



# Managed Forest Ecosystems

**Results from Studies by:**

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# Carbon Sequestration in Fertilized Loblolly Pine Plantations

- ⇒ Loblolly pine (*Pinus taeda*) is the most widely planted species in Southeast U.S. plantations.
- ⇒ 33% of US industrial wood plantations with 13.5 million hectares under management.
- ⇒ Fertilization is required on majority of forest land to correct nutrient deficiencies.
- ⇒ Aboveground growth and LAI greatly increased with fertilization.
- ⇒ CSiTE provided funding to investigate enhancing soil C sequestration with fertilization.



# Southeast Loblolly Pine Plantations Initiation

## ⇒ Objectives

- Evaluate the effects of N and P fertilization on C storage.
- Evaluate the effects of soil texture on soil C storage.

## ⇒ Sites and Establishment

- Escambia County, Alabama
  - ▶ Rhodic Kandudult, well-drained clayey
- Green County, Mississippi
  - ▶ Psammentic Paleudult, well-drained sandy
- Clear-cut harvested in winter of 1989, site preparation following summer with three-pass shear, rake, and disk.
- Herbicide applied to all plots in April 1990, followed by loblolly seedlings at density of 1850 trees ha<sup>-1</sup>.
- Sub-plots with no fertilization, sub-plots with 45 kg N and 50 kg P ha<sup>-1</sup>.
- Resampled 11 years later, May 2001



# Southeast Loblolly Pine Plantations

## Aboveground Growth

**11 year old loblolly pine plantation on contrasting soil textures with and without fertilization at planting.**

Subsoil Texture (Site)	Treatment	DBH	Height	Volume	Basal Area	Stand Density
		- cm -	- m -	- m <sup>3</sup> ha <sup>-1</sup> -	- m <sup>2</sup> ha <sup>-1</sup> -	- trees ha <sup>-1</sup> -
Clayey (AL)	Control	13.0 (0.6) <sub>a</sub>	10.5 (0.3)	134 (9)	24 (1)	1792 (58)
	Fertilized	15.1 (0.4)	12.0 (0.3)	199 (20)	32 (3)	1736 (80)
Sandy (MS)	Control	10.8 (0.4)	8.9 (0.3)	81 (7)	17 (1)	1730 (60)
	Fertilized	12.5 (0.7)	9.9 (1.3)	113 (25)	21 (2)	1656 (27)
Comparison	Effect	----- Probability > F -----				
Across Sites	Site	0.002	0.038	0.003	0.002	0.369
	Fertilization	0.022	0.125	0.047	0.044	0.157
	Site*Fertilization	0.740	0.749	0.427	0.464	0.825
Within Clayey Site	Fertilization	0.066	0.092	0.089	0.113	0.502
Within Sandy Site	Fertilization	0.184	0.481	0.346	0.278	0.114

Numbers in parantheses indicate the standard error (SE) where n=4 for each treatment.



# Southeast Loblolly Pine Plantations

## Initial Soil C

Table 2. Average total C concentration and content for the fine earth fraction (<2 mm) of the surface 0- to 20-cm of mineral soil for samples collected in April 1990 prior to stand establishment.

Subsoil Texture (Site)	Treatment	Depth	Total Carbon	
		- cm -	-- g kg <sup>-1</sup> --	-- Mg ha <sup>-1</sup> --
Clayey (AL)	Control	0-10	27.6 (6.8)	36.9 (9.0) <sup>a</sup>
		10-20	15.8 (2.2)	22.4 (3.7)
		0-20	--	59.3 (12.2)
	Fertilized	0-10	29.5 (4.7)	37.4 (4.2)
		10-20	20.2 (2.2)	30.4 (3.5)
		0-20	--	67.8 (5.4)
Sandy (MS)	Control	0-10	15.2 (0.3)	22.6 (1.3)
		10-20	12.7 (1.4)	20.1 (2.0)
		0-20	--	42.7 (2.3)
	Fertilized	0-10	15.4 (3.0)	22.6 (3.7)
		10-20	12.9 (3.5)	20.5 (5.4)
		0-20	--	43.1 (9.0)

Numbers in parentheses indicate the standard error (SE), where n=4 for each treatment.  
<sup>a</sup> Total C content estimated using bulk density from year 11.



# Southeast Loblolly Pine Plantations

## Soil C Change

Table 5. Average change in total C concentration and content from year 0 to 11 in the fine earth fraction (<2 mm) of the surface 0- to 20-cm of mineral soil in loblolly pine plantations on contrasting subsoil textures with and without fertilization at planting, and t-tests evaluating if the change in C was significantly different from zero.

Subsoil Texture (Site)	Treatment	Depth - cm -	Change in Total C		Probability >  t	
			g kg <sup>-1</sup>	Mg ha <sup>-1</sup>	g kg <sup>-1</sup>	Mg ha <sup>-1</sup>
Clayey (AL)	Control	0-10	-0.8	-2.0	0.914	0.840
		10-20	-2.3	-3.6	0.360	0.329
	Fertilized	0-10	-0.1	-0.3	0.983	0.955
		10-20	-6.8	-11.1	0.206	0.171
Sandy (MS)	Control	0-10	-2.4	-4.0	0.218	0.194
		10-20	-7.2	-12.0	0.003	0.002
	Fertilized	0-10	2.8	2.8	0.503	0.577
		10-20	-5.9	-9.5	0.132	0.122



# Southeast Loblolly Pine Plantations Summary

- ⇒ Increase in volume by  $5.0 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  on clayey site and  $2.9 \text{ m}^3 \text{ ha}^{-1} \text{ y}^{-1}$  sandy site due to fertilization.
- ⇒ No effect of fertilization on Oi litter layer.
- ⇒ Change in soil C from year 0 to 11 showed that there were no significant changes in soil C with the exception of a loss of  $12 \text{ Mg C ha}^{-1}$  in 10-20 cm layer on sandy soil.
- ⇒ Results consistent with Harding and Jokela 1994, Canary et al. 2000, and some studies in Johnson and Curtis (2001).
- ⇒ Rapid turnover of C inputs indicates that potential to increase the size of mineral soil C pool with intensive management appears low.



# Pacific Coastal Coniferous Forest Overview

- ⇒ **Effect of fertilization on C sequestration in aboveground biomass and soil studied.**
- ⇒ **Pacific Northwest Douglas-fir plantations studied on 4 sites with 2 different parent materials.**
  - **Coarse-textured glacial outwash**
  - **Fine-textured volcanic soils**
- ⇒ **At each site a control plot without fertilizer additions and treatment plot with repeated urea applications were established.**



# Pacific Coastal Coniferous Forest Site Characteristics

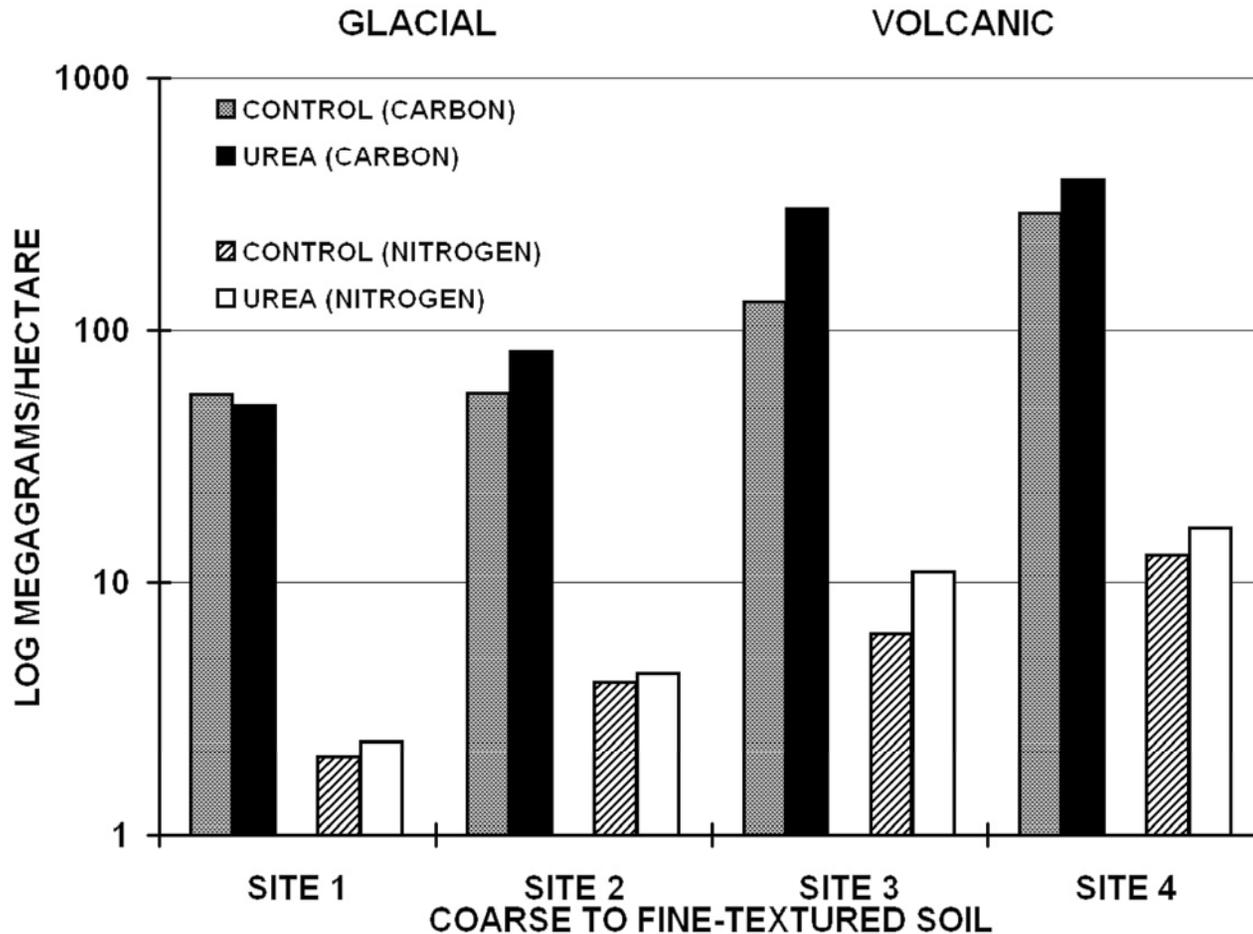
**Site characteristics with installation establishment data. Stands were fertilized with 224 kg ha<sup>-1</sup> elemental nitrogen as urea when established and at 8, 12, and some plots 16 years to a total of 672 or 896 kg ha<sup>-1</sup>**

Parameters	1. Cedar River Control/treated	2. Port Gamble Control/treated	3. Radio Hill Control/treated	4. Mud Mt. Control/treated
Basal area (m <sup>2</sup> ha <sup>-1</sup> )	38.65/48.97	33.07/49.08	51.28/51.82	50.95/53.34
Elevation (m)	320	140	646	555
Mean precipitation (mm yr <sup>-1</sup> )	1250	900	1350	1350
SI50 (m, unfertilized)	26	36	37	43
Soil series	Barneston	Poulsbo	Winston	Winston
Installation establishment year	1972	1975	1980	1980
Age since planting	48 (not planted)	35	31	26
Fertilization dates	1972-1980-1984- 1988	1975-1983-1987- 1991	1980-1988-1996	1980-1988- 1996
Fertilization regime (kg N ha <sup>-1</sup> )	224-224-224-224	224-224-224-224	224-224-224	224-224-224



# Pacific Coastal Coniferous Forest

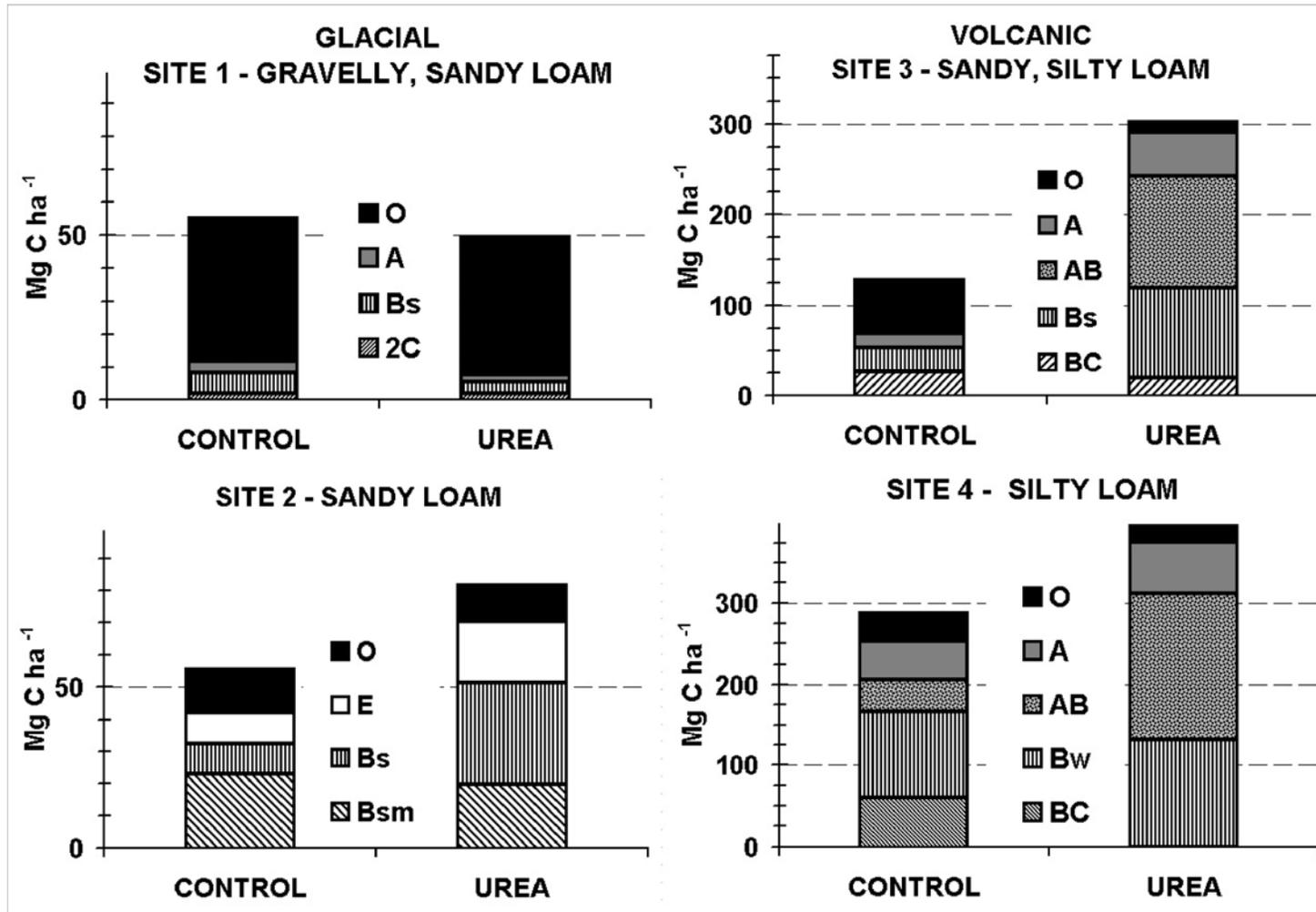
## Fertilizer effect on soil C in fine fraction (<2mm)





# Pacific Coastal Coniferous Forest

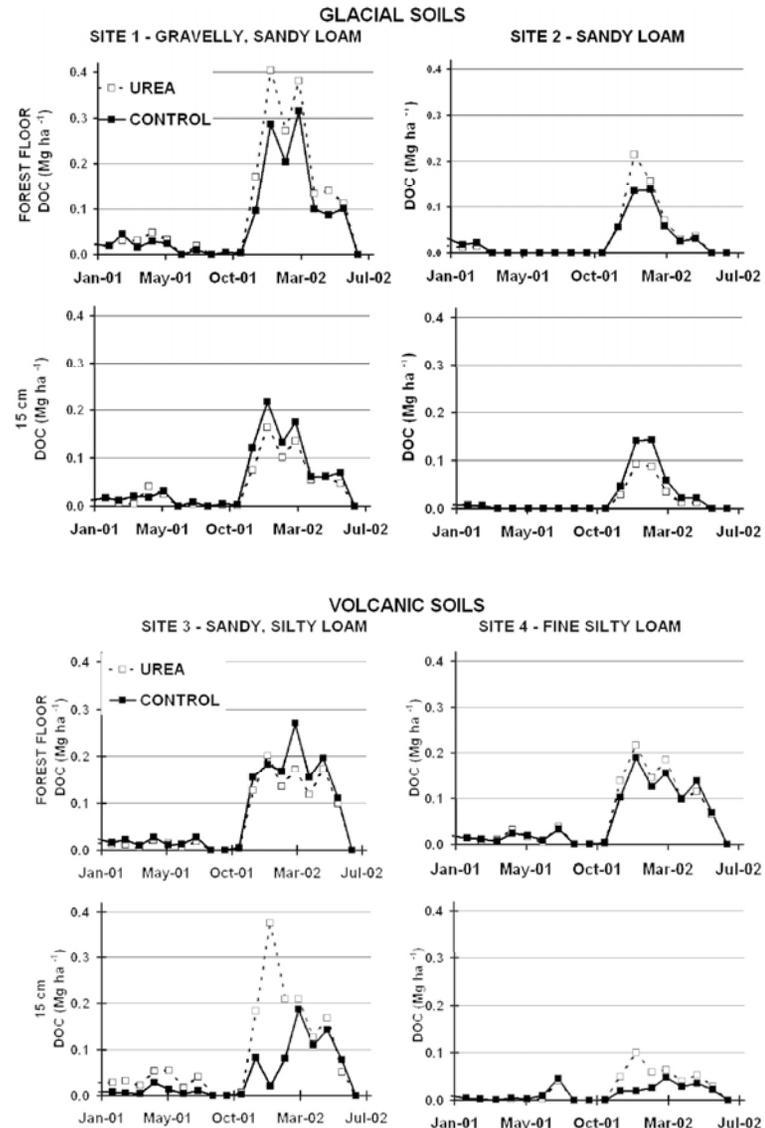
## Fertilizer effect on soil C by horizon





# Pacific Coastal Coniferous Forest DOC Measurement

- ⇒ **Lysimeters were installed at 4 depths:**
  - Immediately below forest floor
  - 15 cm in mineral soil
  - 50 cm
  - 100 cm
- ⇒ **Highest DOC fluxes in fertilized plots especially O layer.**
- ⇒ **DOC flux decreased significantly with depth.**
- ⇒ **5 times as much C leached to 100 cm in glacial soils than in volcanic soils.**





# Pacific Coastal Coniferous Forest Summary

- ⇒ There is an inverse relationship between C in forest floor and C in deeper mineral soil.
- ⇒ Forest floor C is lower in fertilized plots.
- ⇒ Mineral soil C is higher in fertilized plots.
- ⇒ Suggests that O layer decomposition and C solubility was enhanced by fertilization.
- ⇒ C increase in B horizons larger in soils with greater capacity to adsorb DOC.
- ⇒ More C in fertilized plots than can be accounted for by DOC alone.
  - Higher C/N and lower pH associated with higher soil C indicate a reduction in mineral soil decomposition.
- ⇒ Lower aboveground increases must be considered with increased soil C sequestration from fertilization.