Are the high-elevation spruce-fir forests in the Southeastern US sources or sinks of CO₂?

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Problem statement

Role of existing forests in the global C balance

Influence of low-management on ecosystem C sink/source strength

Example Red spruce (*Picea rubens*) – Fraser fir (*Abies fraseri*) forests in the Southeastern US



High elevation (> 1500m)
 Limited Management
 Limited Access – steep terrain
 National Park & Wilderness designation



Natural History



(vegetation)

Spruce-fir forest @ southern end of distribution
Occupy ~ 27,000 ha
Post-Pleistocene relict "islands"
Largest contiguous area in the Great Smoky Mts Nat. Park

Limited historical loggingFire not disturbance agent

Natural distribution of P. rubens Source: www.treeguide.com

Recent Disturbance History

* Fir mortality due to to balsam wooly adelgid (1970s)
* Windfall and ice storms
* No/Limited logging
* No fire disturbance

Natural History (Soils)

Soils not glaciated
Limited historical logging
Fire not disturbance agent



Extent Laurentide Ice sheet Source: www.ngdc.noaa.gov/paleo/glaciation.html

Soil Characteristics





Soils are high in organic matter
 Podzolization process

Classified as Inceptisols or Spodosols
 Landslides

Forest Ecosystem Condition



Large pool of "legacy" C in the soil

Mature/Overmature
Limited Management
Mortality of mature fir
Standing dead trees
Input of downed coarse woody debris

Heterogeneity in forest structure





Study Questions
What are the major C pools?
Do they behave as C sources or sinks?
What is the overall ecosystem C balance?



Study site: Red spruce - Fraser fir forests zone in the Great Smoky Mts Nat.Park, TN and NC.

Vegetation Map of Great Smoky Mountains National Park Classified From Landsat Thematic Mapper Data

Mixed Mesic Hardwood

ruce - Fir

Xeric Dak Pine – Oak Pine G Treeless Water

Prepared by: M. D. MacKenzie and J. R. Carter, Geography Department, University of Tennessee, Knoxville, 1989



200 m

1 Km

54 plots (1520 – 1970 m) 50 in Noland Divide WS (17.4 ha) Close proximity Similar aspect

Measurements

- 1. Overstory Inventory
 - Dead & live trees by species
 - 1993,1998, 2003
 - (NDW, 50 plots)
 - 1996-2002 (NAPAP, 4 plots)
 - Nutrient contents (1998)
- 2. Coarse woody debris
 - By species and decay class
 - Decomposition constants
 - 1994 (Rose, 2000)
 - New input from inventory
- 3. Understory inventory
 - Herbaceous, shrubs, regeneration
 - **2003-2004**



Overstory C pools & fluxes

Forest Inventory and tissue sampling





Legacy: by tree species by decay class decomposition constant (Rose, 2000) New Input: from forest inventory

Downed wood C pools & fluxes



Understory C pools



Shrubs & Regeneration 4x4 m plots diameter allometric equations

Herbaceous: 1x1 m plots cover

Measurements

1. Soils

- Cores 0-50 cm
- 1998 (NDW , 50 plots)
- 2003 (NAPAP, 4 plots)
- Bulk density (2003)

2. Forest floor

- Destructive sampling
- 1998, 1999 (NDW , 50 plots)
- 2003 (NDW & NAPAP, 8 plots)

3. Respiration

- Summer and Fall
- **2002-2004**
- 8 plots (NDW & NAPAP)



Soil Respiration Static Chamber (NaOH)





C pools (Mg/ha)



Live Overstory : 121 (22-242) Standing dead: 38 (3-109)

Understory: 3 (0.5-13)

Downed Coarse woody debris:1994: 181998: 222003: 35 (8-125)

Forest Floor : 21 (4-39) Mineral Soil: 165 (44-262) Ecosystem 415





Spatial heterogeneity C sequestration potential





Temporal variability in C sequestration

Increment and Ingrowth (kg C ha⁻¹ yr⁻¹)







C fluxes and overall ecosystem balance (kg C ha⁻¹ yr⁻¹)

PLOT	Elevation	Overstory Sequestration	Soil Respiration	Balance 1 (Seq Resp)	C release from CWD	Total C Balance
341	1524 m	-2,800	1,900	-900	1,100	+210
352	1537 m	-3,000	1,680	-1,300	3,650	+2310
C5600	1701 m	-1,800	1,500	-300	3,020	+2740
F5600	1701 m	-3,600	1,050	-2,600	780	-1,800
E6000	1835 m	-3,200	1,290	-1,900	790	-1,150
16000	1835 m	-3,250	1,320	-1,950	470	-1,460
337	1966 m	-4,400	1,330	-3,100	1,220	-1,840
343	1966 m	-4,300	1,300	-3,000	1,130	-1,840

Average Ecosystem Balance: -350



 C sequestration by overstory is spatially very variable
 C sink strength has increased over last 5 years, especially at the higher elevations

- Woody debris must be included in ecosystem C balance
- Respiration is temperaturesensitive
- C sinks and sources -- in a dynamic equilibrium
 Future C balance is
 uncertain



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Questions ?

