EVALUATING ECONOMIC IMPACTS OF DIFFERENT SILVICULTURAL APPROACHES IN SWEETGUM- NUTTALL OAK-WILLOW OAK BOTTOMLAND HARDWOOD FORESTS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

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Abstract—This study explains the economic tradeoff, in terms of forgone timber revenue, between even-and uneven-aged management approaches for the sweetgum-Nuttall oak-willow oak forest type of the Lower Mississippi Alluvial Valley (LMAV). Thirty-four stands were collected from the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) database and used to simulate even-and uneven-aged management scenarios with the Forest Service Forest Vegetation Simulator/Southern Variant (FVS/SN). Historical timber prices were applied to the predicted timber volumes to estimate cumulative net present value. The even-aged management scenario outperformed the uneven-aged management scenario; however, the magnitude of the economic tradeoff depended upon the initial stand condition and discount rate. These analyses will allow landowners to understand how much economic gain or loss they may realize by adopting an alternative form of management in the sweetgum-Nuttall oak-willow oak forest in the LMAV.

INTRODUCTION

The Lower Mississippi Alluvial Valley (LMAV) encompasses 26.7 million acres of land along the course of the Mississippi River, covering seven States from southern Illinois to the Gulf of the Mexico (Oswalt 2013, Twedt and others 2012). Historically, much of this area was covered by bottomland hardwood (BLH) forest, but colonial settlement and agricultural conversion have reduced forest cover to less than 20 percent of its original extent (King and Keeland 1999, Oswalt 2013). Management of the remaining BLH forest has received increasing attention, with different approaches being advocated depending upon management priorities. Important management goals in BLH forests of the LMAV include timber production, habitat maintenance for high conservation priority wildlife species, soil and water conservation, and many other concerns.

The sweetgum-Nuttall oak-willow oak forest type is one important forest type in the LMAV, covering approximately 17 percent of the forested land in the LMAV (Oswalt 2013). Forest management approaches for the sweetgum-Nuttall oak-willow oak forest type differ in large degree depending on the objectives of landowners, whether focused on timber, wildlife or other values (Meadows and Hodges 1997). Today, timber-focused management regimes typically favor even-aged forest management approaches aimed at promoting optimal growth of commercially desirable tree species such as green ash and red oaks (Kellison and Young 1997). Silvicultural systems that are considered most suitable include clearcutting and shelterwood regeneration methods, although group selection may also be possible (Meadows and Stanturf 1997). In contrast, wildlife-focused management approaches tend to prioritize structural diversity (Twedt and others 2012). These "wildlife centric" approaches are considered to produce better habitat for some wildlife species (Twedt and Somershoe 2009). For this purpose, BLH forest managers often gravitate to uneven-aged forest management approaches using single tree or group selection methods (Meadows and Stanturf 1997), although an array of different multi-aged silvicultural approaches are possible (O'Hara and Ramage 2013).

Forest landowners and managers face uncertainty with regards to the tradeoff in timber revenue that may result from adopting even or uneven-aged management approaches in BLH forests. Much of this uncertainty stems from limited information on timber yields produced by each management scenario over time. Currently, there is little guidance in the literature that quantifies this economic and yield tradeoff of favoring one management system over another. This can hinder landowners' and managers' ability to evaluate the timber revenue tradeoff that may result. Comparative study of these two strategies in terms of the economic return based on timber production value should help managers and landowners

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to make a more informed management decision for their stands and to achieve their management objectives. Economic guidance could help BLH landowners and managers make more informed decisions about applying even- and uneven-aged management by stand conditions (i.e., forest type, composition, and site productivity) while also allowing them to understand how much economic gain or loss they may realize by adopting an alternative form of management.

In this study, we examined cumulative net present value (NPV) produced by both even-aged and uneven-aged management in the sweetgum-Nuttall oak-willow oak forest type. NPVs were used to evaluate the tradeoff between even-and uneven-aged management. Stand level information was collected from U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) plots to simulate stands under both management scenarios using the Forest Service Forest Vegetation Simulator/Southern Variant (FVS/SN). The objective of this study was to explain the timber revenue-based economic tradeoffs between even- and uneven-aged management in the sweetgum-Nuttall oak-willow oak stands.

METHODS

Stand level data were collected from the FIA database. The study area was limited to three States: Mississippi, Louisiana, and Arkansas. More specifically, the Lower Mississippi Riverine Forest Province "234-Ecoregion category" was selected to confine the study within the LMAV. Selected stands were further classified into three stocking levels based on Goelz (1995): overstocked (>100 percent stocking), fully stocked (60-100 percent stocking), and understocked (<60 percent stocking). Stands were further classified into three site qualities: high quality site (sweetgum 115 feet at base age 50), medium quality site (sweetgum 99 feet at base age 50), and low quality site (sweetgum 83 feet at base age 50). Classification of site quality was estimated based on the site productivity class and site index information available in the FIA database for the selected forest type. All together, 34 stands were selected for the sweetgum-Nuttall oak-willow oak forest type.

Growth of selected stands was simulated using the FVS/SN, which is a distance independent growth and yield model. It does not predict regeneration after disturbance. Therefore, available regeneration information from the FIA database for the simulation stands was averaged and used to regenerate stands during the simulation process. The 34 existing stands were simulated under even- and uneven-aged management scenarios. Even- and uneven-aged management scenarios used in the simulations were developed according to the published literature, described below. For even-aged management, the initial existing stand was managed based on the decisionmaking criteria recommended by Goelz and Meadows (1997) (table 1) to maximize NPV. After harvesting the initial existing stand, the second rotation started with an assumed average regeneration and managed to maximize land expectation value (LEV) (fig. 1). The averaged regeneration was estimated based on average regeneration densities derived from FIA plot data for the sweetgum-Nuttall oak-willow oak forest type. Stands were thinned from below to control stocking level based on the stocking guide for bottomland hardwood forest by Goelz (1995). In each thinning, a majority of oak species were retained and non-oak species were removed by the use of species preference management tools in the FVS/SN simulator.

Uneven-aged management scenarios were developed based on Putnam and others (1961), which suggested a target uneven-aged stand structure with a 1.3 q-factor, 68 square feet per acre residual basal area, and 38 inch maximum DBH limit. Forty cutting cycles (maximum number of cycles possible in FVS/SN) were simulated for cutting cycles of 5−15 years length. Removals were targeted to produce and maintain a balanced uneven-aged diameter distribution. The amount of regeneration provided in the uneven-aged scenarios was adjusted for crown opening size and shade tolerance characteristics of species, and allocated at each cutting cycle.

Economic Analysis

Growth and yield data from the FVS/SN simulation were used to calculate cumulative NPV for both even-and uneven-aged management scenarios. For the even-aged scenario, NPV was calculated for the existing stand, and then revenue for a second rotation was calculated for an infinite series of identical rotations to calculate LEV (equation 1). Thus, cumulative NPV (equation 2) for the even-aged management scenario was a summation of NPV from the existing stand and discounted LEV from the infinitely identical second rotation (fig. 1). This was calculated for a range of possible final harvest ages for the existing stand. The final harvest age with the highest cumulative NPV was selected as the final harvest age for the existing stand.

$$LEV = \frac{NFV}{(1+i)^t - 1} \qquad (1)$$

$$NPV = \frac{NTR + LEV}{(1+i)^k} \qquad (2)$$

Table 1—Decisionmaking criteria for managing BLH stands (Goelz and Meadows 1997)

	Scenario	Prescription
Stand < 10 years from rotation age		Plan to regeneration when appropriate
Stand > 10 years from rotation age	Stocking <100%	
	Stocking of AGS≥C-10 line	Do nothing
	AGS<C-10 & QMD≥16 inches	Consider regeneration
	AGS<C-20 & QMD<16 inches	Consider regeneration
	AGS≥C-20 line & Whole stand stocking > B-line	Consider timber stand improvement
	Whole stand stocking ≤ B-line	Do nothing
	Stocking ≥100%	
	AGS> B-line	Thin stand
	AGS≤ B-line & AGS ≥C-10 line	Timber stand improvement
	AGS<C-10 line & AGS≥ C-20 line, & QMD ≥16 inches	Consider regeneration
	QMD of AGS<16 inches	Timber stand improvement
	AGS≤C-20 line	Consider regeneration

AGS is acceptable growing stock, QMD is quadratic mean diameter, B-line is suggested lower limit of stocking, C-10 lines represent stand needs 10 years to achieve B-line, C-20 line represents stand needs 20 years to achieve B-line stocking.

where:

LEV = land expectation value for infinite series of identical rotations starting at *t*

NFV = net future value of identical rotation at year *t*

i = interest rate expressed as a decimal

t = length of rotation

NTR = net timber revenue at k^{th} year (value of conversion period)

NPV = cumulative net present value (value of conversion period plus LEV)

For the uneven-aged management scenario, the initial cutting cycles tended to produce highly variable periodic NPVs, which eventually stabilized over an extended period of time (fig. 2). A financially optimal cutting cycle was identified for each stand (i.e., cumulative NPV maximization) once this stable condition was achieved. Steady periodic cutting cycle revenue (i.e., balanced uneven-aged condition) was usually achieved after several cutting cycles (i.e., the conversion period to balanced, uneven-aged condition). LEV (equation 3) was calculated for the balanced condition assuming average revenue produced in each cutting cycle as perpetual periodic revenue. Cumulative NPV (equation 2) for the uneven-aged management was also calculated by summing NPVs from the initial cutting cycles (e.g., conversion period) and discounted LEV of the balanced condition.

$$LEV = \frac{R}{(1+i)^t - 1} \qquad (3)$$

where:

LEV= land expectation value of future managed (balanced uneven-aged) forest

R= net timber revenue received every c years from future managed forest

t = number of years in the cutting cycle

i = interest rate, expressed in decimal

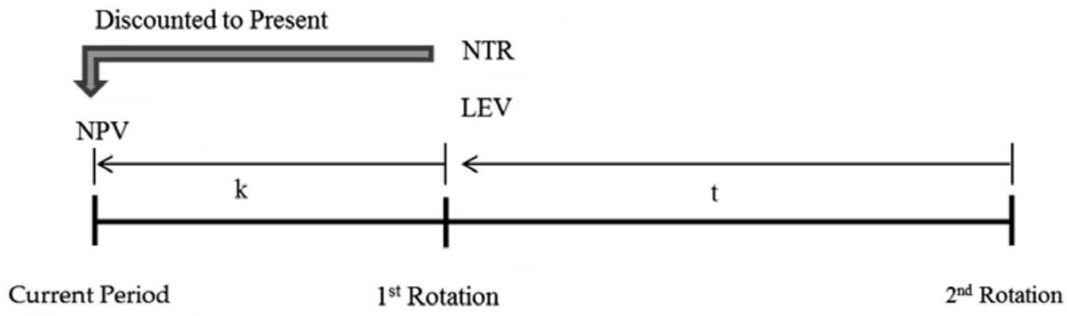

Figure 1—Timeline of NPV calculation in the even-aged management.

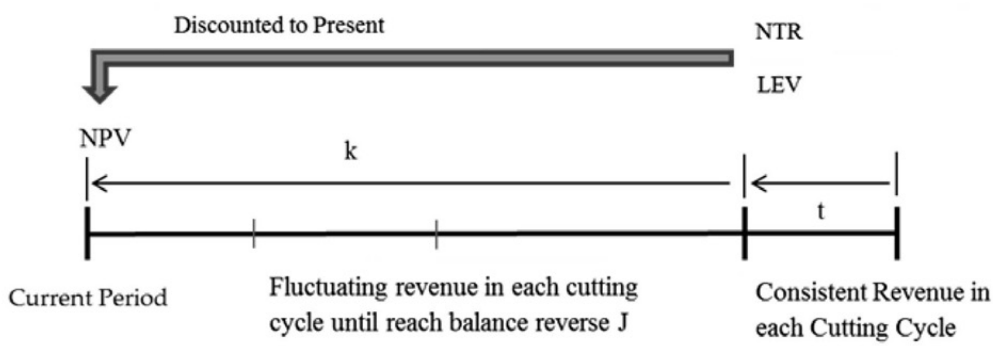

Figure 2—Timeline of NPV calculation in the uneven-aged management.

Product Price and Discount Rates:

Historical Timber Mart-South stumpage prices were used to calculate cumulative NPV for three different discount rates: 3 percent, 5 percent, and 7 percent. For Mississippi, Louisiana, and Arkansas, average stumpage prices from 2004 and 2013 were classified in three categories: oak sawtimber ($34.12/ton), mixed-hardwood sawtimber ($24.76/ton), and pulpwood ($8.43/ton) (Timber Mart-South 2004-2013). This study assumed the same management costs in both even- and uneven-aged management.

RESULTS

Among the 34 simulated stands, even-aged management scenarios produced higher cumulative NPVs as compared with uneven-aged management scenarios (table 2). The highest NPV for even-aged management scenarios was $9,681 and the lowest was $1,291 at a 3-percent discount rate. For uneven-aged management scenarios, the highest NPV was $8,358 and the lowest NPV was $ 787 at a 3-percent discount rate. At a 5 percent discount rate, even-aged management produced a maximum NPV of $8,735 to a minimum NPV of $449, and uneven-aged management produced a maximum NPV of $ 7,519 to a minimum NPV of $ 255. Similarly, at a 7-percent discount rate, even-aged management produced a maximum NPV of $8,454 to a minimum NPV of $192, and uneven-aged management produced a maximum NPV of $7,180 to a minimum NPV of $101.

NPVs for both even- and uneven-aged management increased with higher initial stand basal area (figs. 3 and 4). NPVs for both even- and uneven-aged management decreased with higher discount rates. Among the 34 simulated stands, even-aged management produced higher NPVs compared to uneven-aged management (fig. 5). At the 3-percent discount rate, even-aged management produced a maximum of $2,510 to a minimum of $101 more as compared with uneven-aged management. On average, even-aged management produced $882.56 (26.91 percent) higher NPV as compared with uneven-aged management at 3-percent discount rate.

DISCUSSION AND CONCLUSIONS

As expected, even-aged management scenarios produced higher cumulative NPVs compared to the uneven-aged management scenarios. Previously, Anderssen and Øyen (2002) conducted a similar study in a coastal spruce forest

Table 2—Initial stand conditions and calculated NPVs for the sweetgum-Nuttall oak-willow oak stands at 3%, 5%, and 7% discount rates

Stand		BA		QMD	Stocking	Site	NPV for even-aged scenarios			NPV for uneven-aged scenarios		
BA	BA Oak	Non-oak	TPA	(in.)	%	Quality	3%	5%	7%	3%	5%	7%
179	62	117	84	20	140	Low	$6,712	$6,023	$5,822	$5,742	$5,012	$4,735
178	110	68	96	18	141	High	$9,681	$8,735	$8,454	$8,358	$7,519	$7,180
163	133	30	102	17	131	Low	$7,257	$6,550	$6,342	$6,728	$5,605	$5,130
161	29	132	72	20	126	High	$7,390	$6,458	$6,178	$5,540	$4,787	$4,489
155	58	97	162	13	129	Low	$6,059	$5,367	$5,164	$5,186	$4,629	$4,398
154	59	95	199	12	136	Medium	$4,983	$4,176	$3,932	$3,885	$3,205	$2,962
145	83	62	138	14	121	Medium	$5,374	$4,566	$4,323	$4,556	$3,641	$3,245
145	108	37	114	15	118	High	$7,464	$6,509	$6,229	$6,628	$5,626	$5,205
126	59	67	138	13	106	Medium	$4,612	$3,801	$3,556	$3,803	$2,882	$2,545
125	23	102	211	10	110	Medium	$3,202	$2,477	$2,133	$2,360	$1,641	$1,388
122	87	35	114	14	101	Low	$4,893	$4,208	$4,007	$3,813	$3,225	$2,958
121	21	100	114	14	104	Low	$4,392	$3,705	$3,501	$3,544	$2,795	$2,485
120	54	66	108	14	101	Low	$4,995	$4,313	$4,112	$4,086	$3,257	$2,924
112	43	69	78	16	91	Medium	$4,743	$3,936	$3,693	$3,439	$2,774	$2,503
107	30	77	181	10	95	Medium	$2,676	$1,968	$1,754	$2,120	$1,309	$998
106	23	83	162	11	93	Low	$2,951	$2,061	$1,641	$2,605	$1,759	$1,417
105	46	59	150	11	91	Medium	$3,498	$2,609	$2,424	$3,090	$2,114	$1,698
99	49	50	253	8	93	Medium	$2,543	$1,456	$1,315	$2,369	$1,349	$940
97	76	21	102	13	82	Low	$3,432	$2,813	$2,608	$2,728	$1,909	$1,582
92	48	44	126	11	79	Low	$3,077	$2,408	$2,240	$2,412	$1,688	$1,388
88	65	23	72	15	72	High	$4,748	$3,798	$3,516	$3,333	$2,390	$1,979
88	28	60	120	11	75	Medium	$3,038	$2,599	$2,354	$2,727	$1,837	$1,512
86	65	21	78	14	71	Medium	$3,678	$2,891	$2,654	$2,380	$1,700	$1,387
85	47	38	60	16	69	Low	$4,518	$3,840	$3,638	$3,174	$2,232	$1,825
84	48	36	84	13	64	Low	$2,838	$2,051	$1,854	$2,349	$1,705	$1,444
82	42	40	169	9	74	Low	$2,249	$1,720	$1,519	$1,824	$1,083	$798
78	40	38	229	8	74	Medium	$2,499	$1,385	$894	$1,961	$1,077	$704
74	48	26	150	9	67	Medium	$2,217	$1,553	$1,313	$1,680	$887	$566
74	73	1	24	24	57	High	$5,032	$4,083	$3,802	$2,522	$1,566	$1,157
58	18	40	72	12	49	Medium	$2,327	$1,520	$1,277	$1,082	$537	$343
58	39	19	30	19	46	Medium	$2,978	$2,170	$1,927	$1,608	$755	$437
55	6	49	120	9	51	Medium	$1,927	$1,129	$942	$1,826	$864	$511
45	5	40	78	10	40	Medium	$2,241	$1,242	$822	$1,263	$520	$264
6	0	6	30	6	7	Low	$1,291	$449	$192	$787	$255	$101

Note: BA in square feet was calculated for three >5 inches.

BA=basal area; TPA= trees per acre; QMD=quadratic mean diameter.

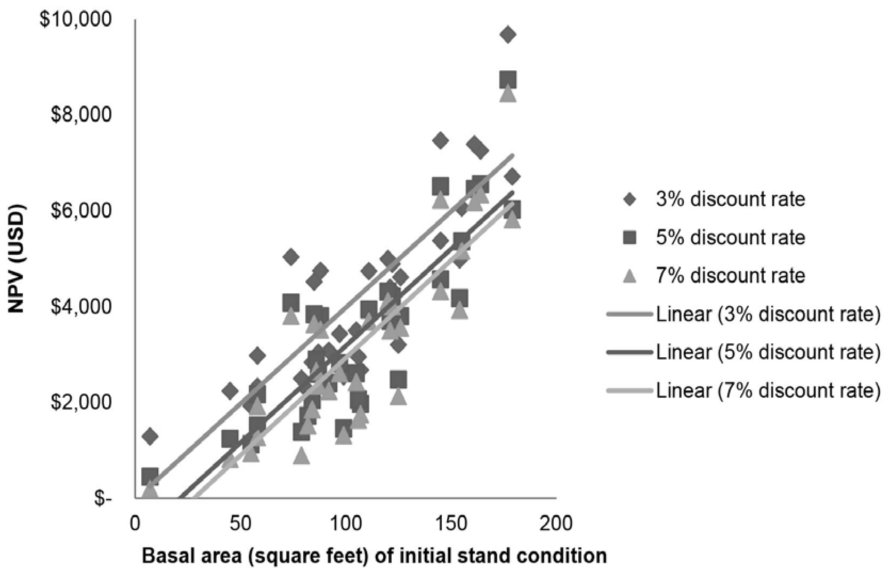

Figure 3—Scatterplot and trend lines showing the relationship between initial basal area and NPV with even-aged management in the sweetgum-Nuttall oak-willow oak forest type across all three discount rates.

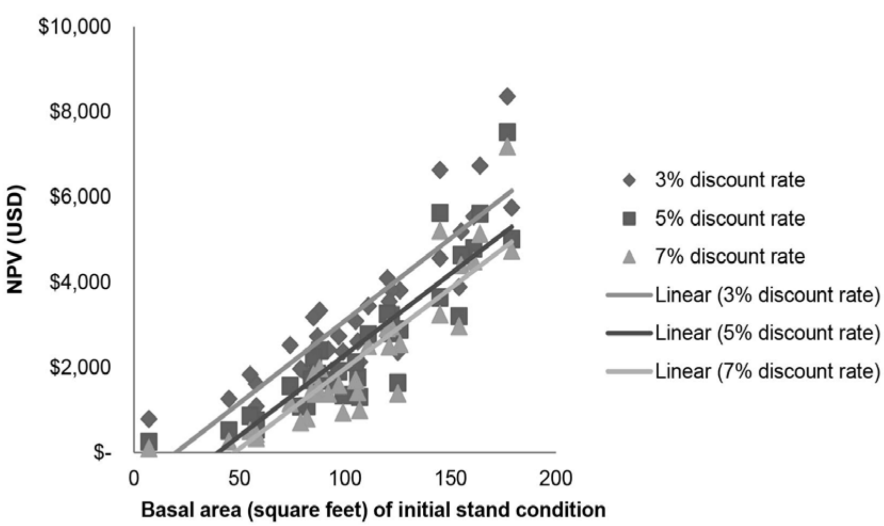

Figure 4—Scatterplot and trend lines showing the relationship between initial basal area and NPV with uneven-aged management in the sweetgum-Nuttall oak-willow oak forest type across all three discount rates.

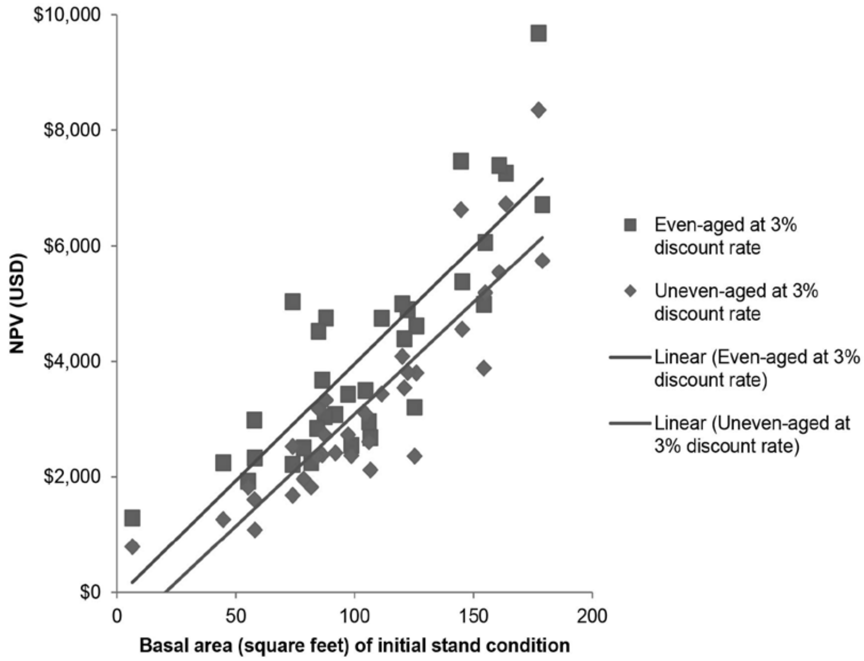

Figure 5—Scatterplot and trend lines showing the difference between NPVs of even-and uneven-aged management at a 3-percent discount rate.

and estimated that clearcut approaches produced NPVs that were 25-percent higher than single tree selection at a 3-percent required rate of return. NPVs in both even- and uneven-aged management decreased with higher required rates of return; further, with all required rates of return, even-aged produced higher NPVs compared to the uneven-aged management scenario. In contrast, Redmond and Greenhalgh (1990) found that natural pine forest with low percent (30-percent and 50-percent) stocking favored uneven-aged management over even-aged management.

The magnitude of the economic tradeoff depended greatly upon the initial stand condition and discount rate. As NPVs were cumulative, they included the revenues from management of the existing stands and the LEV of future grown stands. NPVs from existing stands greatly influenced cumulative NPVs because high basal area stands produced revenue sooner. Due to the time value of money, revenue generated earlier influences cumulative NPVs more than revenue generated later. Thus, initial stand conditions highly influenced cumulative NPVs in both even- and uneven-aged management scenarios. In particular, species composition, site quality, and QMD influenced NPVs to the greatest degree. Cafferata and Klemperer (2000) compared even- and uneven-aged management scenarios in loblolly pine stands and found that even-aged NPVs were higher than uneven-aged management and also suggested that magnitude of the difference in even-aged NPV over uneven-aged depended on the initial stand condition. Our results have similar conclusions to Cafferata and Klemperer (2000) regarding the superiority of even-aged management, in that higher basal areas, larger QMD, and greater oak species composition produced higher NPVs.

In even-aged management scenarios, stands of higher initial basal areas were harvested earlier, resulting in comparably higher NPVs. As a consequence, the second rotation started earlier than for stands of lower initial basal area which resulted in higher discounted LEVs. At the other extreme, stands of lower initial basal area required more time to grow to reach financial maturity (i.e., maximum NPV). Thus, the NPVs of those stands were lower compared to higher basal area stands due to time value of money constraints. The present values of LEVs on those stands were also lower because the second rotation started later. Consequently, cumulative NPVs became lower for stands of lower initial basal area as compared to stands of higher initial basal area. For uneven-aged management scenarios, existing stands with higher basal area produced higher NPVs because of higher timber harvest volumes achieved from initial cutting cycles. For stands of lower initial basal area, delaying several cutting cycle harvests was required to achieve the targeted residual basal area requirements. NPVs were lower in those cases due to time value of money constraints also.

There was not much difference in terms of dollar value between even- and uneven-aged management regardless of basal area (fig. 5); however, if we compare in percentage terms, then lower basal areas produced higher percentage tradeoff. Similarly, higher basal areas produced lower percentage tradeoff between even- and uneven-aged management.

For all simulated stands in a given condition, the even-aged management scenario was profitable, so landowners or foresters who aim to maximize profit may benefit from even-aged management. Revenue forgone by adapting uneven-aged management can be used as an opportunity cost of habitat improvement. Revenue forgone, in terms of percent, was higher in stands with a lower initial basal area and lower in stands with a higher initial basal area. Therefore, landowners or managers would forgo a higher percentage of revenue if they choose uneven-aged management in stands with the lower initial basal area. In summary, landowners and managers need to consider initial stand conditions such as species composition, QMD, and rotation length to estimate exact revenue tradeoff that may result from choosing uneven-aged instead of even-aged management.

LIMITATION AND FUTURE RESEARCH

This study is based solely on the valuation of timber yields. Management and harvesting costs were not considered, nor were price premiums for higher value products, both of which could affect the economic performance under even- or uneven-aged management. This study assumed the same management and harvesting costs for both even- and uneven-aged management (i.e., stumpage prices were the same for both management scenarios). As we were comparing even- and uneven-aged management, we did not consider any management cost in the NPVs estimation. Therefore, this assumption may overestimate NPVs in both management scenarios. Future research should address nonmarket values such as water and wildlife habitat, and costs associated with specific forest management practices in sweetgum-Nuttall oak-willow oak forest type and other BLH forest types in the LMAV.

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