Terrestrial Carbon Inventory at the Savannah River Site, 1951 – 2001* Final Report by US Forest Service

* Information used in this presentation is based in part on the Terrestrial Carbon Report November 2011 by Z. Dai, C. Trettin and B. Parresol with the USFS Southern Research Station

Objectives

1. Create reliable estimates of the carbon stocks and flows to satisfy Federal compliance & mitigation strategies (E.O. 13514).
2. Create reliable estimates of forest and land management effects, including lifecycle analysis.
3. Perform a comparative analysis with recent USFS Region 8 estimates by Heath et al. (2011) and for southern forests

* 2000 is the baseline year for carbon stocks per International Program on Climate Change

Project Tasks

Estimate:

- the changes in carbon stocks from 1951 to 2001
- the carbon distribution in soils and vegetation components
- the landscape distribution of carbon in soils and vegetation
- the major carbon fluxes from forest management activities
- the forest vegetation carbon sequestration rate

Identify significant assumptions and uncertainty affecting results

Savannah River has Extensive Empirical Databases on Carbon

- Comprehensive land & forest inventory from 1951
- Comprehensive forest inventory from 2001
- Land use records and spatial maps
- Annual fire and emissions data
- Annual wood harvest data
- Stream flow and organic carbon data from SRNL
- Local soils data (SRNL) to compare with NRCS data

Savannah River 1951 Inventory (>2300 land parcels)

"-----Acres-----" "-----MBM-----" '-----cords-----'

Segment	Total Ac	Pasture	Crop	Pine	Hdwd	Pine Plant.	Swamp	Pond	Pine	Gum	Poplar	Misc Hdwd	Cypress	Pine Pulp	Hdwd Pulp	Fuelwood
A	10,910.5	387.8	4,637.90	3,444.9	1,121.8	128.0	1,157.1	32.0	2,655.0	1,187.0	488.0	573.0	1.0	1,723.5	6,359.0	470.0
B	7,874.4		1,406.70	1,497.0	808.1	75.0	4,080.6	7.0	1,351.3	3,042.0	225.0	2,945.5	1,824.0	649.0	6,998.0	15.0
C	5,412.4	36.0	2,153.00	1,796.9	404.4	17.0	1,005.1		1,241.6	1,032.2	177.1	1,088.2	298.0	1,505.0	2,185.0	492.0
D	4,854.9	305.0	1,848.70	886.4			1,759.8	55.0	886.0	1,873.0	112.0	3,203.0	2,659.0	477.0	2,256.0	86.0
E	7,824.9	385.0	1,907.90	961.6	625.8		3,914.6	30.0	695.9	2,324.2	45.4	927.9	1,903.1	622.0	6,318.0	194.0
F	10,854.6		3,889.30	2,464.6	2,602.0	1,439.5	959.2		1,789.5	2,027.0	497.0	999.0	6.0	1,516.0	4,599.0	1,144.0
G	3,579.3	15.0	2,322.70	809.6	217.0	51.0	161.0	3.0	789.0	203.0	48.0	149.0	23.0	303.0	686.0	343.0
H	8,530.9	30.0	5,076.30	2,031.9	664.2	95.0	626.5	7.0	1,495.0	993.0	366.0	438.5	17.0	1,099.0	2,327.0	774.0
I	10,553.9	296.2	3,978.10	3,334.1	1,079.2	91.0	1,758.3	17.0	2,599.4	1,822.0	836.2	870.4		2,171.0	4,050.0	340.0
J	8,232.3	223.3	3,735.60	3,883.2	298.4	17.0	60.3	14.5	2,338.0	199.0	16.0	147.0		2,626.0	659.0	2,402.0

Carbon Stocks

Total carbon increased in SRS biomass by a factor of 12 since 1951.

1 Mg ha⁻¹ ~ 0.446 U.S. tons ac⁻¹

A Gigagram (Gg) ~ 1,102 U.S. tons

Land Use	1951			2001		
	Area (ha)	Total C (Gg)	Area Density (Mg ha ⁻¹)	Area (ha)	Total C (Gg)	Area Density (Mg ha ⁻¹)
Pine	27,392	155.7	5.68	50,045.3	3,774.4	75.4
Pine-hardwood	-	-	-	4,104.5	355.0	86.5
Hardwoods	21,512	250.9	11.66	19,686.1	2,051.3	104.2
Agriculture						
Crop	30,984	102.9	3.32	-	-	-
Pasture	1,295	3.1	2.39	-	-	-
Total	81,183	512.6	6.31	73,835.9	6,180.7	83.2

Carbon Stocks

Total carbon density (C Mg ha⁻¹) sequestered in all biomass components increased by a factor of 13 from 1951 to 2001.

LCR = Lifecycle Carbon Residue in Roots and Forest Products

Carbon Stocks

About 57% of the carbon is in mineral soil and 43% in biomass components in 2001. Total carbon in all components is approximately 215 Mg ha⁻¹. Soil mineral carbon is (~2X) >> R8 NFS.

Carbon Stocks

Forested wetlands contain a large percentage of the carbon in both soils & biomass at SRS due to soil C content, stocking and productivity.

Carbon Stocks

Site non-forest development resulted in a ~5% loss in potential carbon stocks. The soil carbon in roads, ponds, ROW and facilities is unknown.

About 4500 hectares were developed into facilities, ROW, roads, cooling ponds, or lost in a land transfer in the 1970's.

Land use area (hectares)			
Land Use	Raster 1951	1951	2001
Forested	49,582	48,904	73,836
Agriculture	28,773	32,279	0.0
Developed	2828		6341
Transfer to Barnwell County	--	--	1006
Total	81,183	81,183	81,183

Carbon Fluxes

Streams are a small component of carbon loss (POC, DOC). The amount of CO₂ lost by evasion is estimated to be between 10 and 16 Gg per year.

Riverine C loss (C_R) was estimated as: $C_R = A \cdot P \cdot R_f \cdot C_x$,

C_R is the riverine carbon loss;

A is the basin area in ha (81,212 ha);

P is annual precipitation in mm (average is 1260 mm);

R_f is the mean annual flow fraction (0.32);

C_x is the organic C concentration in water POC=1.8 mg L⁻¹, DOC=5.3 mg L⁻¹ ;

$C_R = 2.1$ Gg per year (~2.5% of all losses)

Carbon Fluxes

Prescribed fires (&wildfires) are a major component of annual carbon loss and fire losses are comparable to wood harvests.

Average fuel consumption is 1.43 Mg ha^{-1} or about $3.2 \text{ tons acre}^{-1}$.

Future fuel consumptions is expected to be $\frac{1}{2}$ to $\frac{2}{3}$ of current rate.

Carbon Fluxes

Wood harvesting is a major component of annual carbon loss. Pine straw sales from 1991-2002 were ~2-3 Gg per year.

Annual carbon loss from pine and hardwood sawtimber and pulpwood. Sequestration (~1/2) via lifecycle analysis is not included.

Carbon Fluxes

Lifecycle analysis mitigates harvest removals. The fraction of the harvested carbon sequestered in roots is ~14% & ~34% in forest products. These values > R8 NFS.

Cumulative (Accu) and residual (Residue) root biomass following harvests.

Fraction of harvested carbon sequestered in use and in landfills.

Carbon Fluxes

Net carbon sequestration at SRS is high compared with other ecological studies in temperate forests and other lands in Southern U.S.

Comparison of SRS (1951-2001) to other ecological studies (A) and average carbon sequestration rates estimated by Heath for 2005 for Southern U.S. (B).

Assumptions and Uncertainty

Small changes in conversion factors can have a major impact on carbon values (e.g. soil & wood density, partition factors for biomass, soil depth, etc.)

Estimation methods are not standardized among assessments due to data availability & technical capability (e.g. understory/forest floor biomass, lumped species equation)

How Reliable are Interpretations?

- 1) Relative size of stocks and fluxes (factors of 0.5, 1, 5, 10)
- 2) Trend in stocks and fluxes (plus or minus)
- 3) Absolute values over large areas (law of large numbers)

Assumptions and Uncertainty

The Smith et al. 2003 function is biased at low stocking levels (F , G , and H are coefficients for specific regions/forest types).

$$L = F \cdot \{G + [1 - \exp(-V/H)]\}$$

Smith et al (bars) grossly over estimates carbon at low densities

A steep slope at low stocking means *a small change in V can result in a large change for L*

Assumptions and Uncertainty

The specific gravity of trees is assumed to be one value for all pine as a group and all hardwood as a group although it varies significantly.

Average specific gravity for hardwoods varies among species from 0.33 to 0.62 (Jenkins et al. 2003)

Average specific gravity for whole tree loblolly pine varies regionally from 0.42 to 0.52 (Jordan et al. 2008)

Assumptions and Uncertainty

The IPCC recommends a factor of 0.3 to estimate the coarse root system. Above ground biomass ratios or allometric equations are more precise.

Root Biomass vs Above Ground Biomass (Mokany et al. 2006)

Assumptions and Uncertainty

We used simple ratios to estimate biomass of tops and roots for each species class and product class of harvested material.

Aboveground live tree biomass in Mg ha^{-1} :

$$L_{\text{abg}} = V \cdot W \cdot (1 + T)$$

V - wood volume in $\text{m}^3 \text{ha}^{-1}$

W - species conversion factor

T - ratio of tree top to volume

$T = 0.136$ for pine, $=0.179$ for hardwoods, $=0.218$ for bottomland hdwds

Total live tree mass in Mg ha^{-1} :

$$L_{\text{T}} = L_{\text{abg}} \cdot (1 + R)$$

R - ratio of roots to aboveground biomass

$R = 0.3$

Assumptions and Uncertainty

No change in mineral soil carbon between 1951-2001 was assumed.
Variation in soil bulk density can have a big impact on absolute values.

	1951		2001	
	<u>Total (Gg)</u>	<u>Mg ha⁻¹</u>	<u>Total (Gg)</u>	<u>Mg ha⁻¹</u>
Forest Floor	117.4	2.4	432.5	6.0
Mineral soil (NRCS)	9407.2	124.0	9407.2	124.0

Assumptions and Uncertainty

Data that indicates old-field forests may have a significant soil carbon deficit even after 50 years reflecting potential carbon sequestration capacity.

Comparison of SRS soil carbon values (Looney et al. 1990) with NRCS values for similar soil series (all values are Mg/ha).

	SRS	NRCS
Soil series	Mean	Mean
Blanton	47.61	77.23
Fuquay	36.61	45.27
Lakeland	44.27	84.38
Orangeburg	40.78	36.50
Udorthent	15.79	55.31
Vaocluse	54.18	
Mean	33.48	57.49
Median	28.90	55.31

Deficit SOM in paired comparison study of old-fields vs adjacent remnant forests at SRS in 2009 (Bazari, Collins, Brudvig). Deficit roughly equals 21 Mg/ha of potential carbon sequestration

Summary (1951-2001)

	Sequestration (Gg)	Removal (Gg)
Pool (in 2001)		
Biomass (Above & Below Ground)	5486.2	-
Soil (Forest Floor)	315.2	-
Forest Products In Use & Landfill	357.1	
Root Residues (un-decomposed)	193.9	
Total Sequestration	6350.2	
Flux (total cumulative 1951-2001)		
Harvested Commercial Wood (Total)		1078.8
Small Round Wood	-	(725.4)
Large Round Wood	-	(353.4)
Decomposed Tops (after harvest)	-	181.1
Decomposed Roots (after harvest)	-	257.4
Fire - Total	-	587.9
Prescribed	-	(569.5)
Wildfire	-	(18.4)
Runoff (Total Organic Carbon)	-	105.2
Particulate Organic Carbon	-	(26.7)
Dissolved Organic Carbon	-	(78.5)
Total Flux		2180.4

Comparisons Between NFS R8 and SRS

- Heath's calculations use slightly lower values for root system biomass (~0.2) than reported in scientific studies or used by IPCC (0.3).
- SRS soil carbon density values are 2X > than R8 NFS estimates. Possibly a result of soil depth, soil maps or fraction of lands in wetlands.
- Mean live biomass density estimated is similar between R8 NFS and SRS.
- Average forest floor and large woody debris biomass is slightly greater at SRS than R8 NFS average. The area burned was likely lower in 1980-2001 at SRS
- Forest products life cycle carbon in use and landfills is > at SRS (34%) than NFS average (~26%). Root life cycle analysis is not used in the NFS analysis.

How Much CO₂ is Sequestered in SRS Forest Vegetation?

Roughly 25 million metric tons of CO₂ have been sequestered.

- **Enough to offset the Scherer GA Coal-fired power plant for 1 YEAR**

The current rate of sequestration is about 760,000 metric tons annually.

- **The annual rate offsets the CO₂ footprint of**
  - **~45,000 U.S. individuals, or**
  - **~90,000 Western Europeans, or**
  - **~500,000 people in Central America, or**
  - **~5,000,000 Central Africans**

Take Home Messages

- Reforestation of agricultural and cut-over forest land has a HUGE impact
- Estimates of carbon stocks for R8 NFS appear conservative
- The “expansion factor” method may seriously OVER estimate pine savanna C
- Prescribed fire emissions of carbon are similar to forest products
- Wetlands store a lot of carbon (but it is offset by methane emissions)
- There may be a major C deficit-opportunity in old-field upland soils