CARBON SEQUESTRATION DEMONSTRATION PROJECT

FINAL REPORT

April 2003

prepared for

New Jersey Forest Service
Division of Parks and Forestry
Department of Environmental Protection
Post Office Box 404, Trenton, New Jersey 08625

prepared by

Far Horizons Corporation
Post Office Box 257, Princeton Junction, New Jersey 08550

609-275-7066 (fon) — 609-275-8029 (fax)

FAR HORIZONS CORPORATION

Carbon Sequestration Demonstration Project

Final Report — April 2003

prepared by

Charles Vail
Far Horizons Corporation

Robert Northrop
Consulting Forester

This is the final report of the carbon sequestration demonstration project undertaken at the New Jersey Forest Resource Education Center (FREC) located near Jackson, New Jersey. The work was undertaken by Far Horizons Corporation under Purchase Order № 5296574, issued by the State of New Jersey on the behalf of the New Jersey Bureau of Forestry, Department of Environmental Protection.

Introduction

The air around us is the principal source of carbon dioxide taken up by living plants and converted via photosynthesis into glucose, which, in turn, provides both raw materials and energy for plant growth. The chemical formula for photosynthesis is shown below. Carbon dioxide and water, with the addition of energy captured from sunlight, react to form glucose and oxygen. Oxygen is then released back into the air.

$$6CO_2 + 6H_2O + \text{energy} = C_6H_{12}O_6 + 6O_2\uparrow$$

As green plants of all types grow, they respire, in turn, generating carbon dioxide as a by-product that also is released back into the air. The chemical formula for respiration is shown below. Glucose and oxygen react to form water and carbon dioxide and to release energy. This chemical energy is then used in numerous biochemical reactions to form cellulose, lignin, and all the other organic compounds that together comprise the biomass of all plants throughout the forest and elsewhere.

$$C_6H_{12}O_6 + 6O_2 = 6H_2O + 6CO_2\uparrow + \text{energy}$$

As trees and other woody plants grow and mature, there is a net increase in the amount of carbon sequestered in forest. The principal repository of this sequestered carbon in the forest is composed of cellulose and lignin, the primary constituents of woody plants, to the greatest degree in trees, in their roots, trunks, and branches. Likewise, to a smaller degree, carbon is sequestered in understory vegetation. As the trees reach maturity, carbon sequestration in the forest slows and then approaches a steady state where losses by-and-large offset gains.

During the year, all trees, whether deciduous and evergreen, shed either some or all their leaves, all of which fall to the forest floor. Likewise, the herbaceous plants in the understory grow and die with each passing growing season. From time to time—whether due to the actions of pests and pathogens, various kinds of weather, or old age—dead and dying branches and other parts of tree and understory vegetation fall to the forest floor contributing to the coarse organic matter littering the forest floor. Meanwhile, decomposers, principally including various species of bacteria and fungi, are breaking down the coarse and fine organic litter carpeting the forest floor still further, some of which gets incorporated into forest soils along with the mass of living and dying decomposers.

This demonstration project is located in the northern extremes of what is broadly characterized as the New Jersey pine barrens, where there is one additional flow of carbon important to this region though not included in the preceding generic description. Periodically, fire sweeps through different portions of this forest generating carbon dioxide, a by-product of combustion, that returns to the atmosphere. There also are other carbon flows in the forest neither mentioned in the general description above nor considered in this carbon sequestration demonstration project, such as the exchange of carbon to and from minerals in the soils and their underlying geologic strata, mostly in the form of carbonates, or the carbon flows associated with the lifecycles of the herbivores that feed on plant growth and the carnivores that prey on those herbivores.

The particular elements of the carbon cycle considered in this demonstration project are (1) the carbon sequestered in a variety of chemical compounds, principally cellulose and lignin, in living trees and understory vegetation, both above- and below-ground, including leaves, branches, trunks, and roots; (2) the coarse and fine organic debris lying on the forest floor over the soil; and (3) the organic (carbonaceous) material that is a part of forest soils.

In summary, the four principal tasks of this demonstration project were (1) a literature review of tree growth information and forest management literature to construct a knowledge base from which to undertake further work, (2) a cooperative effort between the New Jersey Forest Service and Far Horizons to design a carbon sequestration demonstration that would meet the multiple needs of the New Jersey Forest Service, (3) selecting and demarking a series of plots and then measuring and assessing the carbon sequestered there, and (4) preparation of a report of the findings and supporting materials. The work undertaken and the results produced for each of these enumerated items are addressed in what follows.

Preliminary Literature Review

The original objectives of the first two tasks were (Task 1) to retrieve basic tree growth information needed as a prerequisite for planning, monitoring, analyzing, and reporting carbon sequestration in the demonstration program proposed for the Forest Resource Education Center and (Task 2) to review current forest management literature to identify the forest management techniques particularly suited to New Jersey forests and appropriate for planning and executing the proposed demonstration. The product of this literature search was to be an annotated bibliography

Task 1 proved to be the more difficult of the two: There was, in fact, very little information to be found in the existing forestry literature that provides information of tree growth for species other than those with commercial value and no information concerning the growth of complexes of species as found throughout New Jersey forests. Nonetheless, as much archival material as was available was retrieved for pitch pine (*Pinus rigidia)* given that the Forest Resource Education Center is located in the northern part of the New Jersey Pine Barrens, where pitch pine is a principal species. A copy of a long out-of-date bibliography of pitch pine[(1)] is included as an enclosure with this report.

Task 2 was the more easily accomplished. Given that woodlands might be managed in the future for one or more of a variety of purposes, including biodiversity, fire control, wildlife habitat, avian habitat, watershed, landscape aesthetics, fuelwood production, and timber production – in addition to carbon sequestration – then there was a large body of reference material to review. Also, since the means of assessing the ultimate goal of a carbon sequestration, the accretion of carbon in a forest ecosystem, could be represented by conventional indicators for measuring tree growth and timber production, then standard indicators, such as site index, tree stocking level, age class distribution, and tree rotation length, could be used as key words for screening references.

---

[1] Little, Silas, Jack McCormack, and John W. Andresen. 1970. *A Selected and Annotated Bibliography of Pitch Pine.* U.S. D. A. Forest Service Research Paper NE-164

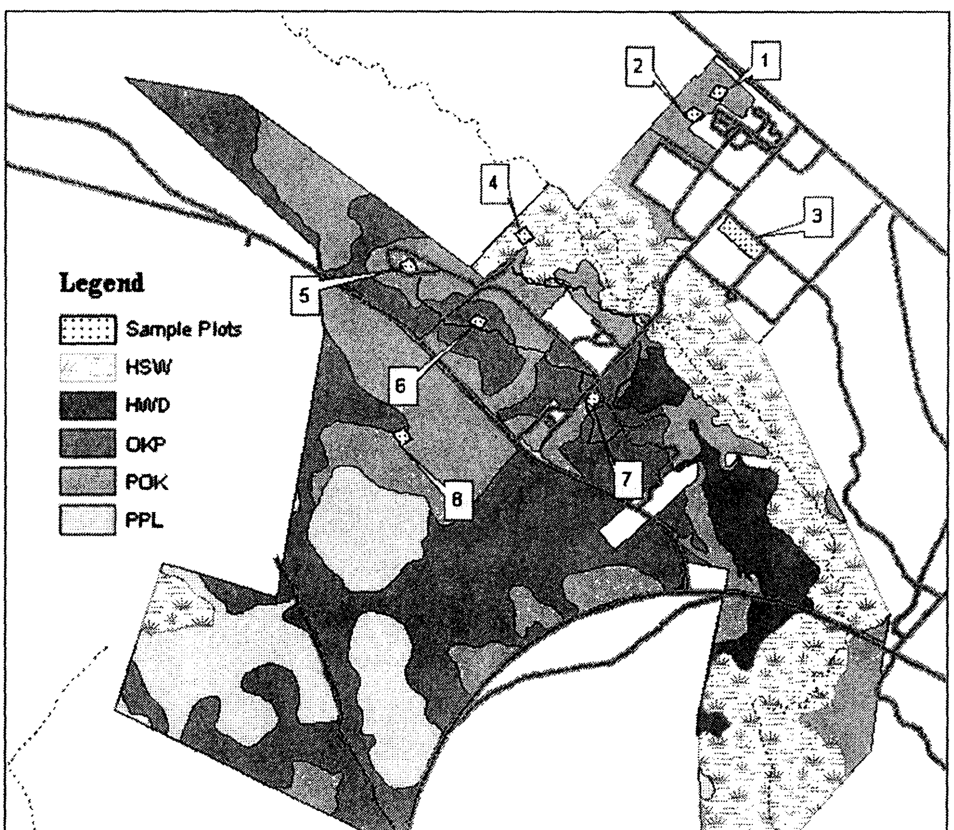
The combined output for the two aforementioned literature searches are shown as Appendix A of this report. The literature base is indeed rich in material to provide an adequate technical foundation for what is required to design and undertake the carbon sequestration project reported here.

Experimental Design

The twin objectives of the third task were (1) to prepare a detailed experimental plan for the proposed demonstration program and (2) to obtain plan approval from the program's sponsors before undertaking to establish demonstration plots. This was accomplished through a series of meetings with Mr. Edward Lempicki, Chief, and Mr. John Benton, Supervising Forester, both of the New Jersey Forest Service. In the discussions that ensued, consideration was given to the project proposed; the resources available at the Forest Resource Education Center; and the constraints of time and budget.

The experiment protocol selected reflected the variety of forest stand and soil types at the Forest Resource Education Center and the most efficient use of funding available. Eight sites were eventually chosen, including two stands that were the product of old-field succession, a loblolly pine plantation, a stand of bottomland hardwoods, a pitch pine lowland site, two stands of pitch pine uplands – a typical site, and a savanna restoration project – all on the same soil type, and a mixed stand of oak and pine. These sites are identified in the illustration on the following page.

Forest Resource Education Center – Site Map



Given budget priorities, it was decided that no forest management treatments would be applied to any of the sites during the course of this project, rather carbon sequestration measurements would be taken using readily available, nondestructive techniques. Following this agreement, specific plots were identified in each of the aforementioned eight stands, measurements were taken, and carbon sequestration was estimated.

Initially, data was to be collected using an inventory methodology provided by the National Carbon Offset Coalition. This methodology was devised by Mr. Neil Sampson of The Sampson Group in Alexandria, Virginia (www.sampsongroup.com). However suitable this form might be for its intended uses, the three-table array, as shown in the section titled, "Results," was chosen as more appropriate for this particular project.

Inventory Methodology

Eight sampling units were chosen within the New Jersey Forest Resource Education Center property to represent the diversity of forest stand and soil types common to the area. The units were identified by use of maps provided by the New Jersey Forest Service showing types of forest stands and soil types documented in the USDA Natural Resource Service Soil Survey for Ocean County.

Sample units were laid out in the field and measured 10,000 sq feet (100 feet on each side). Data were collected on July 7 – 8, 2002 and August 4, 2002. Data were collected using a standardized inventory system developed by the U.S. Forest Service (Twery *et. al.* 1998).

The data types taken within each 10,000 sq. ft. sampling unit include estimated year of stand origin, site index species, site index, rings per inch, height to base of canopy, proximity to water, seeps, streams, temporary ponds, permanent ponds, high perch, low perch, loose soil, rock piles, caves, live cavity trees, and dead cavity trees.

Understory data was derived through the use of a milacre plot that sampled the ground and herbaceous cover (up to 2 feet in height), and a 0.05-acre plot that looked at the shrub cover (from 2 to 10 feet). The data types collected in these understory samples include shrub cover, regeneration of sprout origin, moss cover, litter cover, rock cover, fern cover, grass and sedge cover, riparian plot, deciduous shrubs, ericaceous shrubs, wetland shrubs, wetland ground vegetation, ground and shrub species observed, and the percent cover of each species.

Overstory data included the evaluation of the percent cover of the midstory (from 10 to 30 feet height) and the overstory (greater than 30 feet in height). Canopy closure was determined by the use of an ocular tube with cross hairs, which is held vertically overhead and looked through. If vegetation occurs where the cross hairs meet it is a + (plus sign); if not it is a – (minus sign). At each overstory-sampling unit a total of ten readings were taken for both the midstory and the overstory. These readings were systematically taken within a twelve-foot radius of the sampling unit center.

All trees greater than 5" diameter at breast height (dbh) were measured. Data collected included merchantable height (4" diameter inside bark), presence of tree cavities, crown class, and crown condition and whether they were living or dead.

One transect per 10,000 sq. ft. sampling unit was run diagonal through the plot center to gather data on the diameter, condition, and bark of dead and down coarse woody debris.

Methodology for Estimating Carbon Within Each Sampling Unit

Estimates of carbon storage within the forest includes the carbon stored in live trees, understory vegetation, litter and other organic matter on the forest floor, coarse woody debris and organic matter in forest soils. The general approach taken here included the use of detailed site specific data concerning the biomass and carbon storage in the living trees, and data derived from regional forest inventories and forest-ecosystem studies conducted by the U.S. Forest Service to derive estimates the carbon stored in the soil and on the forest floor.

To create a basic carbon budget, volume estimates were converted from a standard forest inventory to estimates of carbon following the methodology set forth by (Hoover *et al.* 2000) [2]. Each stand was first assigned a stand type based upon stocking. If a stand contained 80 percent of its basal area in a single forest tree species it was consider a single type. The stand types used matched existing biomass-to-carbon conversions factors. They included: natural pine, pine plantations, oak-hickory, oak-pine and bottomland hardwood.

A cubic-foot volume for individual trees was calculated using the Smalian formula, which calculates volume to ±10%. Total merchantable cubic-foot volume for each sampling unit was summed from the inventory. A conversion factor was used to scale up the merchantable volume to reflect the total above- and below-ground biomass. The ratios used were derived from national estimates of biomass by tree section (Birdsey 1992) [3]. Total biomass was then converted to pounds of carbon using regionally appropriate sets of conversion factors (Birdsey 1992).

Estimates of carbon stored in the soil, woody debris and litter were based on the region and stand age using methods as outline in Birdsey (1992). Estimates of carbon losses in litter and soil from fire and site preparation practices are 50 percent litter carbon loss and 20 percent soil carbon loss (Birdsey 1996; Heath and Smith, in press). Reference conditions for soil and litter carbon levels are 50 years post disturbance.

Results

Estimates for the amount of carbon sequestered in each of the eight plots is summarized below. As might be expected, there is more carbon sequestered per acre where soils are better, either less prone to drought or more fertile (higher organic content), and in more mature versus less mature stands on the same soil type.

Carbon Sequestration in Eight Demonstration Plots [4]

№	Stand	Trees	Underst'y Vegetation	Soils	Litter & Debris	Total Carbon
1	Pine/oak stand	48.0	1.1	39.7	6.5	95.4
2	Pitch pine/hardwood	29.2	1.6	32.7	4.9	68.4
3	Loblolly pine plantation	38.8	1.1	36.5	5.6	81.9
4	Bottomland hardwoods	35.0	1.1	40.8	4.4	81.2
5	Pitch pine uplands [5]	22.9	1.1	39.7	6.5	70.2
6	Pitch pine lowlands	1.5	1.6	32.1	4.9	40.2
7	Pitch pine uplands [6]	22.2	1.1	40.3	4.9	68.5
8	Oak/pine stand	36.6	1.1	35.9	5.4	79.1

[2] A copy of this article and another detailing methodology developed by the Winrock Foundation are both enclosed with this report.
[3] A copy of this report is enclosed with this report.
[4] Tons per acre equivalent
[5] Better site, burned less recently
[6] Savanna restoration

Data for each of the individual plots and a photograph of each plot are shown separately in the following sixteen pages. This layout provides for the production of eight double-sided, stand alone pages that can be handed out separately of this report and of each other. Some comparisons can be made between the various stands of trees:

- Stands one and two – the pine/oak stand and the pitch pine/hardwood stand – are comparable in that both have relatively more softwood present than hardwood trees, both appear to be the product of old field succession, and both are found on the same soil type, Evesboro. The pine/oak stand is older with fewer trees (36) while the pitch pine/hardwood stand is younger and has more trees (70) in the quarter-acre plots sampled.
- Stands five and seven – both pitch pine uplands – are similar in soil type (Lakewood) and predominant species (pitch pine). These two sites can be characterized by fewer, larger trees, but there was less carbon sequestered on these sites than any of the others except for stand No. 2, the immature pitch pine/hardwood site.
- Stands one and eight, the pine/oak and the oak/pine stands, are somewhat comparable in that both are on relatively better soils although the first has a greater proportion of softwoods to hardwoods and the reverse is true for the second.
- The bottomland hardwoods is least like the other stands. In contrast to the others, it has the most shrub growth.
- Stands three, five, and seven – the loblolly pine plantation and the two pitch pine upland sites – are all similar in that their existence is due to outside intervention, man's intervention in the loblolly pine plantation and the savanna restoration and fire in the pine barrens. Excepting those three, for all the others it appears that the amount of carbon sequestered in each plot is inversely proportional to the number of trees counted in each plot – that is to say, there is more carbon sequestered in fewer but larger trees.

Suggested Resources for Educational Programs

A number of educational topics or concepts can be explored in association with this carbon sequestration demonstration project, including

- Different types of trees – evergreen versus deciduous, coniferous versus nonconiferous, gymnosperm versus angiosperm;
- Forest structure – trees in forest canopy versus midstory trees, shrubs, and ground cover;
- Decomposition – litter, coarse woody debris, and organic matter in forest soils;
- Tree density as measured by number of stems within a given area; and
- Effects of fire over time through the comparison of the three pitch pine upland sites.

Table 1.1 Stand Summary – Pine/Oak Stand [7]

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
hdwd [8]	5	8	3	2.7	
	5	12	2	2.7	
	5	16	2	3.6	
		subtotal	**7**	**9.0**	**19.2**
sfwd [9]	9	32	1	8.8	
	9	40	1	11.0	
	10	28	1	9.1	
	10	32	1	10.4	
	10	40	1	13.0	
	10	48	1	15.6	
	11	64	1	24.0	
	12	48	1	21.6	
	12	64	10	287.5	
	13	48	1	24.0	
	13	52	1	26.0	
	13	64	2	64.0	
	14	64	1	36.8	
	14	68	1	39.1	
	15	48	1	32.4	
	15	64	1	10.8	
	16	64	2	96.0	
	17	52	1	44.2	
		subtotal	**29**	**806.7**	**1,769.2**
				total	**1,788.4**

Table 1.2 Additional Observations – Pine/Oak Stand

Growth Rate: ≤ 2%	Stand age: 65 years	
Site Index: pitch/shortleaf pine = 75 (Evesboro soil)		
Shrub cover: 10%	Ground Cover: 20%	Litter cover: 100%
Canopy closure: 70%	Midstory closure: 60%	Midstory type: deciduous
Coarse woody debris: 5.3 cu ft		

Table 1.3 Carbon Sequestration – Pine/Oak Stand (lbs per 10,000 sq ft)

Carbon in trees	22,067
Carbon in understory vegetation	500
Carbon in soils	18,250
Carbon in litter and debris	3,000
Total carbon	43,817

[7] Older of two old-field succession stands
[8] Black and white oak, blackgum, red maple, black cherry
[9] Pitch pine, shortleaf pine, Virginia pine

Figure 1.1 Typical View – Pine/Oak Stand

Table 2.1 Stand Summary – Pitch Pine/Hardwood Stand [10]

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
hdwd [11]	5	16	1	1.8	
	6	24	1	3.6	
	11	32	1	12.0	
		subtotal	**3**	**17.4**	**37.2**
sfwd [12]	5	16	6	10.8	
	6	16	2	4.8	
	6	20	11	34.0	
	6	24	5	18.0	
	7	28	1	5.1	
	7	32	20	116.2	
	8	40	13	117.0	
	9	40	4	44.0	
	10	48	1	15.6	
	11	52	1	19.5	
	12	64	2	57.6	
	13	64	1	32.0	
		subtotal	**67**	**473.9**	**1,039.3**
				total	**1,076.5**

Table 2.2 Additional Observations – Pitch Pine/Hardwood Stand

Growth Rate: 5%	Stand age: 25 years	
Site Index: pitch/shortleaf pine = 75 (Evesboro soil)		
Shrub cover: 0%	Ground Cover: 0%	Litter cover: 100%
Canopy closure: 80%	Midstory closure: 50%	Midstory type: coniferous
Coarse woody debris: 4.7 cu ft		

Table 2.3 Carbon Sequestration – Pitch Pine/Hardwood Stand (lbs per 10,000 sq ft)

Carbon in trees	13,401
Carbon in understory vegetation	750
Carbon in soils	15,000
Carbon in litter and debris	2,250
Total carbon	31,401

[10] Younger of two old-field succession stands
[11] Black oak
[12] Pitch pine, Virginia pine

Figure 2.1 – Pitch Pine/Hardwood Stand

Table 3.1 Stand Summary – Loblolly Pine Plantation

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
sfwd	8	24	2	10.8	
	10	32	1	10.4	
	11	36	3	27.0	
	12	40	4	72.0	
	13	44	6	132.0	
	14	44	9	227.7	
	15	44	4	118.8	
	16	44	10	330.0	
	17	44	17	635.8	
	18	44	10	407.0	
	19	44	4	180.4	
	20	44	2	99.0	
		total	**72**	**2,250.9**	**3786.0**

Table 3.2 Additional Observations – Loblolly Pine Plantation

Growth Rate: 3.5%	Stand age: 25 years	
Site Index: loblolly pine = 45 (Evesboro soil)		
Shrub cover: 0%	Ground Cover: 10%	Litter cover: 100%
Canopy closure: 80%	Midstory closure: 40%	Midstory type: coniferous
Coarse woody debris: 0		

Table 3.3 Carbon Sequestration – Loblolly Pine Plantation (lbs per 10,000 sq ft)

Carbon in trees	17,773
Carbon in understory vegetation	500
Carbon in soils	16,750
Carbon in litter and debris	2,550
Total carbon	37,573

Figure 3.1 Typical View – Loblolly Pine Plantation

Table 4.1 Stand Summary – Bottomland Hardwood Stand

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
hdwd	5	16	4	7.2	
	6	16	1	2.4	
	6	24	1	3.6	
	6	28	1	4.2	
	7	40	1	7.5	
	8	32	2	14.4	
	8	40	2	18.0	
	9	44	1	12.1	
	10	20	1	6.5	
	10	24	1	7.8	
	10	32	4	41.6	
	10	40	2	26.0	
	12	32	2	28.8	
	12	36	1	16.2	
	12	44	1	19.8	
	12	48	1	21.6	
	16	56	2	42.0	
	20	64	1	72.0	
		subtotal	**28**	**351.5**	**752.1**
sfwd[13]	10	40	1	13.0	
	12	44	1	19.8	
	12	48	1	21.6	
	13	44	1	22.0	
		subtotal	**4**	**76.4**	**167.5**
				total	**919.6**

Table 4.2 Additional Observations – Bottomland Hardwood Stand

Growth Rate: ≤ 1%	Stand age: 93 years	
Site Index: pitch pine = 60 (Manahawkin soil)		
Shrub cover: 50%	Ground Cover: 10%	Litter cover: 100%
Canopy closure: 70%	Midstory closure: 40%	Midstory type: deciduous
Coarse woody debris: 12.8 cu ft		

Table 4.3 Carbon Sequestration – Bottomland Hardwood Stand (lbs per 10,000 sq ft)

Carbon in trees	16,037
Carbon in understory vegetation	500
Carbon in soils	18,750
Carbon in litter and debris	2,000
Total carbon	37,287

[13] Pitch pine

Figure 4.1 Typical View – Bottomland Hardwood Stand

Table 5.1 Stand Summary – Pitch Pine Uplands, Typical Site

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
sfwd	5	12	7	9.4	
	6	12	4	7.2	
	8	8	1	1.8	
	8	32	8	57.6	
	9	36	1	9.9	
	10	52	7	118.3	
	11	56	2	42.0	
	12	56	2	50.4	
	13	56	2	56.0	
	14	8	1	4.6	
	14	56	1	32.2	
		total	**36**	**389.4**	**854.0**

Table 5.2 Additional Observations – Pitch Pine Uplands, Typical Site

Growth Rate: ≤ 2%	Stand age: 65 years	
Site Index: pitch pine = 50 (Lakewood soil)		
open and grassy with understory of *Quercus illicifolia,* classic pine barrens		
Shrub cover: 20%	Ground Cover: 80% (moss)	Litter cover: 10%
Canopy closure: 50%	Midstory closure: 20%	Midstory type: coniferous
Coarse woody debris: 4.2 cu ft		

Table 5.3 Carbon Sequestration – Pitch Pine Uplands, Typical Site (lbs per 10,000 sq ft)

Carbon in trees	10,497
Carbon in understory vegetation	500
Carbon in soils	18,250
Carbon in litter and debris	3,000
Total carbon	32,247

Figure 5.1 Typical View – Pitch Pine Uplands, Typical Site

Table 6.1 Stand Summary – Pitch Pine Lowlands

Assumptions	Basal area = 90 sq ft Number of tree = 42 (>1 in) Average diameter = 3.74 in One 8 ft stick per tree	
	merch. volume (cu ft)	biomass (cu ft)
total	25.6	56.2

Table 6.2 Additional Observations – Pitch Pine Lowlands

Growth Rate: ≈6%	Stand age: 20 years	
Comments: all trees ≤6 in, stump sprouts are dominant form of reproduction		
Site Index: pitch pine = 50 (Lakewood soil)		
Shrub cover: 0%	Ground Cover: 50%	Litter cover: 90%
Canopy closure: 90%	Midstory closure: 90%	Midstory type: coniferous
Coarse woody debris: n/a		

Table 6.3 Carbon Sequestration – Pitch Pine Lowlands (lbs per 10,000 sq ft)

Carbon in trees	691
Carbon in understory vegetation	750
Carbon in soils	14,740
Carbon in litter and debris	2,250
Total carbon	18,441

Figure 6.1 Typical View – Pitch Pine Lowlands

Table 7.1 Stand Summary – Pitch Pine Uplands, Savanna Restoration

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
hdwd	11	32	2	24.0	
	12	48	1	21.6	
	16	48	1	36.0	
		subtotal	**4**	**81.6**	**174.6**
sfwd [14]	11	40	1	15.0	
	12	24	1	10.8	
	13	28	1	14.0	
	13	32	1	16.0	
	13	64	1	32.0	
	14	60	1	34.5	
	17	64	1	54.4	
		subtotal	**7**	**176.7**	**387.5**
				total	**562.1**

Table 7.2 Additional Observations – Pitch Pine Uplands, Savanna Restoration

Growth Rate: ≤ 2%	Stand age: 85 years	
Comments: grassy, good reproduction – seedlings, open tree crown development		
Site Index: pitch pine = 60 (Lakewoood soil)		
Shrub cover: 10%	Ground Cover: 20%	Litter cover: 100%
Canopy closure: open	Midstory closure: open	Midstory type: n/a
Coarse woody debris: n/a		

Table 7.3 Carbon Sequestration – Pitch Pine Uplands, Savanna Restoration (lbs per 10,000 sq ft)

Carbon in trees	10,176
Carbon in understory vegetation	500
Carbon in soils	18,500
Carbon in litter and debris	2,250
Total carbon	31,426

[14] Pitch pine

Figure 7.1 Typical View – Pitch Pine Uplands, Savanna Restoration

Table 8.1 Stand Summary – Oak/Pine Stand

	dbh (in)	length (ft)	number of trees	merch. volume (cu ft)	biomass (cu ft)
hdwd	5	16	12	21.6	
	6	16	1	2.4	
	6	20	11	3.0	
	7	36	1	6.5	
	7	40	1	7.3	
	8	24	7	37.8	
	8	40	1	9.0	
	9	20	1	5.5	
	9	24	1	6.6	
	9	40	1	11.0	
	10	48	1	15.6	
		subtotal	**38**	**126.3**	**270.3**
sfwd [15]	6	20	1	3.0	
	8	40	4	36.0	
	10	44	5	71.5	
	11	48	2	36.0	
	12	48	7	150.8	
	14	52	3	89.7	
	14	60	1	34.5	
	16	64	1	48.0	
		subtotal	**24**	**469.5**	**996.8**
				total	**1,267.1**

Table 8.2 Additional Observations – Oak/Pine Stand

Growth Rate: ≈ 4%	Stand age: 40 years	
Comment: characteristic – coppice (stump sprouts)		
Site Index: white oak = 70 (Hammonton soil)		
Shrub cover: 10%	Ground Cover: 50%	Litter cover: 100%
Canopy closure: 80%	Midstory closure: 80%	Midstory type: deciduous
Coarse woody debris: 3.1 cu ft		

Table 8.3 Carbon Sequestration – Oak/Pine Stand (lbs per 10,000 sq ft)

Carbon in trees	16,810
Carbon in understory vegetation	500
Carbon in soils	16,500
Carbon in litter and debris	2,500
Total carbon	36,310

[15] Pitch pine

APPENDIX A – ANNOTATED BIBLIOGRAPHY

Barlow, R. J. and S. C. Grado, 2001. Forest and Wildlife Management Planning – An Annotated Bibliography. FWRC Research Bulletin FO 165. Forest and Wildlife Research Center, Mississippi State University.

This annotated bibliography is a compilation of selected journal articles, books, extension publications, conference proceeding articles, Internet publications, and academic theses and dissertations from 1960 to present. They are related to topics of forest and wildlife management planning, with specific applications to effects of manipulating timber growing stock to provide more or less wildlife habitat.

Bormann, F.H. and G.E.Likens. 1979. Pattern and process in a forest ecosystem. New York: Springer-Verlag.

Abstract: Companion document to Biogeochemistry of a Forested Ecosystem. Primary concern of this text is the structure, function and development through time of the northern hardwood ecosystem. It concentrates on the interrelationships among biogeochemical processes, structure, and species behavior within the ecosystem and how these change with time following perturbation.

Bormann, F.H., G.E. Likens, T.G. Siccama, R.S.Pierce, and J.S. Easton. 1974. The export of nutrients and recovery of stable conditions following deforestation at Hubbard Brook. Ecological Monographs. 44:255-277.

Abstract: Authors studied the effects of complete deforestation of a small experimental watershed in New Hampshire. They review nutrient dynamics, water budgets and reorganization of the community structure.

Birdsey, R.A. 1992. Carbon storage and accumulation in United States forest ecosystems. USDA Forest Service. General Technical Report WO-59. 51 pp.

Abstract: A key issue analyzed in the 1989 Resources Planning Act Assessment is the impact of climate change on America's forests (Joyce and others 1990). Another issue undergoing intense analysis at this time but not included in the 1989 RPA Assessment is the evaluation of forestry opportunities for mitigating the effects of global warming. Analysis of forestry opportunities requires knowledge of carbon storage and accumulation in forest ecosystems. It is the purpose of this publication to provide estimates of carbon storage and accumulation in U.S. forests.

Birdsey, R.A. and A.J. Plantinga. 1994. Optimal forest stand management when benefits are derived from carbon. Natural Resource Modeling. Vol. 8, no. 4, pp. 373 – 387.

Abstract: the management of second-growth and old-growth forest stands has important implications for the global carbon cycle. This paper considers that optimal forest rotation when flows of carbon dioxide to carbon have positive value. If benefits are derived only from carbon, then typically it will never be optimal to harvest any forest stands. This result is a formalization and extension of Harmon et al. (1990). Private forest owner will often maximize net returns to timber, ignoring benefits from carbon sequestration. Thus, the privately and socially optimal rotations will not generally coincide. We show that the socially optimal rotation is always greater that the privately optimal rotation and less than or equal to the rotation when only carbon is valued.

Birdsey, R.A. 1996. Carbon storage for major forest types and regions in the conterminous United States. In: Forests and global change: forest management opportunities for mitigating carbon emissions (vol. 2), eds. R.N. Sampson and D. Hair, 1-26. American Forests.

Abstract: This paper presents estimates of carbon storage for the major forest types in the forested regions of the conterminous United States. The estimates include the carbon stored in live trees, understory vegetation, litter and other organic matter on the forest floor, coarse woody debris, soil, and timber removed from the forest. The estimates cover 120 years beginning with the regeneration of clear-cut timberland, cropland or pasture.

Birdsey, R.A. and L.S. Heath. 2001. Forest inventory data, models and assumptions for monitoring carbon flux. Soil Science Society of America. Soil carbon sequestration and the greenhouse effect. Special Publication no. 57.

Abstract: Estimates from forest inventories indicate that U.S. forest ecosystems are a net sink for carbon from the atmosphere. Estimates of carbon storage in forest biomass are based on comprehensive forest inventory data collected periodically by the USDA, Forest Service. Estimate of carbon storage in forest soils (including mineral soil, litter and coarse woody debris) are based on intensive ecosystem studies and models relating soil carbon to climate variables, forest type, and land use history. Estimates of carbon storage in wood products are based on comprehensive models of biomass utilization, recycling and disposal. Opportunities to improve the estimation process include better estimates of soil carbon responses to land use and environmental changes, and the need for more comprehensive data to estimate carbon flux on remote forest lands that rare not significantly influenced by human activities.

Bradshaw, F.J. 1992. Quantifying edge effect and patch size for multiple-use silviculture – a discussion paper. Forest Ecology and Management, vol. 48, pp. 249-264.

Abstract: An argument is presented that the essential difference between even-aged and uneven-aged silviculture lies in the proportion of the patch that is influenced by the edge effect.

Bushman, E.S. and G.D. Therres. 1988. Habitat management guidelines for forest interior breeding birds of Coastal Maryland. MD Dept. Nat. Res.: Wildl. Tech. Pub. 88-1.

Abstract: The authors provide specific guidelines for the conservation of habitat for forest interior obligates within the forested coastal plain of Maryland.

Cathcart, J.F. 2000. Carbon sequestration. Journal of Forestry. Sept 2000.

Abstract: forestry carbon offsets offer an innovative mechanism to stimulate the forestation of thousands of acres of under producing forest land. In 1999, Oregon's Forest Resource Trust received $1.5 million from the Klamath cogeneration Project, for the forestation of 2,400 acres of under producing nonindustrial private forest (NIPF). This forestation effort will accrue 1.16 million metric tons of carbon dioxide emission offsets over a 100-year period.

Christensen, N.L., et al. 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Ecological Applications 6 (3):665-691.

During this century, human populations and their demands for space, commodities, and amenities from ecosystems have increased by over five-fold. At the same time, evidence has mounted that there are limits to the stress such systems can withstand and still remain viable. Recent symptoms of ecological stress include the collapse of agricultural ecosystems in the southeastern United States and western "Dust Bowl," the spread of desert into rangeland in the Southwest, controversy over the management of old-growth forests in the Pacific Northwest, and the decline of marine fisheries. The impact of forest management activities on breeding habitat for migratory fishes is a dramatic reminder that the sustainability of many ecosystems depends on connections to other systems that do not respect individual ownerships, management borders, or international boundaries.

In recent years, sustainability has become an explicitly stated, even legislatively mandated, goal of natural resource management agencies. In practice, however, management approaches have often focused on maximizing short-term yield and economic gain rather than long-term sustainability. Several obstacles contribute to this disparity, including: 1) inadequate information on the biological diversity of environments; 2) widespread ignorance of the function and dynamics of ecosystems; 3) the openness and interconnectedness of ecosystems on scales that transcend management boundaries; 4) a prevailing public perception that the immediate economic and social value of supposedly renewable resources outweighs the risk of future ecosystem damage or the benefits of alternative management approaches.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. Science. 199: 1302-1310.

Abstract: the commonly observed high diversity of trees in tropical rain forest and corals on tropical reefs is a nonequilibrium state which, if not disturbed further, will progress toward a low-diversity equilibrium community.

Cost, N.D. et. al. 1990 the forest biomass resource of the United States. USDA Forest Service. General Technical Report WO-57. 21 pp.

Abstract: Over the last decade, biomass statistics have been published for most states. However, the existing aggregate data are either limited or out of date. The most recent statistics on biomass were for 1980. The development of such data continues to lag even thought user interest in high. This study was initiated to provide current biomass data for the United States and was conducted by Forest Service research units throughout the country.

DeGraaf, R. M., and D. D. Rudis. 1986. New England wildlife: habitat, natural history, and distribution. Gen. Tech. Rep. NE-108. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 491 p.

Abstract: This is the first volume in a two-volume set under the general title New England Wildlife. It provides detailed information on the natural history, range, and habitats of 338 species of forest wildlife in New England.

DeGraaf, R. M., M. Yamasaki, W. B. Leak, and J. W. Lanier. 1992. New England wildlife: management of forested habitats. Gen. Tech. Rep. NE-144. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 271 pp.

Abstract: This guide is the second in a two-volume set under the general title New England Wildlife. This volume presents a discussion of habitats, communities and relationships at various scales; procedures to inventory small nonindustrial ownerships for wildlife habitat opportunities; methods to develop wildlife habitat prescriptions that address owner goals and objectives; and alternative ways to carry out vegetation prescriptions that meet owner objectives.

Dissmeyer, G.E. (editor). 2000. Drinking water from forests and grasslands. USDA Forest Service. SRS-39. pp. 246

Abstract: A synthesis of the scientific literature concerning the protection of drinking water coming off of forest and grasslands.

Ehrenfeld J. G., X. Han, W. F. J. Parsons, W. Zhu. 1997. On the nature of environmental gradients: Temporal and spatial variability of soils and vegetation in the New Jersey Pinelands. Journal of Ecology , Volume: 85 , Number: 6 , Page: 785-798.

Abstract: Environmental variability can occur over various spatial scales, ranging from small patches at the scale of individual plants to long gradients over hundreds of meters. In the New Jersey Pinelands, different species in the diverse shrub understory of pitch pine (Pinus rigida Mill.) forests are patterned at these various scales.

Environmental Protection Agency. 1995. Water quality functions of riparian forest buffer systems in the Chesapeake Bay watershed. EPA 903-R-95-004.

Abstract: synthesis of scientific understanding of the role riparian forest in affecting water quality through the interception of shallow ground water.

Fernandez, I., Cabaneiro, A. and T. Carballas. 1997. Organic matter changes immediately after a wildfire in an Atlantic forest soil and comparison with laboratory soil heating. Soil Biology and Biochemistry. Vol. 29, no. 1, pp 1 – 11.

Abstract: The quantity, chemical composition and mineralization kinetics of the organic matter of an acid Humic Cambisol, developed over granite, under Pinus sylvestris L. were determined in 0-5 and 5-10 cm samples collected immediately after a high-intensity wildfire and compared with those of an unaffected

site nearby. Organic matter is responsible for forest ecosystem productivity because of its nutrient content and its influence on physico-chemical and biological characteristics. Because of this the aim of the study was to evaluate the effects of fire on the composition, stability and carbon mineralization of the soil organic matter immediately after a high-intensity wildfire.

Franklin, J.F. 1995. Sustainability of managed temperate forest ecosystems. In: Defining and measuring sustainability, the biogeophysical foundations. Ed. M. Munasinhe and W. Shearer. The World Bank. Pp. 355-385.

Abstract: This a review of what we know about the sustainability of managed temperate forest ecosystems. It is primarily an overview with emphasis on recent knowledge and emerging concepts of the productivity and maintenance of the forest ecosystems rather than a comprehensive review of the last 100 years of forest science.

Fraver, S.. 1994. Vegetation responses along edge-to-interior gradients in the mixed hardwood forests of the Roanoke River basin, North Carolina. Conservation Biology. 8 (3): 822-832.

Abstract: Compared with forest interiors, forest edges typically have a different plant species composition and community structure. The objective of this study was to estimate how far the effects of agriculturally maintained edges penetrate the mixed hardwood forests of the Roanoke River Basin.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, and K.W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. In: Advances in ecological research, volume 15, pp. 133 – 302.

Abstract: Coarse woody debris is an important, but often neglected component of many terrestrial and aquatic ecosystems. This article provides a comprehensive review of the available literature, with emphasis on temperate forest and stream ecosystems.

Hartley, M.J. 2002. Rationale and methods for conserving biodiversity in plantation forests. Forest Ecology and Management. Vol. 155, pp. 81-95.

Abstract: Industrial forest managers and conservation biologists agree on at least two things: 1. plantation forests can play a role in conserving biodiversity, and 2. plantations will occupy an increasing proportion of future landscapes. The literature is reviewed from around the world on the relationship between biodiversity and plantation management, structure and yield. A new plantation paradigm is suggested based on a hypothesis that minor improvements in design and management can better conserve biodiversity, often with little or no reduction in fiber production.

Harty, F.M. 1986. Exotics and their ecological ramifications. Natural Areas Journal. 6 (4): 20-26.

Abstract: Mounting evidence indicates that the introduction of exotic species has clearly opened a Pandora's box across the North American continent. The effects of several more well known introduced species are examined in terms of their immediate impacts and potential to disrupt ecological processes.

Hoover, C.M., Birdsey, R.A., Heath, L.S. and S.L. Stout. 2000. How to estimate carbon sequestration on small forest tracts. Journal of Forestry. September 2000.

Abstract: International climate change agreements may allow carbon stored as a result of afforestation and reforestation to be used to offset carbon dioxide emissions. Monitoring the carbon sequestered or released through forest management activities thus becomes important. Estimating forest carbon storage is feasible even for nonindustrial private forestland (NIPF) owner, and the necessary tools are available. We develop methodology for estimating forest carbon storage at the management unit scale and tested the impacts of hypothetical management scenarios on carbon sequestration over time. We demonstrate the procedure on two military installations in the southeastern United States and discuss some practical considerations.

Hunter, M.L. 1990. Wildlife, forests and forestry: principles of managing forests for biological diversity. New Jersey: Prentice-Hall.

Abstract: This book investigates the concepts that form the foundation for specific guidelines pertaining to the conservation of biological diversity within the practice for forest management.

Jenkins, R.E. and W.B. Bedford. 1973. The use of natural areas to establish environmental baselines. Biological Conservation. 5 (3): 168-173.

Abstracts: In order that wise decision can be made in environmental management, an understanding is needed of ecosystem functioning and reaction to change. To obtain this information we must have continuing knowledge of the undisturbed ecosystem as a baseline against which to measure the effects of modifications. It is proposed that relatively undisturbed natural areas form the basic research tool for the establishment of such baselines.

Johnson, D.W. 1992. Effects of forest management on soil carbon storage. Water, Soil and Soil Pollution. Vol. 64, pp. 83-120.

Abstract: the literature on soil carbon change with forest harvesting, cultivation, site preparation, burning, fertilization, nitrogen fixation and species change is reviewed. No general trend toward lower soil carbon with forest harvesting was apparent.

Johnson, K.H. et. al. 2001. Meeting global policy commitments, carbon sequestration and southern pine forests. Journal of Forestry. April 2001.

Abstract: in manger forests, 1 will determine the amount of carbon further sequestered. The increase amount of carbon in standing biomass (resulting from land-use changes and increased productivity); 2. the amount of recalcitrant carbon remaining below ground at the end of rotation; and 3. the amount of carbon sequestered in products created from harvested wood. Because of the region's high productivity and industrial infrastructure, carbon sequestration via southern pine forests could be increased, and this may benefit the nation in terms of global policy commitments.

Keller, C.M.E., C.S. Robbins, and J.S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. Wetlands. 13 (2): 137-144.

Abstract: Based upon a series of 117 surveys, the authors recommend that riparian forest by at least 100-meteres wide to provide some nesting habitat for area-sensitive species of birds. Wider riparian forest would be preferable and should be preserved.

Keller, E.A. and T. Tally. 1979. Effects of large organic debris on channel formation and fluvial processes in the coastal redwood environment. In: Adjustments of the fluvial system. 1979 proceedings of the tenth annual geomorphology symposium. pp. 169-197.

Kuser, J.E. 1994. Five-year heights of pitch pine progeny at two New Jersey plantations. Northern Journal of Applied Forestry, vol. 11, no. 4, pp. 146 – 149.

Abstract: Within-species selection was chosen as the method to improve pitch pine for a seed orchard to furnish seedlings for revegetation in southern New Jersey. In a progeny test of 68 families of open-pollinated plus tree seedlings at two plantation dies, after 5 growing seasons the top family among selected pitch pine progeny was as tall as the best pitchxloblolly check stock, and the best five pitch families were in the same range with another pitchxloblolly and two loblolly families. Mean heights were slightly greater on a worked-out sandpit site than on undisturbed sand topsoil.

Kuusipalo, J. and J. Kangas. 1994. Managing biodiversity in a forestry environment. Conservation Biology. 8 (2): 450-460.

Abstract: In forest management other land-use planning ecological, social and economical demands often conflict. The authors use the Analytic Hierarchy Process method for resource allocation and priority setting. They discuss the applicability of the approach in solving different forest management and conservation planning problems.

Laderman, A.D. 1989. The ecology of Atlantic white cedar wetlands: a community profile. USDI, Biological Report 85 (7.21), pp. 114.

Abstract: Atlantic white cedar is geographically restricted to freshwater wetlands in a narrow banc along the eastern coastal United States from Maine to Mississippi. The shallow, dark, generally acid peatland waters are low in nutrients and are buffered by complex organic acids. Distinctive biotic assemblages grow under conditions too extreme for the majority of temperate-dwelling organisms.

Likens, G.E., F.H. Bormann, R.S. Pierce, J.S. Eaton and N.M. Johnson. 1977. Biogeochemistry of a forested ecosystem. Springer-Verlag. 146 pp.

Abstract: A detailed examination of the biogeochemistry of an undisturbed, aggrading, second-growth northern hardwood forest at Hubbard Brook, New Hampshire. Major emphasis of the book is on the physical aspects on nutrient and hydrologic flow through the ecosystem and nutrient budgetary.

Lindenmayer, D.B., Margules, C.R. and D.B. Botkin. 2000. Indicators of biodiversity for ecologically sustainable forest management. Conservation Biology, vol. 14, no. 4, pp. 941-950.

Abstract: the conservation of biological diversity has become one of the important goals of managing forest in an ecologically sustain be way. Ecologists and forest resource managers need measure to judge the success or failure of management regimes designed to sustain biological diversity. Given our limited knowledge of both indicator species and structure-based indicators, we advocate the following four approaches to enhance biodiversity conservation in forest: 1. establish biodiversity priority areas (e.g. reserves); 2. within production forest, apply struture-based indicators including structural complexity, connectivity, and heterogeneity; 3. using multiple consecration strategies at multiple spatial scales, spread out risk in wood production forest; and 4. adopt an adaptive management approach to test the validity of structure-based indices of biological diversity by treating management practices as experiments.

Little, S. XXX. Effects of fire on temperate forests: northeastern United States. Pp. 225 – 250.

Abstract: The author discusses the frequency and types of presettlement and prost settlement fires; the effect of fires on various northeastern forest types (pitch pine and Atlantic white cedar) and provides a dated but valuable set of references.

Little, S., J. McCormick, and J. w. Andersen, 1970. A Selected and Annotated Bibliography of Pitch Pine (*Pinus rigida* Mill.). U. S. D. A. Forest Service Research Paper NE-164.

A somewhat dated but important annotated bibliography of original information about pitch pine. Citations are organized by subject, author, and date according the following categories: Distribution & Resource Statistics; Botanical Characteristics; Forest Ecology; Silviculture & Management; Forest Damage & Protection; and Wood Technology & Utilization.

MacDicken, K.G. 1997. A guide to monitoring carbon storage in forestry and agroforestry projects. Winrock International Institute.

Abstract: A comprehensive guide to the general principles and underlying concepts associated with monitoring and quantifying a carbon budget.

Marco, B.G., M.J. Wisdom, H.W. Li and G.C. Castillo.1994. Managing for featured, threatened, endangered and sensitive species and unique habitats for ecosystem sustainability. USDA Forest Service, General Technical Report, PNW-GTR-329.

Abstract: A discussion of the relative merits of using featured, threatened, endangered and sensitive species as indicators for ecological sustainability.

Matlack, G.R. 1994. Plant species migration in a mixed-history forest landscape in eastern North America. Ecology, vol. 75, no. 5, pp. 1491 – 1502.

Abstract: This study (conducted in the Delaware/Pennsylvania piedmont) suggest that accessibility to colonists plays an important role in determining in understory composition of successional stands. The extremely low migration rates of some species threaten their continued existence in the second-growth landscape.

McCarthy, E.J. and R.W. Skaggs. 1992. Simulation and evaluation of water management systems for a pine plantation watershed. Southern Journal of Applied Forestry, vol. 16, pp 48-56.

Abstract: Water management on forest watershed can have off-site impacts on the environment as well as on-site impacts on soil water conditions for plant growth. Water management systems were evaluated by criteria quantifying both on and off-site impacts to plant-water relationships in a loblolly pine plantation in the coastal plain of North Carolina. Stand development and silviculture were shown to have significant effects on the hydrology of the forest.

McClanahan, T.R. and R.W. Wolfe. 1993. Accelerating forest succession in a fragmented landscape: the role of birds and perches. Conservation Biology. 7 (2): 279-288.

Abstract: Previous research suggests that in highly fragmented forest landscape ecological succession can be arrested by lack of seeds, but that seed deposition abundance and diversity of bird-dispersed plants can be enhanced by bird-attracting structures such as snags.

Noss, R.F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology. Vol. 15, no. 3, pp. 578-590.

Abstract: Policies to reduce global warming by offering credits for carbon sequestration have neglected the effects of forest management on biodiversity. Properties of forest ecosystems and management options for enhancing the resistance and resilience of forests to climate change are reviewed.

Pastor, J and W.M. Post. 1986. Influence of climate, soil moisture and succession on forest carbon and nitrogen cycles. Biogeochemistry. 2: 2-27.

Abstract: The interactions between the biotic processes of reproduction, growth, and death and the abiotic processes, which regulate temperature and water availability, and the interplay between the biotic and abiotic processes regulating nitrogen and light availabilities are important in the dynamics of forest ecosystems. Equations and parameters derived directly from field studies and observations forest in eastern North America, resulted in a model that can make accurate quantitative predictions of biomass accumulation, nitrogen availability, soil humus development and net primary production.

Pickett, S.T.A. and P.S. White. 1985. The ecology of natural disturbance and patch dynamics. New York: Academic Press Inc. pp. 1 – 9

Abstract: The goal of this volume is the exploration of general themes in diversity, in this particular chapter the goal is fostered by defining three central concepts: patch dynamics, perturbation, and disturbance. These definitions lead to a discussion of endogenous and exogenous factors in community pattern.

Pickett, S.T.A. and V.T. Parker. 1994. Avoiding the old pitfalls: opportunities in a new discipline. Restoration ecology. 2 (2): 75-79.

Abstract: This paper discusses the two pitfalls that ecology continues to fall into: 1. the assumption that there is one reference state or system that can inform restoration; and 2. that restoration can be thought of as a discrete event.

Pickett, S.T.A. 2001. The ecology behind conservation: biodiversities. Proceedings: The conservation of biological diversity, a key to the restoration of the Chesapeake Bay. MD Dept. of Nat. Res. http:\www.dnr.md.us.state.

Abstract: the goal of this paper is to provide an overview of the theory that supports the conservation of biological diversity. This paper focuses on the ecological assumptions underwriting conservation, and outlines a framework of the current ecological thinking on the subject. This paper is an overview of the theory of biological diversity in the context of conservation.

Poiani, K. 1996. Ecological models and site conservation planning. The Nature Conservancy.

Abstract: A planning tool used to develop appropriate models for conservation of sensitive sites.

Post, W.M. and K.C. Kwon. 2000. Soil carbon sequestration and land-use change: processes and potential. Global Change Biology. Vol. 6, 317-327.

Abstract: When agricultural land is no longer used for cultivation and allowed to revert to natural vegetation or replanted to perennial vegetation, soil organic carbon can accumulate. This accumulation process essential reverses some of the effect responsible fore sol organic carbon losses from when the land was converted from perennial vegetation. We discuss the essential elements of what is known about soil organic matter dynamics that may result in enhance soul carbon sequestration with changes in land-use and with management. We review literature that reports changes in soil organic carbon after changes in land-use that favor carbon accumulation. This data summary provide a guide to approximate rate of SOC sequestration that are possible with management, and indicates the relative importance of some factors that influence the rates of organic carbon sequestration in soil.

Reich, P.B. and R.G. Amundson. 1985. Ambient levels of ozone reduce net photosynthesis in tree and crop species. Science. 230: 566-570.

Abstract: Experiments were conducted to measure the photosynthetic response of three crop and four tree species to realistic concentrations of ozone and simulated acid rain. Since exposure to ozone concentrations typical of levels of the pollutant observed in the eastern half of the United States reduced the rates of net photosynthesis of all species tested, reduction in net photosynthesis may be occurring over much of the eastern United States.

Robbins, C.S., D.K. Dawson and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. The Wildlife Society, Wildlife Monographs. No. 103.

Abstract: The comprehensive distillation of several decades of surveys (Breeding Bird Survey) leading to a series of recommendations concerning the aerial requirements of birds within the mid Atlantic region.

Row, C. and R. B. Phelps. 1996. Wood carbon flows and storage after timber harvest. In Forests and global change: Forest management opportunities for mitigating carbon emissions (vol. 2), eds. R.N. Sampson and D. Hair, 27-58. American Forests.

Abstract: Timber harvest and wood utilization directly and indirectly influence the amount of carbon dioxide in the atmosphere. In the short term, harvests redistribute carbon from forested terrestrial ecosystems to other carbon sinks and to the atmosphere. In the long term, harvesting followed by forest regeneration increases total storage of atmospheric carbon in forest growth and in forest product sinks. The model described in this chapter (HARVCARB) simulates detailed impacts of the harvest and use of wood on the carbon cycle by tracing the flows of carbon from various types of forest stands through harvesting, processing, use and disposal into long-term, wood-in-use and landfill sinks, or back into the atmosphere, with and without energy generation.

Runkel, J.R. 1985. Disturbance regimes in temperate forests. Pp. 17-33, In: The ecology of natural disturbance and patch dynamics. Academic Press.

Abstract: different forest types can be characterized by the mortality patterns of their canopy trees. Descriptions of natural disturbance regimes are compared with the results of manipulative studies or artificial disturbance regimes. Special attention is given to the relative importance of large-scale versus small-scale disturbance.

Sanchez, F.G. and R.J. Eaton. 2001. Sequestering carbon and improving soils. Journal of Forestry. January 2001.

Abstract: Restoring the carbon and nutrient capital of degraded soils is an important goal for forestland managers in the southern United States. Models and preliminary field studies on loblolly pine indicate that incorporating slash into forest soil improves nutrient and carbon accumulation. Model simulations describe the potential to sequester carbon in soil, biomass, and wood products. The anticipated increases in carbon sequestered provide an opportunity for significant mitigation of atmospheric carbon levels. Moreover, the changes in soil properties, including better aeration, improved the environment for seedling survival and growth.

Savely, H.E. 1939. Ecological relations of certain animals in dead pine and oak logs. Ecological Monographs. 9 (3): 321-385.

Abstract: Many animals are known to live in dead tree trunks and much is known of the habits of some of the species. Entomologists interested in economic species, taxonomists and naturalists in general have long been interested in various groups. The purpose of this study was to make a general survey of animals in dead pine and oak tree trunks that had been cut for various lengths. This is an older publication that is still consistently cited in contemporary scientific literature.

Scott, J.M., F. Davis, B.Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T.C. Edwards, J. Ullman, and R.G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildlife Monographs No. 123. Wildlife Society.

Abstract: The authors describe the use of geographic information system technology to match vertebrate distribution maps with maps of know habitat to identify areas of high species diversity and endemic species.

Skog, K.E. and G.A. Nicholson. 1998. Carbon cycling through wood products: the role of wood and paper products in carbon sequestration. Forest Products Journal. Vol.48, no. 7/8, pp. 75 – 83.

Abstract: This study provides historical estimates of projections of U.S. carbon sequestered in wood and paper products and compares them to amount sequestered in U.S. forests. There are large pools of carbon in forest, in wood and paper products I use, and in landfills. The size of these carbon pools in increasing. Since 1910, an estimated 2.7 Pg of carbon have accumulated and currently reside in wood and paper products in use in dumps and landfills, including net imports. Net sequestration is increasing in products and landfills because of an increase in wood consumption and a decrease in decay in landfills compared with phased-out dumps. If the total projected amount of products required is regarded as fixed, the net carbon sequestration in precuts and landfills can be increased by 1. shifting product mix to a greater proportion of lignin-containing products, which decay less in landfills; 2. increasing product recycling; 3. increasing product use-life; and 4. increasing landfill methane burning in place of fossil fuels.

Small, M.F. and M.L. Hunter. 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia. 76: 62-64.

Abstract: the size of forest fragments, the use of land bordering fragments, and the distance of nests from an edge all affect the frequency of predation upon bird nests in Maine, an are where the forest has been fragmented by roads, but not significantly reduced in area. Report suggests that an influx of predators from nearby habitats may be responsible for much of the nest predation in forest fragments.

USDA Forest Service. 1981. Effects of fire on flora. Gen. Tech. Report WO-16.

USDA Forest Service. 1991. Riparian forest buffers; function and design for protection and enhancement of water resources. NA-PR-07-91.

USDA Forest Service 1995. Landscape Aesthetics – A Handbook for Scenery Management. Agriculture Handbook 701.

Wigley, T.B. and M.A. Melchlors. 1994. Wildlife habitat and communities in streamside management zones: a literature review for the eastern United States. In: Riparian ecosystems in the humid United States, functions, values and management. National Assoc. of Conservation Districts. Pp. 100- 121.

Abstract: the authors summarize available literature pertaining to wildlife communities in SMZs in the eastern United States, discuss the suitability of extant studies for regulatory purposes, and identify topics needing additional research.

Young R.J., Row, C., Tonelli, J.P., Cote, W.A. and C. Lenocker. 2000. Carbon sequestration and paper, a carbon balance assessment. Journal of Forestry. September 2000.

Abstract: A carbon balance assessment estimates that growth of wood fiber and the production and use of paper from three integrated pulp and paper mills resulted in a net sequestration ratio of roughly 1.3 times as much carbon as is emitted to the atmosphere. The study shows the positive contribution of managed forest in mitigating emissions of carbon dioxide from paper manufacture, use and disposal.

Zampella, R.A., Moore, G. and R.E. Good. 1992. Gradient analysis of pitch pine (Pinus rigida Mill.) lowland communities in the New Jersey Pinelands. Bulletin of the Torrey Botanical Club 119 (3), pp. 253-261.

Abstract: Gradient analysis was used to relate water-table level, soil moisture, soil texture, available nutrients, and disturbance to forest composition along pitch pine dominated lowland community gradients in the New Jersey Pinelands. Twenty-seven forest stands were classified as mesic pine-scrub oak forest, dry pitch pine lowland, wet pitch pine lowland, or pine-maple swamp. Because changes in soil moisture and soil organic matter are functionally related to water table level. Hydrologic regime may be the primary factor underlying observed vegetation patterns along pitch pine lowland gradients in the New Jersey Pinelands.

Zeide, B. 2001. Thinning and growth. Journal of Forestry. January 2001.

Abstract: Is it possible to increase natural growth of forest stands by judicious removal of some trees? This question inspired generations of foresters to design and test many methods of thinning, invent the ultimate arbiter of forest science-permanent plots-and develop much of this science to boot. From the initial feeling that our actions can only undermine the plentitude of undisturbed forest, we went through several more assertive stances only to return to the original belief. In the process, we have realized that we are interested mostly in the value of forest output rather than in its quantity, and that the method to maximize this value is yet to be discovered.