Comparison of Carbon Assimilation Capacity by Restored Prairie with Natural Plant Communities

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Introduction:

Photosynthesis is the process used by plants to convert carbon dioxide and water into carbohydrate and oxygen:

$$6H_20 + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2.$$

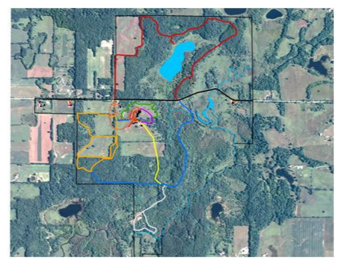
Roughly half of the carbon dioxide assimilated through the process of photosynthesis is sequestered in wood products, or more importantly, in soils as soil organic carbon where it can be stored for long time periods while enhancing soil quality. In effect, plants could be used as a tool to harvest CO_2 from the atmosphere, countering emissions from combustion.

Objectives:

- Compare light use efficiency relationships of the various species that predominate Peirce Cedar Creek Institute (PCCI)
- Compare the potential of plant communities to fix carbon
- Empirically estimate the quantity of carbon assimilated by the property at large

Methods:

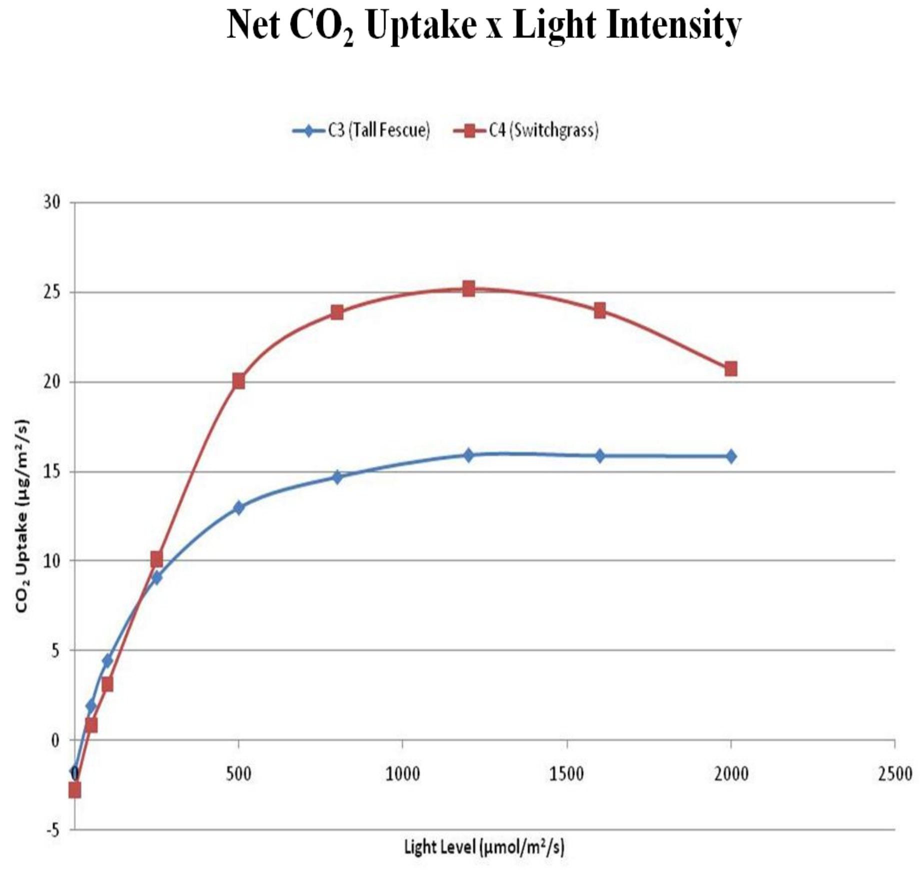
- Map surface area and determine canopy composition of seven plant community types in replicate locations using GIS.



- Calculate leaf area index (LAI) for each plant community by contrasting leaves against the sky in hemispherical photographs.

- Determine Solar radiation levels for each hour of the growing season, and at the incident and successive leaf canopy layers using a fixed and portable quantum sensor.

- Measure light use efficiency relationships of predominate species using a LI-COR 6400 XTR.



Results:

Species	Fourth Order Line Equation	R² Value
Tall Fescue (C3)	$y = -8E\text{-}12x^4 + 4E\text{-}08x^3 - 7E\text{-}05x^2 + 0.0551x - 0.9592$	0.9954
Switchgrass (C4)	$y = -4E\text{-}12x^4 + 2E\text{-}08x^3 - 6E\text{-}05x^2 + 0.0709x - 2.8505$	0.9989
Goldenrod	$y = -8E\text{-}12x^4 + 4E\text{-}08x^3 - 7E\text{-}05x^2 + 0.0571x - 1.7536$	0.9978
Sedge	$y = -4E\text{-}12x^4 + 2E\text{-}08x^3 - 4E\text{-}05x^2 + 0.0343x - 0.8526$	0.9959
Tamarack	$y = -8E\text{-}12x^4 + 4E\text{-}08x^3 - 7E\text{-}05x^2 + 0.0613x - 1.9576$	0.9987
White Cedar	$y = -1E\text{-}11x^4 + 5E\text{-}08x^3 - 7E\text{-}05x^2 + 0.046x - 0.2658$	0.9722
Autumn Olive	$y = -5E\text{-}12x^4 + 3E\text{-}08x^3 - 4E\text{-}05x^2 + 0.0362x - 1.4827$	0.9976
White Ash	$y = -8E\text{-}12x^4 + 4E\text{-}08x^3 - 7E\text{-}05x^2 + 0.0502x - 1.1196$	0.9968
Black Cherry	$y = -1E\text{-}11x^4 + 5E\text{-}08x^3 - 8E\text{-}05x^2 + 0.0605x - 1.5121$	0.9968
American Elm	$y = -2E\text{-}12x^4 + 1E\text{-}08x^3 - 3E\text{-}05x^2 + 0.0345x - 1.054$	0.9981
Red Oak	$y = -6E\text{-}12x^4 + 3E\text{-}08x^3 - 6E\text{-}05x^2 + 0.0471x - 1.5247$	0.9993
Sugar Maple	$y = -7E\text{-}12x^4 + 3E\text{-}08x^3 - 6E\text{-}05x^2 + 0.0427x - 1.2256$	0.9948
Beech	$y = -6E\text{-}12x^4 + 3E\text{-}08x^3 - 4E\text{-}05x^2 + 0.0274x + 0.2824$	0.9698

Fig 1. LUE curves of 13 predominant plant species at PCCI

- These Mathematical line equations depict the relationship between light and photosynthesis rate for each plant species. If X is known (solar radiation level), then Y can be solved for (apparent photosynthesis rate in µg $CO_2/m^2/s$).
- LUE curves are significantly different among species (P>0.05).

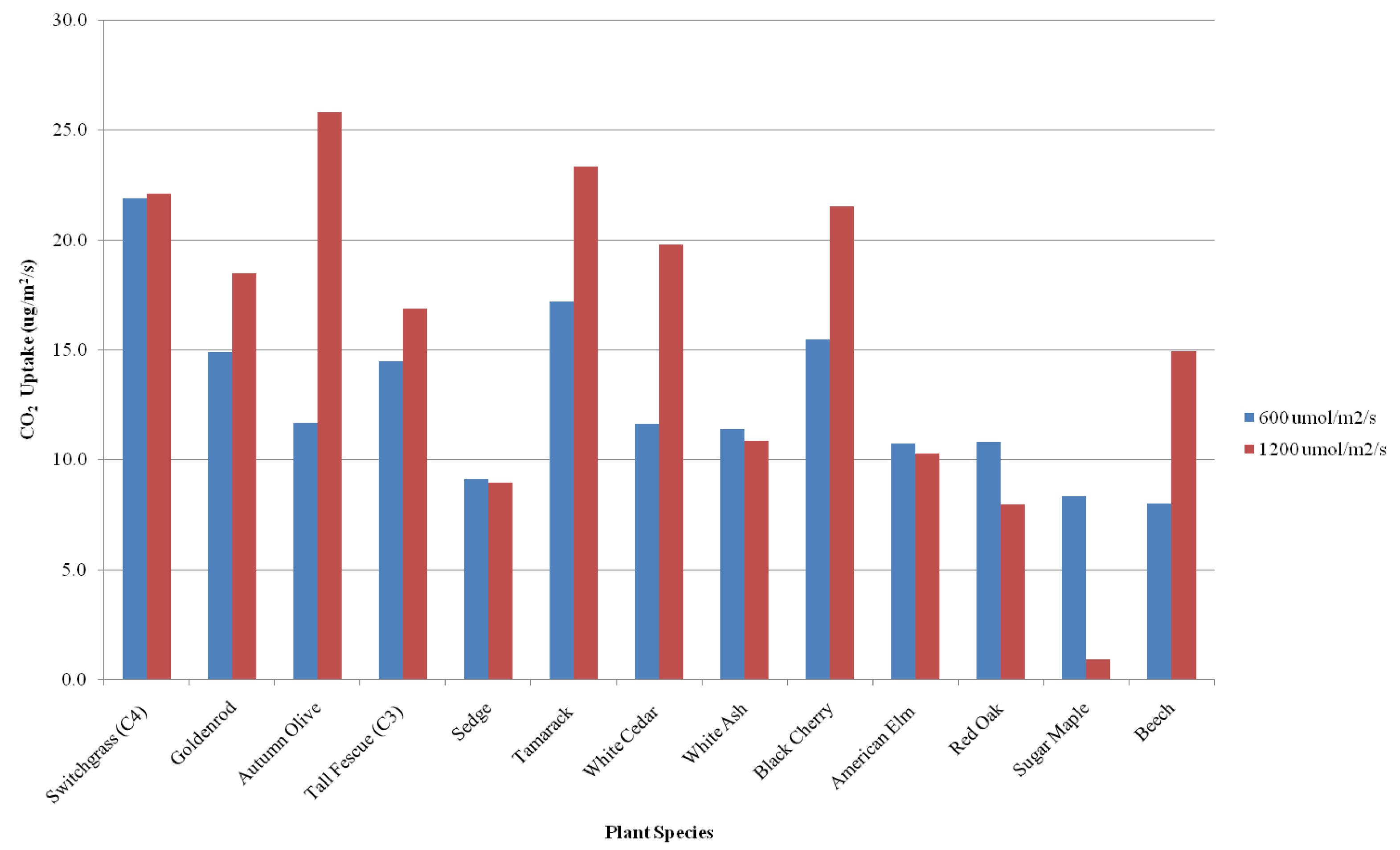


Fig. 2 Average CO_2 assimilation rate of predominate or representative species at medium and high light levels

- C4 prairie grasses and prairie forbs produced particularly high CO_2 uptake rates at both medium and high light levels.
- Autumn Olive, a woody invasive shrub, produced among the highest CO_2 uptake rate at high light intensities – consistent with observations of its invasive habit in abandoned farm fields or along road sides.

Plant community	Prairie	Field	Sedge Fen	Mixed Swamp	Shrubby Field	Young Forest	Mature Forest
Total Percent	77	71	57	60	85	66	73

Fig. 3 Percent canopy accounted for by predominate or representative plant species

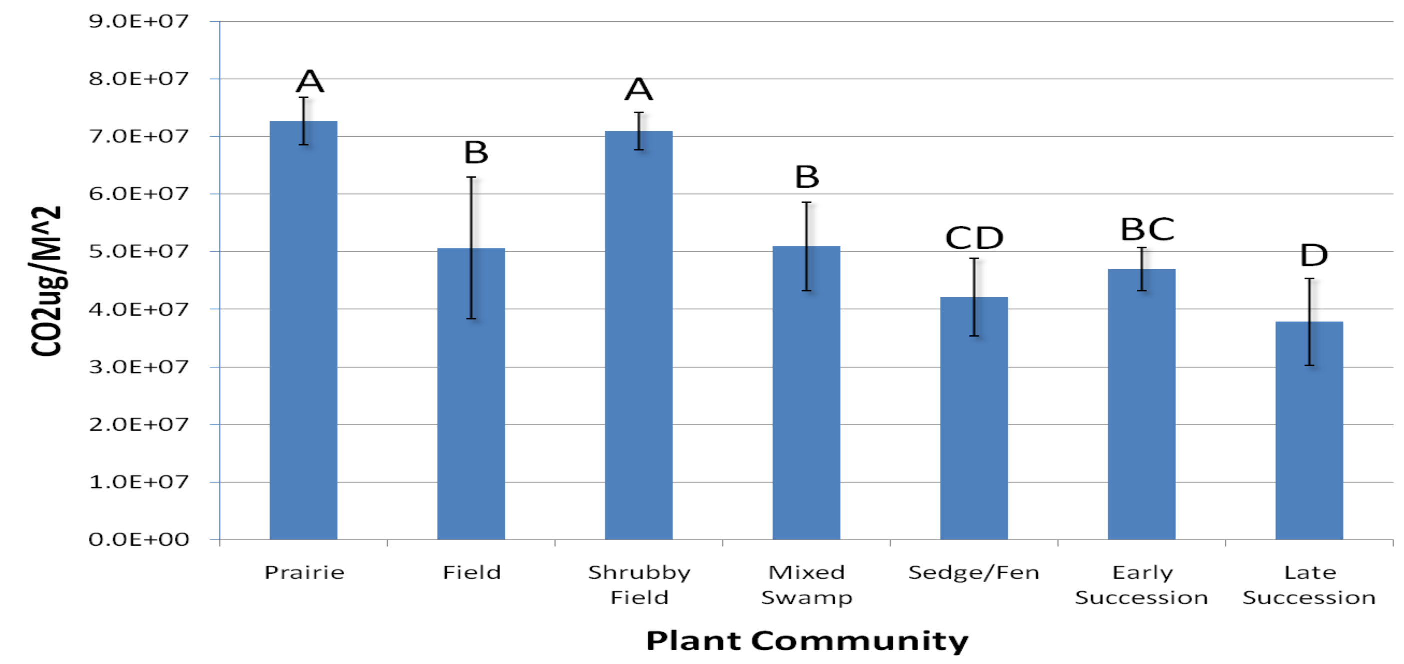


Fig. 4 Plant community CO_2 assimilation per m^2

- Significant differences existed for CO_2 assimilation rate among plant communities.
- Prairie and shrubby fields assimilate CO_2 at a rate substantially faster than that of other plant communities.
- Late succession forest exhibited lower GPP than early succession forest.

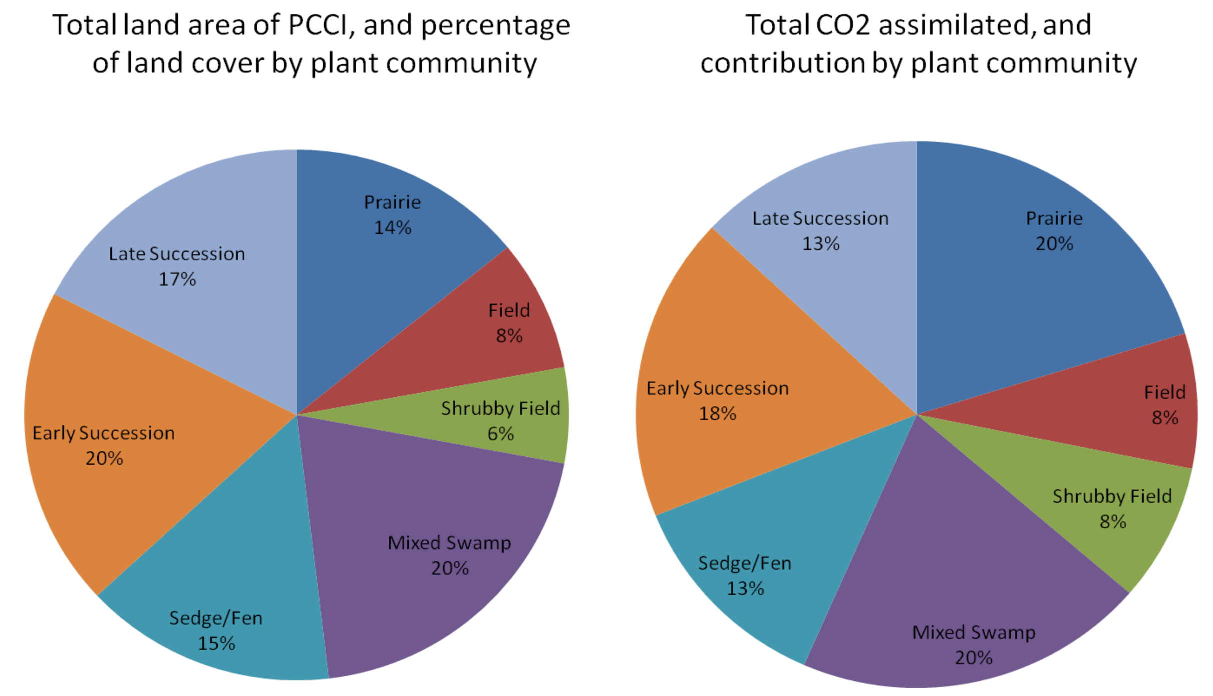


Fig. 5 Plant community affect of CO_2 assimilation rate

While restored prairie only represents 14% of the PCCI land area, it represents 20% of the assimilated CO_2 contribution. Conversely, the late succession forest area of 17% represents 13% of the total assimilated CO_2 contribution. If PCCI's goal were to optimize CO_2 contribution of natural areas, it would be beneficial to:

- restore overgrown fields as tall grass prairie
- convert autumn olive infested shrubby fields to prairie
- practice selective tree harvest to maintain early succession forest

Total Assimilated Carbon at PCCI between April 15 and August 9 = 132 MT

Conclusions:

- Significant differences in carbon assimilation rate among species heavily impact the total quantity of carbon assimilated by its respective plant community
- Restored prairie and brushy fields were significant contributors of assimilated carbon.
- When appropriate and non-destructive to natural ecosystems, we encourage efforts to restore prairie ecosystems and direct selective tree harvest to maximize carbon storage.

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