Carbon Storage in Temperate Forests: The Role of Biodiversity and Functional Evenness

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Background:

-Northeast forests are the one of the largest terrestrial C-sink in North America (Ciasis *et al.* 1995)

-NPP drives this sink through storage and cycling of terrestrial biomass (which is composed in part of carbon)

- Forest ecosystems constitute 50% of global NPP and 80% of terrestrial NPP (Shimel 1995)

Questions:

-How does biodiversity influence the capacity of this sink?

-How will biodiversity change in the face of three different drivers?

1. N-Deposition
2. CO2 fertilization
3. Sudden Oak Death

Methods:

-Using data from BRF apply mortality and growth statistics found in other forest ecosystems experiencing these drivers

-Apply Framework set by Naeem and Wright (2003) using effect and response traits when measuring ecosystem function

-Calculate resulting AGB in four different scenarios

Driver of biodiversity change (1)

(1) N-deposition

- 10 fold increase in N-deposition in some parts of the US (Aber *et al.* 2001)
- "N-saturation syndrome," tree mortality caused by excess N (Magill *et al.* 2004)
- Initial increase in NPP and can be expected in the short term
- Harvard Forest study found an average 30% increase in NPP over a 14 year study (Magill *et al.* 2004)
- Fast growing understory species account for most of this growth

Chronic N-Deposition at the Harvard Forest (Magill *et al.* 2003)

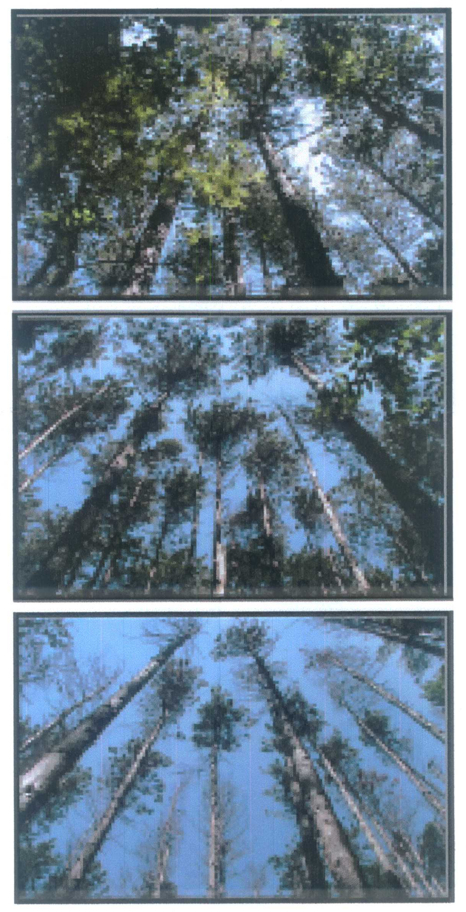


Fig. 9. View of the control (top panel), low N (middle panel) and high N (bottom panel) canopy in the pine stand at the Harvard Forest (images courtesy of Christian Arabia).

Driver of biodiversity change (2)

(2) CO2 increases

- DeLucia and Moore (2005) found that under levels of CO2 projected by 2050 (550 ppm) deciduous tree species experienced a 44% growth rate
- 23% increase in NPP at 550 ppm CO2 (Norby *et al.* 2005)
- CO2 fertilization favors shade tolerant trees (Aber *et al.* 2001)
- Most studies done on immature trees
- Mature stand experienced short-term enhanced growth rates (Korner *et al.* 2005)

Web-FACE (free air CO2 enrichment)
Crane and tubes releasing CO2 in 35-meter-tall temperate forest stand (Korner *et al.* 2005)

Driver of biodiversity change (3)

(3)Invasive exotic (*Phytophthora ramorum*)

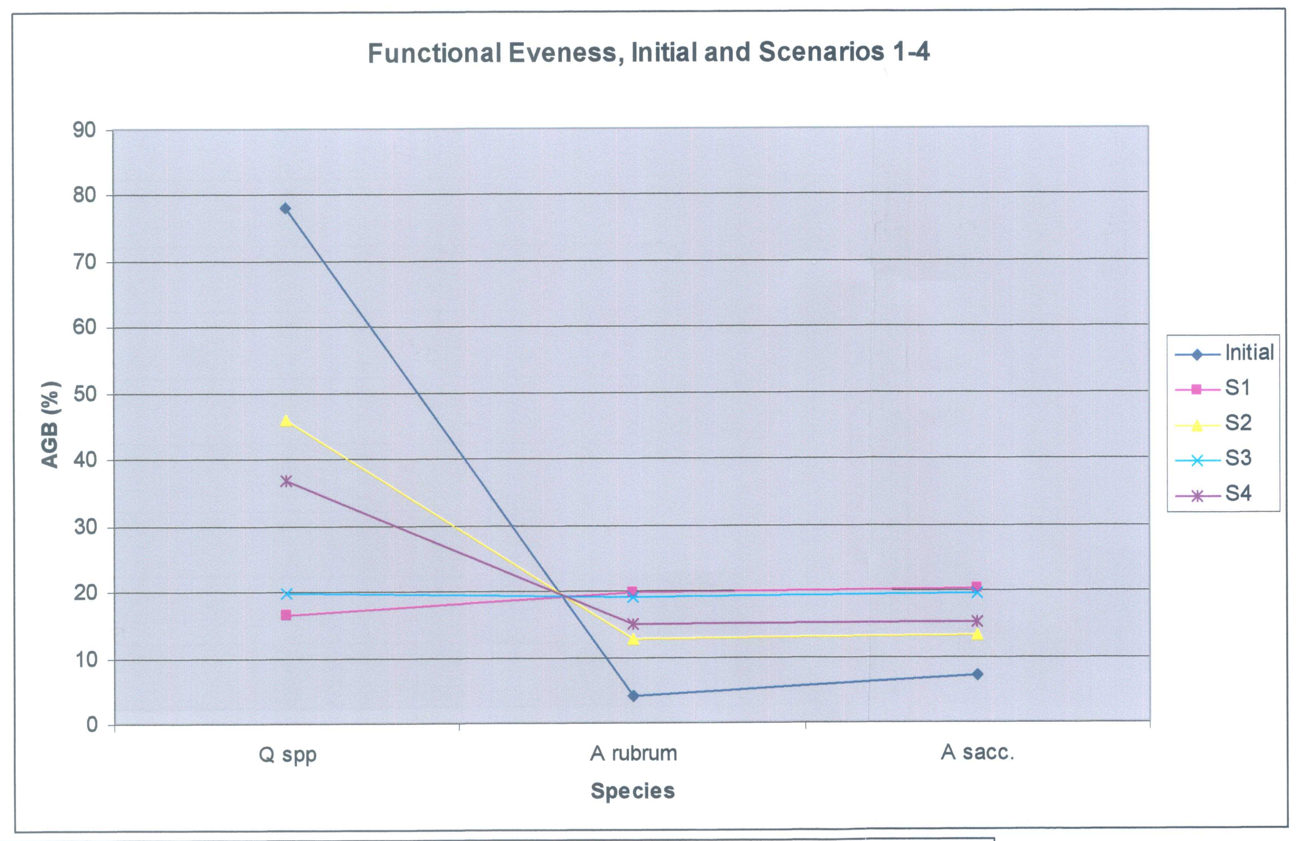
- Fungal pathogen has caused upwards of 66% mortality amongst *Quercus* species in western forests (Rizzo and Garbelotto 2003)
- Eastern *Quercus* species shown to be susceptible (Maloney *et al.* 2005)
- Forests under abiotic stress (N and CO2 saturations) more susceptible to infection (Rizzo and Garbelotto 2003)
- *P ramorum* targets trees with largest DBH
- Time of tree mortality post infection varies from months to years
  - Important in terms of soil respiration rates and SOM decomposition

Results of Sudden Oak Death in Western Forests (Rizzo and Garbelotto 2003)

Figure 3 Overstory mortality of tanoak (*Lithocarpus densiflorus*) caused by *Phytophthora ramorum* in (*A*) Marin Co., CA and (*B*) Monterey Co., CA. (Photos by D. Rizzo, S. Frankel)

Functional traits of each species and functional groups

	Driver 1a	Driver 1b	Driver 2	Driver 3
	N-Deposition (high)	N-Deposition (low)	CO2 fertilization	Invasive Exotic (*P ramorum*)
Spp	**Response Trait (N-high)**	**Response Trait (N-low)**	**Response Trait (CO2)**	**Response Trait (*P ramorum*)**
Q spp	N-tolerance	N-tolerance	Photosynthetic rate	Susceptibility
A r.	N-tolerance	N-tolerance	Photosynthetic rate	na
A sacc.	N-tolerance	N-tolerance	Photosynthetic rate	na
B lenta	N-tolerance	N-tolerance	Photosynthetic rate	na
Spp	**Effect Trait (N-high)**	**Effect Trait (N-low)**	**Effect Trait (CO2)**	**Effect Trait (*P ramorum*)**
Q spp	% Mortality (36.8)	% Mortality (22.2)	% growth increase (23)	% mortality (66)
A r.	% Mortality (72.7)	% Mortality (19.1)	growth rate (high)	na
A sacc.	% Mortality (na)	% Mortality (na)	growth rate (med.)	na
B lenta	% Mortality (100)	% Mortality (65)	growth rate (high)	na



Recruitment rates from Taylor and Lorimer (2003) and gap capture rates from Lorimer (1981) used to construct a new canopy composition

Species	Recruitment Rate	Gap Capture Rate (%)
Q spp	Low	Low (20)
A rubrum	High	High (80)
A sacc.	Medium	Medium (50)
B lenta	Medium	Medium (50)

Scenario 1
-All three drivers at low N-Deposition

Scenario 2
-Low N-deposition and CO2

Scenario 3
-Sudden Oak death

Scenario 4
-High N-deposition and CO2

Results:

-Initial reduced functional magnitude (C-storage)

-Increase functional evenness and distribution of AGB

-Concentration of ecosystem function in one functional group (*Q spp*) creates instability in the face of the modeled drivers

Management and conclusions:

"Long-term rates of C sequestration can be deliberately manipulated through forest management" (Barford *et al.* 2001, p. 1690)

1. Manage for long-term soil storage (2/3 of terrestrial carbon sink)
2. Avoid bare ground, net release of C and loss of SOM
3. Maintain canopy structure
4. Selectively log *Quercus* species if *P ramorum* is imminent
5. Manage for a "wave" of species loss rather "flash"
6. This entails enhancing ecosystem stability by distributing ecosystem function amongst species outside of *Quercus* functional group
7. To balance C-storage and ecosystem function maintain a functional diverse mid-aged stand (period of maximum C-sequestration) over the long-term