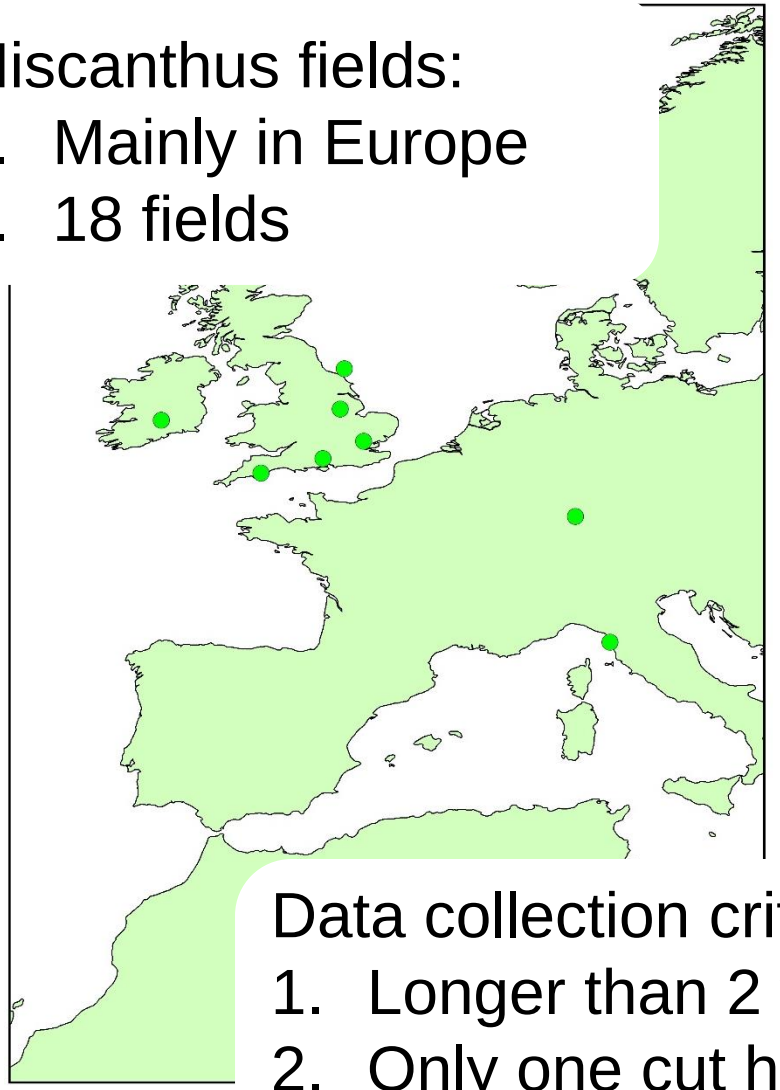
Objectives

- Understand establishment stages for perennial bioenergy crops
- Develop growth curves of biomass and LAI
- Improve SWAT algorithms to represent establishment stage

Yield data collection

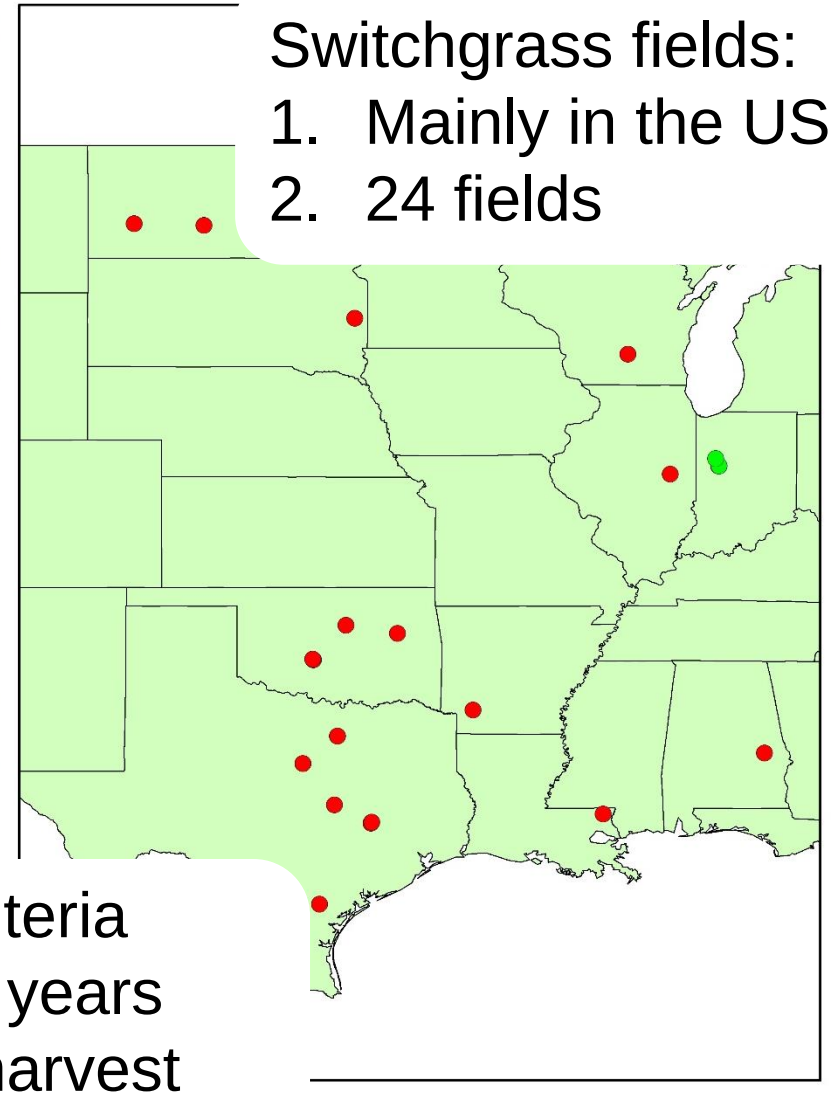
Miscanthus fields:

1. Mainly in Europe
2. 18 fields



Switchgrass fields:

1. Mainly in the US
2. 24 fields



Data collection criteria

1. Longer than 2 years
2. Only one cut harvest
3. All N fertilization rates

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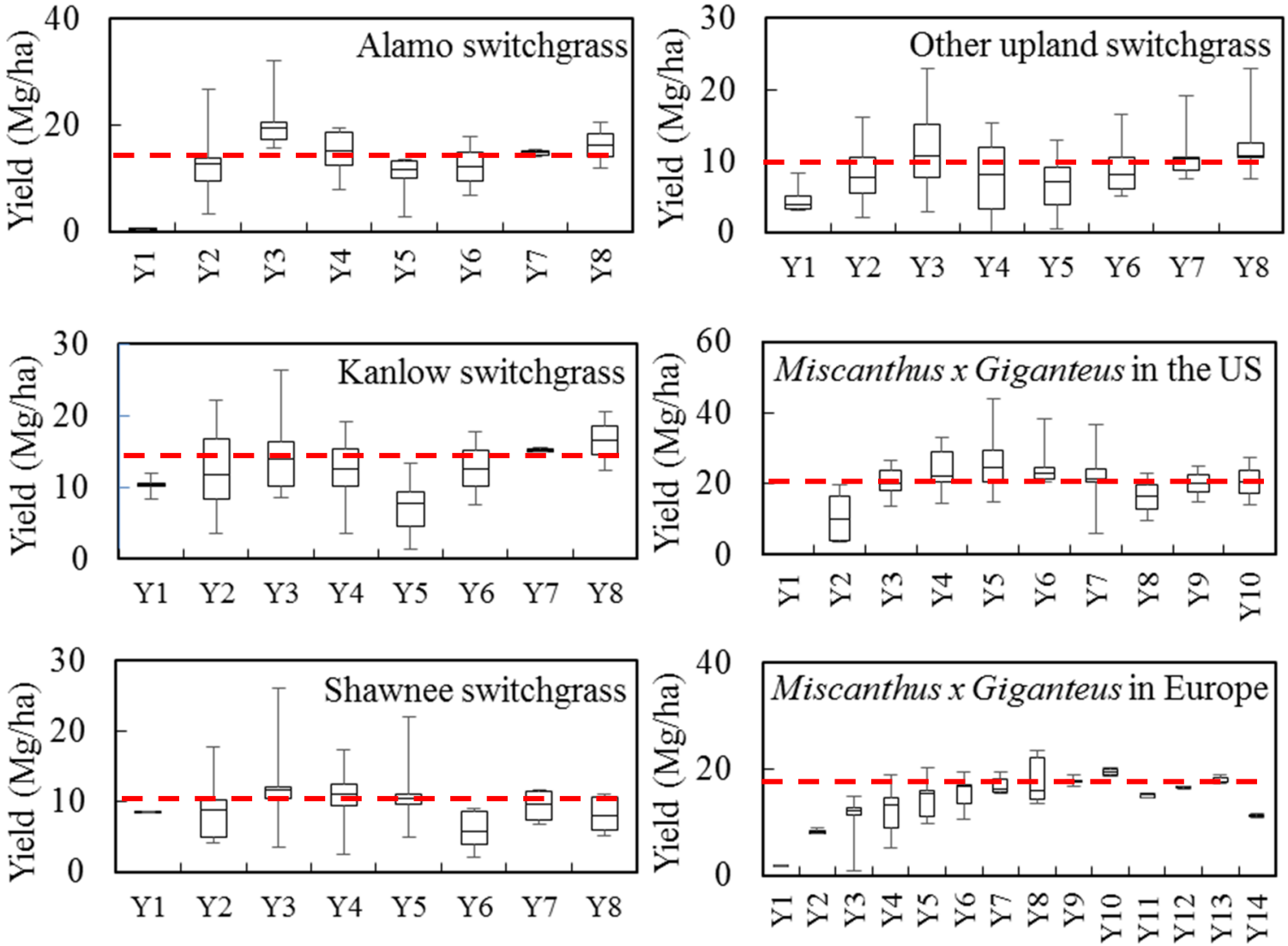
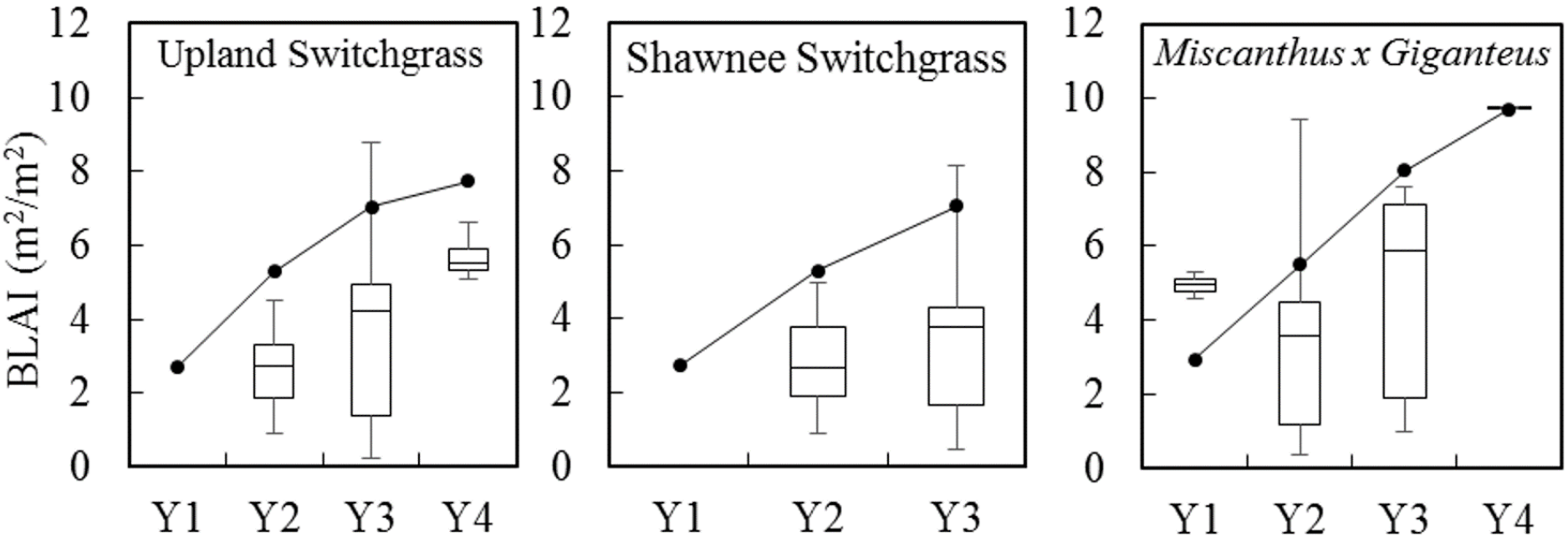
Threshold yield for determining establishment period was recommended



Threshold yield for determining establishment period was recommended

Threshold yields	Establishment period
15 Mg/ha for lowland switchgrass	2 to 3 years for switchgrass of both cultivars
10 Mg/ha for upland switchgrass	
15 Mg/ha for Miscanthus in Europe	3 to 6 years for *Miscanthus* in Europe
20 Mg/ha for Miscanthus in the US	2 to 4 years for *Miscanthus* in the US

Leaf Area Index (LAI) also increased during the establishment period

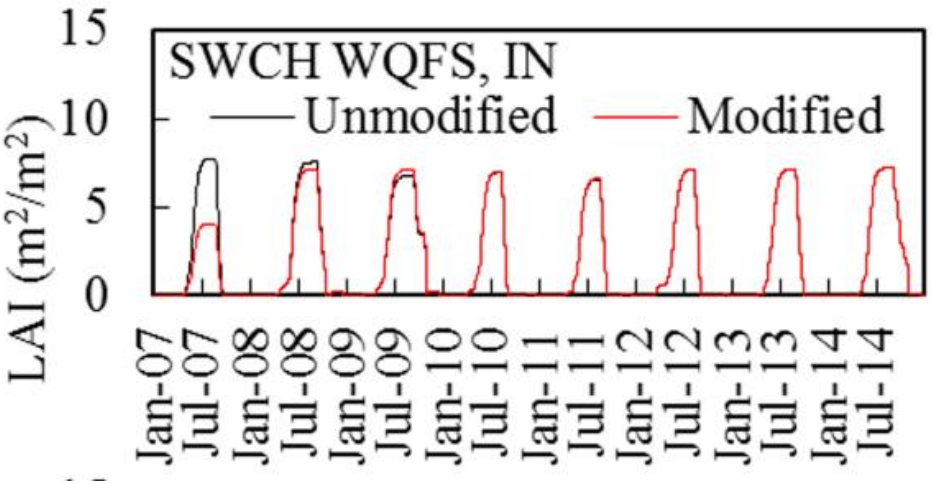


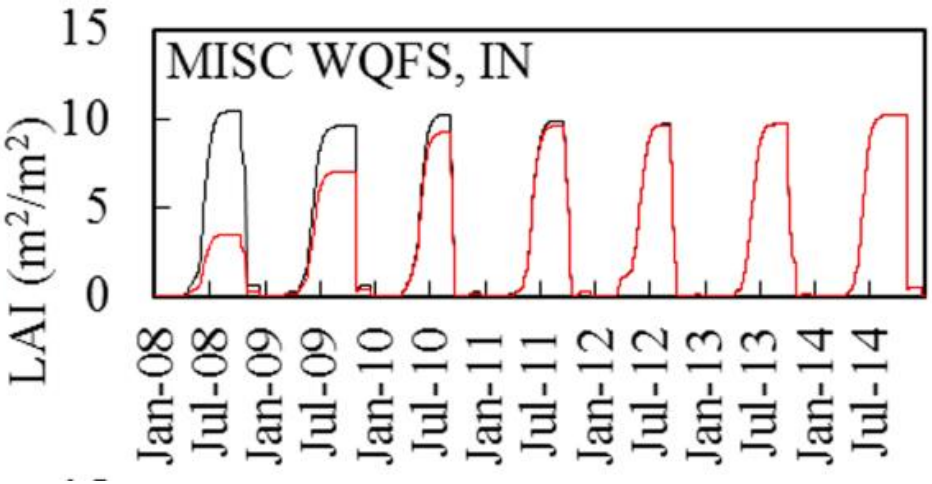
$$f(x) = \frac{\emptyset_1}{1 + exp((\emptyset_2 - x)/\emptyset_3)}$$

(Miguez et al. 2008)

$\emptyset_1$: the maximum LAI for established *Miscanthus*.
$\emptyset_2$: the point at which the crop achieved half of the maximum LAI.
$\emptyset_3$: the time between achieving ½ and approximately ¾ of the maximum LAI by the crop.

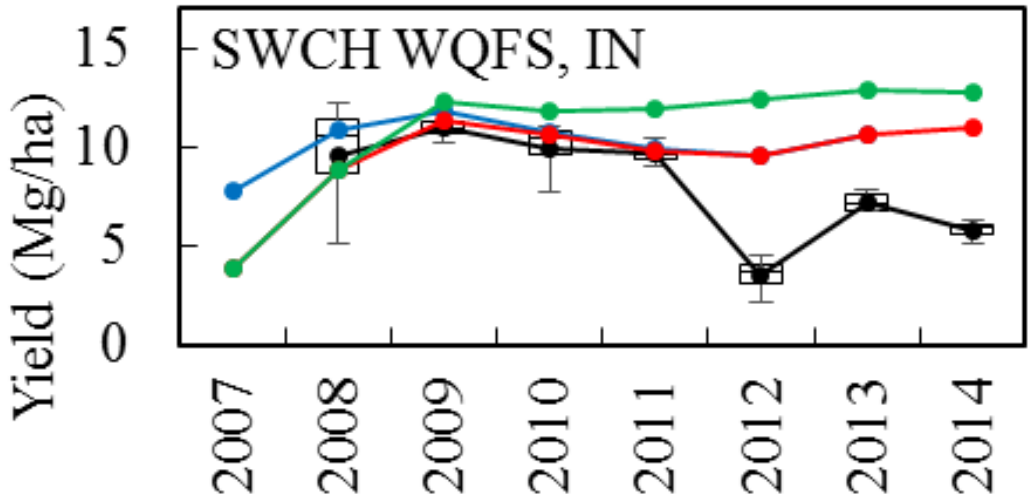
SWAT model improvements tested with field scale simulation – One HRU models

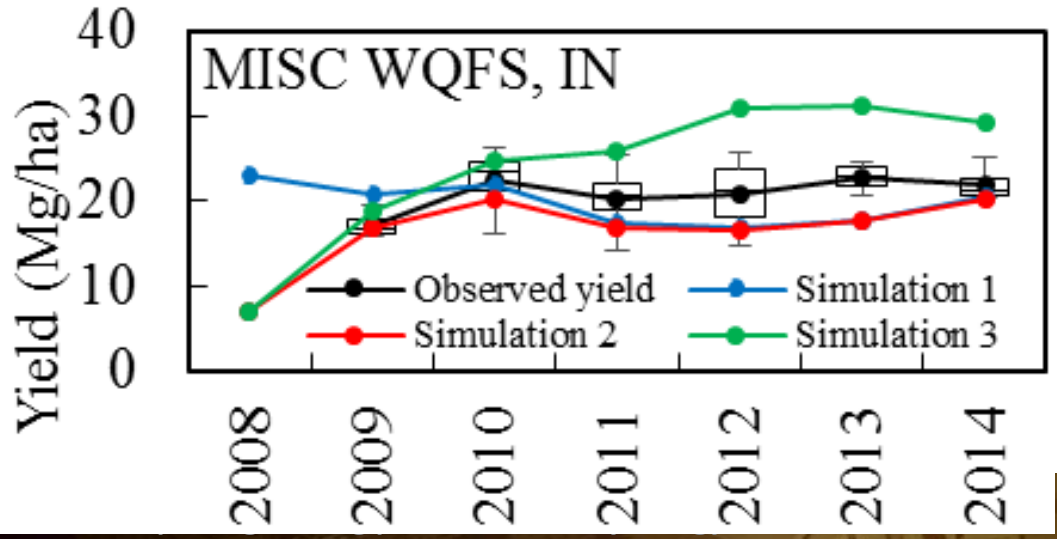




Location	State
Water Quality Field Station	Indiana
Throckmorton Purdue Agriculture Center	Indiana
Brookings	South Dakota
Arlington	Wisconsin
Lafayette	Indiana
Schochoh	Kentucky

SWAT model modification validation: Yield simulation





Conclusion

Establishment period

Threshold yield recommended for switchgrass and *Miscanthus*

SWAT model modification

Leaf Area Index calculation equation updated for representation of establishment post establishment period.

Modified SWAT model provide good simulation results of yield against the observed data

Impacts on hydrology and water quality

Lower Evapotranspiration are expected to happen during the establishment period, which tend to increase water yield and soil erosion as well as nitrogen and phosphorus loss.

Other model improvements at Purdue

- Woody bioenergy crops representation in SWAT
  - The improved model could simulate reasonably well
- Soil moisture representation in SWAT
  - Better simulation of bioclimate stress effects on annual yield and interannual variability
- CO2 input to the model as time series for climate change representation
- Vegetative Filter Strip (VFS) representation SWAT model to simulate energy crop production in VFS areas (Session K2)

SWAT model modification


```
select case(idc(idp))
    case(6)
        rto_per = 1/(1+
        Exp((bio_leaf(idp)-
```

Calculate the ratio of BLAI development according to the equation provided by

```
    if (co2(hru_sub(j)) > 330.) then
        beadj = ((100. * co2(hru_sub(j))
            / (co2(hru_sub(j)) +
            Exp(wac21(idp)-
            co2(hru_sub(j))
            * wac22(idp)))))*rto_per
end
```

Bio_E was also assumed to be reduced proportionally according to the ratio used for BLAI. Thus the Bio_E was multiplied with

```
el
    select case (idc(idp))
        case (1,2,3,4,5)
            laimax = blai(idp)
        case (6)
            laimax = blai(idp)*rto_per
        case (7)
            laimax = rto * blai(idp)
```

Modified the BLAI calculation choices, to include the case of perennial grasses and reduce BLAI according to "rto_per".