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Assessing Productivity in Prairie Biomass Feedstocks with Different Levels of Diversity

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Abstract

High-diversity mixtures of tallgrass prairie vegetation provide many ecosystem services and could be effective biomass feedstocks for marginal farmland in Iowa. In this study, we measured productivity in four prairie biomass feedstocks with different diversity: 1, 5, 16, and 32 species. Each feedstock was replicated four times on three soil types (48 research plots, 0.33 – 0.56 ha each). For the past seven years, we have monitored productivity in these feedstocks by harvesting tissue from randomly selected quadrats. In addition to continuing the productivity survey, we examined the efficacy of remote sensing (NDVI) and leaf area index (LAI) imaging for estimating productivity in 2015 and 2016. Across soil types, the 1-, 16-, and 32-species feedstocks are equally productive and outperform the 5-species feedstock. Regions with high LAI correspond with regions of high productivity at the plot- and quadrat-level. NDVI does not correspond with productivity at the plot- or quadrat-level. The low predictive power of our regressions suggests that neither metric is a suitable replacement for annual biomass harvest.

Background

- Rising global energy use and decreasing fossil fuels have increased demand for renewable energy.
- High-diversity mixtures of native prairie vegetation could be ideal biomass feedstocks for marginal farmland in the Midwestern US [1].
- These mixtures should require less fertilizer than many of the traditional monoculture feedstocks used for bioenergy (e.g., switchgrass, corn-ethanol) because of superior niche differentiation and the inclusion of legumes for enriching soil nitrogen [2].
- Assessing productivity typically requires annual biomass harvest of plots and/or randomly selected quadrats: a time consuming and laborious process.
- Remote-sensing has been used to assess productivity in other systems [e.g., 3] and could be an effective technique for expediting annual productivity surveys in prairie biomass feedstocks.

The goal of this study was to assess whether remote sensing and/or leaf area indices effectively estimate productivity in prairie biomass feedstocks with different diversity.

Methods

Study Site: This research was conducted at Cedar River Ecological Research Site (CRERS) in Black Hawk County, Iowa. The site was established in 2009 by the Tallgrass Prairie Center to study the ecosystem services provided by prairie biomass feedstocks. There are four feedstocks at CRERS with different levels of diversity: 1-species (a *Panicum virgatum* [switchgrass] monoculture), 5-species (a mixture of C_4 grasses), 16-species (a mixture of C_3 and C_4 grasses, legumes, and forbs), and 32-species (a mixture of C_3 and C_4 grasses, legumes, forbs, and sedges). Each feedstock was replicated four times on the three different soil types at the site (Fig. 1).

Biomass Harvest: We harvested all standing tissue from ten randomly selected $0.3m^2$ quadrats at the end of the growing season (September-October). The tissue was sorted into functional groups: C_4- grasses, C_3-grasses, legumes, forbs, and weeds. Samples were dried to constant mass and weighed. This protocol was replicated every year of the study (2010-2016).

Remote-Sensing: We imaged the site on July 21, 2016. We produced an NDVI map of the plots on the Flagler sandy loam soil only. We collected GPS coordinates for each harvested quadrat and quantified the NDVI value for that position. NDVI values were regressed on productivity at the quadrat-level, within and across feedstocks.

Leaf Area Indices (LAI): During biomass harvest, we measured LAI for each harvested quadrat (n=480) using the CI-110 Plant Canopy Imager. Images were processed in the lab to quantify LAI. LAI values were regressed on productivity at the quadrat-level, within and across feedstocks. This analysis was performed in 2015 and 2016.

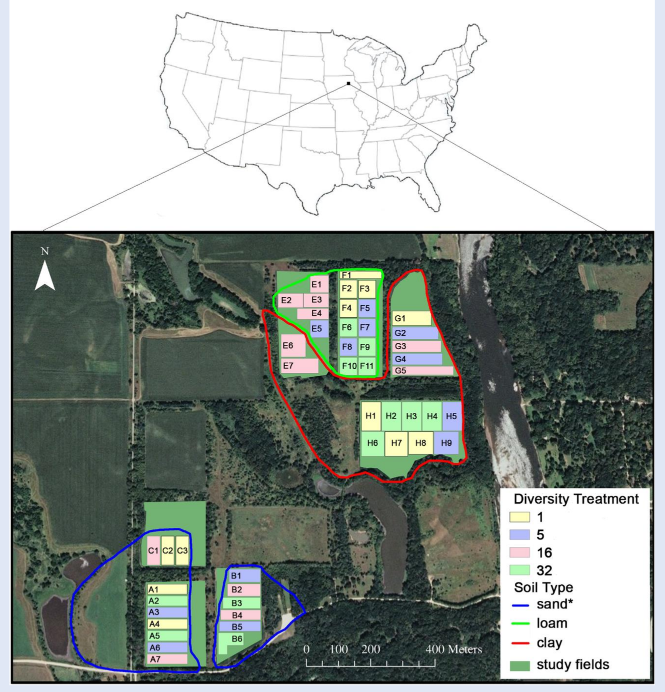


Figure 1. Map of study site.

Biomass harvest selfie. .

Results

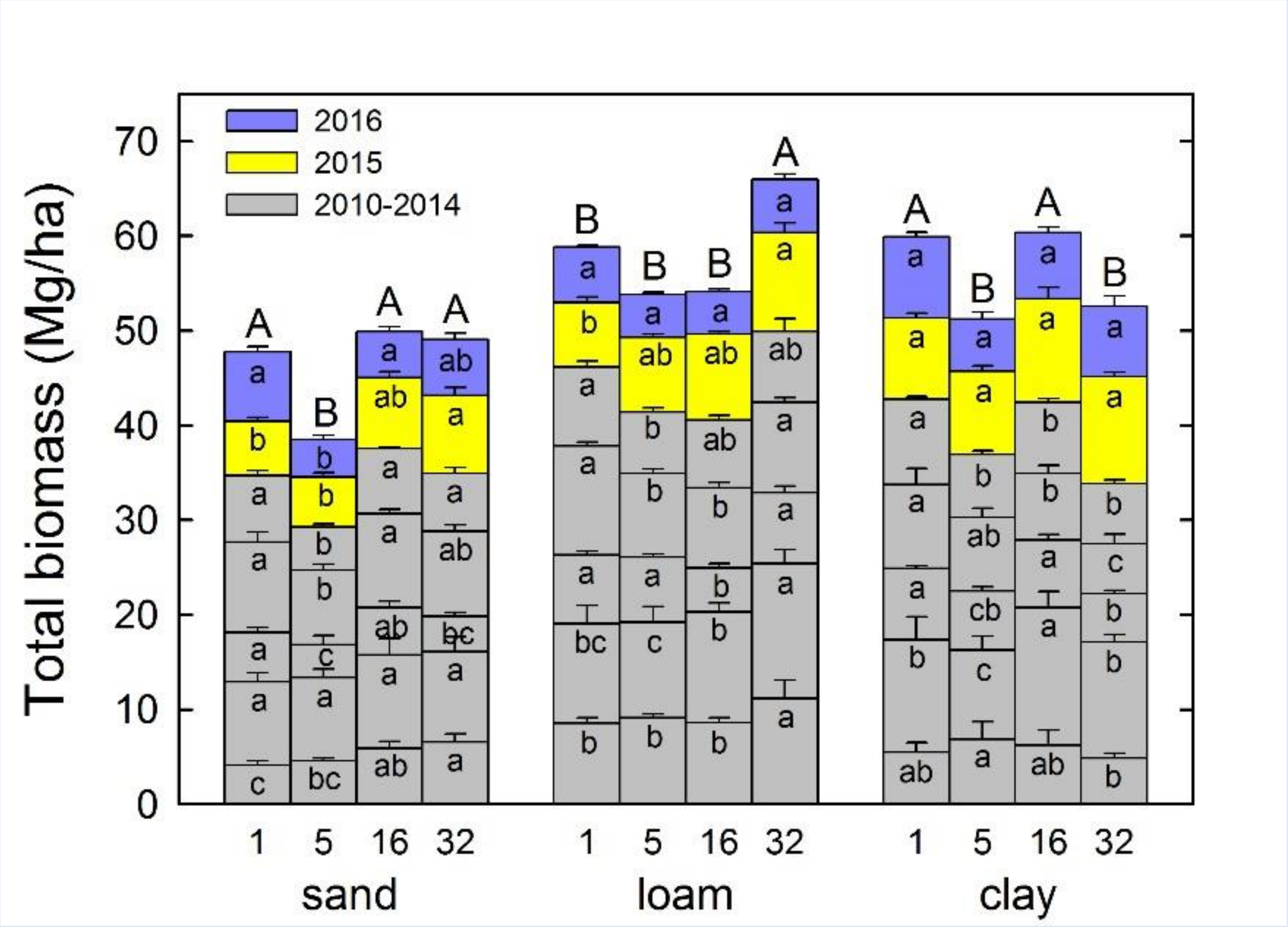
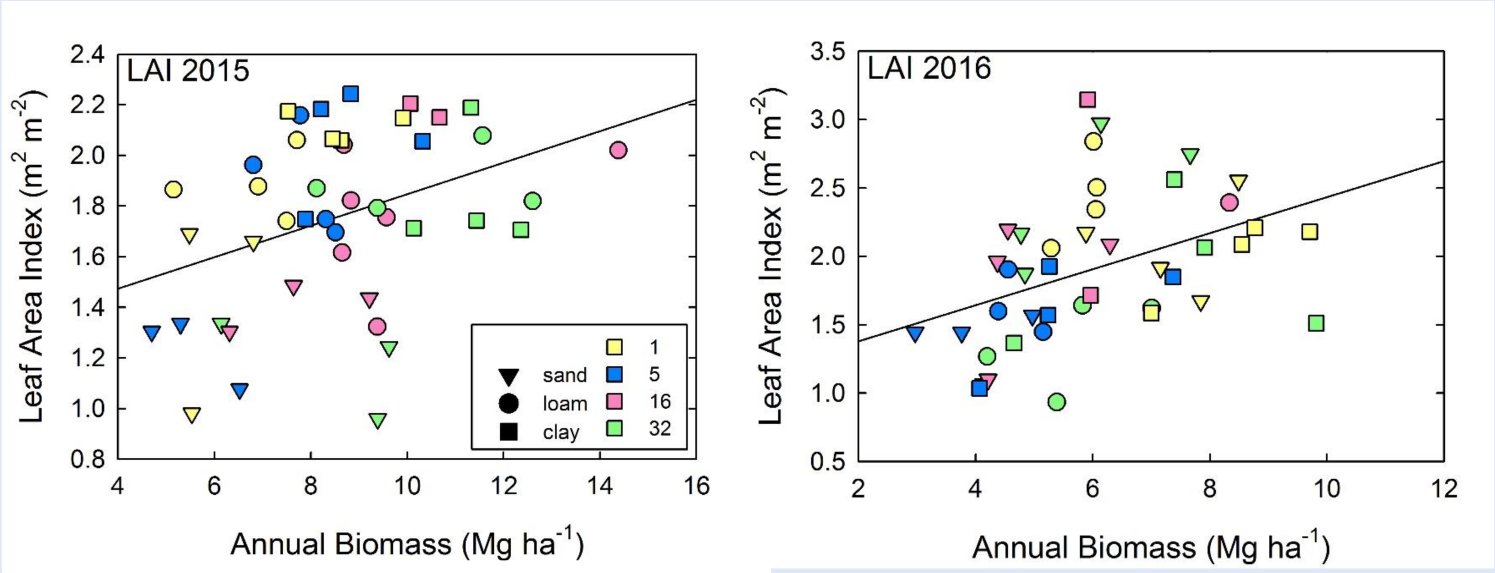


Figure 2. Cumulative productivity of each soil × feedstock treatment. Totals are the sum of annual averages for each treatment combination. Uppercase letters indicate significant differences between feedstocks within a soil type and lower case letters indicate significant differences between feedstocks in a given year × soil combination. Annual productivity values are presented as means +/- 1SE. Data in gray, previously published in [4].



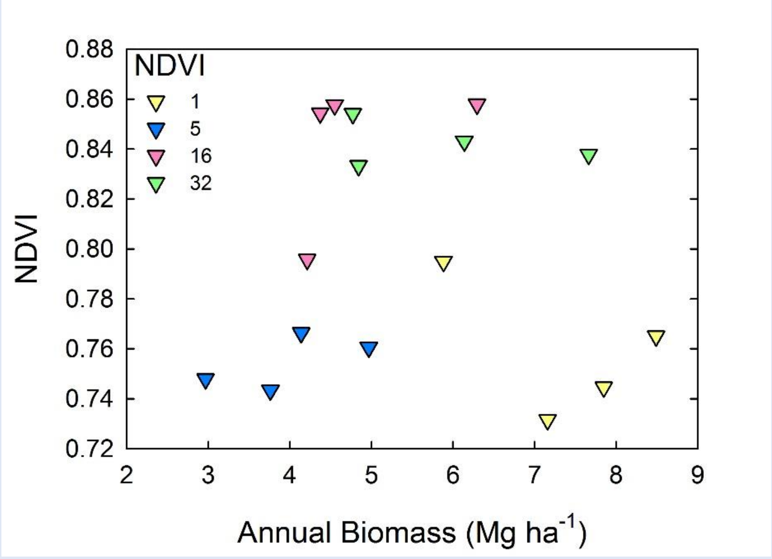


Figure 3. Linear regressions of annual productivity on leaf area index and NDVI values. Data presented are plot-level averages of 10 quadrats. Feedstock and soil type are indicated by color and shape respectively.

Variation in Productivity

- **Soil Effect:** loam > clay > sand
- **Feedstock Effect:** 5-species feedstock was least productive across soil types
- **Soil × Feedstock Effect:** Variation in productivity between feedstocks differed between soil types. For, example:
  - 16 > 32 (clay) vs 32 > 16 (loam)

Estimating Productivity

- **LAI:** Higher LAI values corresponded with higher productivity values at the plot- (Fig. 3) and quadrat- (data not shown) level in both 2015 and 2016.
- **NDVI:** NDVI values did not correspond with productivity at the plot- (Fig. 3) or quadrat- (data not shown) level in 2016.

Interpretation

- Differences in productivity between soil types were consistent with corn suitability ratings.
- Low productivity in the 5-species feedstock could be due to higher soil N depletion. Switchgrass plants in this feedstock display lower leaf N, chlorophyll concentration, and photosynthetic rate than plants in the other three feedstocks [5].
- The soil × feedstock effect indicates that soil type should be considered when choosing a feedstock for biomass production on marginal farmland.
- Differences in soil type could be driving the significant relationship between LAI and productivity. This could explain why no pattern was detected between NDVI and productivity.
- Future analyses with other UAV-measured spectral parameters better estimate productivity (e.g., thermal data, MSAVI2)
- Regardless of significance, the weak predictive power of our regressions suggests that neither technique is a suitable substitute for annual biomass harvest.

Acknowledgments / References

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1) Tilman, Hill, and Lehman (2006) Science 314:1598-1600.
2) Fargione and Tilman (2006) Functional Ecology 20:533-540.
3) Wang et al. (2016) Remote Sensing 8:214-234.
4) Abernathy et al. (2016) Global Change Biology Bioenergy 8: 1082-1092.
5) Sherrard et al. (submitted) Biomass and Bioenergy