FINANCIAL FEASIBILITY OF SEQUESTERING CARBON FOR LOBLOLLY PINE STANDS IN INTERIOR FLATWOODS REGION IN MISSISSIPPI

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Abstract

There has been increasing interest in forest-related carbon sequestration because carbon trading can provide forest owners with supplemental income. Mississippi pine forests may play a significant role in increasing carbon sequestration through afforestation and reforestation. However, the magnitude of possible carbon storage in these forests is not fully understood. The objective of this study was to examine the potential for sequestrating carbon in loblolly pine (*Pinus taeda* L.) stands under three production regimes: "timber production only", "carbon sequestration only", and "joint production of timber and carbon" in the interior flatwoods region of Mississippi. The Forest Vegetation Simulator (FVS) model developed by the USDA Forest Service was used to simulate growth and yield of timber and carbon under selected management scenarios. A sensitivity analysis was conducted to determine the financial tradeoffs associated with carbon sequestration using Land Expectation Value (LEV). Results indicated that an "unthinned" scenario accumulated almost twice as much carbon as a "thinned" scenario. The financially optimal harvest age for the "carbon sequestration only" production regime increased from 40 to 50 years for the "unthinned" scenario and from 30 to 50 years for the "thinned" scenario when compared to "timber production only" regime. At a 5% minimum acceptable rate of return (MARR) and a carbon credit price of \$4.50/ton of CO_2, the LEV at the financially optimal rotation ages for the "timber production only" and "carbon sequestration only" regimes in the "unthinned" scenario was \$927.01/ac and \$483.44/ac, respectively. In the "thinned" scenario, the corresponding LEV values were \$1,475.58/ac and \$271.41/ac. A penalty for releasing carbon back to the atmosphere at the time of thinning and final harvest had little effect on the LEV for "unthinned" scenario (a reduction of less than \$218/ac). However, the penalty impact was greater for the "thinned" scenario (a reduction of up to \$758/ac).

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Introduction

Concern over negative effects of global warming has resulted in increased interest in forest-related carbon sequestration. Trees have been gaining increased attention because they can help reduce carbon dioxide (CO_2) in the atmosphere in a cost effective manner. Trading of carbon credits not only allows market mechanisms to address global warming in more efficient ways, but also provides forest owners with a unique opportunity to generate additional income. Financial incentives available through carbon programs have been considered in management decisions by an increasing number of forest owners. Consequently, carbon trading can encourage sustainable management of forests and help mitigate the negative effects of global warming (Ruddell and Walsh 2007).

Currently, several emission programs in the U.S. provide an opportunity to trade carbon credits. The Chicago Climate Exchange (CCX) is currently the only legally binding voluntary program for trading greenhouse gases in the U.S. (CCX 2007). In contrast, the Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort of 10 states in the Northeastern U.S. to achieve a 10% reduction in CO_2 emissions by 2019 (Malmsheimer et al. 2008). Currently, only afforestation projects qualify for this program. Likewise, California Climate Action Registry (CCAR) is a statewide program for inventorying greenhouse gases. Participants can earn credits for forest management and conservation and reforestation projects (CCAR 2007).

Mississippi can contribute significantly to CO_2 reduction by increasing sequestration in forests via afforestation and reforestation efforts (Cason et al. 2006). The Carbon Fund (2003) estimated that agricultural lands, if afforested, would sequester from 400 to 500 tons of CO_2 per acre (ac) during 70 to 99 years. Landowners can receive an upfront payment of $1 for each ton of sequestered CO_2 (The Carbon Fund 2003). However, it is still unclear how much CO_2 can be sequestered in different geographic regions in Mississippi (Cason et al., 2006).

Most studies on the economics of carbon sequestration have focused on the cost effectiveness of carbon sequestration through forestry activities, and several of them have found that growing trees could provide significant CO_2 reductions at relatively low cost (Richards, 2004; Sedjo, 2001; Newell and Stavins 2000). Cason (2006), evaluating the impacts of different management practices on carbon storage potential in loblolly pine (*Pinus taeda* L.) forests in Mississippi, found that the maximum carbon storage potential was 160 tons per ac in terms of biomass equivalents. Stainback and Alavalapati (2005) examined the effects of carbon markets on the optimal management of slash pine (*Pinus elliottii* Engelm.) plantations and established that carbon payments allowed for previously too costly fertilizer application. Huang et al. (2003) conducted an analysis to determine costs and profitability of sequestering carbon in green ash (*Fraxinus pennsylvanica* Marsh.) forests in the Lower Mississippi River Valley. They found that profitability ranged from \$3,645/ac to -\$248/ac at 2.5% and 15% real rates of return, respectively. In another study, Huang and Kronrad (2001) analyzed the cost of sequestering carbon in private forests in east Texas and calculated the compensation needed for forest landowners to manage forests for carbon and convert unstocked lands to productive forestlands.

Newell and Stavins (2000), on the other hand, used an analytical model of relevant land-use forest and farm options to examine sensitivity of carbon sequestration costs to changes in key factors such as management regimes, tree species, relative prices, and discount rates. They found that the cost of carbon sequestration could be greater if trees were periodically harvested rather than permanently established and that higher discount rates resulted in higher marginal costs of sequestered carbon.

Since some carbon trading programs permit payments for both carbon sequestration and timber (e.g. CCX and CCAR), both can be viewed as joint outputs that forest owners should consider when maximizing revenues through forest management. Based on carbon and timber prices, timber yields, and expected rates of return, it is possible to determine optimal financial forest rotations. Higher financial returns can be expected because of the two simultaneous outputs.

This study evaluated the financial feasibility of managing loblolly pine stands to sequester carbon in the interior flatwoods region of Mississippi. It evaluated two thinning scenarios (thinning and no thinning) and three production regimes: “timber production only”, “carbon sequestration only”, and “joint production of timber and carbon”. The study determined the physical quantities of carbon sequestered under these three production regimes and evaluated the financial tradeoffs associated with carbon sequestration.

Methods

Volume estimates for timber in a loblolly pine stand were determined using the Forest Vegetation Simulator (FVS) growth and yield model developed by the USDA Forest Service. Estimates were derived for selected harvest ages assuming regeneration of the stand from bare ground. A medium quality site (site index 105, base age 50) in the interior flatwoods of Mississippi was selected for the analysis.

Carbon estimates were determined for herbaceous, shrub, standing dead, litter, duff and woody debris carbon pools using the carbon sub-model of the Fire and Fuel Extension to the FVS (Reinhard and Crookston 2007). The pools for live and dead root biomass were estimated using a set of allometric equations included in the FVS and described by Jenkins et al. (2003). The carbon released back to the atmosphere due to thinnings and final harvest was estimated using four decay-fate categories presented by Smith et al. (2006). The analysis assumed that stems smaller than a threshold diameter of 9 inches diameter at breast height (dbh) were harvested for pulpwood. Stems equal to or greater than the threshold diameter were harvested for sawlogs. The fate of the carbon in each of the two categories (pulpwood and sawlogs) was recorded as being in use, deposited in a landfill, emitted with energy capture, or emitted without energy capture. Carbon accumulated in harvested merchantable products can be stored in these products and landfills for a long time. However, as decay occurs, carbon is emitted back to the atmosphere (Reinhardt and Crookston 2007). The transfer of carbon among fate categories was based on regional estimates from Smith et al. (2006).

The study evaluated two different thinning scenarios (no thinning and thinning from below) with minimum intervals of five years between successive thinnings. The first thinning occurred when the stand reached age 15. We assumed a residual target basal area after thinning of 70 square feet per ac and a minimum merchantable harvest volume of 400 cubic feet (cu ft) per ac. The analysis evaluated two management intensities: no site preparation and chemical site preparation. In addition, the analysis examined the effect of a penalty for releasing CO_2 due to thinnings and final harvests on the financial feasibility of carbon sequestration.

Land Expectation Value (LEV) was calculated at 5%, 10%, and 15% minimum alternative rates of return (MARR) to determine optimal harvest ages for three production regimes: “timber production only”, “carbon sequestration only”, and “joint production of timber and carbon”. The payment for carbon sequestration was based on mean annual increment of carbon and was made to the landowner every year. The penalty for releasing carbon due to thinnings and final harvest was applied at a rate equal to the payment for sequestering carbon. Assumptions related to forest management and economic factors are summarized in Table 1.

Table 1. Summary of activities and costs associated with management of loblolly pine stand for timber production and carbon sequestration in Mississippi interior flatwoods region

Item	Value/Assumption
Site Index (base age 50)	105
Number of trees planted/ac	600
Site preparation	None and chemical
Thinning type	None and thinning from below
Thinning intensity	Residual basal area of 70 ft^2/ac
Minimum removal volume	400 cu ft of merchantable timber
Harvest age	20, 30, 40, and 50 years
Seedling cost[1]	$27.00/ac
Planting cost[1]	$52.00/ac
Chemical site preparation cost[1]	$90/ac
Sawtimber price[2]	$37.05/ton
Pulpwood price[2]	$7.86/ton
Carbon price	$ 4.50 and $10.00 /ton of CO_2 equivalent
A real minimum acceptable rate of return	5%, 10%, and 15%
Carbon payment	Annually based on mean annual increment of accumulated carbon
Penalty for carbon release	At thinning and final harvest based on amount of carbon released

[1] 2007 costs. Source: Dr. Andrew W. Ezell, Professor, Mississippi State University (Personal communication, 2008).
[2] Source: Timber Mart-South, 2008 (average price for four quarters in 2007).

Results

Carbon Sequestered and Released

The amount of carbon sequestered in a loblolly pine stand, and the amount of carbon released back to the atmosphere increased with final rotation harvest age for both thinned and unthinned management regimes (Figure 1). The largest amount of carbon was accumulated at age 50 years when an unthinned loblolly pine stand accumulated 269 tons of CO_2 per ac (1 ton of carbon = 3.33 tons of CO_2). At the same age, a loblolly pine stand thinned from below accumulated 141 tons per ac. An unthinned stand achieved maximum mean annual increment (MAI) of CO_2 at year 30 (7.85 CO_2 ton/ac/yr), whereas a thinned stand achieved maximum MAI of CO_2 at 15 years (6.20 CO_2 ton/ac/yr).

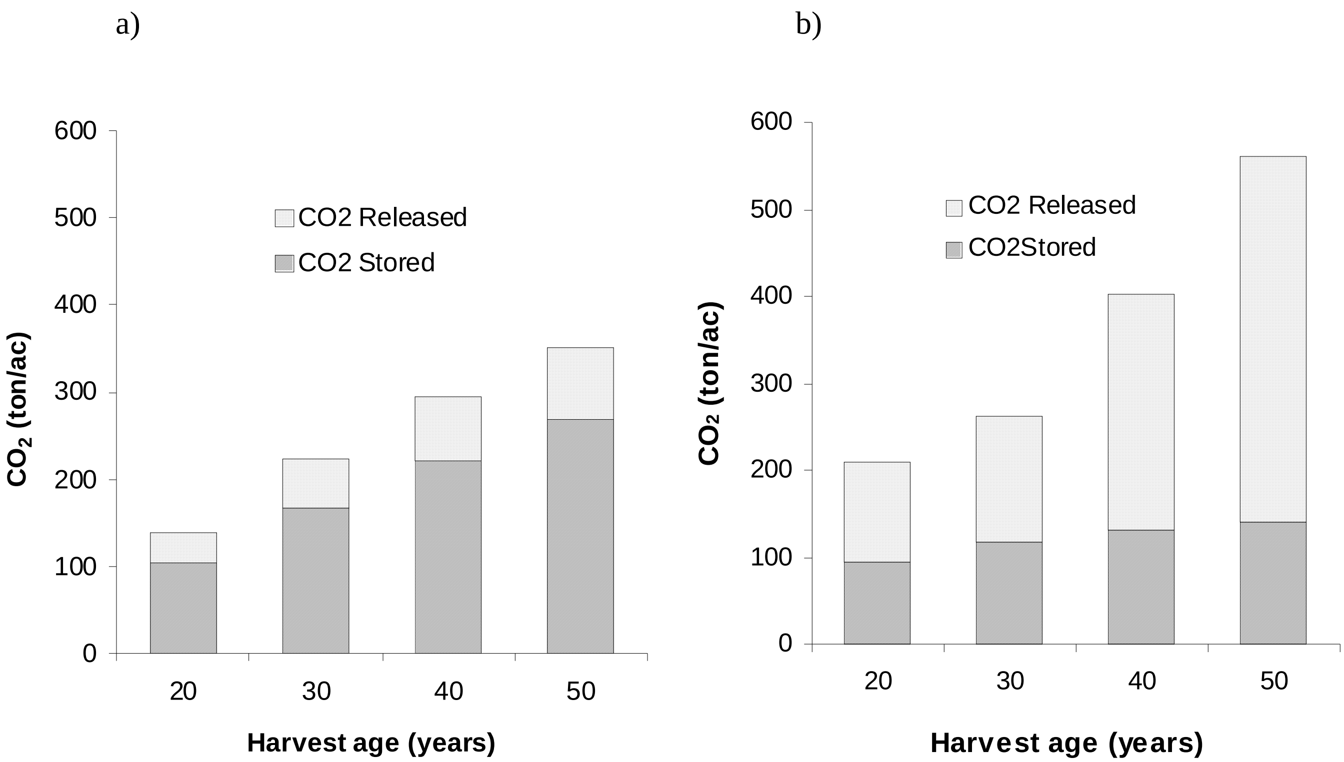

Figure 1. Carbon sequestered and released by loblolly pine stand in Mississippi interior flatwoods region managed in (a) "no thinning" and (b) "thinning" scenarios

Optimal harvest ages

No site preparation and no thinning scenarios

In the scenario assuming no site preparation and no thinning, results indicated that at a 5% real MARR and a carbon credit price of \$4.50/ton of CO_2, revenues from the "timber production only" regime were higher for harvest ages of 30 years and older when compared to the "carbon sequestration only" regime. At a 10% MARR, returns from "timber production only" regime were; however, lower than the returns from the "carbon sequestration only" regime for all harvest ages. At a 15% MARR the "timber production" regime generated financial losses at all harvest ages (LEV was negative). The return from the "carbon sequestration only" regime was still positive at a 15% MARR.

At a 5% MARR and a carbon credit price of \$4.50/ton of CO_2, the optimal harvest ages for the "carbon sequestration only" and "timber production only" regimes were 50 and 40 years, respectively, with corresponding LEVs of $483.44/ac and $927.01/ac (Table 2). At a 10% MARR and a carbon credit price of $4.50/ton of CO_2, the optimal harvest age for the "timber production only" regime was 30 years, whereas for the "carbon sequestration only" regime the optimal harvest age was 50 years with corresponding LEVs of $70.77/ac and $181.13/ac.

At a 5% MARR and a carbon credit price of $4.50/ton of CO_2, the "joint production of timber and carbon" regime resulted in an optimal harvest age of 40 years and an LEV of $1,394.20/ac. At 10% and 15% MARR, the optimal harvest age was 30 years with LEVs of $239.99/ac and $38.69/ac, respectively (Table 2).

At a carbon credit price of $10.00/ton of CO_2, return from the "carbon sequestration only" regime was higher than the return from the "timber production only" regime for all MARRs. The optimal harvest age was 50 years with corresponding LEVs of $1,180.04/ac, $499.84/ac, and $281.13/ac at 5%, 10% and 15% MARR, respectively.

Table 2. Land Expectation Value (LEV) for selected production regimes in loblolly pine stands with no site preparation and no thinning in Mississippi interior flatwoods region

Harvest age (years)	Production regime	Land Expectation Value ($/acre)		
		5%	10%	15%
20	Timber only	218.61	6.94	-46.94
	Carbon only, $4.50/ton of CO_2	358.08	143.29	69.06
	Carbon only, $10.00/ton of CO_2	950.61	431.77	256.25
	Joint production, $4.50/ton of CO_2	576.69	150.22	22.11
	Joint production, $10.00/ton of CO_2	1,169.23	438.71	209.30
30	Timber only	662.46	70.77	-41.19[1]
	Carbon only, $4.50/ton of CO_2	433.16	169.22	79.88
	Carbon only, $10.00/ton of CO_2	1,088.13	478.42	275.51
	Joint production, $4.50/ton of CO_2	1,095.62	239.99	38.69
	Joint production, $10.00/ CO_2	1,750.59	549.19	234.32
40	Timber only	927.01	58.32	-56.19
	Carbon only, $4.50/ton of CO_2	467.20	178.06	82.44
	Carbon only, $10.00/ton of CO_2	1,150.70	494.37	280.08
	Joint production, $4.50/ton of CO_2	1,394.20	236.38	26.25
	Joint production, $10.00/ton of CO_2	2,077.71	552.70	223.88
50	Timber only	793.12	-0.53	-70.53
	Carbon only, $4.50/ton of CO_2	483.44	181.13	83.04
	Carbon only, $10.00/ton of CO_2	1,180.04	499.84	281.13
	Joint production, $4.50/ton of CO_2	1,276.56	180.60	12.51
	Joint production, $10.00/ton of CO_2	1,973.16	499.31	210.60

[1] The calculated optimal rotation remained the same even with increased MARR because a 10-year increment was used to define potential harvest ages. A negative LEV indicates that regime was financially infeasible.

Site preparation and thinning scenario

For the scenarios assuming chemical site preparation and thinning, the optimal financial harvest age for the "carbon sequestration only" regime was generally longer compared to the "timber production only" regime. Results showed that at 5% and 10% MARRs, the optimal harvest age for the "timber production only" regime was 30 years with LEVs of $1,475.58/ac and $228.91/ac, respectively. However, at a 15% MARR, the "timber production only" regime generated a financial loss (LEV = -$29.82/ac). At a carbon credit price of $4.50/ton of CO_2, the optimal harvest age for the "carbon sequestration only" regime was 50 years at both the 5% and 10% MARRs with LEVs of $271.41/ac and $60.86/ac, respectively. The "carbon sequestration only" regime was not financially feasible at a 15% MARR and a carbon credit price of $4.50/ton of CO_2. However, this regime was financially feasible at the higher carbon credit price of $10.00/ton of CO_2 and the optimal harvest age was 50 years at 5%, 10%, and 15% MARRs with LEVs of $834.36/ac, $343.53/ac and $168.26/ac, respectively. The optimal harvest age for the "joint production of timber and carbon" regime was 30 years at 5%, 10%, and 15% MARRs at both carbon credit prices of $4.50 and $10.00/ton of CO_2 (Table 3).

Table 3. Land Expectation Value (LEV) for selected production regimes in a loblolly pine stand with chemical site preparation and thinning from below in Mississippi interior flatwoods region

Harvest age (years)	Production regime	Land Expectation Value		
		5%	10%	15%
20	Timber only	364.04	15.62	-77.78
	Carbon only, $4.50/ton of CO_2	197.24	31.56	-29.66
	Carbon only, $10.00/ton of CO_2	769.72	312.69	154.03
	Joint production, $4.50/ton of CO_2	561.28	47.18	-107.44
	Joint production, $10.00/ton of CO_2	1,133.77	328.31	76.25
30	Timber only	1,475.58	228.91	-29.82[1]
	Carbon only, $4.50/ton of CO_2	251.30	53.44	-19.67
	Carbon only, $10.00/ton of CO_2	827.12	337.81	165.96
	Joint production, $4.50/ton of CO_2	1,726.88	282.35	-49.49
	Joint production, $10.00/ton of CO_2	2,302.70	566.72	136.14
40	Timber only	1,430.27	169.87	-54.58
	Carbon only, $4.50/ton of CO_2	266.75	59.17	-17.71
	Carbon only, $10.00/ton of CO_2	833.48	342.66	167.91
	Joint production, $4.50/ton of CO_2	1,697.03	229.03	-72.29
	Joint production, $10.00/ton of$CO_2$	2,263.76	512.52	113.34
50	Timber only	1,270.49	126.07	-64.52
	Carbon only, $4.50/ton of CO_2	271.41	60.86	-17.30
	Carbon only, $10.00/ton of CO_2	834.36	343.53	168.26
	Joint production, $4.50/ton of CO_2	1,541.90	186.93	-81.81
	Joint production, $10.00/ton of CO_2	2,104.86	469.60	103.74

[1] The calculated optimal rotation stayed the same even with increased MARR because a 10-year increment was used to determine harvest ages. A negative LEV indicates that regime was financially infeasible.

Financial impact of penalty for releasing carbon

Our analysis revealed that in the “no thinning” scenario a penalty for releasing carbon back to the atmosphere had no effect on the optimal harvest ages, and had only a marginal effect on the total revenue. The total reduction in LEV ranged from $36/ac to $218/ac. However, in the “thinning” scenario, the penalty had a more substantial impact. The total revenue reduction ranged from $154/ac to $339/ac (at a carbon credit price of $4.50/ton of CO_2). By comparison, at a carbon credit price of $10.00/ton of CO_2, the decrease in revenue was substantially larger, ranging from $342/ac to $758/ac (Table 4).

Table 4. Expected revenues generated from managing loblolly pine plantations located in Mississippi interior flatwoods region for carbon sequestration

Scenario	Land Expectation Value (MARR 5%)			
	Harvest age (years)			
	20	30	40	50
No thinning, no penalty, $4.50/ CO_2 ton	358.08	433.16	467.20	483.44
No thinning, penalty, $4.50/ CO_2 ton	259.80	355.32	411.54	447.68
Thinning, no penalty, $4.50/ CO_2 ton	197.24	251.30	266.75	271.41
Thinning, penalty, $4.50/ CO_2 ton	43.56	35.00	-23.95	-67.48
No thinning, no penalty, $10.00/ CO_2 ton	950.61	1,088.13	1,150.70	1,180.04
No thinning, penalty, $10.00/ CO_2 ton	732.22	915.16	1,027.03	1,100.58
Thinning, no penalty, $10.00/ CO_2 ton	769.72	827.12	833.48	834.36
Thinning, penalty, $10.00/ CO_2 ton	428.21	346.44	187.46	76.27

Discussion

The results of this study were similar to those presented by Huang and Kronrad (2006), Stainback and Alavalapati (2005), Huang et al. (2003), and Huang and Kronrad (2001). These studies indicated that the optimal rotation age will tend to be longer and a greater proportion of long-lived products will be produced in response to a carbon market. The optimal harvest age for the “carbon sequestration only” regime was 50 years regardless whether the stand was thinned or unthinned. The optimal rotation age for the “timber production only” regime was 40 years for “no site preparation” and “no thinning” scenarios, and 30 years for “site preparation” and “thinning from below” scenarios. The optimal harvest age for the “joint production of timber and carbon” regime was the same as for “timber production only” regime (40 years at 5% MARR and 30 years at 10% and 15% MARR for stand with no site preparation and no thinning; 30 years for the stand with site preparation and thinning stand at 5%, 10%, and 15% MARRs).

Analysis indicated that in the “no thinning” scenario, the “carbon sequestration only” regime generated higher revenue at 10% and 15% MARR relative to the “timber production only” regime. The “no thinning” scenario reduced diameter growth in the stand causing the “timber production only” regime to be less profitable than the “carbon sequestration only” regime. However, in the thinning scenario, our analysis indicated that the “carbon sequestration only” regime generated less revenue than the “timber production only” regime for a 5% MARR and carbon credit prices of $4.50 and $10/ton of CO_2 (except 20-year rotation). This suggests that the financial incentives for carbon sequestration in this scenario were too small to induce forest owners to manage their stands for carbon sequestration only. The “carbon sequestration only” regime tended to generate more revenue than the “timber production only” regime for higher MARRs (10% and 15%). However, if payments are allowed for both timber and carbon sequestration (e.g., CCX and CCAR allow such payments), the “joint production of timber and carbon” regime increased financial returns to forest owners managing loblolly pine stands. The results of this analysis indicated that returns from a “joint production of timber and carbon” regime were always greater than the “timber production only” and “carbon sequestration only” regimes.

Currently, there are various regulatory mechanisms to account for potential losses in forest carbon. They include requirements of long-term conservation easements (e.g. RGGI) and the establishment of carbon reserve pools to offset carbon losses (e.g. CCX).

Many studies indicated that the penalties for releasing carbon could serve as a policy tool for maintaining a proper balance between carbon sequestered in forests and carbon released back to the atmosphere. However, imposing carbon release penalties could discourage landowners from managing their forests for increased carbon sequestration. This study explored the effect of imposing a penalty for releasing carbon during thinnings and final harvest and established that it had a relatively small impact on the financial returns in the “unthinned” scenarios – reduction in LEV ranged from $36/ac to $218/ac. However, the penalty had a greater impact in the “thinned” scenarios, where the LEV reduction ranged from $154/ac to $758/ac.

Conclusion

Results of this analysis indicated that loblolly pine stands on medium quality sites in the interior flatwoods of Mississippi offered a good potential to sequester carbon with a maximum mean annual carbon increment of 7.85 CO_2 ton/ac/yr. Results also indicated that more carbon was stored in “unthinned” stands than in “thinned” stands. Further, it was determined that the optimal harvest age was longer if the stand was to be managed only for carbon sequestration. Managing the same stand jointly for timber and carbon or for timber only resulted in a shorter rotation. Returns from the “joint production of timber and carbon” regimes at optimal rotation age were always greater than returns from the “timber production only” and “carbon sequestration only” regimes. A penalty for releasing carbon back to the atmosphere had a marginal impact for the unthinned stands.

Increased rotation lengths associated with carbon production regimes suggest that landowners may need to be compensated for managing forests solely for carbon sequestration as it would require retaining trees for longer time period. Further research is needed to expand this analysis beyond the interior flatwoods region of Mississippi, and to evaluate the financial feasibility of carbon sequestration for other commercially important species.

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