

Changes to forest structure and productivity during an accelerated succession experiment in Northern Michigan

Kyle D. Maurer¹, Gil Bohrer¹, Peter S. Curtis², Chris S. Vogel³, Valeriy Y. Ivanov⁴, Brady S. Hardiman²

¹Ohio State University, Department of Civil and Environmental Engineering and Geodetic Science, ²Ohio State University, Department of Evolution, Ecology and Organismal Biology, ³University of Michigan Biological Station, ⁴University of Michigan, Department of Civil and Environmental Engineering

Abstract

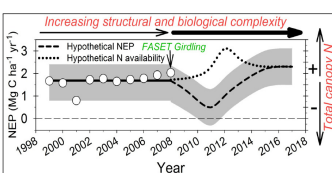
Mixed deciduous forests of the upper Midwest, USA are approaching an ecological threshold in which the colonizing species, aspen and birch, which continue to dominate the forest, are reaching maturity and beginning to die. Carbon uptake, which can be quantified as net ecosystem exchange (NEE), is predicted to decline in such maturing forests. The Forest Accelerated Succession Experiment (FASET), a large scale ecosystem manipulation, is testing this hypothesis. In 2008, all aspen and birch over 34 hectares of the FASET treatment plot were girdled to induce mortality. Aspen and birch mortality occurred within 2-3 years. This treatment simulates a natural disturbance that forces the forest into a later successional stage dominated by maples, oaks, and white pines. To quantify resulting changes in canopy structure we used ground-based and airborne LiDAR measurements of forest canopy structure. Canopy structural complexity and canopy height variability increased following onset of the treatment effect. Two micro-meteorology towers were used to observe changes inside the canopy and in the way the canopy interacts with the atmosphere. As the treatment begins to take effect, NEE rates in the treatment plot are declining relative to control plots. We hypothesize that this change in NEE can be attributed to the effect of the large scale disturbance that characterize this treatment. Continued measurements will determine whether NEE eventually recovers or even surpasses pre-treatment levels.

References:

- (1) Gough C.M. *et al.* 2008. *Agricultural Forest Meteorology*, **148**: 158-170.
- (2) Nave L.E. *et al.* 2011. *Journal of Geophysical Research-Biogeosciences*, under review.
- (3) Hardiman B.S. *et al.* 2011. *Ecology*, in press.

Long-term Project Predictions

The over-arching hypothesis of FASET is that an initial decoupling of the carbon (C) and nitrogen (N) cycles, seeing a decrease in NEP (forest C storage) and an increase in N availability. At some later time period, we expect to see a re-coupling of these nutrient cycles in which NEP has surpassed it's original level due to a more structurally complex forest canopy and the reallocation of N to those canopies. The early results of FASET support this hypothesis and will continue to be monitored.



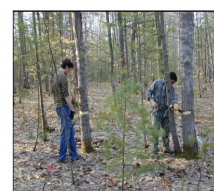
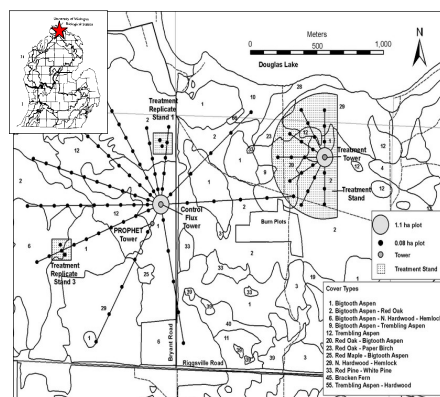
*Figure courtesy of C.M. Gough.

Acknowledgments

Eddy-flux data collection in the UMBS Ameriflux and FASET sites was funded by DOE-NICCR-Midwestern Center, Grant DE-FC03-90ER610100. Data analysis was funded by NSF-DEB-0918869 and by NSF-IGERT-BART fellowship to Kyle Maurer.

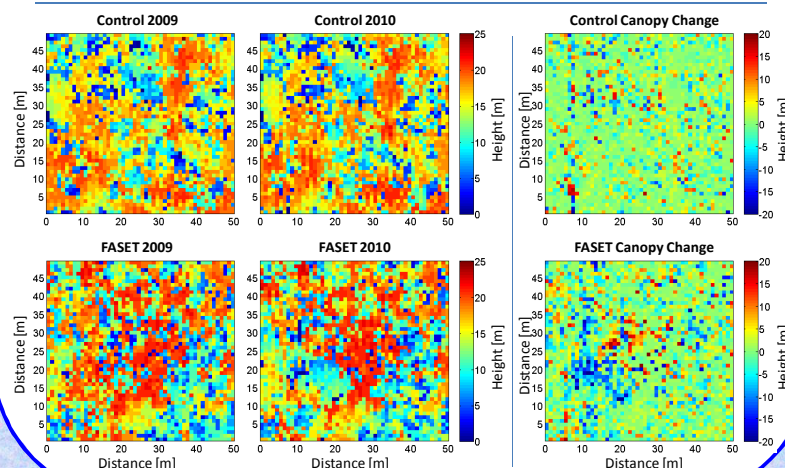
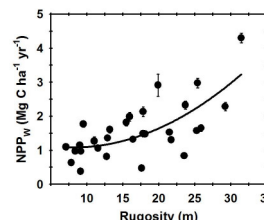
Site Description and the FASET Project

The research site is located at the University of Michigan Biological Station in USA. The Forest Accelerated Succession Experiment (FASET) began in 2008 to give researchers a close look at the effects of abrupt changes to canopy structure. An adjacent AmeriFlux network meteorological tower has been recording data since 1999 and serves as an untreated reference site.⁽¹⁾



Canopy Structural Change and Forest Productivity

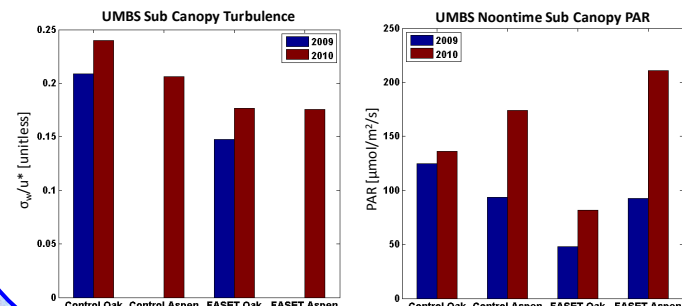
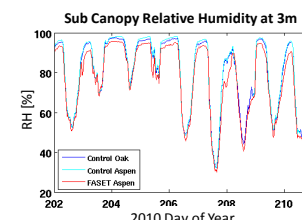
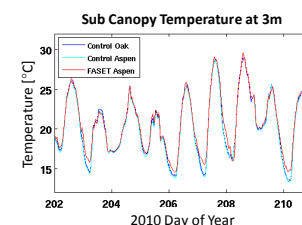
Remote sensing of forest canopy structure was performed using ground-based Light Detection And Ranging (LiDAR) technology. High density plots of 50x50m were set up at the control and FASET sites for yearly analysis of canopy structure changes. The figures below show canopy height at 1m² resolution at each site for 2009 and 2010. The control site has seen minimal changes to canopy structure, whereas the FASET site is seeing drastic canopy structural changes in areas where downed trees have created gaps. The quantity and frequency of downed trees at the FASET site will increase in the coming years as the girdled Aspen and Birch trees continue to die. The structural complexity of the FASET forest should increase as the late successional species become dominant. Structural complexity can be quantified by a measure of rugosity. Net Primary Productivity of wood (NPP_w) has been shown to increase in the UMBS forest with an increase to rugosity (right).⁽³⁾ This increase in rugosity should make the FASET site more productive than the pre-treated site.



Below Canopy Changes to Micro-Meteorology

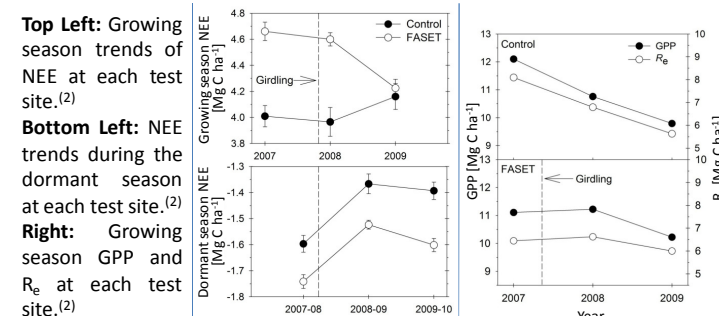
Each site contains two sub-canopy micro-meteorology towers (3m tall) with paired soil moisture and temperature vertical profiles. One under a group of oak trees (unchanged) and one under a group of aspen trees (changed at FASET). These systems will quantify changes to micro-meteorology inside the canopy and determine how these changes will affect sub-surface hydrology and the exchange of water and C between the atmosphere and biosphere.

The accompanying figures show measurements of temperature (T), relative humidity (RH), normalized growing season standard deviation of vertical wind velocity (σ_w/u^*), and growing season sub canopy PAR. One apparent difference is the generally higher nighttime T and lower RH at the FASET site. PAR is generally higher at the aspen sites, and the FASET aspen site has become the highest sub canopy PAR location. All of this is most likely due to a more open canopy. Surprisingly, σ_w/u^* is lower at each aspen site compared to their partnered oak site and the FASET site in general is lower than the control site.



Carbon Exchange Between the Biosphere and Atmosphere

Prior to the FASET girdling, seasonal trends of NEE were relatively consistent between test sites. We are observing a divergence in NEE between the control plot (enhanced carbon uptake) and the treatment plot (reduced carbon uptake), as the treatment has left the physiological processes of the girdled trees hindered by a slow mortality. We hypothesize that NEE will rebound at the FASET site as the late successional species replace early successional species to create a more structurally complex forest canopy.



(+) values describe C storage by the forest
(-) values describe C release by the forest