Management and Conservation Article

Economics of Northern Bobwhite and Timber Management in the Southeastern United States

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ABSTRACT Populations of northern bobwhite (*Colinus virginianus*) have declined significantly over the past 50 years, and the primary factor contributing to this decline has been the loss of habitat. Forest landowners who are concerned with providing bobwhite habitat as well as generating revenue from timber should balance the silvicultural requirements of timber production with the biological needs of the bobwhite. The goal of this study was to determine the economic tradeoffs between bobwhite and timber management and how to minimize loss or maximize profit when managing for bobwhite and timber simultaneously. I performed discounted cash flow analyses, calculated land expectation value, and determined the financially optimal rotation age and optimal timing and intensity of thinnings for loblolly pine (*Pinus taeda*) plantations under specific management objectives. My results show that the annual per-hectare economic gains of managing for both bobwhite and timber ranged from US$19.27 to $41.37 on site index 50 land, and ranged from $32.63 to $50.02 on site index 90 land. My analysis indicates that bobwhite management provides an investment opportunity to landowners whose low-productivity sites would be unprofitable if timber is the only product. My study provides an example of integrating multiple uses of goods and services in a way that maximizes economic returns and aids land managers in producing better habitat for bobwhite. (JOURNAL OF WILDLIFE MANAGEMENT 73(8):1355–1361; 2009)

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KEY WORDS *Colinus virginianus*, economic trade-offs, northern bobwhite, optimal bobwhite management, timber.

Despite the northern bobwhite's (*Colinus virginianus*) widespread popularity as a game bird, bobwhite populations have been declining throughout many regions of the United States for several decades (Brennan 1991, Church et al. 1993, Burger 2002, Williams et al. 2003, Sauer et al. 2004). With an alarming trend estimated at −3.05% per year, the North American Breeding Bird Surveys have shown a steady decline in northern bobwhite population from 1966 to 2007 in the surveyed portion of their range. Many factors have been considered as causes of this decline, and the primary causes have been identified as clean-farming practices, silvicultural systems that maximize basal area (Brennan 1991), succession advancing to a closed-canopy climax state, and intensive monoculture farming and timber management (Burger 2002). Bobwhite are dependent on herbaceous and shrubby cover often associated with early succession plant communities. As such, bobwhite are disturbance dependent. Management practices such as forest thinning, grazing, herbicide, burning, and disking are often prescribed for creation and maintenance of bobwhite habitat.

Practical stand-level management recommendations for balancing timber revenue and bobwhite production include using the widest practical spacing when planting, introducing fire at the earliest possible juncture, using frequent fire (1-yr to 3-yr burn interval), thinning heavily and at the earliest practical time, and shaping individual stands through harvesting so that mature stands in the basal area range between 9 m^2/ha and 23 m^2/ha (Tall Timbers Research Station 2003). The appropriate basal area on this scale depends on landowner objectives. The optimal range for bobwhite management is between 9 m^2/ha and 14 m^2/ha; however, the potential for income from forest products begins to decline below 14 m^2/ha. When the basal area of stands is below 9 m^2/ha, potential for steady income from timber products is decreased considerably (Tall Timbers Research Station 2003).

Almost 90% of the forestland in the southeastern United States today is in private ownership (Smith et al. 2004), and much of it comprises dense, intensively managed, fast-growing loblolly pine (*Pinus taeda*) plantations. Private landowners are facing an increasing demand for nontimber values such as biodiversity, and this can create conflict over forest management practices (Zobrist et al. 2005). Nonindustrial private forest (NIPF) landowners in the southeast can manage plantations to provide the northern bobwhite's year-round needs by balancing the silvicultural requirements of timber production with the biological needs of the bobwhite. Planting at lower densities, at least in some well-drained sites, and wise use of optimal thinning regimes, selective herbicides, and prescribed burning can meet this objective.

Wildlife habitat improvement necessarily involves economic tradeoffs. Therefore, my goal was to determine the economic tradeoffs between bobwhite management and timber management and how to minimize loss or maximize profit when managing for bobwhite and timber simultaneously for loblolly pine plantations on NIPF land. My 3 objectives were to 1) determine the optimal thinning and final harvest schedules that maximized financial revenues of managing timber, 2) determine the optimal thinning and final harvest schedules that maximize financial revenues of managing bobwhite and timber simultaneously, and 3) determine the economic trade-offs between bobwhite management and timber management.

STUDY AREA

I used PTAEDA2 (Burkhart et al. 1987), a forest stand simulator, to predict stand growth data on diameter, height, and volume from establishment to final harvest. The

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permanent plot locations used to develop growth and yield relationships in PTAEDA2 covered 12 states in the southeastern United States. Data for PTAEDA2 growth and yield model came from 186 permanent plots established in cutover, site-prepared plantations throughout much of the natural range of loblolly pine. The site index (base age 25) range for the permanent plots was between 12 m and 28 m with a mean of 19 m. The planted loblolly basal area was between 5 m^2/ha and 53 m^2/ha with a mean of 25 m^2/ha at plot establishment and between 11 m^2/ha and 54 m^2/ha with a mean of 29 m^2/ha at remeasurement, which occurred 3 years after establishment. The ranges of site index and basal area applied in this study are included in the data used in calibrating the PTAEDA2 model (H. Burkhart, Virginia Tech, person communication). The details about PTAEDA2 can be found in Burkhart et al. (1985, 1987).

METHODS

To determine the economic tradeoffs between timber and bobwhite management and to minimize loss or maximize profit when managing for bobwhite and timber simultaneously, I determined the financially optimal rotation age and optimal timing and intensity of thinning for loblolly pine plantations on NIPF land under 2 specific management objectives. I refer to the first management objective, which maximized financial revenues solely from managing timber, as timber-only management. I refer to the second management objective, which maximized financial revenues from managing bobwhite and timber simultaneously, as bobwhite and timber management. For timber-only management, I defined the financially optimal regime as a thinning and final harvest schedule that performed optimal thinning intensity, frequency, and timing and optimal rotation to generate the maximum financial revenues from timber production. For bobwhite and timber management, I defined the financially optimal regime as a thinning and final harvest schedule that performed thinnings at the earliest practical time and removed sufficient timber volume to qualify as an operable cut and generate the maximum financial revenues from bobwhite and timber management.

I used biological data derived from PTAEDA2 to 1) perform discounted cash flow analyses; 2) calculate equivalent annual annuity (EAA), net present worth (NPW), and land-expectation values (LEVs); and 3) determine the financially optimal thinning and final harvest schedules given a range of site index and landowner's interest rate. Net present worth of a project is the present value of its revenues minus the present value of its costs over one rotation. Equivalent annual annuity is an equal annual real income with the same present value over the project life as the project's NPW all computed at the same real discounted rate. Equivalent annual annuity was used for comparing forestry investments of unequal rotation lengths. The project with the greatest EAA would offer a present value advantage and would be preferred. I chose the management regime that had the greatest EAA as the financially optimal thinning and final harvest schedule for each combination of site index and landowner's alternative rate of return (ARR). Alternative rate of return is the discount rate used when performing a NPW analysis. Alternative rate of return is the earning rate available on an investor's best alternative, and is the interest rate at which one can invest elsewhere. Therefore, new projects should earn at least the ARR. I then applied the Faustmann formula to calculate LEV. Land-expectation value, which includes the first rotation plus the infinite series of rotation that come after it, is commonly used to calculate the NPW of bare land used for growing a perpetual series of forest crops. Given a range of site indices and real ARRs, I conducted discounted cash flow analyses to obtain EAA, NPW, and LEV for all the operable management regimes. I employed the following Faustmann formula:

$$LEV = \left[\sum_{y=0}^{n}\left[\frac{Ry}{(1+r)^y} - \frac{Cy}{(1+r)^y}\right]\right]\left[\frac{1}{(1+r)^n - 1} + 1\right]$$

where R_y = revenue in year y, C_y = cost in year y, r = real annual interest rate, n = number of years of compounding or discounting, and y = year when revenue or cost occurs.

I used site indices of 15 m, 18 m, 21 m, 24 m, and 27 m (base age 25) in these analyses. I assumed that bare land would be site-prepared and planted, and that site preparation methods included herbicide and mechanical (chop) treatments. Results of this site preparation method generate mean levels of hardwood competition, as reflected in the PTAEDA2 model. I limited the maximum possible rotation length to age 60. I set thinning frequency at 2. The method for the first thinning would be a combination of low and row thinning; the method for the second thinning would be a low thinning only. The first thinning could not be conducted until the stand was at least 10 years old. The minimum number of years between thinnings, or between a thinning and the final harvest, could not be <5 years. For all the runs, a thinning and final harvest regime would be considered to be operable only if it passed the following 2 threshold constraints. First, every thinning or final harvest had to yield a minimum of 15 cords/ha of pulpwood or sawtimber to guarantee that volume removed during the harvest would be sufficient for an operable cut. It is crucial to adjust this constraint to procure a logger or harvesting crew when the price of pulpwood is depressed, and pulpwood is the only product that loggers will harvest from the stand. Second, the number of residual trees after each thinning had to be at least 123/ha to avoid problems associated with inadequate residual stand density.

Thinning intensities varied based on the management objectives. For timber-only management, I used 4 thinning intensities: 20%, 25%, 30%, or 35% of basal area removal. For bobwhite and timber management, I used 5 thinning intensities: 35%, 40%, 45%, 50%, or 55% of basal area removal. This wide range of thinning intensities guaranteed that thinning was performed at the earliest practical time to reduce stand basal area, and that heavy thinning was conducted to sufficiently open the canopy to create a ground

Table 1. Management activities, labor costs, and frequencies for timber-only management for loblolly pine plantations on nonindustrial private forest land in the southeastern United States, 2007.

Management activities	Cost (US$/ha)	Frequency	Start	End
Boundary location	49.40	Once only	Yr 0	
Boundary maintenance	4.94	Every 10 yr	Yr 10	Final harvest
Initial management plans	12.35	Once only	Yr 0	
Updated management plans	12.35	Every 10 yr	Yr 10	Final harvest
Chop site preparation	247.00	Once only	Yr 0	
Herbicide site preparation	209.95	Once only	Yr 0	
Hand planting, labor	185.25	Once only	Yr 0	
Planting density: 3.66 m × 1.83 m[a]	74.70	Once only	Yr 0	
Prescribed burning	61.75	Every 5 yr	Yr 10	Final harvest
Thinning and final harvest costs	10% of revenues	As necessary		
Miscellaneous maintenance	2.47	Every yr	Yr 0	Final harvest

[a] 1,494 seedlings/ha, $0.05/seedling.

cover response and to generate sufficient operable timber volume to avoid the cost of precommercial thinning.

I acquired the predicted biological variables of diameter at breast height and total height from PTAEDA2, and then applied Amateis and Burkhart's taper functions (1987) to estimate upper stem diameters and merchantable heights, and the Doyle log rule (Avery and Burkhart 1994) to predict board-foot volume. The Doyle log rule is the method used by many forest consultants and timber buyers to measure and purchase standing timber from NIPF landowners in the southeast, even though it has a built-in bias (Avery and Burkhart 1994). I did not apply cull percentages because I assumed culled trees would be removed in early thinnings before sawtimber harvests. I set a 25.4-cm diameter at breast height and one 4.9-m log up to a minimum top diameter of 15.2 cm inside bark as minimum sawlog requirements. I measured pulpwood volume in cords to a 10.2-cm outside bark top diameter for trees in the 12.7-cm, 15.2-cm, 17.8-cm, 20.3-cm, and 22.9-cm diameter at breast height classes. I computed cordwood volumes from the 2.5-cm diameter at breast height class conversion factors presented by Burkhart et al. (1972). These conversion factors ranged from 2.4 m^3 outside bark per standard cord for the 12.7-cm diameter at breast height class to 2.7 m^3 for the 33.0-cm and above class (Burkhart et al. 1987). I assumed any change in the quality of wood resulting from thinning to be negligible, although the superior diameter growth induced by thinning usually improves wood quality and large trees tend to have better quality than small ones (Smith et al. 1997).

I chose 4 ARRs, which spanned the range of before-tax earning rates available for most landowners, for the economic analyses. They were 2.5%, 5.0%, 7.5%, and 10.0% in real terms, meaning that inflation was removed from these numbers. I applied a conservative approach to consider anything less than 25.4-cm diameter at breast height as pulpwood. I downgraded "chip-n-saw" products as pulpwood to reflect the possibilities of inexperienced loggers who were not able to differentiate the product classes and insufficient chip-n-saw on the job to justify the time in making the sort. Therefore, I considered only sawtimber and pulpwood products for economic evaluation. I projected annual compound softwood sawtimber and pulpwood stumpage price growth in the South between levels in the late 1990s and 2050s at 0.6% and 0%, respectively (Haynes 2003). I assumed labor costs to increase at a real rate of 1.7% per year (Council of Economic Advisers 2007). I assumed the price of sawtimber to be US$37.32/ton ($300/Doyle mbf [1,000 board feet]), and pulpwood price to be $6.68/ton ($18/cord, Timber Mart-South 2001–2007).

I assumed that proper forest management activities would be conducted. In general, management costs are incurred for establishing, maintaining, and harvesting the stand. All the current management costs came from a survey of local forest consultants. Different silvicultural practices and management activities would be applied based on the management objectives. I present assumed management activities, frequency, and labor costs for forestlands in the southeast managed for timber only and for both bobwhite and timber (Tables 1 and 2, respectively) and reasons for the differences.

Table 2. Management activities, labor costs, and frequencies for northern bobwhite and timber management for loblolly pine plantations on nonindustrial private forest land in the southeastern United States, 2007.

Management activities	Cost (US$/ha)	Frequency	Start	End
Boundary location	49.40	Once only	Yr 0	
Boundary maintenance	4.94	Every 10 yr	Yr 10	Final harvest
Initial management plans	12.35	Once only	Yr 0	
Updated management plans	12.35	Every 10 yr	Yr 10	Final harvest
Chop site preparation	247.00	Once only	Yr 0	
Herbicide site preparation	209.95	Once only	Yr 0	
Hand planting, labor	185.25	Once only	Yr 0	
Planting density: 3.66 m × 3.05 m[a]	44.85	Yr 0		
Prescribed burning	61.75	Every 2 yr	Yr 9	Final harvest
Thinning and final harvest costs	10% of revenues	As necessary		
Miscellaneous maintenance	2.47	Every yr	Yr 0	

[a] 897 seedlings/ha, $0.05/seedling.

For timber-only management, I assumed planting density to be 1,494 trees/ha, planted at exact regular spacing with the distance between rows and trees of 3.7 m and 1.8 m, respectively. For bobwhite and timber management, I assumed the widest practical planting density to be 897 trees/ha, planted at exact regular spacing with the distance between rows and trees of 3.7 m and 3.0 m, respectively. Heavy thinnings would be performed at the earliest practical time to shape individual stands through thinnings so that mature stands were in the recommended basal area range between 9 m^2/ha and 23 m^2/ha. I reduced prescribed burning interval from every 5 years (starting at age 10) for timber-only management to every 2 years (starting at age 9) for bobwhite and timber management.

I assumed that managing for bobwhite habitat would transform the location to prime hunting and recreational property because the open forest structure and enhanced herbaceous ground cover produced by managing for bobwhite habitat would improve the habitat for turkey and deer as well (Tall Timbers Research Station 2003). Therefore, annual hunting lease revenues were calculated by stacking hunting leases charging for bobwhite, turkey, and deer separately. I assumed that the annual hunting lease was $12.35/ha for bobwhite during January–February, $7.41/ha for turkey in April, and $14.82/ha for deer during October–December. In addition, NIPF landowners could lease to horseback riders and provide camera tours and receive additional revenue of $4.94/ha (D. Dietz, Campbell Timberland Management, LLC, personal communication).

Given a range of site indices and real ARRs, I conducted discounted cash flow analyses to obtain NPW for all the operable management regimes. I then computed EAA and chose the management regime that had the greatest EAA as the financially optimal thinning and final harvest schedule for each combination of site index and landowner's ARR. I then applied the Faustmann formula to calculate LEV. Performing bobwhite habitat management will change the outputs of timber production; therefore, I conducted trade-off analysis to determine the economic trade-offs between the 2 management objectives and calculated financial incentives necessary if there was financial loss given a range of site index and landowner's ARR.

RESULTS

I calculated the EAA that optimized for joint bobwhite and timber management (EAAqt), the equivalent annual annuity that optimized solely for timber management (EAAt), and economic gain (=EAAqt − EAAt) between these 2 management objectives for loblolly pine plantations managed on NIPF land. Simulations under the proscribed assumptions predicted that, when NIPF landowners with an ARR of 2.5% on site index 50 land managed their forests for timber only, it would yield a positive EAAt of $5.43/ha (Table 3). This means that landowners would earn 2.5% on every dollar they invested in timber production, plus an additional $5.43/ha. If land was managed for both bobwhite habitat and timber production, it would realize an EAAqt of $24.70/ha, resulting in an economic gain of $19.27/ha

Table 3. The equivalent annual annuity (EAA; US$/ha) differences between optimized for joint northern bobwhite and timber management (EAAqt) and optimized solely for timber management (EAAt) for loblolly pine plantations managed on nonindustrial private forest land in the southeastern United States, 2007.

	Real alternative rates of return																			
	2.5%					5.0%					7.5%					10.0%				
SI[a]	EAAqt	EAAt	Gain[b]	Gain (q)[c]	% gain[d]	EAAqt	EAAt	Gain	Gain (q)	% gain	EAAqt	EAAt	Gain	Gain (q)	% gain	EAAqt	EAAt	Gain	Gain (q)	% gain
50	24.70	5.43	19.27	100	355	2.64	−26.23	28.85	na[e]	na	−17.07	−53.30	36.21	na	na	−35.67	−77.04	41.37	na	na
60	49.87	34.46	15.41	100	45	21.46	−7.46	28.92	na	na	−2.64	−39.52	36.90	na	na	−24.50	−66.99	42.46	na	na
70	104.88	76.84	28.03	100	36	57.87	22.63	35.25	100	156	22.92	−17.96	40.88	na	na	−5.38	−50.36	44.98	na	na
80	169.44	146.22	23.22	100	16	108.43	70.62	37.82	100	54	58.76	16.45	42.29	93	257	18.97	−24.85	43.82	na	na
90	252.95	220.32	32.63	100	15	167.76	125.99	41.77	95	33	105.77	55.30	50.46	78	91	56.24	6.20	50.02	79	807

[a] Site index in feet, base age 25.
[b] Gain = EAAqt − EAAt.
[c] Percentage of economic gains contributed by the annual hunting lease revenues of $34.58/ha and annual recreational revenues of $4.94/ha.
[d] % gain = [(EAAqt − EAAt)/EAAt] × 100.
[e] na = Not applicable due to negative EAAt.

Table 4. Net present worth (US$/ha) of the financially optimal thinning and final harvest schedules for loblolly pine plantations managed for both northern bobwhite and timber on nonindustrial private forest land in the southeastern United States, 2007.

	Real alternative rates of return			
Site index[a]	2.5%	5.0%	7.5%	10.0%
50	601.40	43.55	−210.86	−342.71
60	1,214.03	339.28	−30.78	−229.61
70	2,427.57	876.28	268.14	−48.86
80	3,382.91	1,615.40	679.97	170.53
90	5,526.80	2,364.48	1,178.96	505.21

[a] Site index in feet, base age 25.

(=$24.70 − 5.43). In comparison with managing only for timber production, this was a 355% (=19.27/5.43) increase. The economic gain of including bobwhite habitat management on site index 50 land ranged from $19.27/ha to $41.37/ha as ARR increased from 2.5% to 10.0%. Neither managing for timber only nor for bobwhite and timber simultaneously was profitable for NIPF landowners who own site index 50 land with an ARR of 7.5% or 10.0% (Tables 3–5).

Using an ARR of 5.0% and a site index of 50 as an example, the financially optimal thinning and final harvest schedule for both bobwhite and timber management would generate an EAAqt of $2.64/ha (Table 3) with a corresponding NPW of $43.55/ha (Table 4) and LEV of $52.64/ha (Table 5). This financially optimal schedule would require the first thinning at age 16 (50% of basal area removed), the second thinning at age 31 (35% of basal area removed), and a final harvest at age 36 (Table 6). The timing and intensities of the thinnings met the criteria of performing thinning at the earliest practical time to reduce stand basal area, sufficiently open the canopy, create a ground cover response, and generate operable timber volume to create timber revenue and avoid the cost of precommercial thinning. For site index 50, the timing of the final harvest was reduced from age 38 to 34 as ARR increased from 2.5% to 10.0%. The range of basal areas of the financially optimal thinning and final harvest schedules throughout the stand age ranged between 7.89 m^2/ha and 17.75 m^2/ha.

For NIPF landowners owning site index 90 land, managing forests only for timber production would generate positive values of EAAt ranging from $220.32/ha (2.5% ARR) to $6.20/ha (10.0% ARR, Table 3). The values of EAAqt ranged from $252.95/ha (2.5% ARR) to $56.24/ha (10.0% ARR). Managing for both bobwhite and timber would earn landowners more profits, and economic gains were realized between a 15% (2.5% ARR) and 807% (10.0% ARR) increase. When ARR was 2.5%, the percentage of economic gains contributed by the annual hunting lease revenues of $34.58/ha and recreational revenues of $4.94/ha was 100% regardless of site index (Table 3). When ARR was 10.0% and site index was 90, 79% of economic gains in profitability come from the increased hunting lease and recreational revenues (Table 3), and only 21% (=100% − 79%) of gains come from the increased diameter growth due to the lower basal area. Lowering basal area on high–site index lands (i.e., 80 and 90) could increase some timber revenues; however, increased hunting lease and recreational revenues had a much higher relative contribution to the economics gains for all the site index–ARR combinations.

Table 5. Land expectation value (US$/ha) of the financially optimal thinning and final harvest schedules for loblolly pine plantations managed for both northern bobwhite and timber on nonindustrial private forest land in the southeastern United States, 2007.

	Real alternative rates of return			
Site index[a]	2.5%	5.0%	7.5%	10.0%
50	987.98	52.64	−227.71	−356.67
60	1,994.40	429.38	−35.07	−245.05
70	4,195.37	1,157.49	305.69	−53.82
80	6,777.73	2,168.61	783.36	189.79
90	10,118.08	3,355.32	1,410.20	562.30

[a] Site index in feet, base age 25.

Using the combination of site index 90 and ARR 5.0% as an example, the financially optimal thinning and final harvest schedule for both bobwhite and timber management would generate an EAAqt of $167.76/ha (Table 3) with a corresponding NPW of $2,364.48/ha (Table 4) and LEV of $3,355.32/ha (Table 5). The financially optimal timing of the first thinning occurred at age 10, followed by the second thinning at age 20, and the final harvest at age 25. Due to higher site productivity, the timing of the optimal first and second thinning and final harvest occurred earlier on site index 90 land.

In summary, the economic gain increased as ARR increased from 2.5% to 10.0%. For example, the per hectare economic gain of managing for both bobwhite and timber in comparison of managing only for timber increased from $23.22 to $43.82 on site index 80 land as ARR increased from 2.5% to 10.0% (Table 3). Data in Table 3 provide financial incentives necessary to induce NIPF landowners to engage in bobwhite habitat improvement using bobwhite management techniques. As far as the financially optimal management regimes are concerned, as site index increased from 50 to 90, the timing of the first thinning decreased from ages 16 to 10, the timing of the second thinning decreased from ages 31 to 19, and the timing of the final harvest decreased from age groups of 34–38 to 24–32 (Table 6). As ARR increased from 2.5% to 10.0%, the timing of the final harvest decreased. The optimal rotation age dropped from age 38 to 34 for the low site index of 50, and from age 32 to 24 for the high site index of 90. The optimal thinning intensity of the first thinning was in the range of 45–55% of basal area removed; the optimal thinning intensity of the second thinning was in the range of 35–40% of basal area removed. The optimal thinning intervals (between the first and second thinning) were in the range of 9 years to 19 years.

DISCUSSION

Habitat quality for bobwhite is diminished by the presence of a dense overstory in pine forests. Nonindustrial private forest landowners are facing the challenge of managing

Table 6. Financially optimal thinning and final harvest schedules for loblolly pine plantations managed for both northern bobwhite and timber on nonindustrial private forest land in the southeastern United States, 2007.

Site index and basal area	Real alternative rates of return			
	2.5%	5.0%	7.5%	10.0%
Site index[a] 50				
Optimal thinning and final harvest regime	16-31-**38**[b]	16-31-**36**	<16-31-**36**>[c]	<16-28-**34**>
% BA[d] removed during first and second thinning	50; 35	50; 35	50; 35	50; 40
BA before first thinning	17.75	17.75	17.75	17.75
BA after first thinning	8.83	8.83	8.83	8.83
BA before second thinning	13.99	13.99	13.99	13.20
BA after second thinning	9.02	9.02	9.02	7.89
BA before the final harvest	9.99	9.84	9.84	8.84
Site index 60				
Optimal thinning and final harvest regime	13-28-**38**	13-26-**32**	<13-24-**29**>	<13-24-**29**>
% BA removed during first and second thinning	55; 35	55; 35	55; 35	55; 35
BA before first thinning	17.36	17.36	17.36	17.36
BA after first thinning	7.80	7.80	7.80	7.80
BA before second thinning	14.58	14.15	13.61	13.61
BA after second thinning	9.43	9.13	8.77	8.77
BA before the final harvest	10.52	10.01	9.38	9.38
Site index 70				
Optimal thinning and final harvest regime	11-30-**35**	11-24-**29**	11-24-**29**	<11-20-**25**>
% BA removed during first and second thinning	55; 35	55; 35	55; 35	55; 35
BA before first thinning	16.86	16.86	16.86	16.86
BA after first thinning	7.55	7.55	7.55	7.55
BA before second thinning	18.94	17.03	17.03	15.01
BA after second thinning	12.18	11.06	11.06	9.73
BA before the final harvest	12.53	12.18	12.18	11.45
Site index 80				
Optimal thinning and final harvest regime	10-23-**28**	10-23-**28**	10-23-**28**	10-19-**24**
% BA removed during first and second thinning	55; 35	55; 35	55; 35	55; 35
BA before first thinning	17.16	17.16	17.16	17.16
BA after first thinning	7.71	7.71	7.71	7.71
BA before second thinning	19.17	19.17	19.17	16.95
BA after second thinning	12.30	12.30	12.30	10.99
BA before the final harvest	13.97	13.97	13.97	12.78
Site index 90				
Optimal thinning and final harvest regime	10-21-**32**	10-20-**25**	10-20-**25**	10-19-**24**
% BA removed during first and second thinning	45; 40	45; 40	45; 40	45; 40
BA before first thinning	19.84	19.84	19.84	19.84
BA after first thinning	10.90	10.90	10.90	10.90
BA before second thinning	24.61	23.67	23.67	23.00
BA after second thinning	14.66	15.28	15.28	12.51
BA before the final harvest	18.49	16.42	16.42	15.03

[a] Site index in feet, base age 25.
[b] Bold type indicates the age of final harvest, and the numbers to the left indicate age at thinnings.
[c] Brackets indicate a negative land-expectation value. Schedules shown minimize losses.
[d] Basal area (m^2/ha).

forest resources for joint production of bobwhite habitat and timber products. Incorporating effectual costs and benefits into economic analysis is critical in deciding whether to manage for improving bobwhite habitat. I compared management regimes that maximized financial revenues derived from timber products versus joint production of bobwhite habitat and timber products, and generated quantitative measures useful for NIPF landowners to evaluate economic tradeoffs inherent in the multiple uses of bobwhite and timber management. My results will aid NIPF landowners in quantifying the economic tradeoffs relative to bobwhite habitat resulting from manipulation of timber growing stock to produce better habitat for bobwhite.

My analysis demonstrates that the potential economic impacts of hunting leases and additional revenues derived from quail habitat management on the profitability of forest management are significant. I drew 3 main conclusions. First, the effect of hunting leases and additional revenues on the percentage gain in EAA is greater on low-productivity sites than on high-productivity sites. Second, the effect of hunting leases and additional revenues on the percentage gain in EAA is greater for high interest rates than for low interest rates. Third, because the revenue from quail habitat management increases the profitability of pine plantations, NIPF landowners may extend their investments on low-productivity sites that would be unprofitable if timber is the only product.

The magnitude of profitability derived from bobwhite management depends on a number of variables such as species, stand age, site quality, planting density, and forest practices. In addition, NIPF landowners may receive potential financial assistance from state or federal cost-sharing programs targeted to address water quality, soil erosion, forest protection, and wildlife habitat concerns. Therefore, analyses should incorporate the reduction in management or establishment costs due to landowners' participation in cost-sharing programs. Nonindustrial private forest landowners also need to be aware of changes in the variation of hunting leases relative to regions in question, local management costs, and stumpage prices and adjust their management practices accordingly.

MANAGEMENT IMPLICATIONS

Strictly from an economic perspective, investing money in enhancing bobwhite habitat has potential to generate more economic returns. Because of the extra revenues associated with creating and maintaining bobwhite habitat on the stands, this study indicated that managing for bobwhite and timber simultaneously would result in some financial gain. For example, for landowners owning site index 50 land with a 5.0% ARR, managing for bobwhite and timber simultaneously could turn the forest management into a profitable investment and change annual financial returns from a negative \$26.23/ha to a positive \$2.64/ha (Table 3). Hunting lease prices usually are determined by the quality of habitat and quantity of game. As Brennan (2007) pointed out, bobwhites are becoming an economic magnet that attracts dollars from wealthy urbanites to economically challenged rural communities; meanwhile, blue-collar bobwhite hunting is disappearing from the landscape. Compared to bobwhite hunting leases 30 years ago, hunting leases have risen from \$10/ha/yr to greater than \$30/ha/yr in many south Texas locations and have reached record high prices (Brennan 2007). My study provides an example of integrating multiple-use of goods and services from the forest in a way that maximizes economic returns. According to each individual NIPF landowner's preference, the desired level of bobwhite habitat and potential bobwhite hunting leases can be determined, and economic analysis can serve as a useful tool to aid landowners in this decision making process.

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