Carbon storage as a function of successional stage in forests of the Upper Midwest, USA.

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ABSTRACT

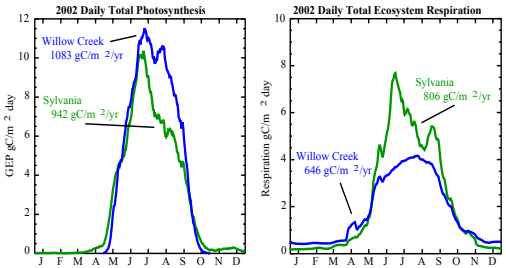
Understanding how net primary productivity (NPP) and carbon storage change in forests over time is essential to accurately predict NPP globally and the potential of forests to store carbon in the future. We are examining how processes controlling carbon acquisition and loss change over the course of succession by measuring and comparing net ecosystem exchange (NEE) of CO_2 at two AmeriFlux sites in the upper Midwest: Willow Creek, a mid-successional northern hardwood forest in northern WI, and Sylvania, a late-successional undisturbed old-growth hemlock-northern hardwood forest in the upper peninsula of Michigan. Both sites are located in the Upper Wisconsin/Michigan Moraines ecosystem type and share the same climate, soil parent material, soil type, and presettlement vegetation type thereby making an ideal system for examining how processes controlling NEE change over the course of stand development. NEE of CO_2 is measured by the eddy-covariance/surface layer budget method. In 2002 both sites were net carbon sinks. Spring and summer of 2002 had abundant precipitation, average temperatures, and no insect outbreaks resulting in favorable growing season conditions. The annual NEE for Sylvania of -137 gC m^{-2} yr^{-1} was lower than at its paired mid-successional site, Willow Creek, WI, USA (-438 gC m^{-2} yr^{-1}). Sylvania NEE in 2002 was also less than reported NEE for other old-growth sites in the AmeriFlux Network (e.g. Metolius, OR, –266-324 gC m^{-2} yr^{-1}; Howland, ME, –210 gC m^{-2} yr^{-1}), but similar to another mature forest site within the same region (Pellston, MI, –167 gC m^{-2} yr^{-1}). Preliminary comparisons between the Sylvania and Willow Creek sites suggest that differences in respiration between the sites are greater than differences in gross primary productivity.

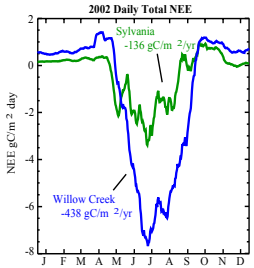
SITE DESCRIPTIONS

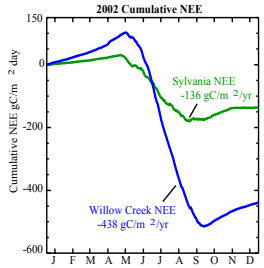
	Sylvania	Willow Creek
Location	46° 14' 31.26" N, 89° 20' 51.54" W	45° 48.47' N, 90° 04.72' W
Elevation	500 m above sea level	520 m above sea level
Annual Average		
Precipitation/Snowfall	77.1 / 249.7 cm	81.8 / 126.2 cm
Temperature	3.8°C	4.8°C
Stand age	Current year regeneration to > 350 years old	70 years
Species Composition	sugar maple (*Acer saccharum*), basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis*), eastern hemlock (*Tsuga canadensis*)	sugar maple (*Acer saccharum*), basswood (*Tilia americana*), white ash (*Fraxinus americana*)
Canopy height	26-27 m	24.3 m
Leaf Area Index (LAI)	3.92	4.18
Established	August 2001	May 1998

SYLVANIA

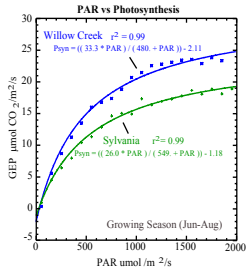
WILLOW CREEK

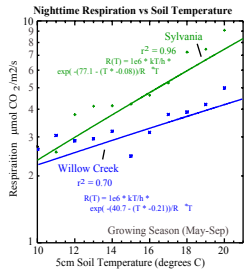






Daily and cumulative total net ecosystem exchange (NEE) of CO_2 in 2002 for Sylvania and Willow Creek as measured by eddy covariance flux towers. Sylvania annual NEE was -136 gC/m^2; Willow Creek annual NEE was -438 gC/m^2. Missing data are filled using fitted functions of soil temperature to respiration (R) and PAR to gross ecosystem production (GEP = R-NEE).





June-August 2002 half-hourly daytime gross ecosystem production (GEP=R-NEE) versus above-canopy PAR, and May-Sept 2002 half-hourly nighttime NEE versus 5cm soil temperature binned in 1 degree Celsius intervals for Sylvania and Willow Creek. Photosynthesis data were fit using a three-parameter big leaf model. Respiration data were fit using an Eyring activation barrier equation. Correlation coefficients are for the curves versus the binned GEP values. When computing daily photosynthesis and respiration, the curves are computed for every day using a 4-week moving window and a statistical goodness-of-fit test.

Daily total gross ecosystem production (GEP) of CO_2 (photosynthesis) and respiration in 2002 for Sylvania and Willow Creek. Photosynthesis is found by subtracting NEE from respiration. The latter is computed by fitting nighttime NEE to 5cm soil temperature. Annual GEP for Sylvania is 942 gC/m^2, whereas for Willow Creek, it is 1083 gC/m^2. Respiration is computed by fitting nighttime NEE to 5 cm soil temperature and extrapolating this fit to all times. Annual respiration for Sylvania was 806 gC/m^2, and 646 gC/m^2 Willow Creek. Respiration was 25% greater and photosynthesis was 13% lower at Sylvania than at Willow Creek in 2002.

FUTURE DIRECTIONS

Further comparisons between mid- and late-successional stands over additional growing seasons will allow us to determine the relative sensitivity of young versus old stands to interannual climate variability, thereby allowing us to make inferences regarding how stands at different stages of succession may respond to climate change.

Data from Willow Creek, Sylvania, and other sites in the Great Lakes will be synthesized to provide a regional approach for predicting carbon exchange as a function of forest age and management.

Net ecosystem productivity will be measured at additional sites and combined with USDA Forest Service Forest Inventory and Analysis data to expand our analysis from the intensively sampled tower sites to forested areas throughout the upper Midwest.

The Sylvania and Willow Creek flux towers are part of the AmeriFlux Network and the Chequamegon Ecosystem-Atmosphere Study (ChEAS) Research Coordination Network

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