Optimizing Nutrient Uptake in Shrub Willow and Switchgrass to Provide Multiple Ecosystem Services

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Background

Agricultural runoff is likely the primary contributor of non-point source pollution to US waterways, leading the EPA to declare a majority (55%) of streams and rivers to be impaired.

The Chesapeake Bay watershed is a classic example, where impairment causes losses in the billions annually. Crop breeding and better land management can help mitigate excess N and P runoff. Perennial biomass crops provide an opportunity to provide multiple ecosystem services, chiefly water quality improvement.

A two-pronged approach

Breeding, selection and management for:

1—high nutrient use efficiency on marginal lands

2—luxury nutrient uptake in riparian buffer zones

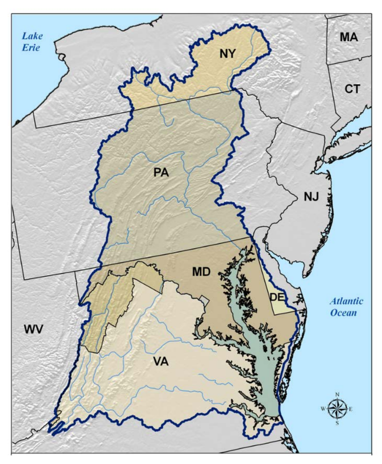


Fig 1. Perennial shrub willow & switchgrass crops & the Chesapeake Bay watershed

Tracking N cycling in willow

A series of experiments provide important insights into N cycling in willow production.

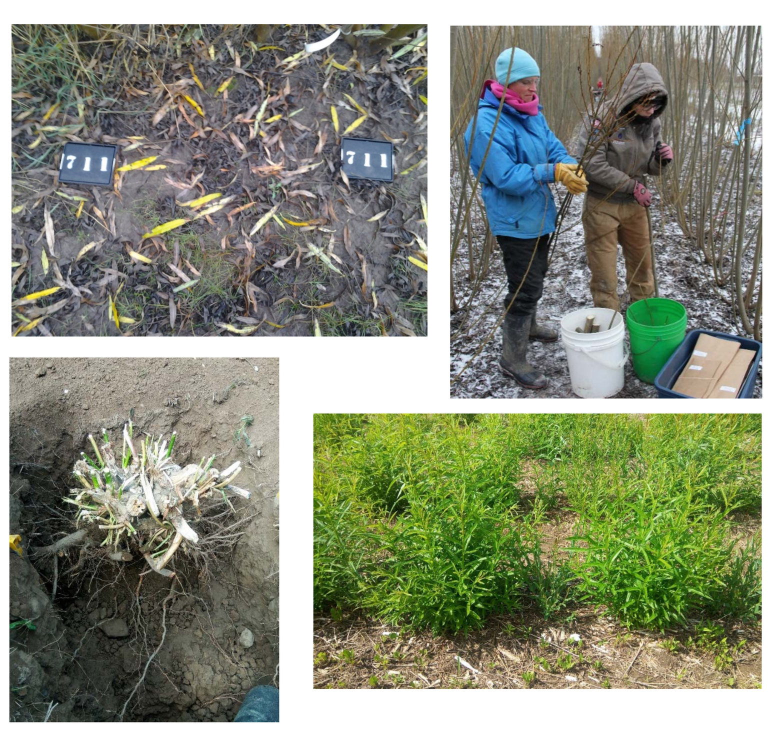
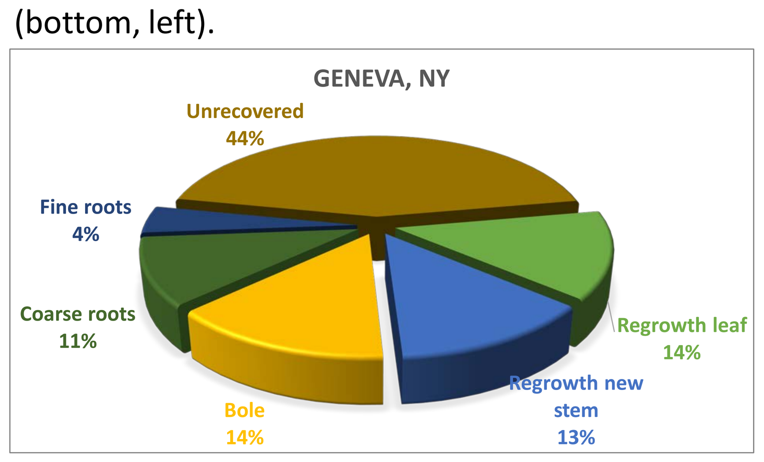


Fig 2. Deployment of ^{15}N fertilizer treatments (top, left), sampling treated stems (top, right), regrowth after sampling (bottom, right), excavation of bole and roots for ^{15}N content (bottom, left).



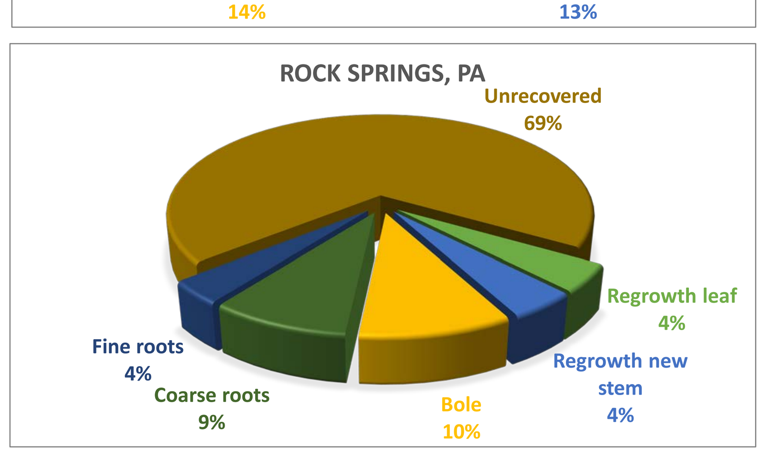
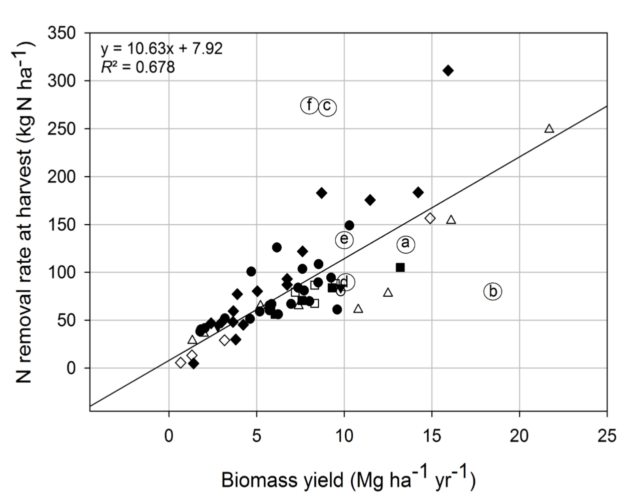
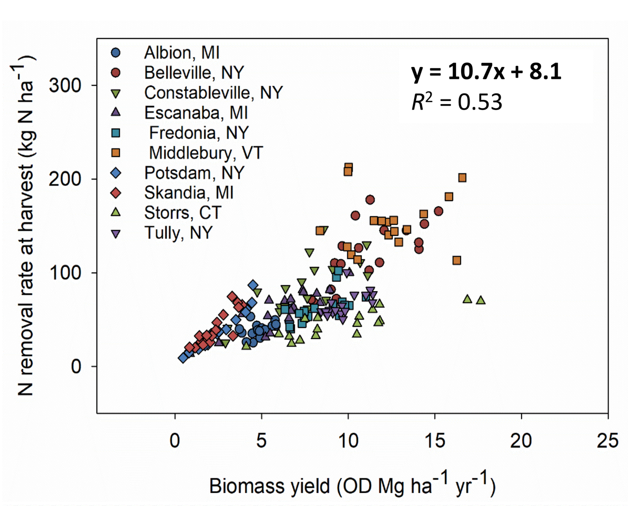


Fig 3. Partitioning of ^{15}N recovered in plant tissues after treatment 3 yrs prior in Geneva, NY and Rock Springs, PA.





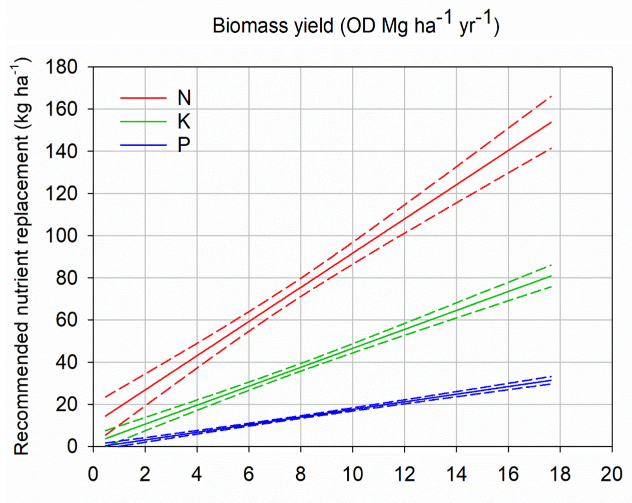


Fig 3. Meta-analysis of N removal rates as a function of biomass yield (top), independent analysis of the same function from 10 trials & 6 cultivars (mid), prediction models for N, K & P removal rates at harvest (bottom).

Genetic basis for N uptake

A highly significant marker for SPAD was detected in the field for a F_2 QTL mapping population. To confirm this, 15 individuals from each allele group were treated with 5 levels of fertilizer. The 'BB' allele group responded to fertilizer with greater SPAD across all levels. These findings will inform breeding strategies for luxury N uptake in riparian buffers.

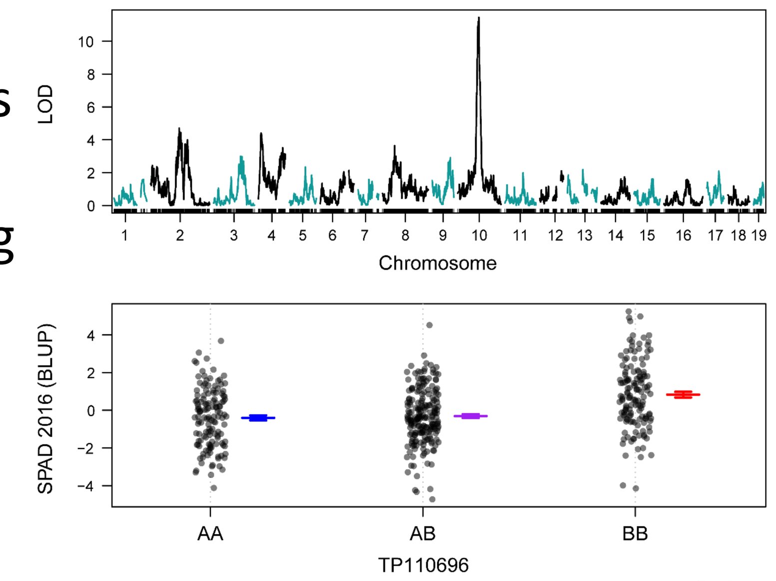


Fig 4. SPAD QTL hit on chromosome 10 of the *Salix purpurea* genome (top), & mean SPAD estimates for the 3 allele variants (bottom).

Fig 5. Examples of group 'AA' with low N treatment & group 'BB' with high N in the greenhouse SPAD QTL trial.

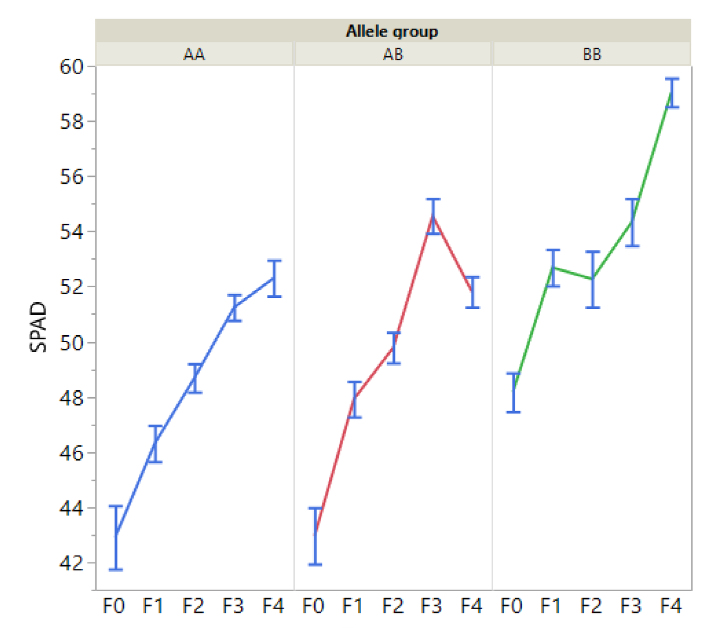


Fig 6. Mean SPAD reading response to fertilization for the 3 SPAD QTL allele groups

Switchgrass N utilization

Two switchgrass trials in Ithaca, NY were monitored for fertilizer N response. Site 1 measured yield response of two cultivars and a fallow control along a soil moisture gradient with multiple annual harvests. Runoff quantity and quality was measured at a weir at the bottom of the field. Outflow and nitrate concentrations were compared to conventional corn production system (S5).

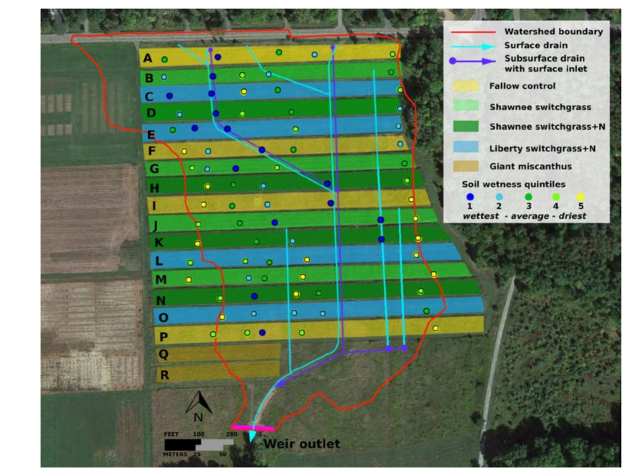


Fig 7. Site 1 SWG trial with 2 cultivars & N fertilizer treatments

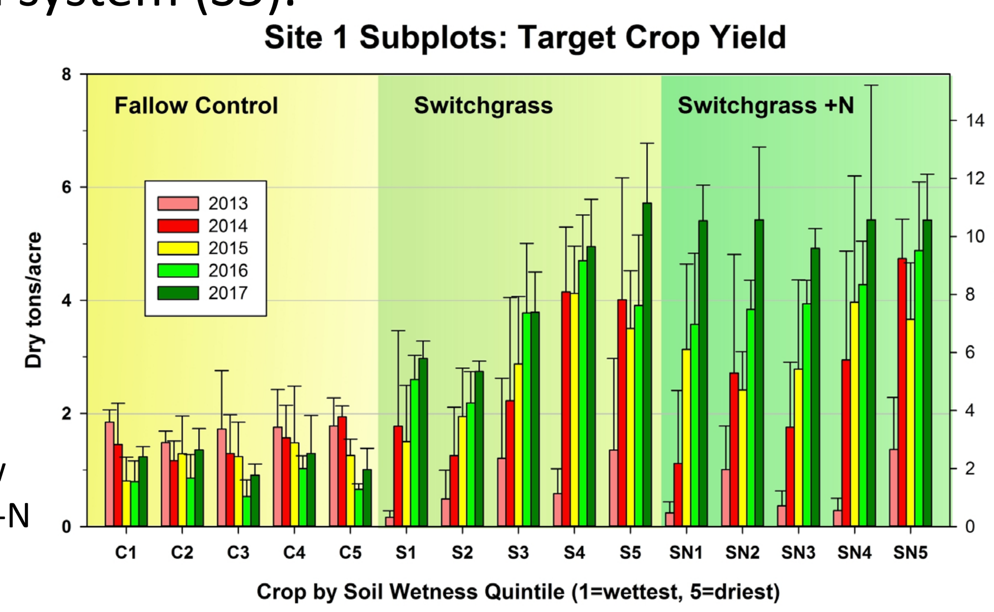
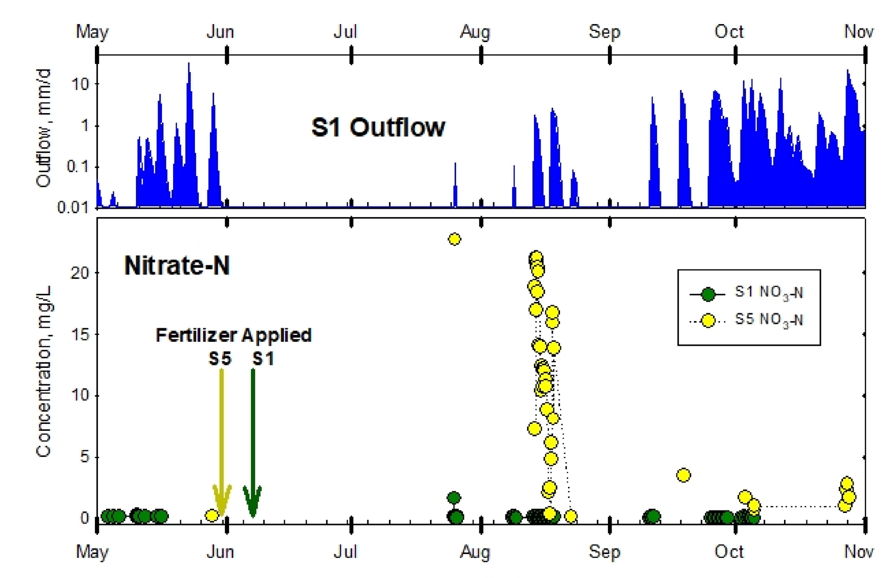


Fig 8. Site 1 SWG & control yields across 5 years by soil wet-ness quintile.

Fig 9. (below) Site 1 weir flow outflow & NO_3-N concentrations



For Site 2, consistent & positive yield increases were realized across 7 years. By 2018, 25 & 67% yield increases were measured in the high & low N fertilizer treatments, respectively.

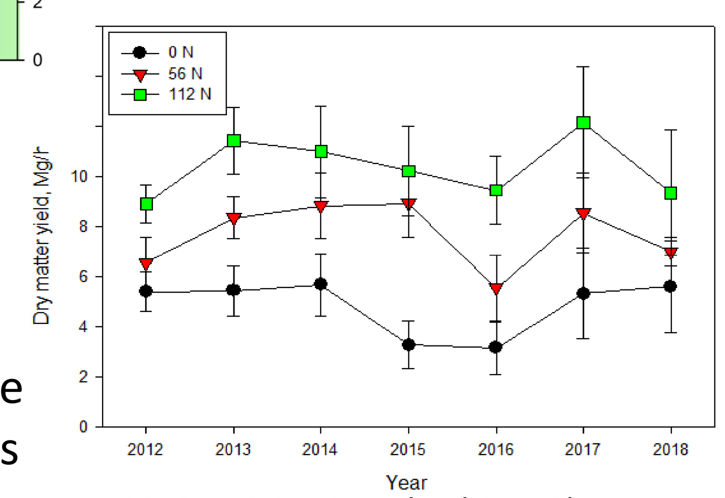


Fig 10. Site 2 SWG trial cultivar Shawnee with 3 N levels with yields across 7 years.

Future research using remote sensing

Willow trials imaged with a small unmanned aerial system (sUAS) equipped with RedEdge & RGB sensors began in 2018. Images are processed in specialized software and vegetation indices are developed in QGIS. Indices are then correlated ground-based foliar N content and plant growth. With validation, these tools should allow for rapid assessments of the nutrient status of trials and commercial production scenarios.

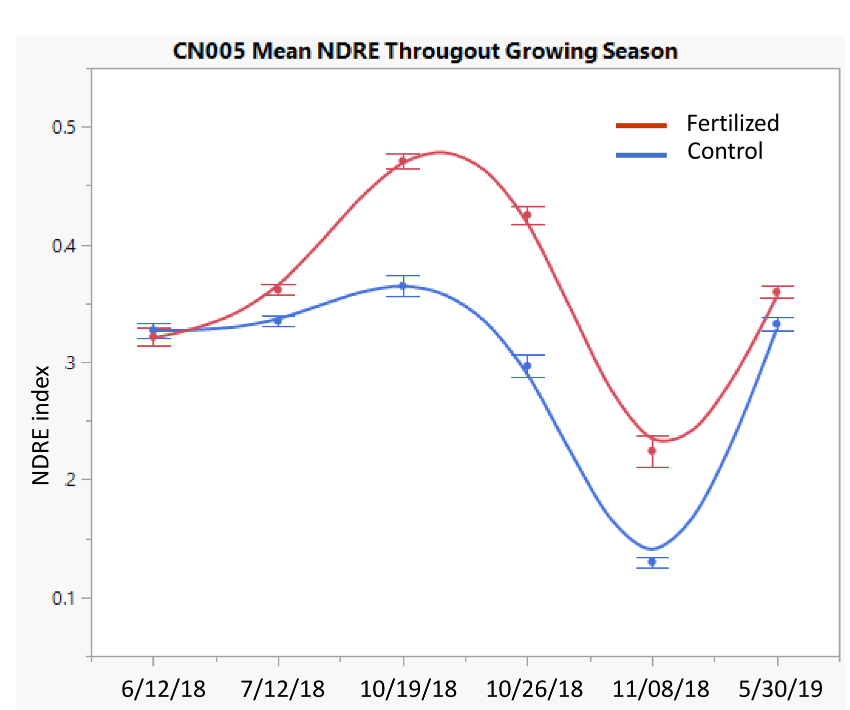


Fig 11. Normalized Difference Red Edge (NDRE) vegetation index across 6 dates in a fertilizer trial in Geneva, NY

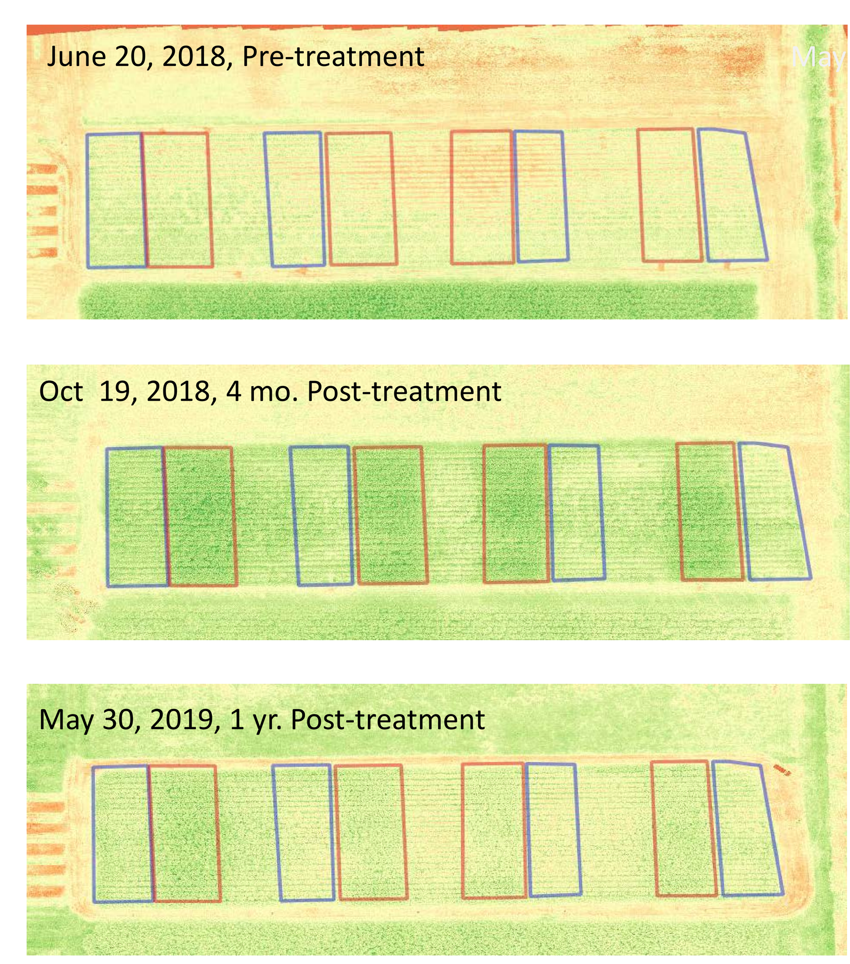


Fig 12. Time series of NDRE vegetation index of fertilized and control treatments in a polyculture willow trial

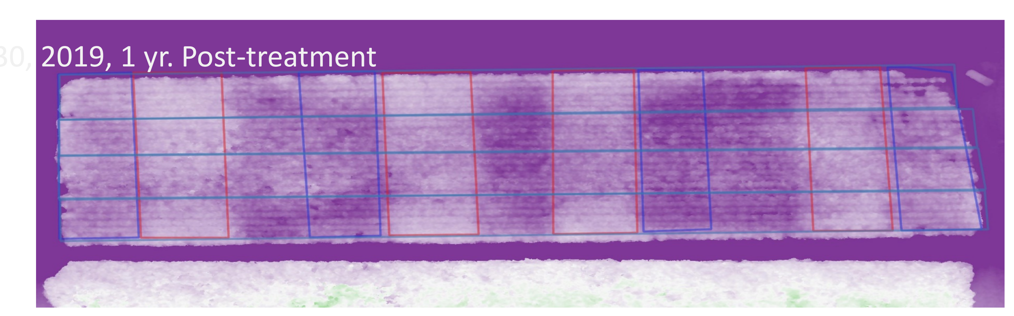


Fig 13. Canopy height model derived from UAS imagery.

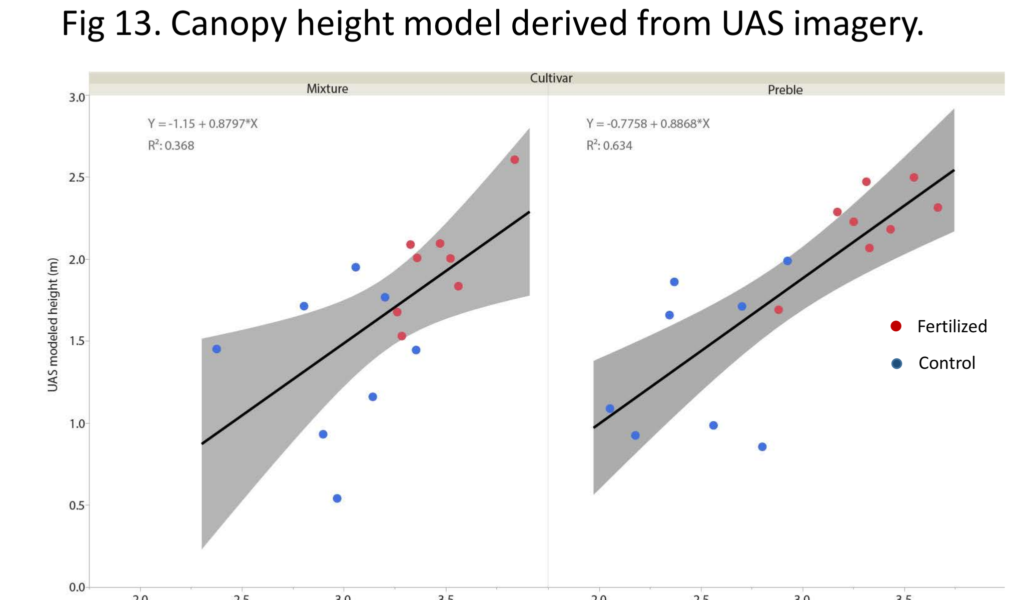


Fig 14. Ground-based willow heights vs. sUAS image derived canopy height model estimates

Acknowledgements

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SunGrant Initiative

USDA United States Department of Agriculture National Institute of Food and Agriculture