Effects of invasive insects and fire on carbon and hydrologic cycling in the New Jersey Pinelands

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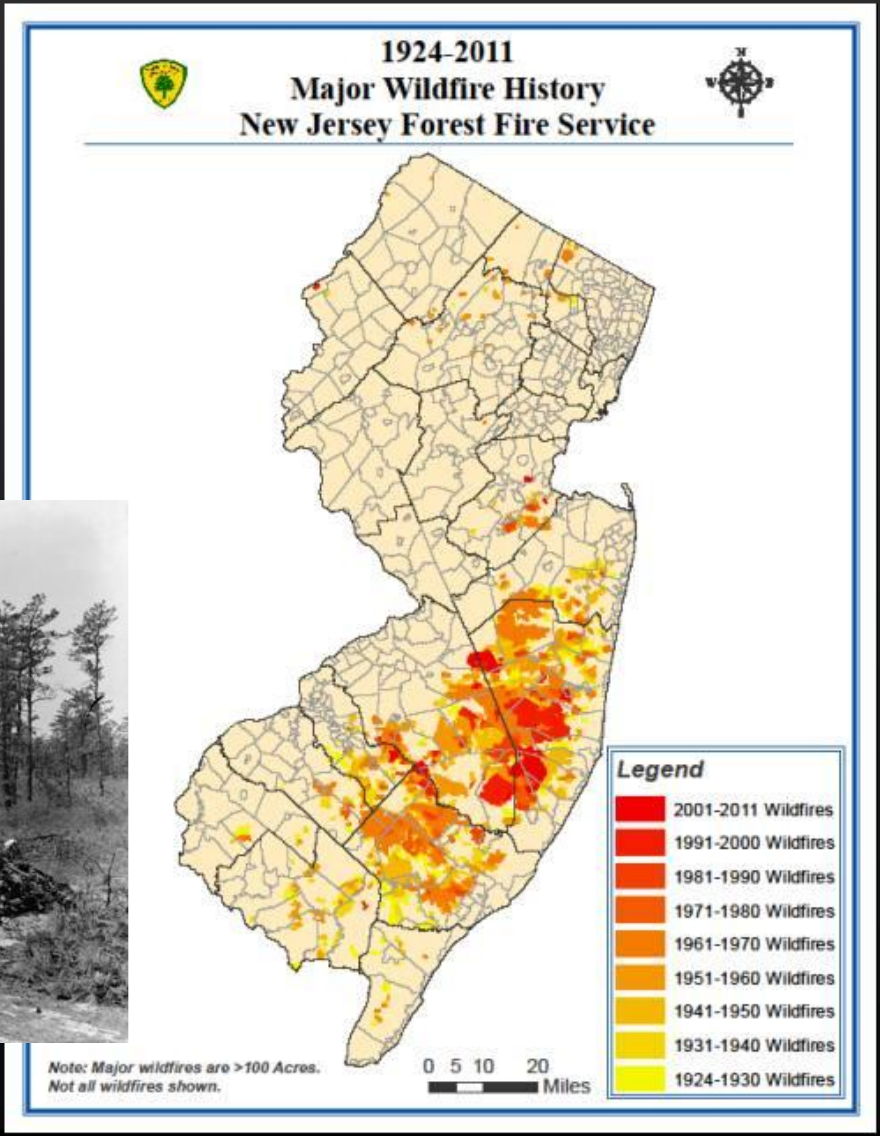
National Fire Plan
Managing the Impact of Wildfires on the Communities and the Environment


6-291


1924-2011
Major Wildfire History
New Jersey Forest Fire Service
Legend
2001-2011 Wildfires
1991-2000 Wildfires
1981-1990 Wildfires
1971-1980 Wildfires
1961-1970 Wildfires
1951-1960 Wildfires
1941-1950 Wildfires
1931-1940 Wildfires
1924-1930 Wildfires
Note: Major wildfires are >100 Acres.
Not all wildfires shown.
0 5 10 20
Miles

Flux towers in upland forests of the NJ Pinelands



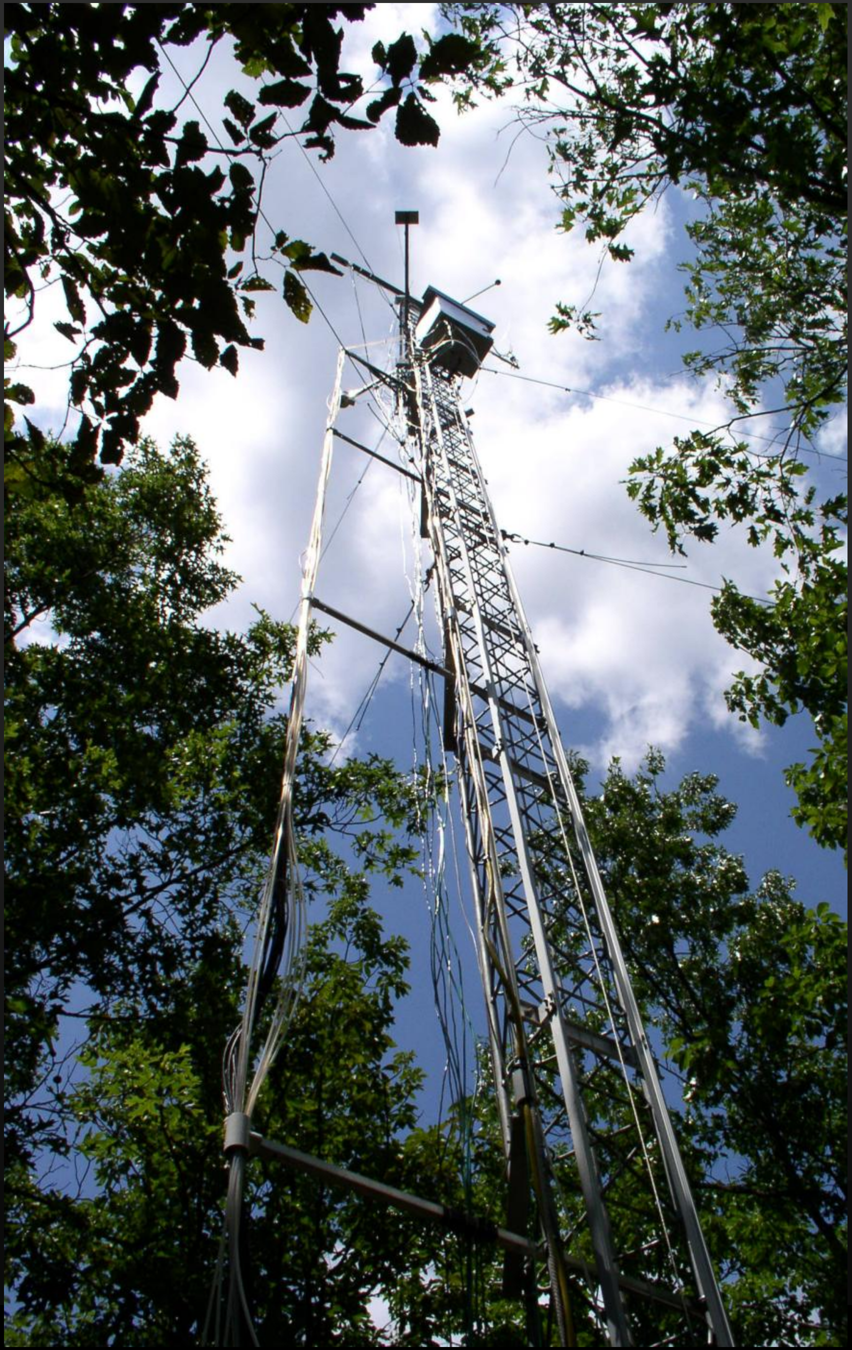
Flux towers

Eddy Covariance

Net CO_2 exchange
Evapotranspiration
Sensible heat flux

Meteorology

Solar radiation
(R_g, PAR, R_{net})
Air temperature
Relative humidity
Windspeed and direction
Precipitation



Methods:

We measured net ecosystem exchange of CO_2 (NEE_{CO_2}) using eddy covariance, and then calculated half-hourly to annual NEE_{CO_2}, ecosystem respiration (R_{eco}) and gross ecosystem production (GEP) before and after each disturbance:

$$NEE_{CO_2} = GEP - R_{eco}$$

Methods:

We measured latent (λe) and sensible (H) heat fluxes using eddy covariance and then calculated evapotranspiration (Et; mm day^{-1}, mm $year^{-1}$).

Energy balance terms:

$R_g = R_{net} – R_{shortwave\ up} – R_{longwave\ up}$

$R_{net} – G – S = \lambda e + H$

R_g = Incident solar radiation
R_{net} = Net radiation
$R_{net} – G – S$ = Available energy

Methods:

Energy balance closure for the oak, mixed and pine stands from 2005 to 2009. Half-hourly flux data were fit to the equation $R_{net} – G – S_{air} - S_{bio} = a (H + \lambda E) + b$. Values are means ± 1 SE, and all correlations are significant at $P < 0.001$.

Site	a	b	r^2	n
Oak	0.962 ± 0.001	14.53 ± 0.27	0.861	44,941
Mixed	0.994 ± 0.001	8.88 ± 0.26	0.924	21,682
Pine	0.960 ± 0.001	8.39 ± 0.26	0.898	44,912

Methods:

Water use efficiency at the ecosystem scale (WUE_e) was estimated as:

$$WUE_e = GEP / Et$$

For dry canopy conditions (days with no precipitation, and days after < 10 mm precipitation excluded).

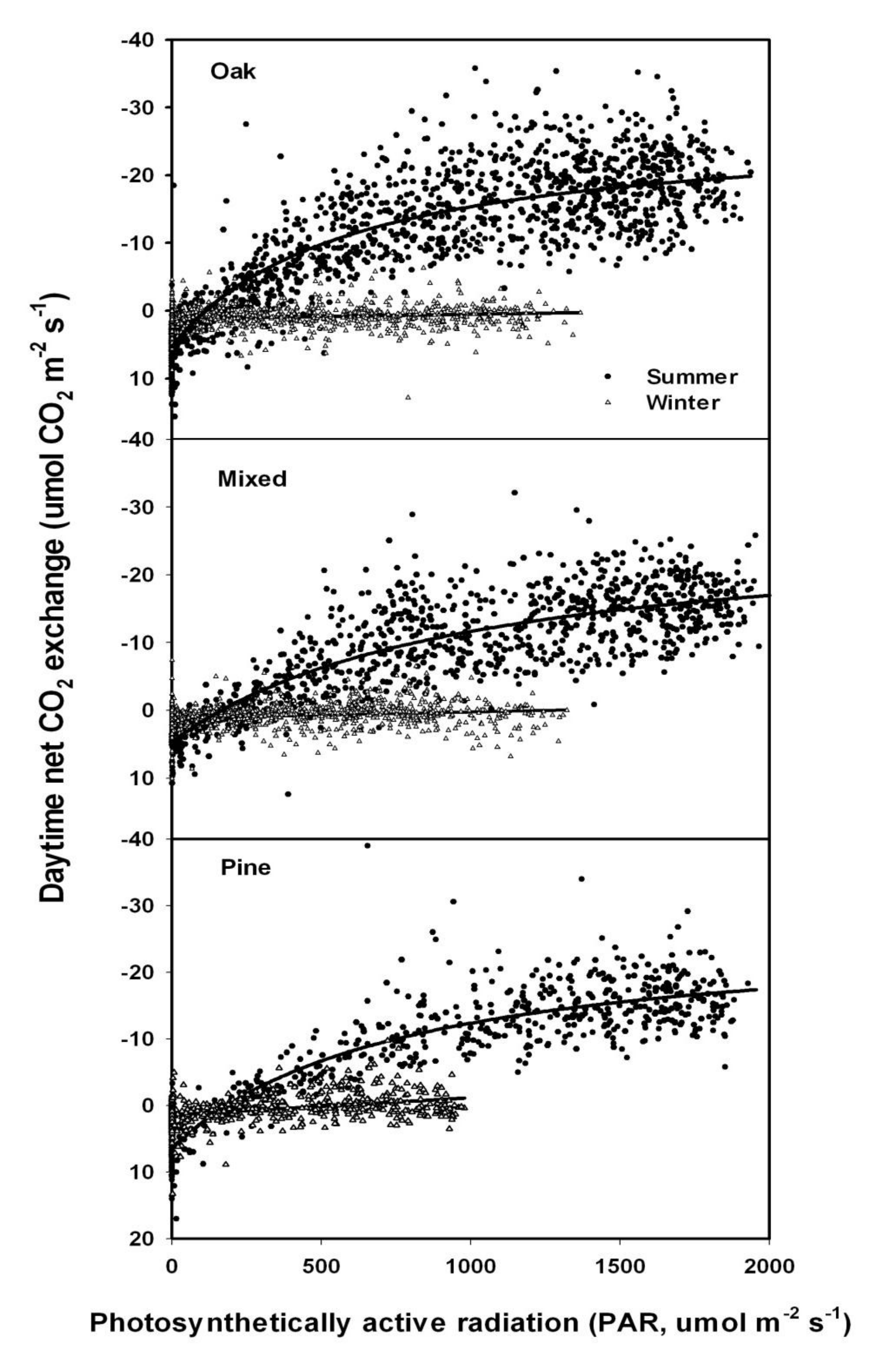
Methods:

Understory and overstory productivity, LAI and N dynamics were quantified using biometric measurements.

Leaf, stem, litterfall, frass, litterbag, and soil samples were analyzed for C and N content.

NEE$_{CO2}$ at the oak, mixed and pine stands

Summer and winter net CO_2 exchange (NEE$_{CO2}$ µmol m^{-2} s^{-1}) as a function of photosynthetically active radiation before each disturbance.

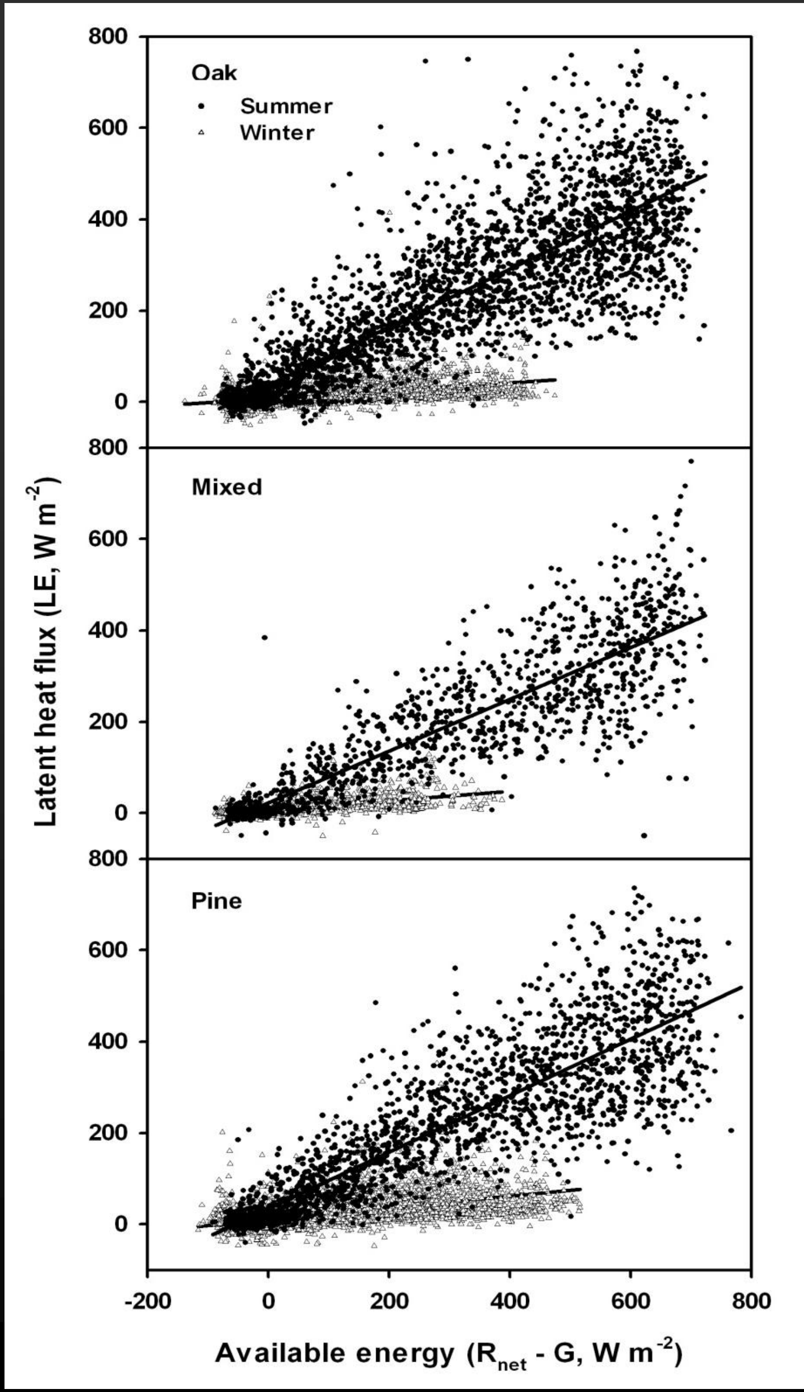


Annual net CO_2 exchange at the oak, mixed and pine stands before disturbance in g Carbon m^{-2} yr^{-1}.

Stand/Year	NEE	R_{eco}	GEP
Oak			
2005	185	- 1285	1470
2006	140	- 1395	1535
Mixed			
2005	99	- 1068	1167
Pine			
2005	204	- 1332	1536
2006	161	- 1477	1638

Latent heat (water vapor) flux at the oak, mixed and pine stands

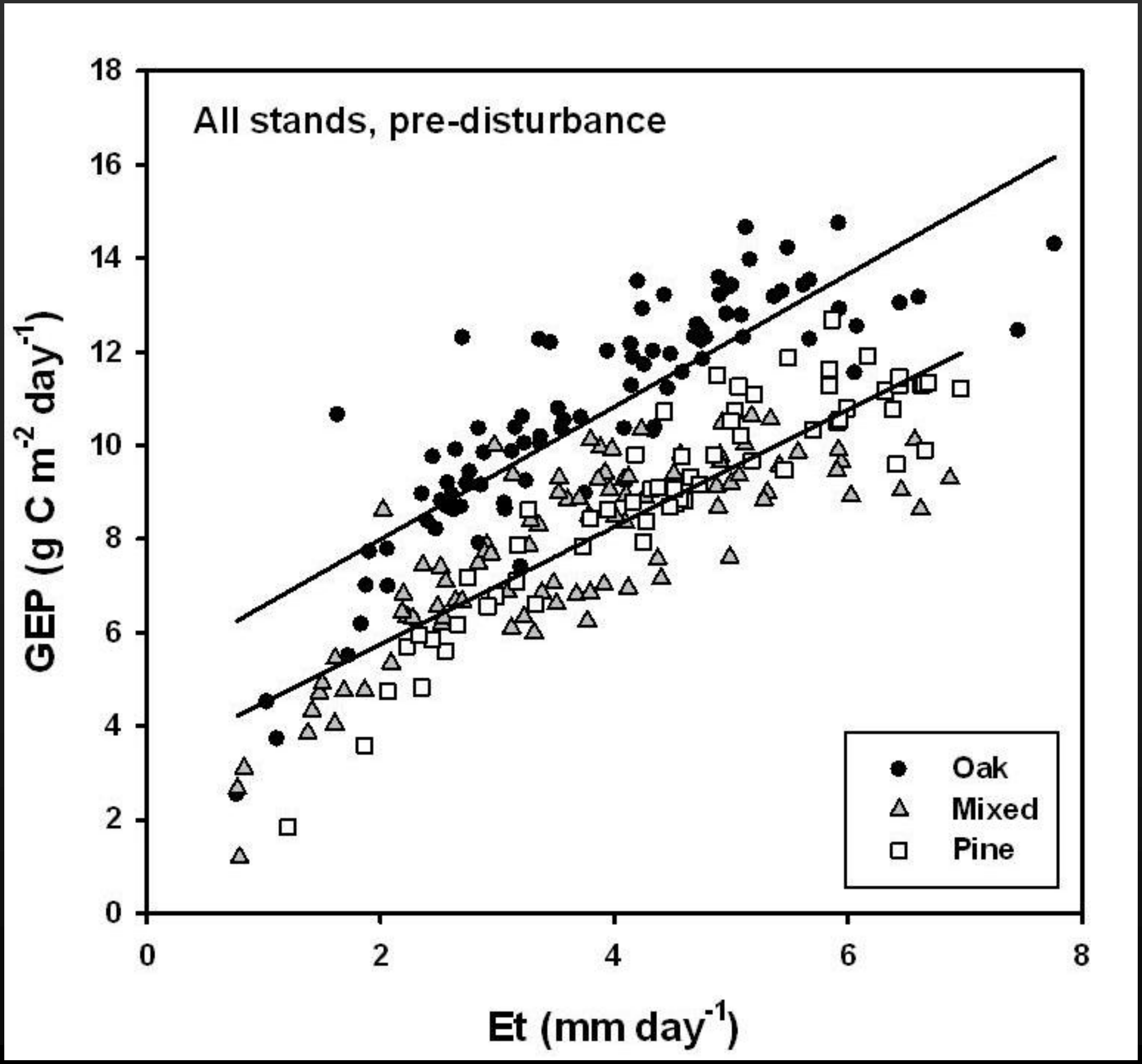
Summer and winter water vapor flux (λE, W m^{-2}) as a function of available energy before each disturbance.



Daily and annual evapotranspiration at the oak, mixed and pine stands before disturbance. Values are mm day^{-1} or mm $year^{-1}$

Stand/Year	Daily Et	Precip.	Annual Et	%
Oak				
2005	4.2 ± 1.5	1092	616	56.4%
2006		1108	677	61.1%
Mixed				
2005	3.3 ± 1.2	1184	607	51.3 %
Pine				
2006	3.9 ± 1.3	1230	757	61.5 %

Ecosystem water use efficiency (WUE_e) at the oak, mixed and pine stands before disturbance in 2005 - 2006

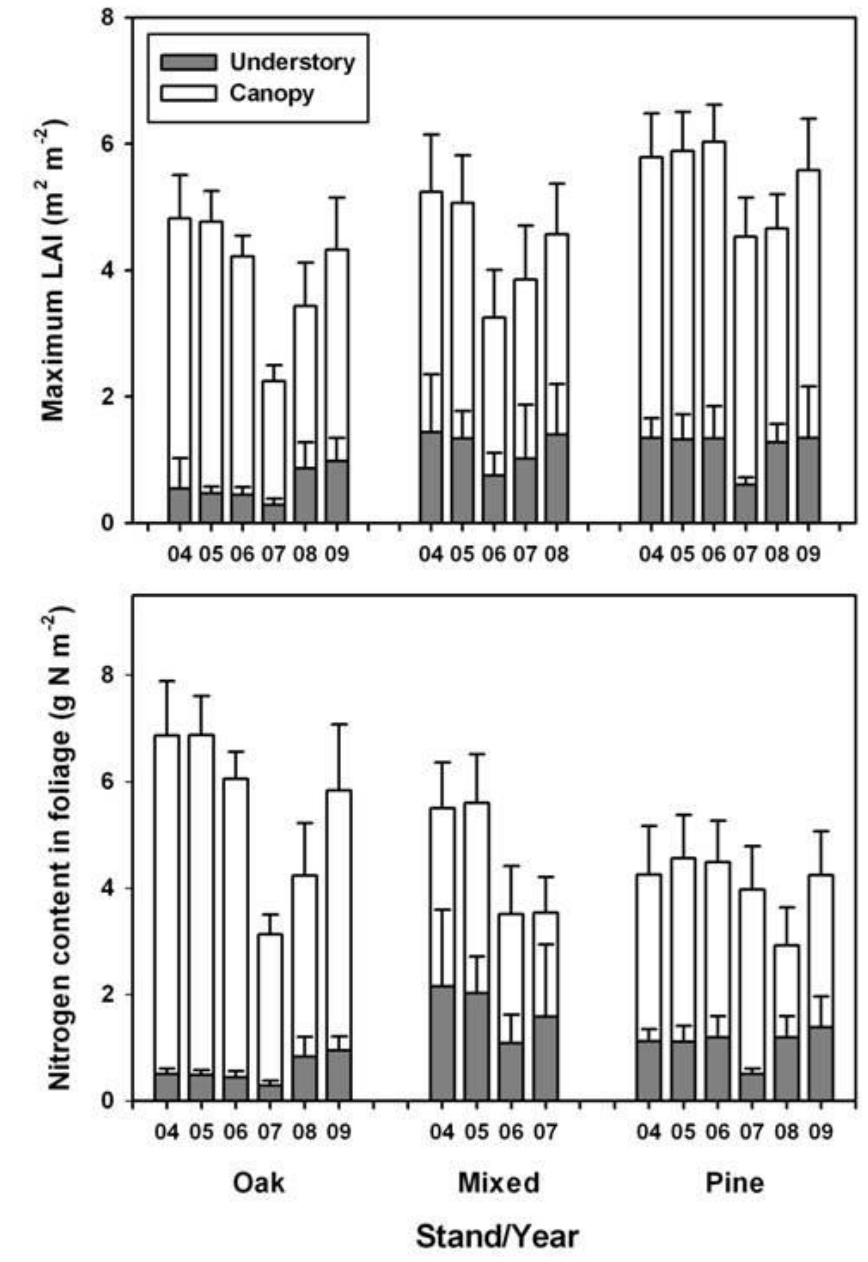


Gypsy moth defoliation in the Pinelands

Flux towers in upland forests of the NJ Pinelands

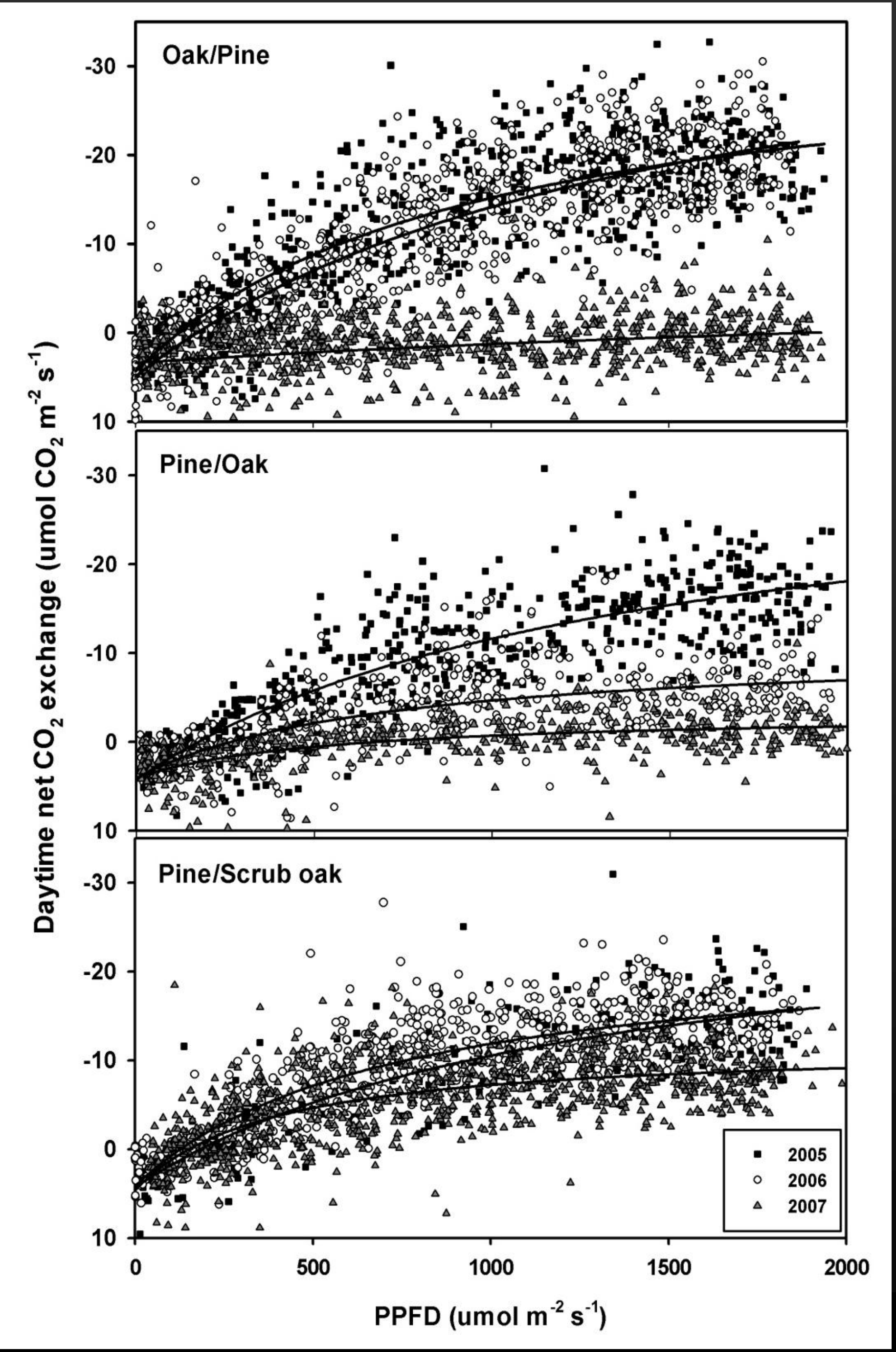
Foliage at the oak, mixed and pine stands

Leaf area expressed as LAI (m^2 leaf area per m^{-2} ground area), and nitrogen in canopy and understory foliage from 2004 to 2009.



Defoliation and daytime net CO_2 exchange

Gypsy moth defoliation reduced daytime net CO_2 exchange from June 1st to July 15th at the Oak, mixed and pine stands.



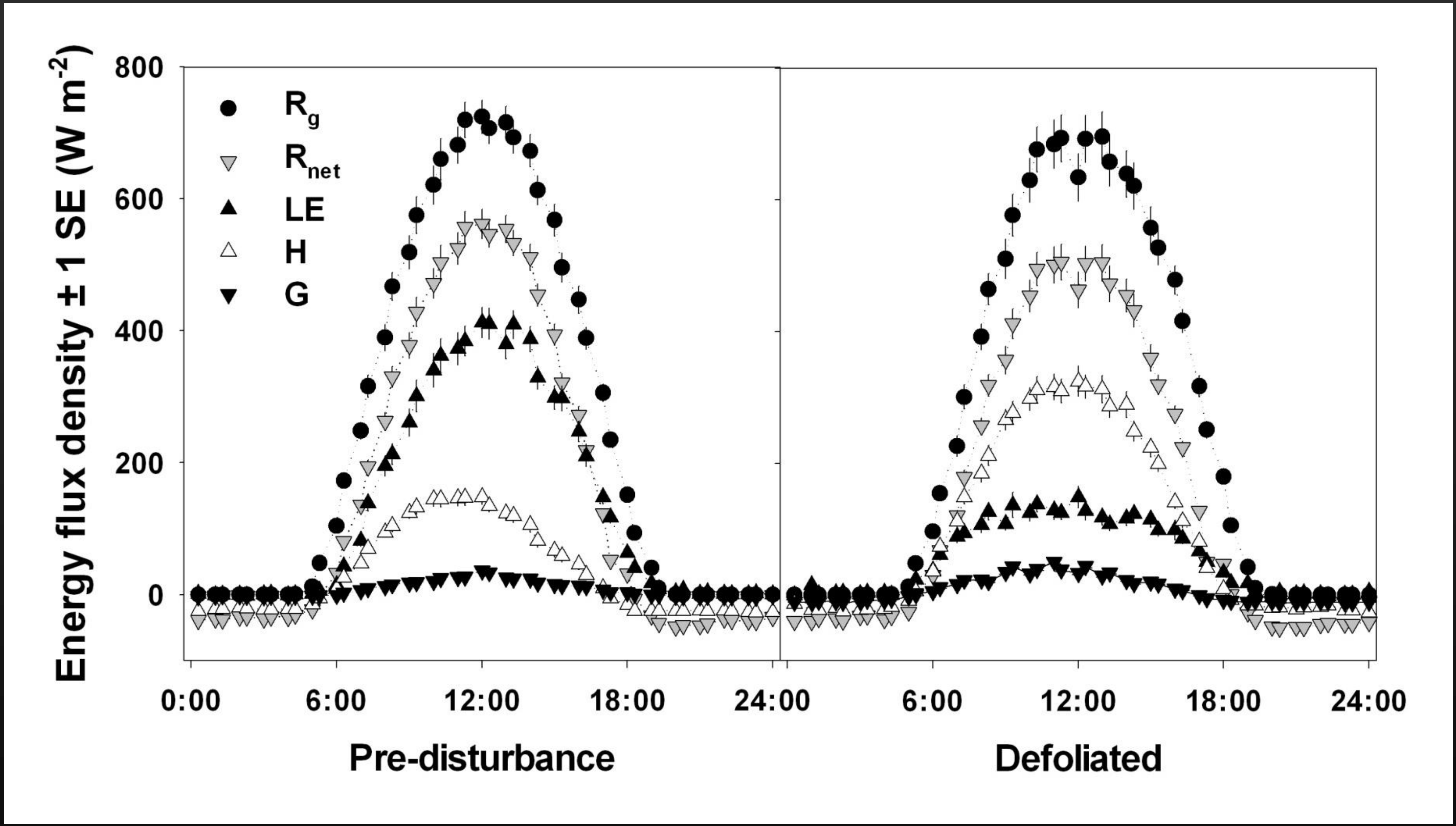
Clark et al. 2010
Global Change Biology

Annual net CO_2 exchange at the Oak- pine site.

Year	NEE	R_{eco}	GEP
		g C m^{-2} yr^{-1}	
2005	185	- 1285	1470
2006	140	- 1395	1535
2007	- 246	- 972	726
2008	77	- 1066	1143
2009	9	- 1523	1532
2010	15	- 1391	1406
2011	49	- 1673	1722

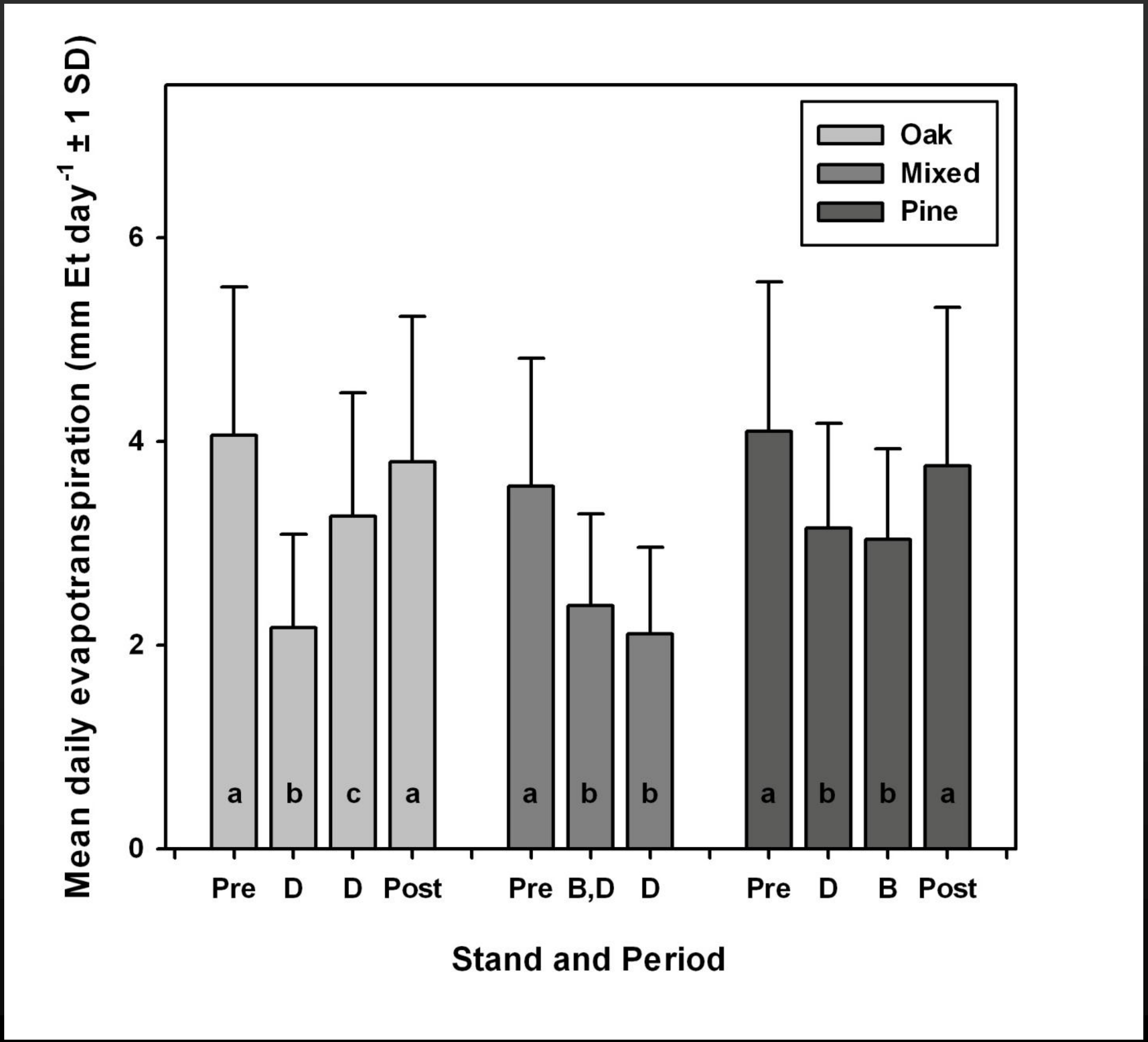
Mean R_{eco} ± 1 SD - 1224 ± 210 cv = 0.171

Energy exchange before and during defoliation in the summer at the Oak stand



Clark et al. 2012 Ag and Forest Met

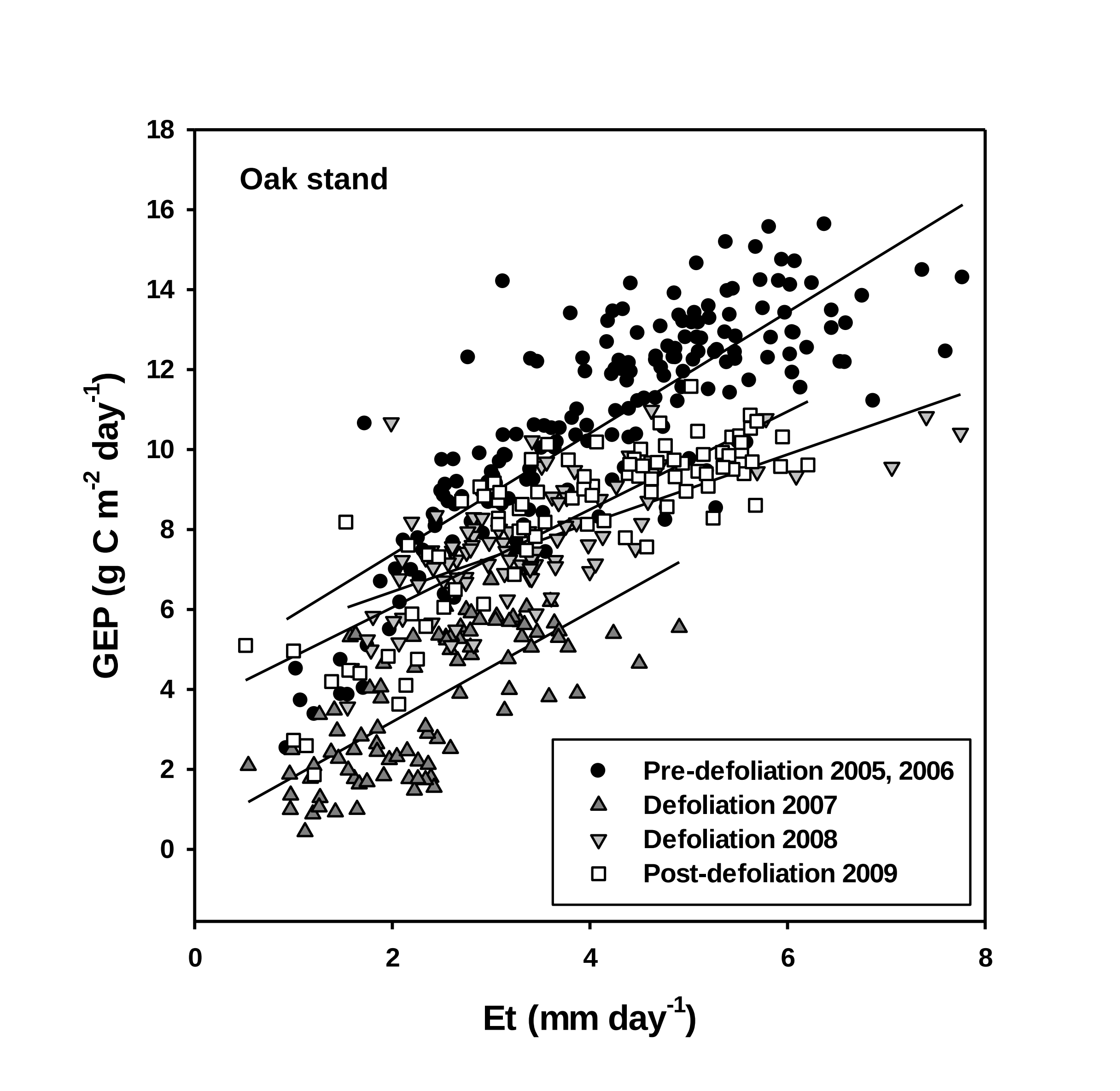
Daily Et (mm day^{-1}) during the summer at the oak, mixed, and pine stands 2005-2009.



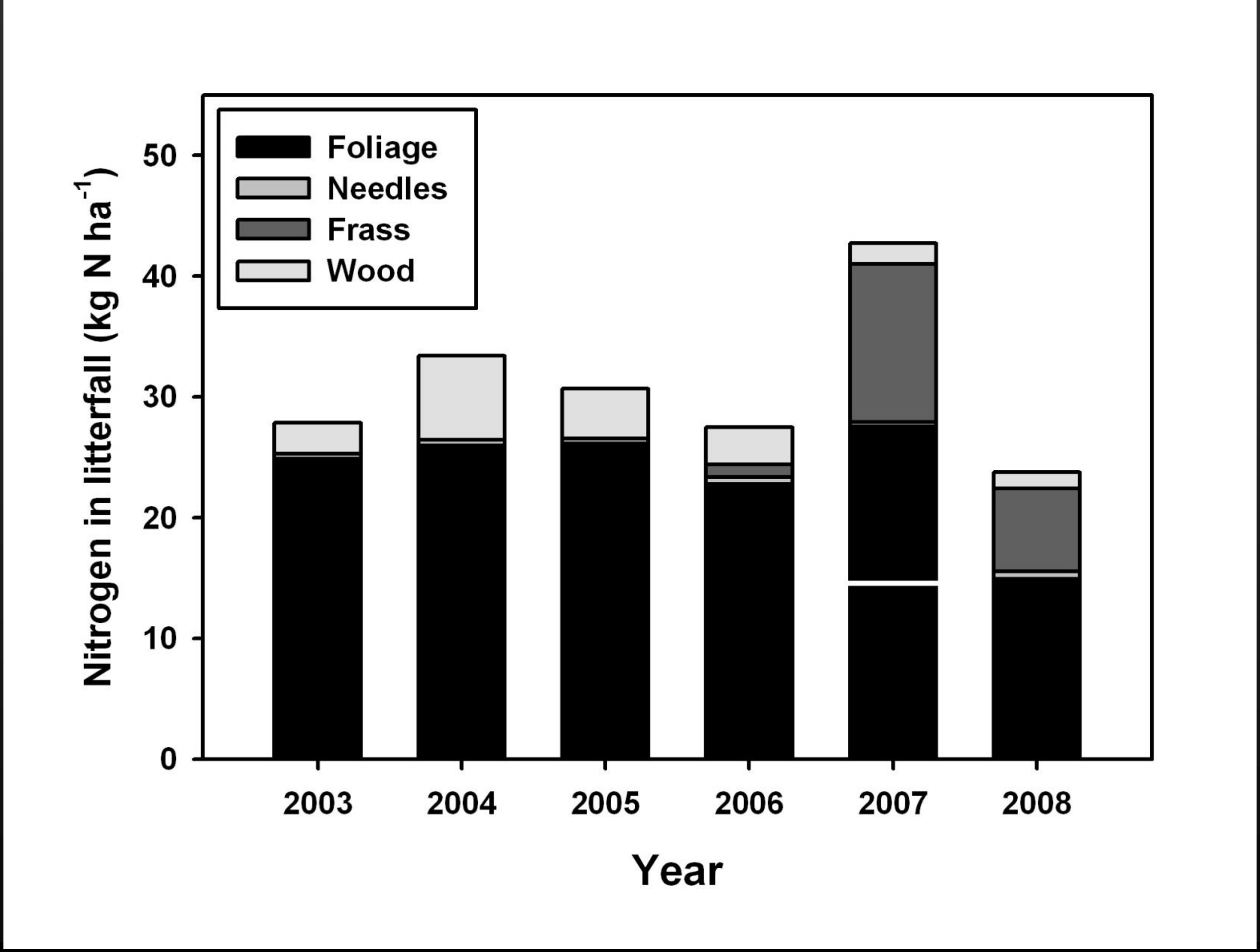
Annual evapotranspiration estimates for the Oak stand. Values are mm year^{-1}.

Site, Disturbance	Precipitation (mm)	ET (mm)	% ET
2005	1092	616	56.4 %
2006	1108	677	61.1 %
2007, completely defoliated	934	442	47.3 %
2008, partially defoliated	936	637	68.0 %
2009	1173	699	59.6 %
Average	1049	614	58.6 %

Ecosystem water use efficiency at the Oak stand 2005-2009

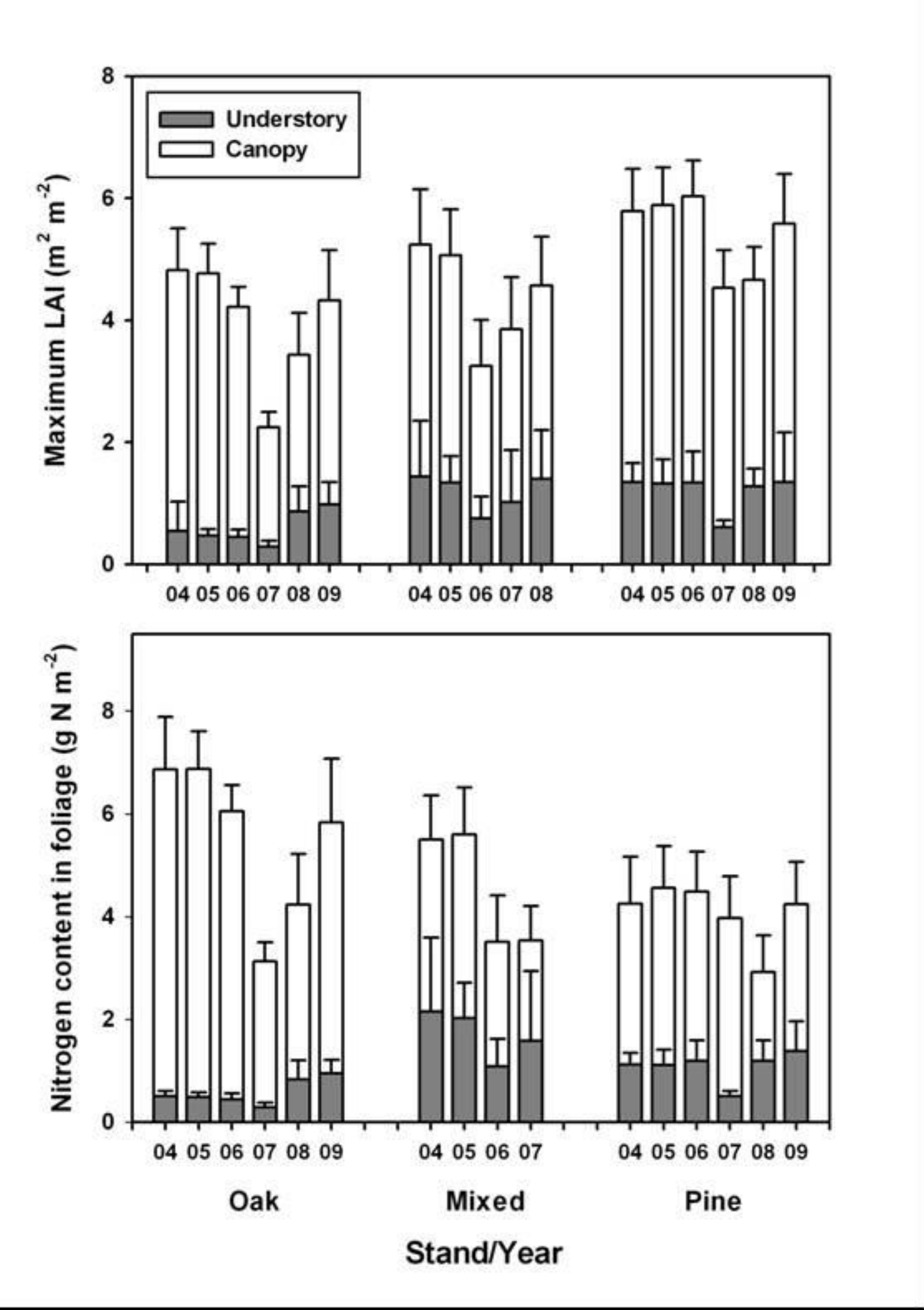


Nitrogen flux in canopy litterfall at the Oak stand



Oak, mixed and pine stands

Leaf area expressed as LAI (m^2 leaf area per m^{-2} ground area), and Nitrogen in canopy and understory foliage from 2004 to 2009.

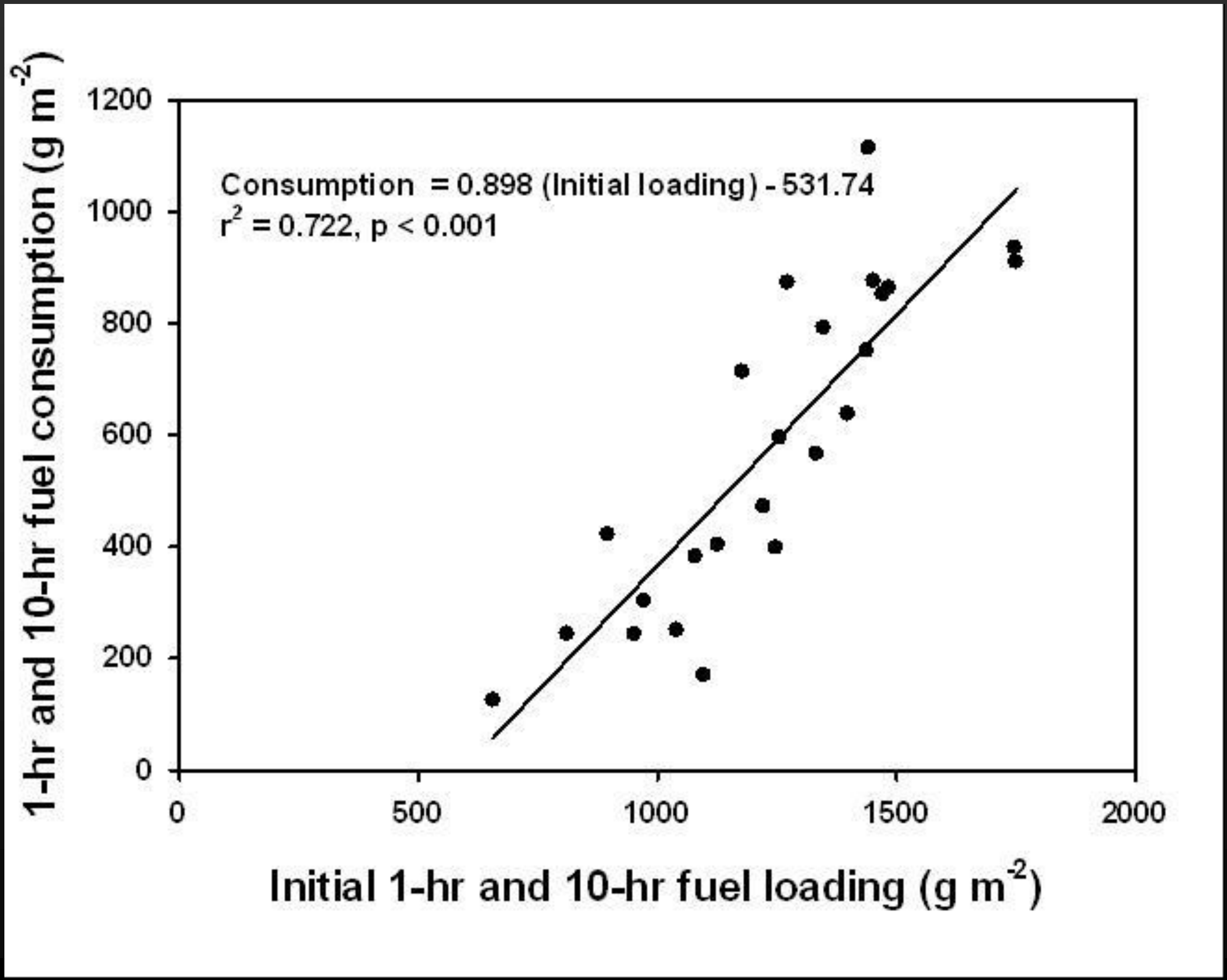


Prescribed burn, Pinelands National Reserve, NJ

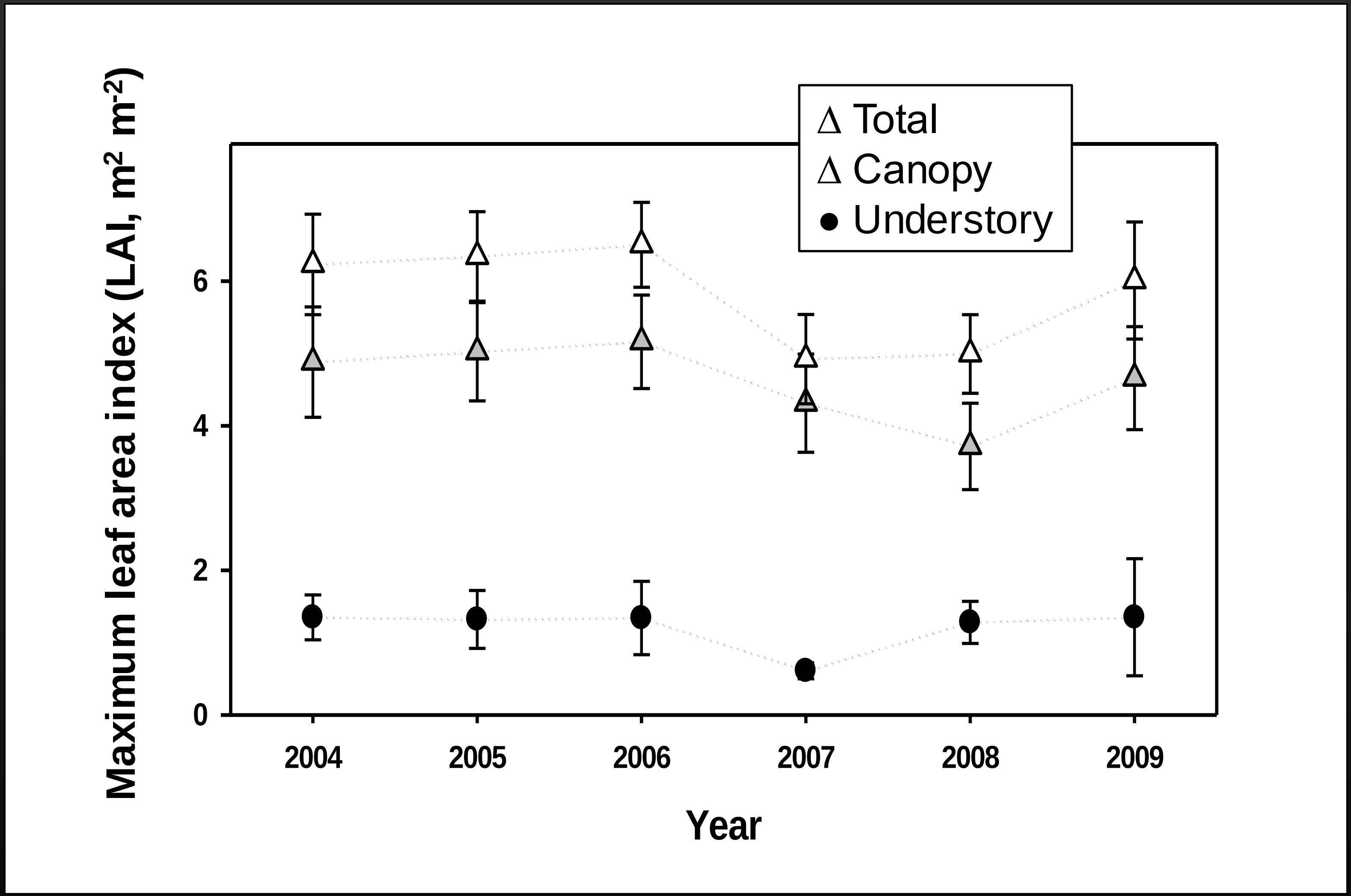
Flux towers in upland forests of the NJ Pinelands

Prescribed burn, Pinelands National Reserve, NJ

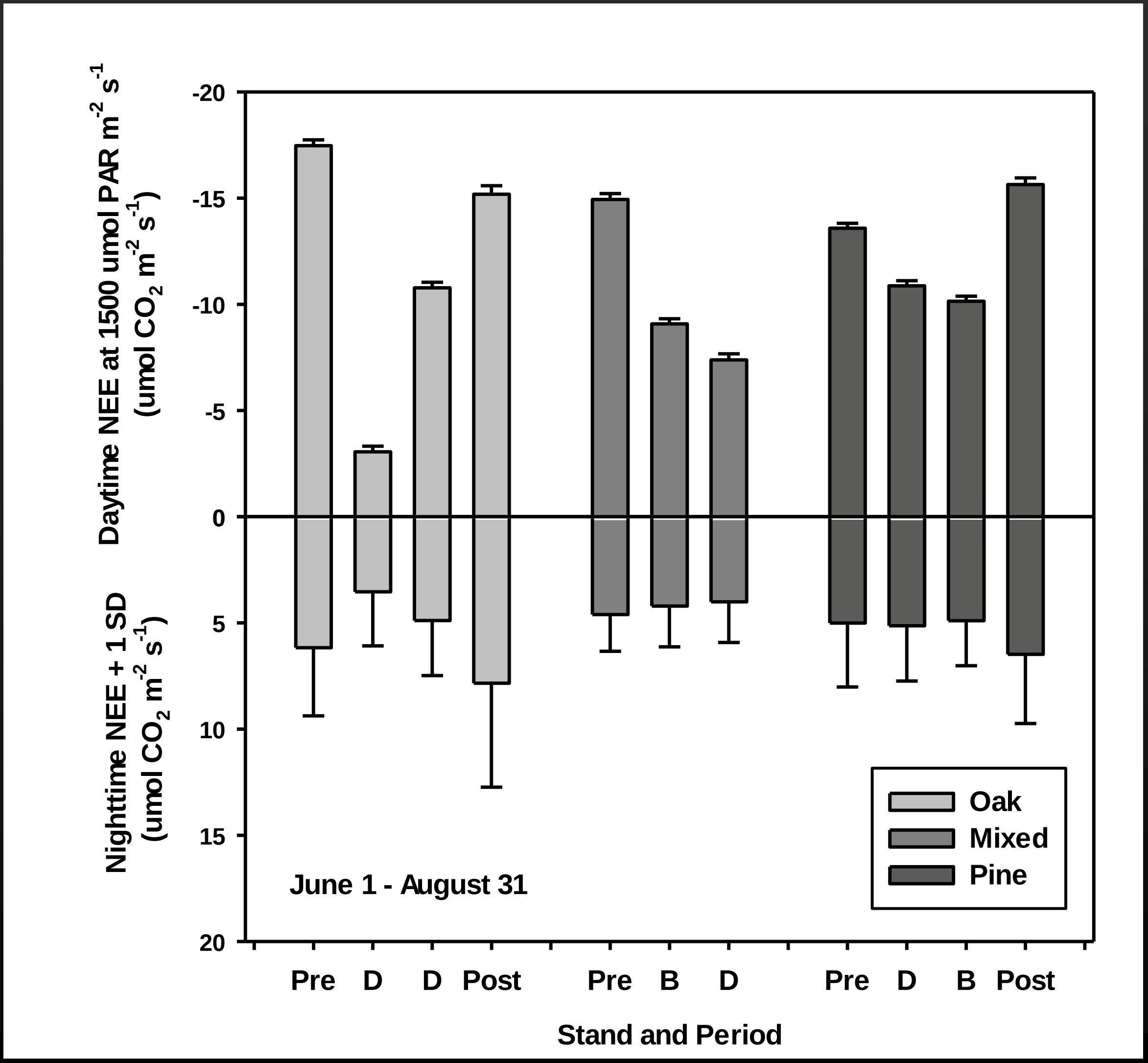
Initial fuel loading on the forest floor vs. fuel consumption for 2004-2009 prescribed fires in the Pinelands



Changes in leaf area at the pine stand



Daytime and nighttime NEE_{CO2} during the summer at the oak, mixed and pine stands

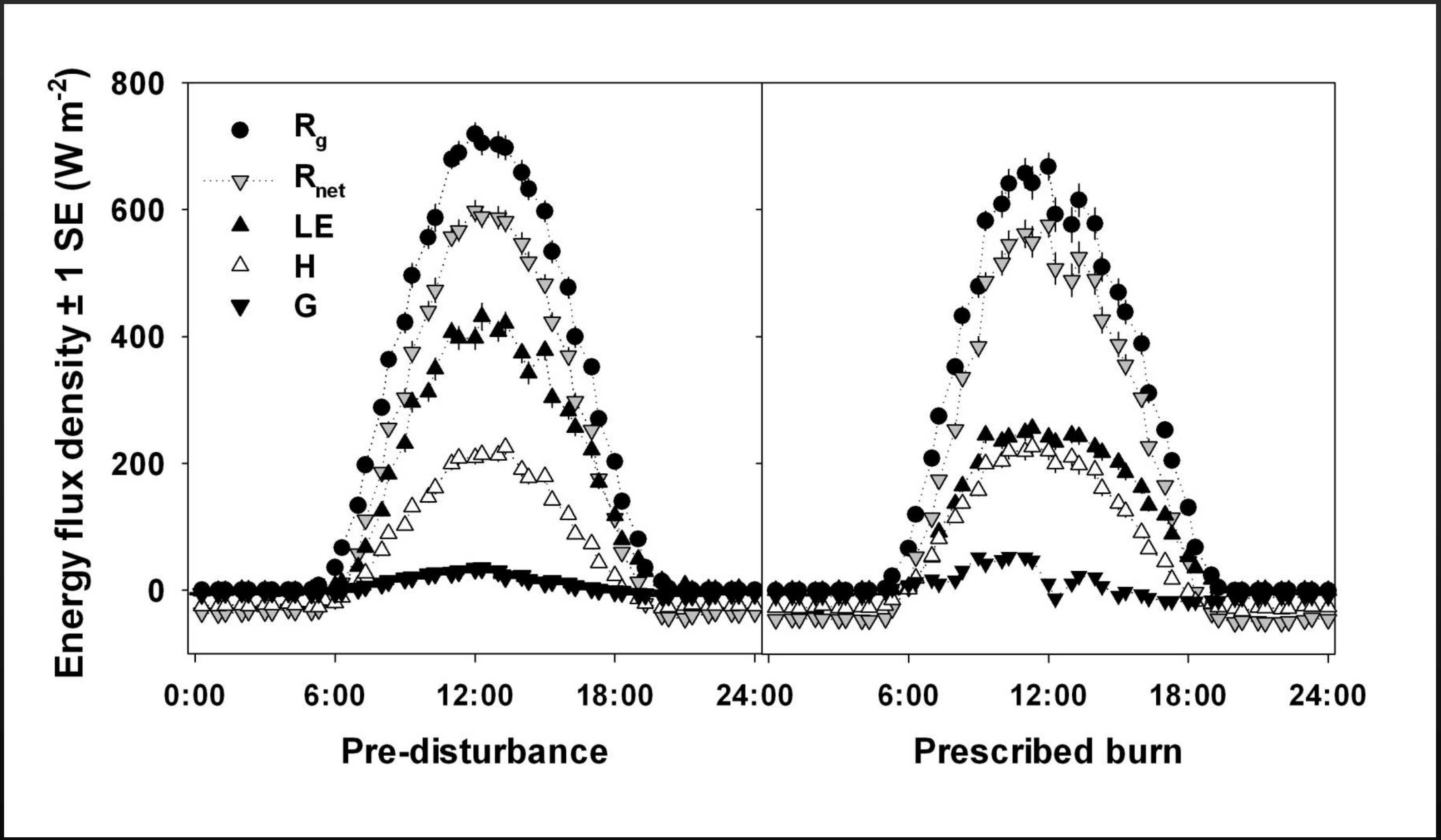


Annual net CO_2 exchange at the pine stand.

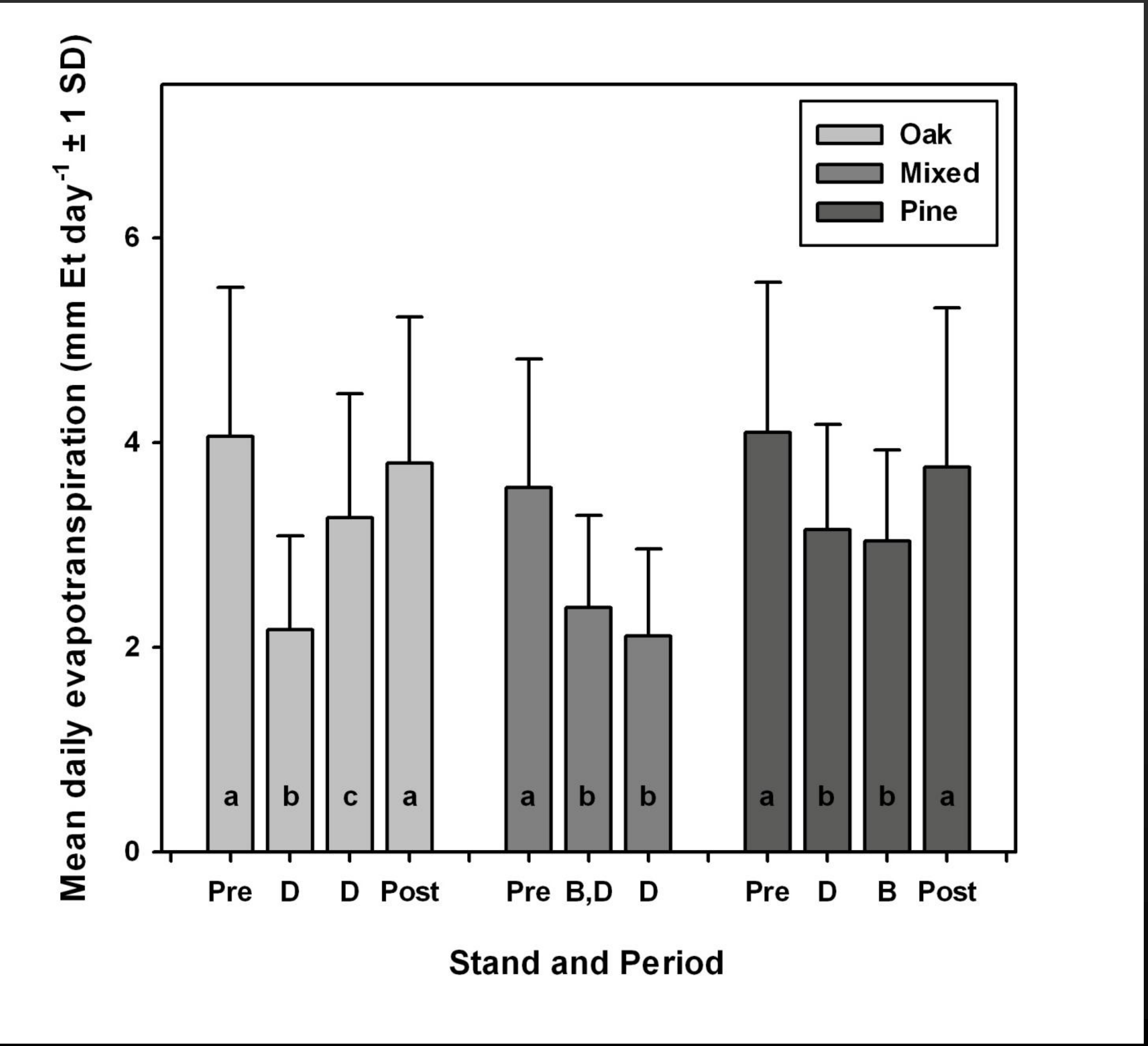
Year	NEE	R_{eco}	GEP
		g C m^{-2} yr^{-1}	
2005	204	1432	1636
2006	161	1477	1638
2007	40	1362	1402
2008	48	1329	1377
2009	85	1597	1682
2010	174	1220	1394
2011	116	1734	1849

Mean R_{eco} ± 1 SD 1450 173 cv = 0.119

Energy exchange before and following the prescribed burn in the summer at the Pine stand

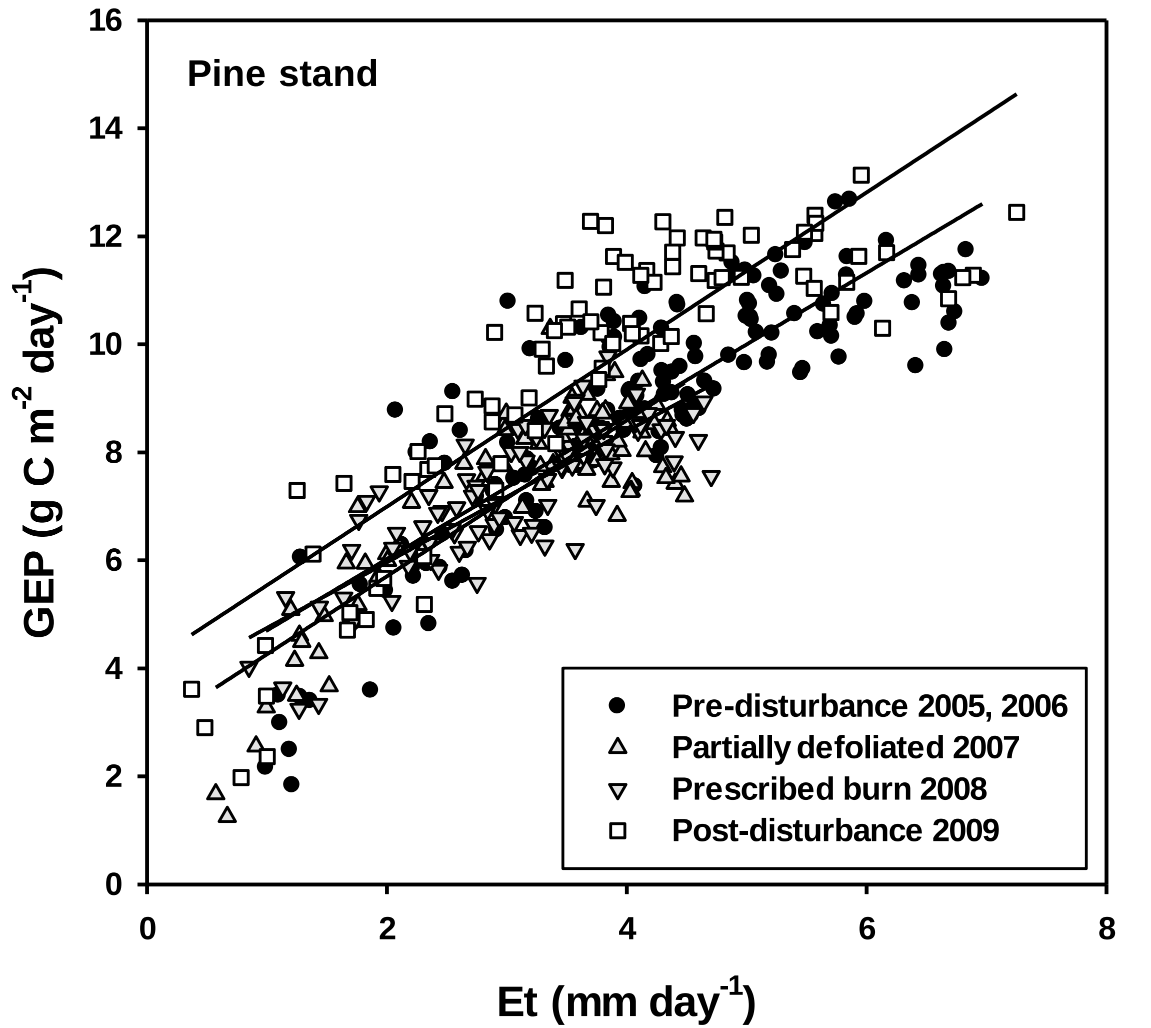


Daily Et (mm day^{-1}) during the summer at the oak, mixed, and pine stands 2005-2009.



Annual evapotranspiration estimates for the pine stand. Values are mm year^{-1}.

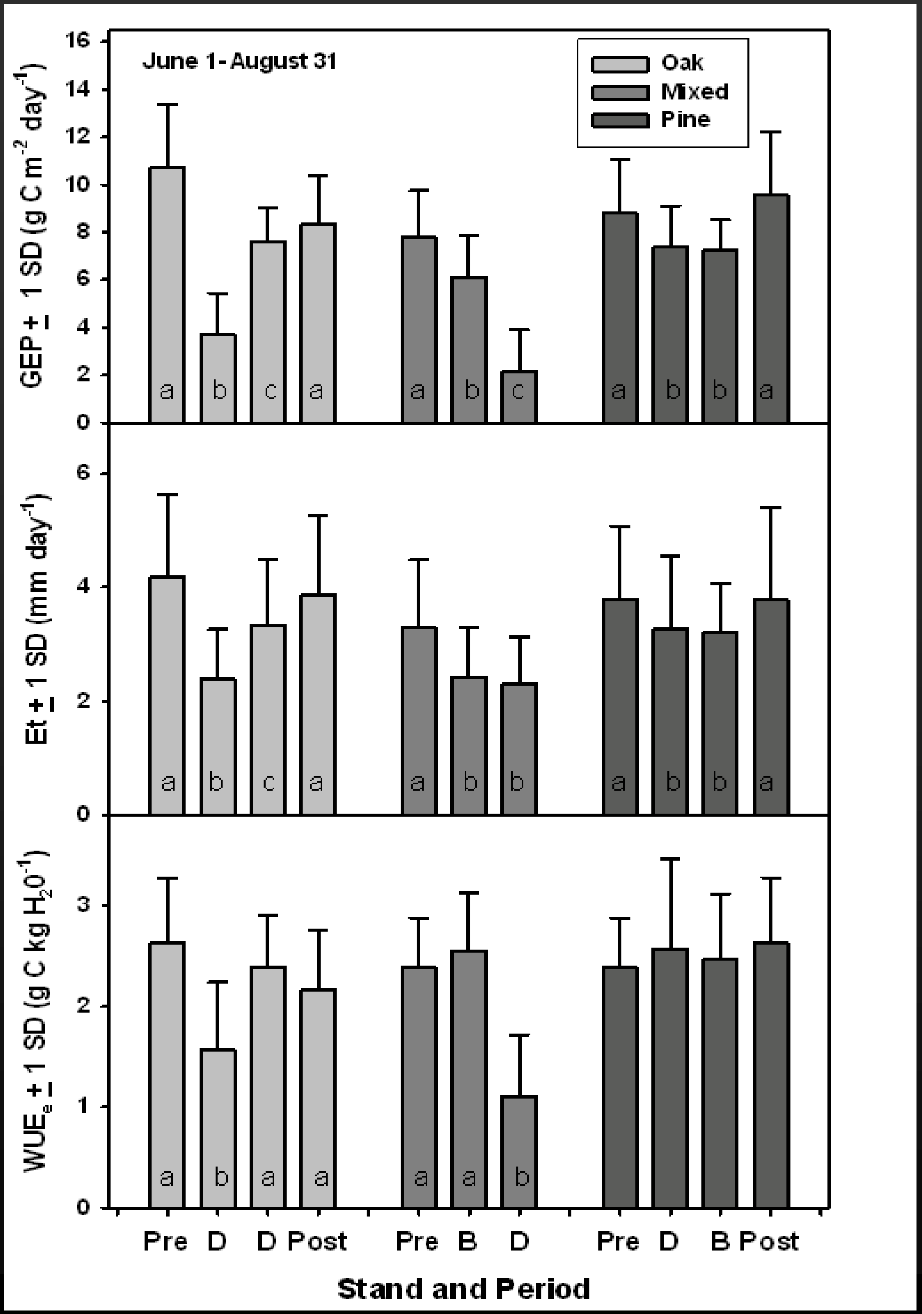
Site, Disturbance	Precipitation (mm yr^{-1})	ET (mm yr^{-1})	% ET
2006	1230	757	61.5 %
2007, partially defoliated	1052	593	56.3 %
2008, prescribed fire	1163	611	53.5 %
2009	1382	759	54.9 %



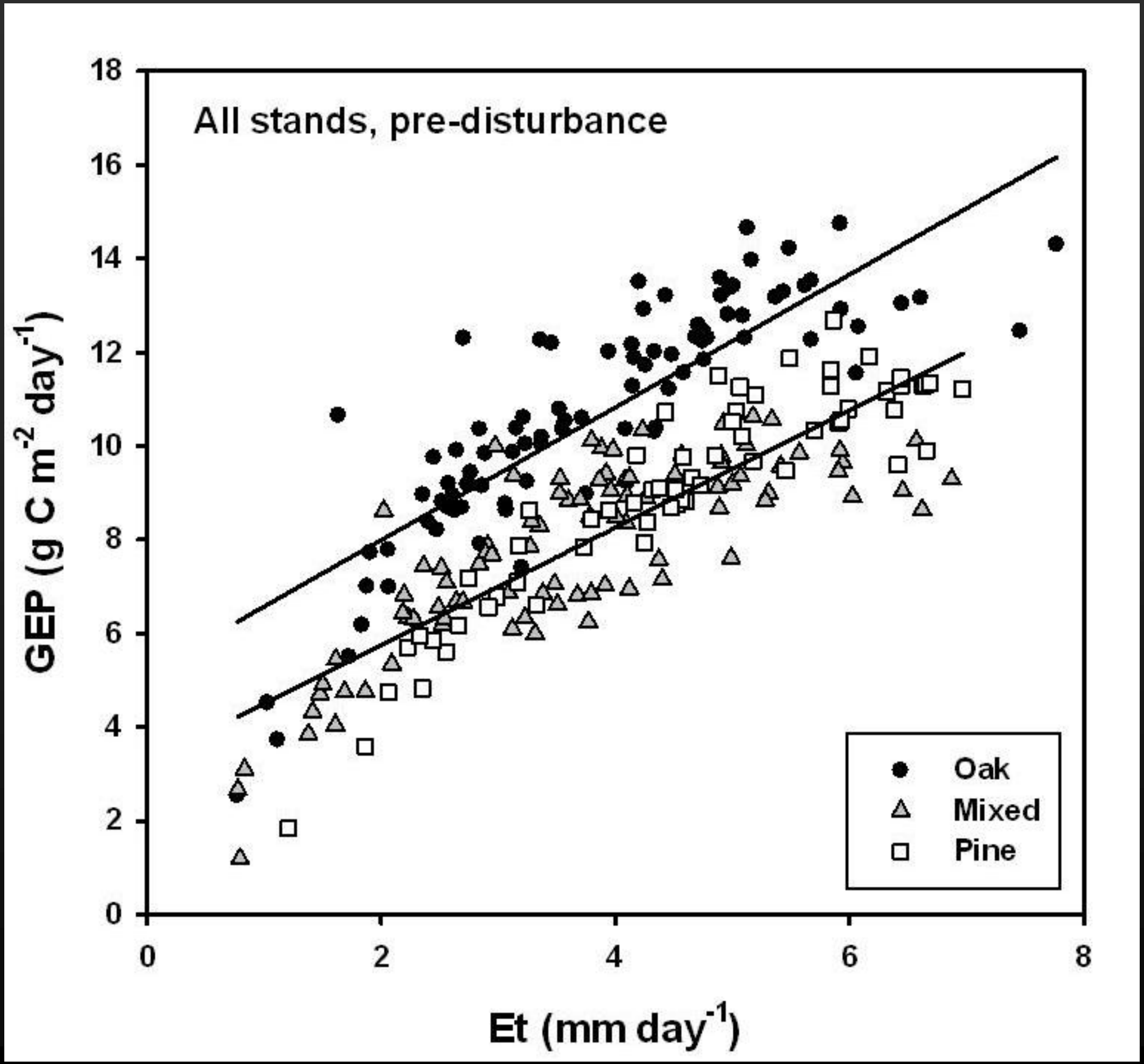
Pine stand
GEP (g C m-2 day-1)
Et (mm day-1)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
Pre-disturbance 2005, 2006
Partially defoliated 2007
Prescribed burn 2008
Post-disturbance 2009

Summary of the effects of defoliation and prescribed fire on carbon and hydrologic fluxes; GEP, Et and WUEe at the oak, mixed and pine stands

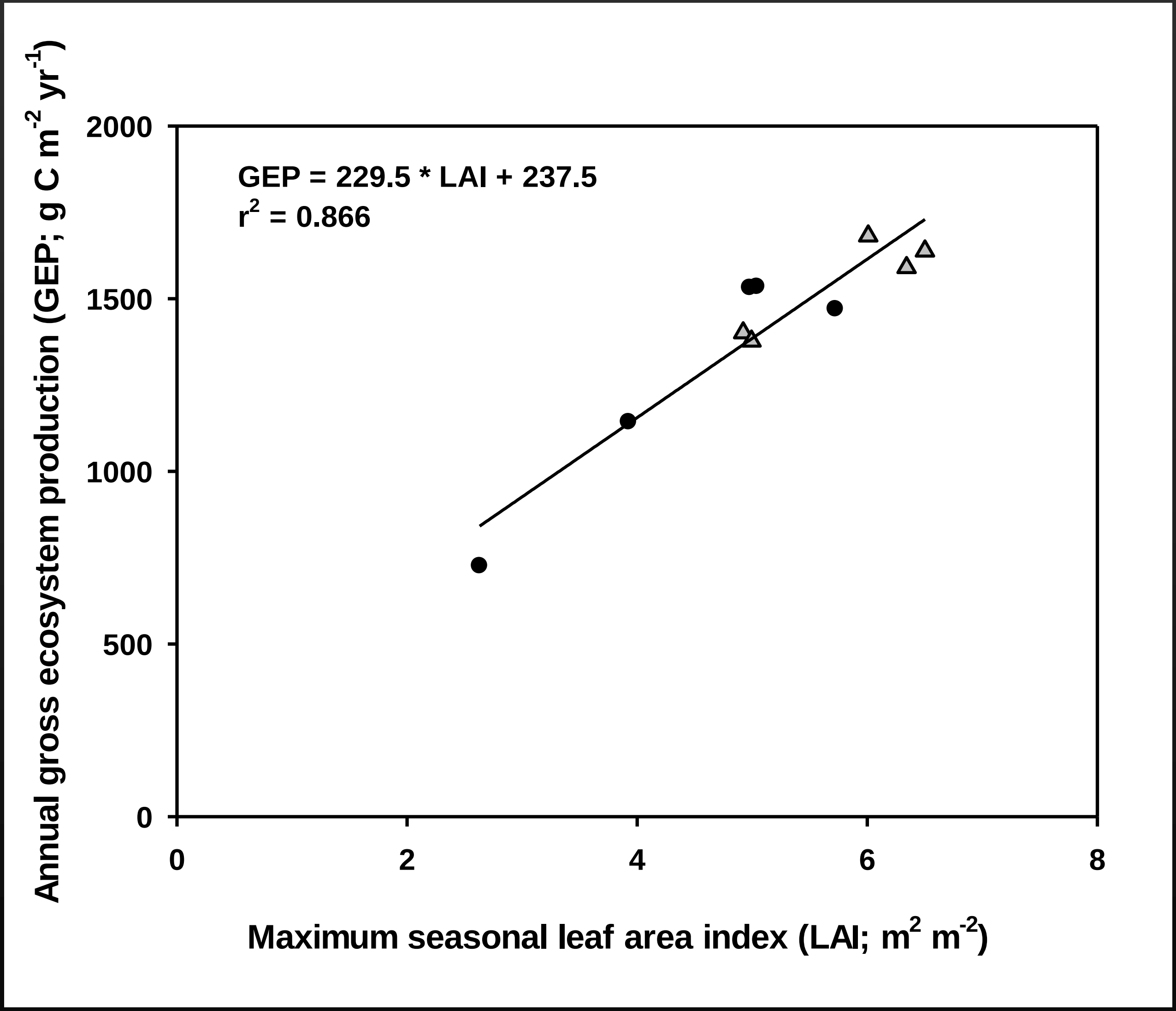
Some general patterns…



Ecosystem water use efficiency (WUE_e) at the oak, mixed and pine stands before disturbance in 2005 - 2006



Maximum seasonal leaf area vs. annual GEP



Correlation between maximum canopy and understory N content (g N m-2) and daily gross ecosystem productivity (GEP, g C m-2 day-1) during the summer, or annual gross ecosystem productivity (GEP, g C m-2 yr-1.).

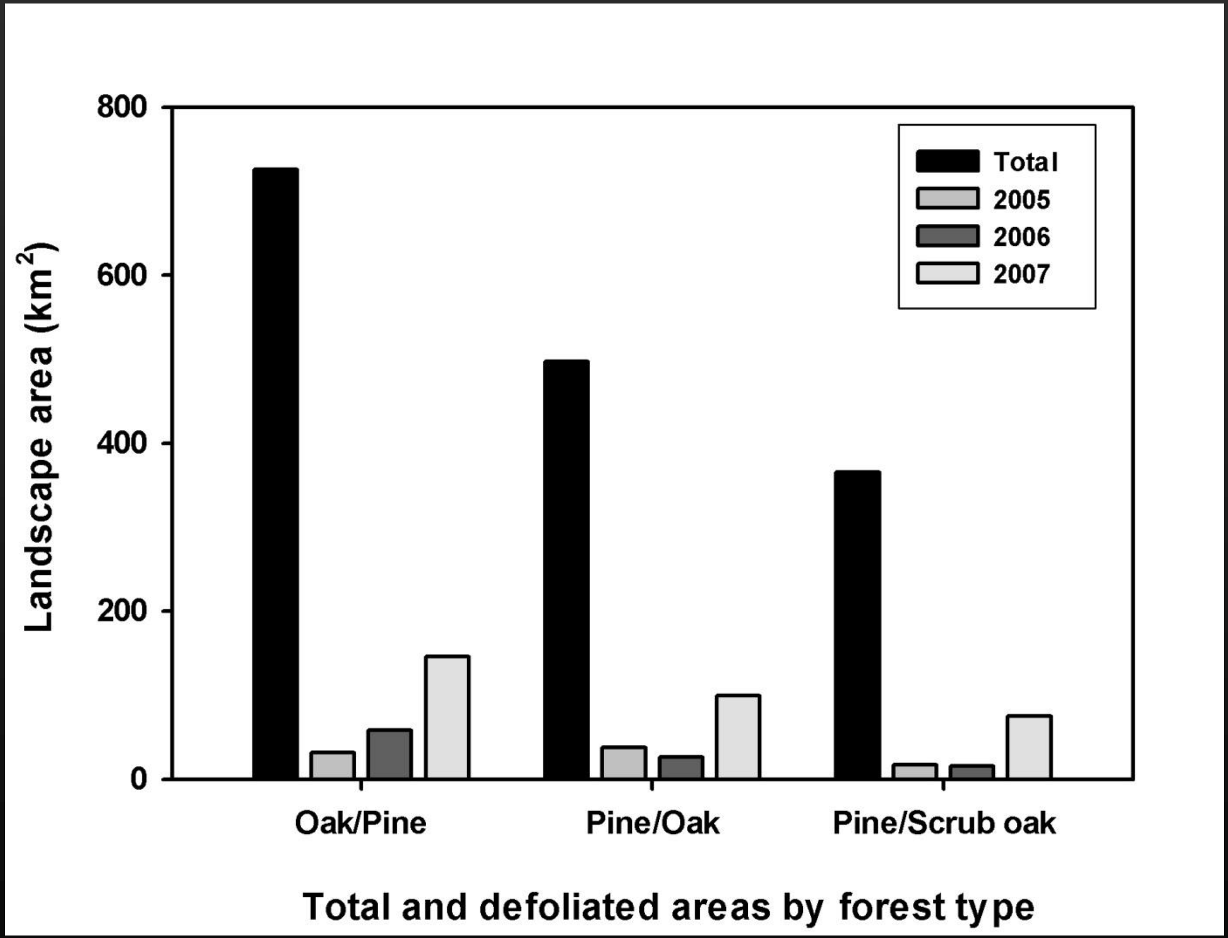
	Stand	a	b	r^2
Daily GEP (g C m^{-2} day^{-1})				
	Oak	1.504	0.578	0.883
	Oak, mixed	1.637	-0.485	0.818
	Pine	1.21	3.511	0.539
Annual GEP (g C m^{-2} yr^{-1})				
	Oak	215.3	156.9	0.869
	Oak, mixed	182.5	320.4	0.797
	Pine	179.7	822.9	0.620

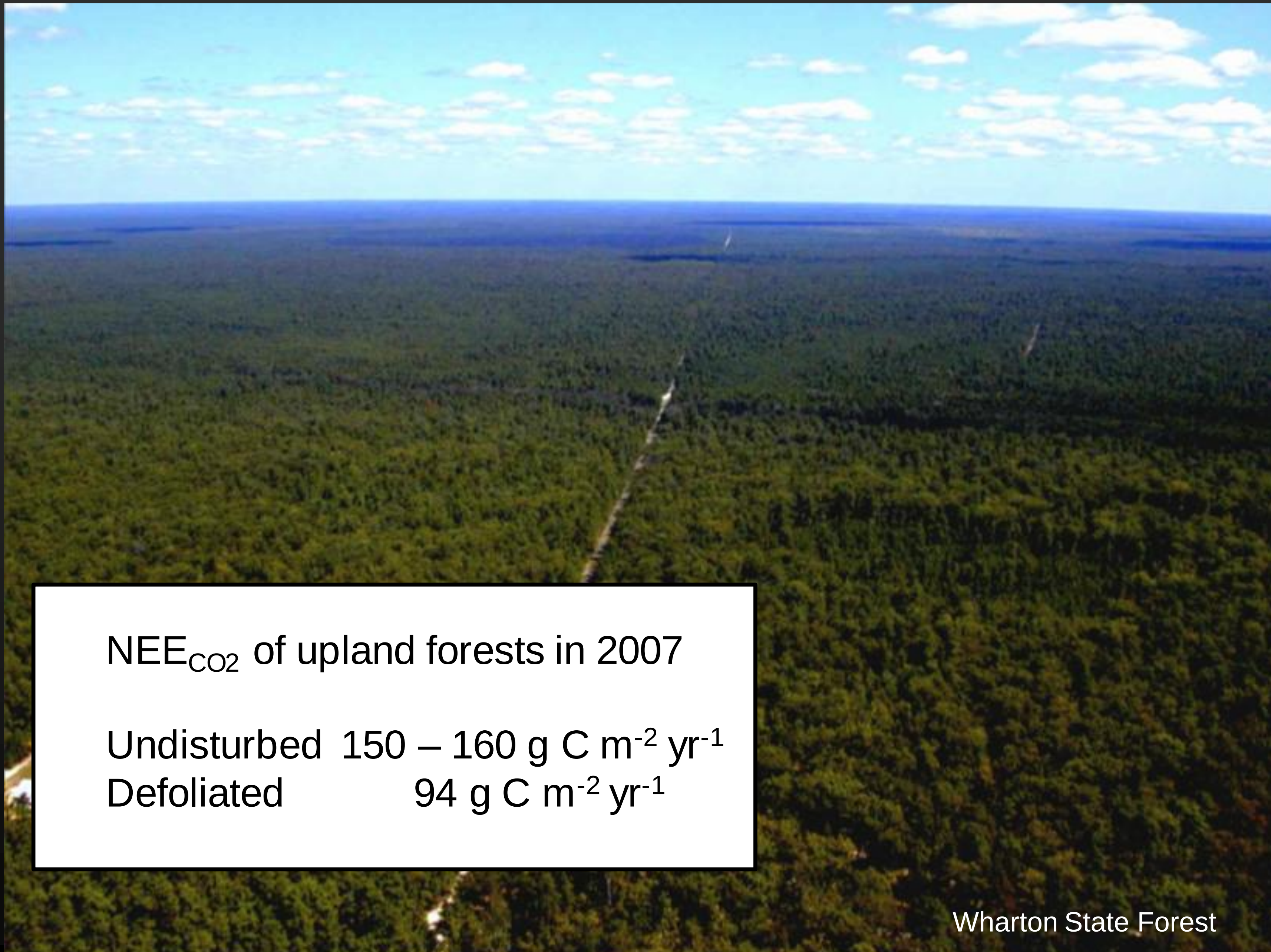
Flux towers in the Pinelands of New Jersey

Longer term fluxes at the oak and pine stands. Values are g C m^{-2}.

Years	Oak	Pine
2005-2006	163	183
2007-2011	-19	93
Big fluxes	750-1000 g C coarse wood	- 410 g C consumed
2005-2011 total	229	418
"No disturbance"	1138	1278
Actual/Potential (%)	20%	34%

Total area by forest type and area defoliated by Gypsy moth from 2005-2007





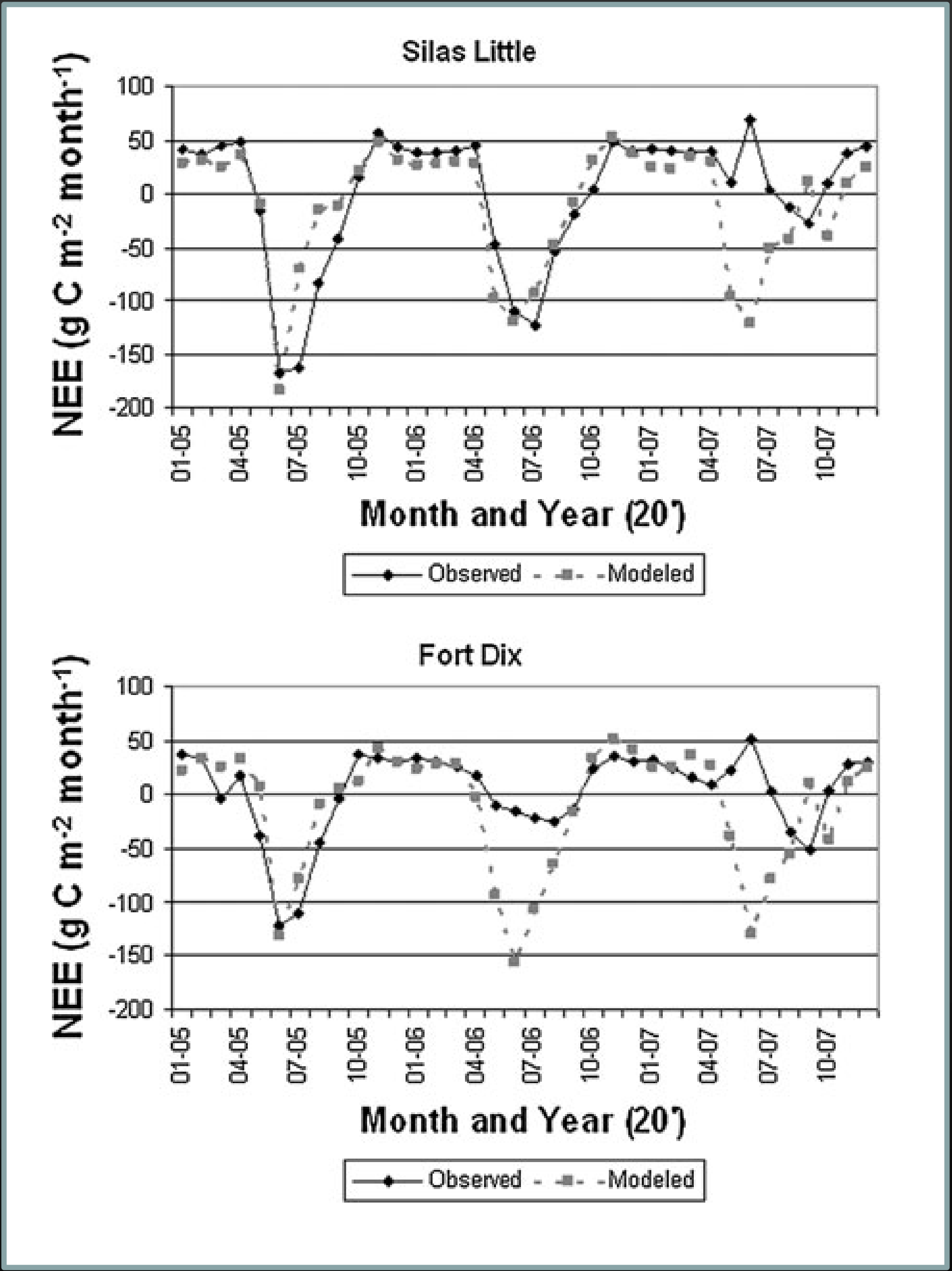
NEE_{CO2} of upland forests in 2007

Undisturbed 150 – 160 g C m^{-2} yr^{-1}
Defoliated 94 g C m^{-2} yr^{-1}

Carbon Sequestration in the New Jersey Pine Barrens Under Different Scenarios of Fire Management

Ecosystems 2011

R. M. Scheller, S. Van Tuyl, K. L. Clark, J. Hom, and I. La Puma



Conclusions:

- Non-stand replacing disturbances can have significant effects on NEE_{CO2} and GEP, while R_{eco} varies less pre- and post disturbance.

- Recovery of NEE_{CO2} is tightly linked to leaf area display. GPP is a linear function of LAI or N content of foliage within stand types; a reasonable approximation of GEP and Et can be calculated from maximum seasonal LAI values.

- Incorrect modeling of within-season changes in LAI results in poor model performance; high resolution remote sensing of LAI will be essential to characterize changes in LAI during disturbances and subsequent recovery.

Conclusions:

- Long-term measurements of Et which included non-stand replacing disturbances reflected other estimates of annual Et and groundwater recharge in the Pinelands.

- Non-stand replacing disturbance may play an important role in regulating C sequestration, nutrient cycling, and Et and groundwater recharge in other forest ecosystems.