# The Utility of Tallgrass Prairie Reconstructions as Bioenergy Feedstocks

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# THE UTILITY OF TALLGRASS PRAIRIE RECONSTRUCTIONS AS BIOENERGY FEEDSTOCKS

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## Abstract

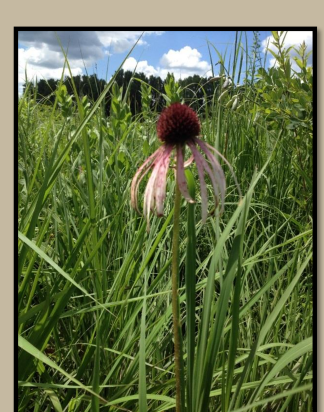
Two of the more pressing, yet opposing, ecological challenges that we face at the global-scale are the loss of biodiversity and rising demand for energy. Many ecological experiments have shown the importance of biodiversity for ecosystem services and functions, but the simultaneous demand for energy has led to greater conversion of natural landscapes to low-diversity energy production crops (e.g., corn for ethanol). One potential solution to these seemingly opposing issues would be to grow diverse native vegetation for bioenergy. Native tallgrass prairie produces large amounts of aboveground biomass but also provides great habitat for wildlife and other ecosystem services. In this study, we compared the productivity, yearly biomass variability, and invasion resistance of four potential bioenergy feedstocks with contrasting diversity: 1 species - a switchgrass monoculture; 5 species - a mix of C4 grasses; 16 species - a mix of grasses, forbs and legumes; and 32 species - a mix of grasses, forbs, and legumes. Each diversity treatment was replicated four times on three different soil types (clay, loam, and sand soil) for a total of 48 plots (0.33-0.56ha each). We compared productivity by harvesting all plant material to ground level in 10 randomly placed 0.3m² quadrats per plot. Weed biomass was compared using basal area sampling of 10 randomly placed 0.1m² quadrats per plot. Across soil types, the 1, 16 and 32 treatments produced the same amount of aboveground biomass over the 5-yr study, with the 1 treatment producing significantly more biomass than the 5 treatment. Despite the overall similarity between the 1, 16, and 32 treatments, the relative ranking of the four diversity treatments varied depending on soil type. Weed biomass was higher in low-diversity treatments than high-diversity treatments. Year-to-year variation in productivity did not differ between treatments. As we attempt to meet the bioenergy goals mandated by the Energy Policy Act (2005) and Energy Independence and Security Act (2007), our results indicate that diverse mixtures of native tallgrass prairie plants are a reliable source of bioenergy and also provide the ecosystem benefits associated with increased diversity. However, variation in the relative productivity of the four diversity mixtures on different soil types suggests that seed mixes of bioenergy crops must be tailored to their specific site for maximum productivity and stand success.

## Background

- Renewable energy fuel sources are needed to replace diminishing, non-renewable supplies
- Using native perennial vegetation as a bioenergy feedstock could be part of the solution to this growing energy demand[1]
- High-diversity mixtures produce more biomass than low-diversity mixtures in native plantings grown for bioenergy[1] and this relationship becomes more pronounced with time[2]
- Diverse mixtures also tend to be more resistant to weeds than low-diversity mixtures, which helps maintain their higher productivity[3]

- **Hypotheses**:
  1. Treatments with greater diversity will produce more aboveground biomass
  2. Treatments with greater diversity will be more resistant to weedy invasion
  3. Treatments with greater diversity will display less yearly variation in productivity

## Methods



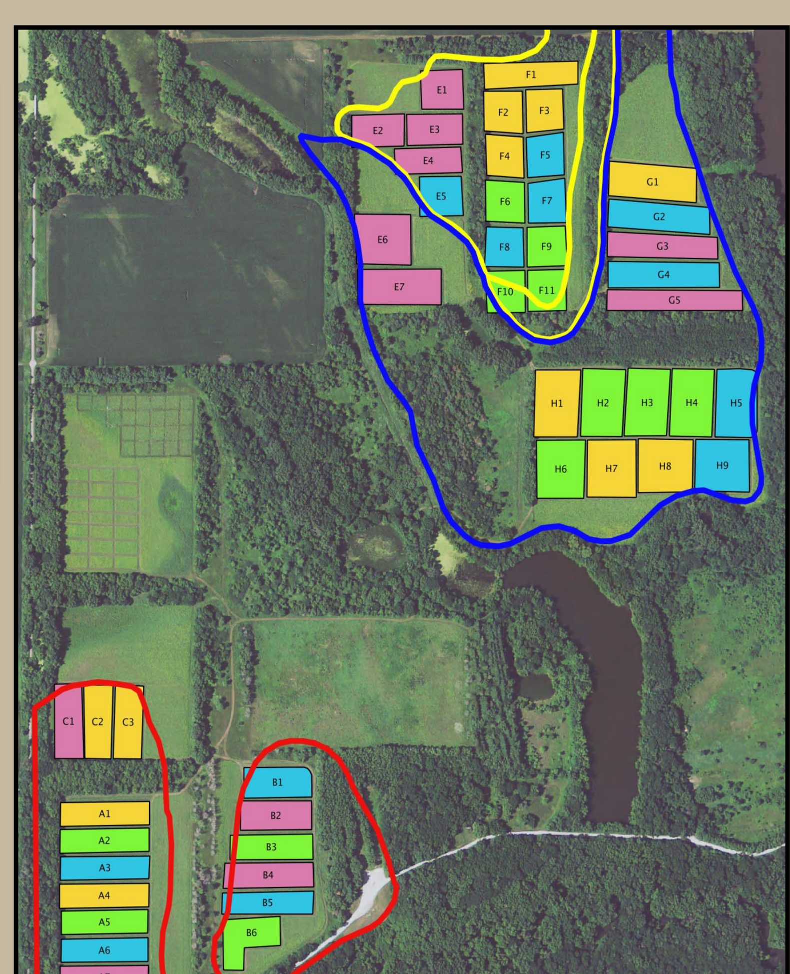



Figure 1: Map of the study site in the CRNA, Black Hawk County, IA. Plots are coded using a letter/number combination where the letter indicates the field and the number represents plot within that field (numbered sequentially from north to south).

- Experimental Design: 4 replicate plots (0.33-0.56ha each) of 4 diversity treatments on 3 soil types

  Diversity Treatments
  - 1 = switchgrass monoculture
  - 5 = warm season C4 grasses
  - 16 = grasses, forbs, legumes
  - 32 = grasses, forbs, legumes, sedges

  Soil Types
  - Flagler sandy loam
  - Waukee loam
  - Spillville-Coland Alluvial Complex

- We measured species composition to see yearly and soil differences by sampling basal area in 0.1 m² quadrats along two 10m transects per plot (July 1-24)
- We sampled end of season biomass from ten 0.3m² quadrats (August 25-September 19)
  - Sorted into functional groups: warm season grasses, cool season graminoids, legumes, forbs, and weeds
  - Samples were dried to constant mass and weighed
- Above ground biomass, weed biomass, and bare ground were analyzed using repeated measures ANOVA
- Species composition data was analyzed using a nonparametric PERMANOVA

## Results

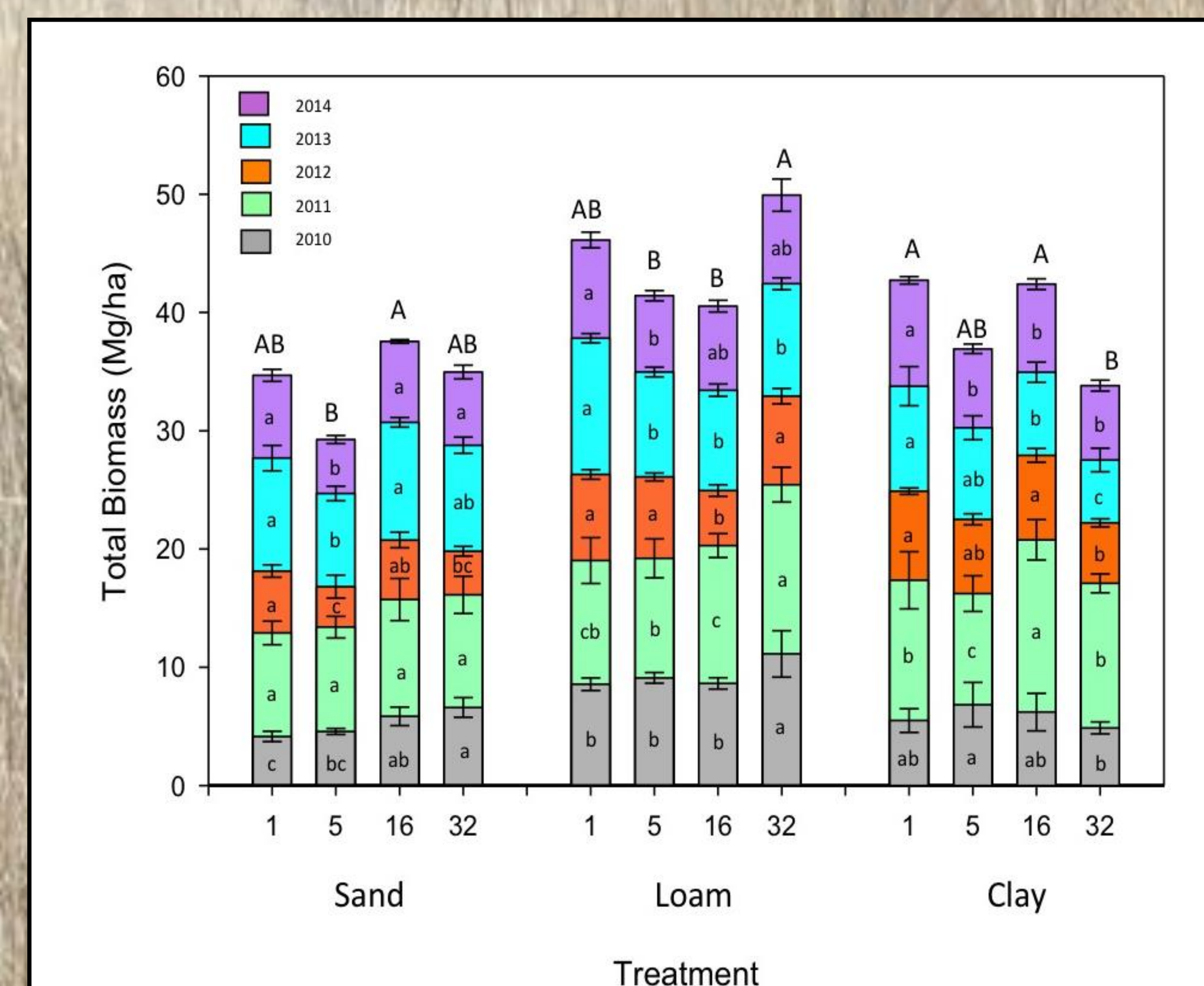



Figure 2: Cumulative productivity of each soil × diversity treatment combination. Totals are the sum of annual averages for each treatment combination. Uppercase letters indicate significant differences between treatments within a soil type and lower case letters indicate significant differences between treatments in a given year×soil combination. Annual productivity values are presented as means +/- 1SE

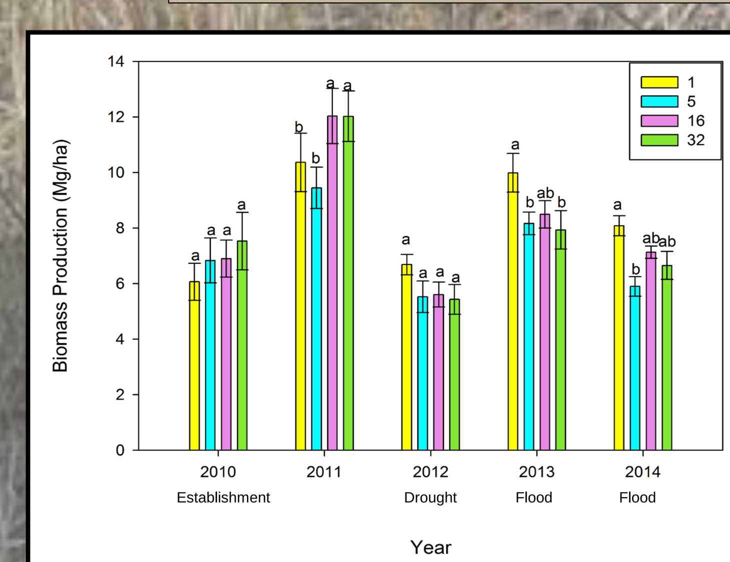



Figure 3: Annual productivity for each treatment, across soil types. Data presented are means of 12 treatment plots (+/- 1SE). Different letters indicate significant differences between treatments within a year.

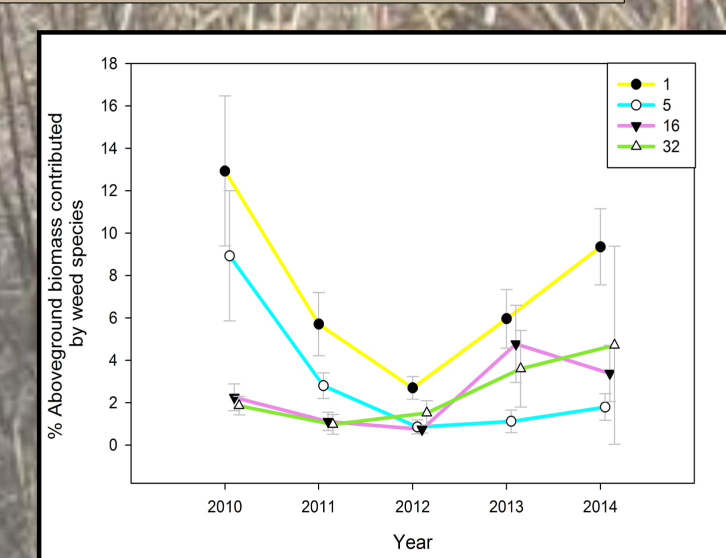



Figure 4: Annual average (+/- 1SE) % aboveground biomass that is contributed by weed species.

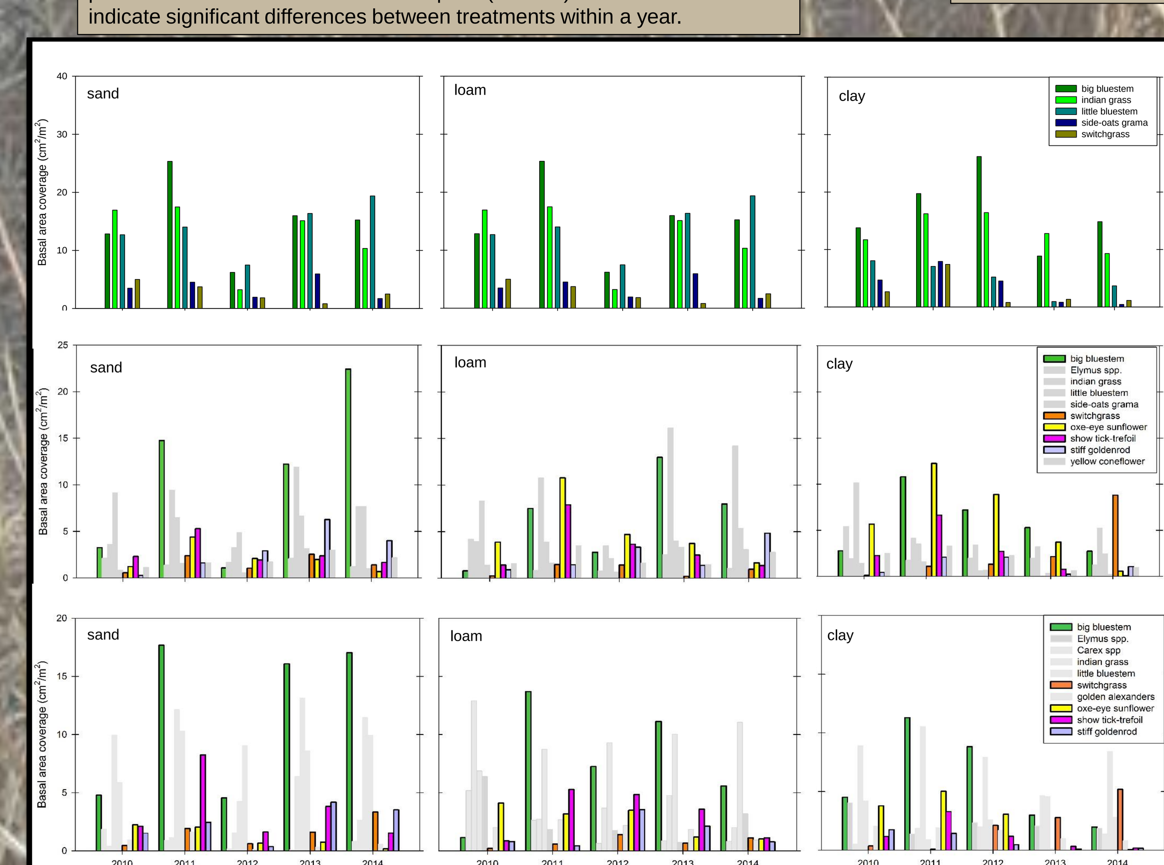


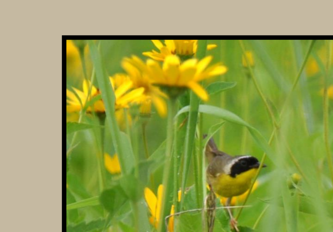

Figure 5: Change in species composition in the 5 (a – c), 16 (d –f), and 32 (g – i) treatments during the 5-yr study. All species with coverage $> 2$ cm²/m² in any soil × year combination are shown.

- Overall, the 1 treatment was more productive than the 5 treatment, but not more than the 16 or 32 treatments (Fig 2, 3)
- However the most productive treatment did vary between year and soil type
- Treatments with higher diversity showed higher yearly variation in productivity, though this trend was non-significant
- Weed biomass decreased with time, until flooding occurred in 2013 (Fig 4)
- The 1 treatment had more weed biomass than the other three diversity treatments
- % bare ground was highest in the 1 treatment in all years except 2014 where it was highest in the 1 and 5 treatment
- Species composition changed significantly over the 5 year study, and it also varied by soil type (Fig 5)

## Conclusions

- I found the high diversity treatments (16 and 32) produced as much biomass as switchgrass monocultures suggesting that they are viable bioenergy feedstocks
- Differences in the relative ranking of the diversity treatments between soil types suggests that practioners need to optimize their seed mixes to maximize productivity
- The 5 treatment produces significantly less biomass than the 1 treatment, this may be caused by the nitrogen uptake efficiency of big bluestem, little bluestem, and Indian grass,[4] which could lead to nutrient depletion and stunted growth
- The 16 and 32 treatment provide more ecosystem services, such as carbon sequestration and wildlife habitat [5,6], than the 1 treatment, but there is an additional cost to plant these mixtures.
- Consequently, in areas that experience frequent disturbance such as flooding the 1 and 16 treatment are better candidates than the 32 treatment.
- Weed biomass was probably highest in the 1 treatment because this treatment had high percentages of bare ground and more nutrient availability than the 5 treatment. This effect could limit long-term productivity as exotic diversity does not have the same positive effect on productivity as native diversity.[3]
- Changes in species composition influenced treatment productivity
  - Big bluestem and Indian grass both have high coverages in the 16 and 32 treatment. Their decrease on the clay soil after the 2013 and 2014 flooding may have led to the decrease in productivity of these two treatments
  - Oxe-eye sunflower and showy ticktrefoil have decreased in coverage since 2011 and may be why overall biomass levels have declined since 2011

## Future Directions



- Carbon sequestration of the different treatments at the site.
- Analysis of soil nutrients under each treatment
- Comparison of bee population at our site compared to organic and conventional farms

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