Impact of vegetation cover and stand age on scaling carbon fluxes in the upper Midwest: A multiple eddy flux site study

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1.) Introduction

- 8 permanent and 3 roving flux towers measured surface-atmosphere CO_2 exchange in 14 ecosystems across N. Wisconsin and Michigan in 2002 and/or 2003 (Table 1)

- Focused on growing season (Jun.-Aug.) of 2002 and 2003, when largest difference between sites occurred (Fig. 1)

- Objective is to understand difference in carbon exchange within a small area with similar climate for purposes of regional scaling

- Results show veg. type, climate variability and stand age are important factors in region for explaining variation in net ecosystem exchange (NEE), ecosystem respiration (ER) and gross ecosystem production (GEP) in region.

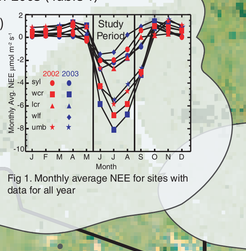

Fig 1. Monthly average NEE for sites with data for all year

2.) Site Descriptions

Site	Abbrev	Range of data	Location	Veg Class	Dominant cover	Lat	Age Class	Age
Deciduous Broadleaf								
Young Hardwood	yhw	summer 2002	Ashland, WI	Hardwood	*aspen, red maple*	1.2	Young	7
Intermediate Hardwood	ihw	summer 2003	Ashland, WI	Hardwood	*aspen*	3.0	Intermed.	17
Mature Hardwood	mhw	9/2002-10/2003	Ashland, WI	Hardwood	*red maple, sugar maple, aspen, birch*	3.9	Mature	65
Willow Creek	wcr	2002-2003	Willow Creek, Chequamegon NF	Hardwood	*sugar maple, basswood, green ash*	5.3	Mature	70
Evergreen Needleleaf								
Young Red Pine	ryp	2002-2003	Alberta, NW	Jack Pine	*jack pine*	0.9	Young	14
Pine Barren A	pba	summer2002	Ashland, WI	Pine Barrens	*sweet fern, black cherry, willow, red pine*	0.3	Young	12
Pine Barren B	pbb	summer 2003	Ashland, WI	Pine Barrens	*sweet fern, black cherry, willow, red pine*	1	Young	2
Young Red Pine	yrp	summer 2002	Ashland, WI	Red Pine	*red pine*	0.6	Young	6
Intermediate Red Pine	irp	summer 2003	Ashland, WI	Red Pine	*red pine*	2	Intermed.	15
Mature Red Pine	mrp	9/2002-10/2003	Ashland, WI	Red Pine	*red pine, aspen*	2.5	Mature	65
Mixed Forest								
WLEF	wlf	2002-2003	Park Falls, WI	Mixed	*N. hardwoods, aspen, lowland conifers*	3.5	Mature	70
UMBS	umb	2002-2003	Pellston, MI	Mixed	*aspen-birch, hemlock-white pine-birch*	4.5	Mature	90
Sylvania	syl	2002-2003	Watersmeet, MI	Mixed	*slippery elm-hackberry, sugar maple, birch*	4.1	Old	200
Wetland								
Lost Creek	lcr	2002-2003	Lac Du Flambeau, WI	Wetland	*alder, willow, shrubs*	1.4	Intermed.	20

Table 1.Description of all sites with eddy flux measurements in the region over any part of 2002 and 2003.

3.) Regional Scaling

- Region has wide range of stand ages (Fig.2) and a highly heterogeneous landscape (Fig. 3), thus scaling eddy fluxes requires adequate sampling of subregions

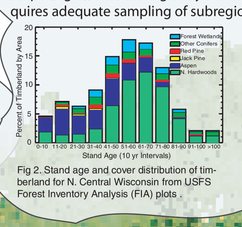

Fig 2. Stand age and cover distribution of timberland for N. Central Wisconsin from USFS Forest Inventory Analysis (FIA) plots.

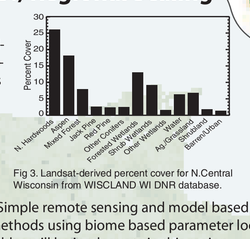

Fig 3. Landsat-derived percent cover for N.Central Wisconsin from WISCLAND WI DNR database.

- Simple remote sensing and model based scaling methods using biome based parameter look-up tables will be inadequate in this region.

Wisconsin + Michigan

4.) Vegetation

- Diurnal patterns of NEE across vegetation classes were relatively similar, when not separated by stand age class (Fig 2)

- In mature sites, hardwood sites had the largest NEE, followed by conifers and mixed sites. ER was largest in mixed sites, while GEP was relatively similar.

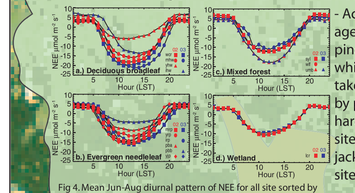

Fig 4.Mean Jun-Aug diurnal pattern of NEE for all site sorted by vegetation class for 2002 (red) and 2003 (blue)

- Across young/intermediate aged sites, jack pine and red pine sites had similar NEE, which was larger (more uptake) than wetlands, followed by pine barrens and then by hardwood sites. Hardwood sites had the largest ER and jack pine and red pine sites had the largest GEP.

5.) Stand Age

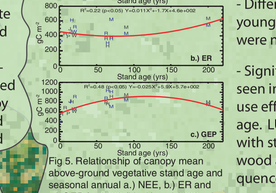

Fig 5. Relationship of canopy mean above-ground vegetative stated age and seasonal aerkial a.) NEE, b.) ER and c.) GEP for 2002 (black) and 2003 (blue). Letters indicate primary vegetation type.

- Forest stand age has a strong effect on NEE and GEP, but only a weak effect on ER (Fig. 5).

- Differences in NEE between young and intermediate species were not significant

- Significant differences were seen in GEP:ER ratio and light use efficiency (LUE) with stand age. LUE consistently declined with stand age for both hardwood and red pine chronosequences.

6.) Interannual Variability

- Sites all had similar temperature, PAR and precipitation, though latter was most variable (Fig. 6)

- 2002 was warmer and wetter than 2003

- NEE at all sites was more negative (greater uptake) in 2003 compared to 2002, but change in ER and GEP was mixed among the sites

- Most sites had higher light use efficiency and water use efficiency in 2003

- Interannual variability over two years was of similar magnitude to that seen at sites with longer records (e.g., WLEF)

- In-site variability for all sites of NEE, ER and GEP was smaller than across site variability

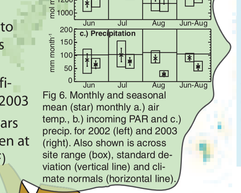

Fig 6. Monthly and seasonal mean (titan) monthly a.) air temp., b.) incoming PAR and c.) precip. for 2002 (left) and 2003 (right). Also shown is across site range (box), standard deviation (vertical line) and climate normals (horizontal line).

Summary & Future Work

- Stand age is a strong predictor of NEE and GEP in the region, due mainly to its influence on GEP parameters (e.g., LUE). ER appears to increase from mature to old sites.

- Veg. type and interannual climate variability impact NEE, ER and GEP by about the same magnitude, but not as strongly as stand age.

- Young aspen stands and forested wetlands are undersampled. Work is underway to currently measure fluxes in these regions along with multi-tier measurements at many sites

- Bottom-up scaling of regional fluxes will require remote sensing, eddy flux and ancillary data of stand age, climate and veg type. Other factors such as moisture, harvest, soil, disturbance and pests are also being considered.

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Background: MODIS-derived (MOD17A2) 1-km resolution annual GEP for 2002 in N. Wisconsin and Michigan. Site locations are marked with a + symbol.