Integrating the immediate effects of forest management activity on the carbon cycle

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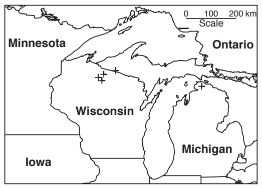
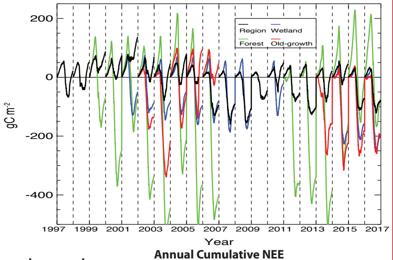
MOTIVATION



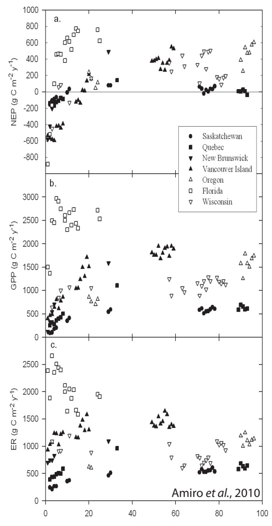


Productive forests and wetlands make the upper Midwest (**upper left**) a significant North American terrestrial carbon sink

However, 20 years of cumulative net ecosystem exchange (NEE) at a very tall tower (US-PFa- black) has smaller regional C sink (or source) than stand-scale flux towers in dominant cover types (forests: *US-WCr*- green, *US-Syv*- red, wetland: *US-Los*- blue) (Desai, 2010) (**upper right**)

Prior syntheses (**right**) shows strong effect of age and land management (Amiro *et al.*, 2010) and undersampling of young forests (Desai *et al.*, 2008)

New observations in managed harvested forests could help improve predictions of the future regional carbon sink



METHODS

Acquired eddy covariance flux tower observations over two different forest management approaches (thinning and clear-cut regeneration) and compared to Ameriflux long-term core site cluster and nearby sites (*ChEAS*: Chequamegon Ecosystem-Atmosphere Study)

Experiment 1: Commercial thinning and selection harvest in long-running (1999-) mature hardwood site (*US-WCr*) removed 30% of biomass in tower footprint over course of two winters (2013-2014)

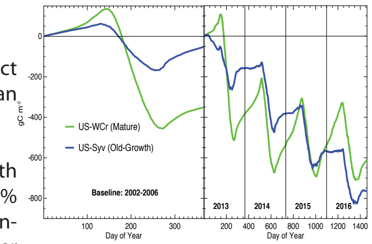
Experiment 2: Ten-year old aspen forest tower observations collected by U.S. Forest Service after a clear-cut was compared to previously measured NEE from both older and younger sites

Hypotheses: Both types of harvest increase ecosystem respiration (R_{eco}) more than they reduce gross primary production (GPP) in 1st ten years

EXPERIMENT 1: Selective thinning at Willow Creek

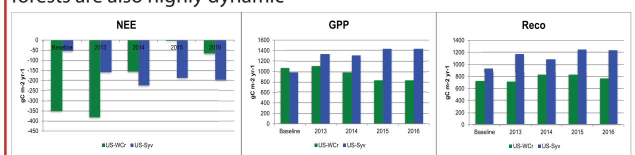
U.S. Forest Service sought to harvest and increase gaps in even-aged mature forest (**top**), so each winter, 15% overstory hardwood biomass removed

Compared to baseline (**middle**), cumulative NEE at US-WCr reduced over the 4 year period (2012-2016), now similar to old-growth NEE



Surprisingly, stronger effect from GPP (18% decline) than R_{eco} (12% increase) (**bottom**)

At same time, old-growth (*US-Syv*) site had surprising 40% increase in GPP and 27% increase in R_{eco} showing older forests are also highly dynamic

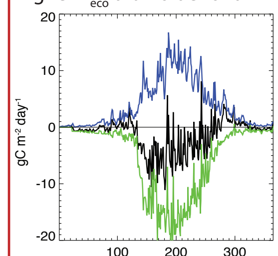


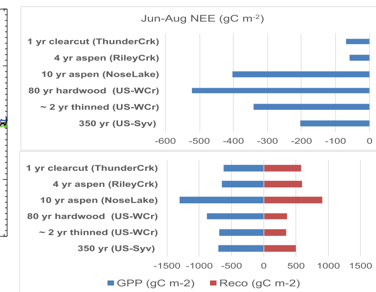
EXPERIMENT 2: Regeneration at Nose Lake

Aspen is fast-growing tree commonly planted in upper Midwest

Flux tower ran in 10-yr old aspen 2008-2012 (**right photos**). Gap-filled data from 2010 shown as example (**bottom left**). Site was a significant carbon sink, with large GPP and ER

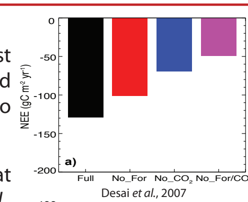
Compared to other sites (**bottom right**), including more recent clearcuts (4-yr RileyCreek and 1-yr ThunderCreek), growing season NEE was driven by significantly higher GPP, but site also had much higher R_{eco}. All recent cut sites had higher R_{eco} than older or thinned sites



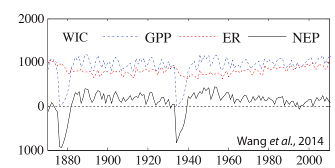


IMPLICATIONS

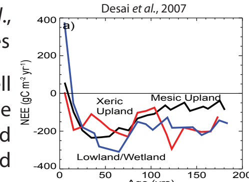
Dynamic vegetation models (ED) run in region (**upper left**) show forest management (black vs red) had similar effect on region C cycle as CO_2 and climate effects (black vs blue) over 20th century (Desai *et al.*, 2007), leading to positive NEE in first 10 years and maximum uptake around 50 yrs (**lower left**)

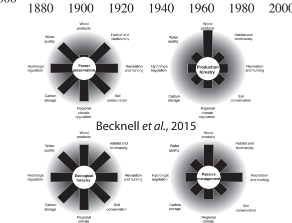


Most models do a good job with stand-replacing harvest, for example, at simulating establishment of US-WCr in PnET-CN (**upper right,** from Wang *et al.*, 2014), but miss carbon sinks in older forests and differences among harvest types



Other types of management are becoming more prevalent (**lower right**, Becknell *et al.*, 2014). Harvest type and species have a large effect on how forest age since disturbance affects net carbon fluxes. R_{eco} may not necessarily be elevated and GPP reductions large. Incorporation of management functional types and lifecycle analysis in models and data assimilation approaches are a path forward





WORKS CITED & ACKNOWLEDGEMENTS

Amiro *et al.*, 2010 Ecosystem carbon dioxide fluxes after disturbance in forests of North America. *JGR-G*, doi:10.1029/2010JG001390
Becknell *et al.*, 2015 Assessing interactions among changing climate, management, and disturbance in forests: A macrosystems approach *Bioscience*, 65:263-274, doi:10.1093/biosci/biu234
Desai *et al.*, 2007 Regional carbon fluxes from a biometrically-constrained dynamic ecosystem model: Impact of disturbance, CO2 fertilization and heterogeneous land cover. *JGR-G* doi:10.1029/2006JG000264
Desai *et al.*, 2008 Influence of vegetation and seasonal forcing on carbon dioxide fluxes across the Upper Midwest, USA *Agricultural and Forest Meteorology*, 148(2): 288-308, doi:10.1016/j.agrformet.2007.08.001
Desai, 2010 Climatic and phenological controls on coherent regional interannual variability of carbon dioxide flux in a heterogeneous landscape. *JGR-G*, doi:10.1029/2010JG001423
Wang *et al.*, 2014 Quantifying the effects of harvesting on carbon fluxes and stocks in northern temperate forests. *Biogeosciences*, 11, 6667-6682, doi:10.5194/bg-11-6667-2014

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