AN ECONOMIC ANALYSIS OF EVEN- AND UNEVEN-AGED MANAGEMENT IN BOTTOMLAND HARDWOOD FORESTS OF THE LOWER MISSISSIPPI ALLUVIAL VALLEY

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Abstract—A challenge for managers of bottomland hardwood forests is the lack of information about economic tradeoffs among different management approaches. This study evaluated economic tradeoffs, in terms of timber revenue, between even- and uneven-aged management approaches in four common bottomland hardwood forest types in the Lower Mississippi Alluvial Valley (LMAV). Even and uneven-aged management scenarios were simulated using the U.S. Department of Agriculture Forest Service Forest Vegetation Simulator. Data from 107 stands, representing a wide-range of initial conditions, were acquired from the Forest Service Forest Inventory and Analysis (FIA) program. Timber volume outputs under the different scenarios were valued using regional timber price data and evaluated using net present value and equivalent annual annuity measures. As expected, even-aged management generally produced higher timber revenue, but the tradeoff differed among forest types and initial conditions. The magnitude of the tradeoff increased as average diameter increased and was larger for oak-dominated stands. These findings provide guidance to managers and landowners about economic tradeoffs associated with alternative management approaches in common forest types of the LMAV.

INTRODUCTION

The Lower Mississippi Alluvial Valley (LMAV) encompasses the southern extent of the Mississippi River floodplain, an area of nearly 27 million acres extending from southern Illinois to the Gulf of the Mexico (Oswalt 2013, Twedt and others 2012). Historically this vast floodplain was covered by bottomland hardwood (BLH) forest; however, agricultural conversion, facilitated by Mississippi River flood control efforts (Stanturf and others 2000), had, by the early 1970s, reduced forest cover to less than 20 percent of its original extent (King and Keeland 1999, Oswalt 2013). A history of fragmentation and high-grading have further degraded its condition (Bowling and Kellison 1983). Increasing concerns about degradation of soil and water quality and habitat loss associated with forest loss prompted significant efforts to improve BLH forest conditions in the LMAV (Stanturf and others 2000). Afforestation of marginal agricultural lands, subsidized primarily through Federal conservation programs under various iterations of the U.S. Farm Bill (i.e., Wetland Reserve Program and Conservation Reserve Program), has managed to restore tree cover on hundreds of thousands of acres in the region (Gardiner and others 2004, Twedt 2004). At the same time, management of remaining native BLH forests has received increasing scrutiny, with different approaches being advocated depending upon whether timber production, wildlife habitat, soil or water conservation, recreation, or other values are desired.

Evaluating the economic tradeoffs of different forest management approaches in BLH forests is challenging due to complex biophysical conditions and varied management objectives. There are more than 70 different tree species (Putnam and others 1960), which produce structural and compositional diversity, and complex forest stand dynamics (Hodges 1997). Furthermore, the dynamics of past alluvial deposition and frequency and duration of flooding create a wide range of soil and site conditions that affect site productivity and support different forest compositional associations (Hodges 1997). In addition, stand disturbance history creates a range of different stand developmental conditions (Hodges 1997). Ownership of BLH forests is distributed largely among nonindustrial private forest (NIPF) landowners, but also public agencies and

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timberland holding companies. As a consequence, a diversity of management interests exists, and different management approaches are favored depending upon objectives. These typically range from timber production to wildlife habitat to a range of other values (Meadows and Hodges 1997). Timber-oriented management regimes in BLH systems have in the past relied upon selection of individual trees of high value (effectively an uneven-aged selection approach), but have come to favor even-aged management approaches in recent decades as they are seen as more favorable to growing commercially desirable 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 habitat-oriented approaches tend to prioritize structural diversity, which is considered to be important for many wildlife species, particularly those of high conservation concern such as neotropical migratory birds (Twedt and Somershoe 2009, Twedt and others 2012). Wildlife-oriented forest managers in BLH may thus consider uneven-aged forest management approaches such as single tree or group selection methods more favorable (Meadows and Stanturf 1997), although an array of different multi-aged silvicultural approaches are possible (O'Hara and Ramage 2013).

A significant challenge for landowners and managers in the LMAV is the lack of information about economic tradeoffs among these different management approaches. Recent efforts to manage for enhanced wildlife habitat in BLH forests through partial harvesting and maintenance of continuous cover (e.g., Twedt and others 2012) have raised questions about the economic tradeoffs of alternative management approaches. While recreational values tend to be a high priority among NIPF landowners, the adoption of such novel approaches will often hinge on an understanding of economics. For BLH management this remains an area of great uncertainty for both private landowners and managers alike given the variation in soil types, topography, and stand conditions across the LMAV.

In this study, we evaluated timber revenue tradeoffs of even- and uneven-aged management for a wide range of stand conditions in four common BLH forest types in the LMAV: sweetgum-Nuttall oak-willow oak (*Liquidambar styraciflua*, *Q. texana*, and *Q. phellos*, respectively), overcup oak-water hickory (*Q. lyrata* and *Carya aquatica*, respectively), sycamore-pecan-American elm (*Platanus occidentalis*, *C. illinoinensis*, and *Ulmus americana*, respectively), and sugarberry-hackberry-elm-green ash (*Celtis laevigata*, *C. odccidentalis*, *Ulmus* spp, and *Fraxinus pennsylvanica*, respectively). We used a modeling approach to simulate forest growth and yield, which was valued using regional timber price data for the Southeastern United States to identify the economically optimal management regime under even- and uneven-aged scenarios. The objective was to provide landowners and managers with economic information to better evaluate the tradeoffs associated with different silvicultural approaches and thereby allow them to make more informed decisions about management of their BLH forests.

METHODS

Study Area and Stand Conditions

Stand-level data were acquired in 2015 from the Forest Service Forest Inventory and Analysis (FIA) program. The study area was confined to the States of Arkansas, Louisiana, and Mississippi, in which most of the LMAV lies (Sternitzke 1976). Within this study area, bottomland stands designated as Forest Service Ecoregion 234 - Lower Mississippi Riverine Forest Province (Bailey 1995) were identified, and four forest types were selected for the analysis: sweetgum-Nuttall oak-willow oak, overcup oak-water hickory, sycamore-pecan-American elm, and sugarberry-hackberry-elm-green ash forest types (table 1). These dominant forest types represent approximately half of the BLH forest cover in the LMAV (Oswalt 2013). The stand-level data provided by FIA plots covered a wide range of conditions, spanning different site types, stand ages, tree diameter distributions, and stocking conditions. Based on stand characteristics, stands were classified as overstocked (>100 percent), fully stocked (60–100 percent), or understocked (<60 percent) based on the southern bottomland hardwood stocking guide by Goelz (1995). We further classified stands into three site qualities based on sweetgum site index (base age 50): low quality (83 feet), medium quality (99 feet), and high quality (115 feet). Where site index was not provided in the FIA stand-level data, it was estimated based on a regression model that related site productivity class data to site index data (Nepal 2016).

Modeling Approach

We modeled forest stand growth and yield under different silvicultural regimes using the Forest Service Forest Vegetation Simulator (FVS) Southern Variant (Keyser 2008). The FVS is an individual tree, distance-independent growth simulator which can project growth and yield for a wide range of forest types and stand structures and can accommodate a range of silvicultural management scenarios. In the Southern Variant of FVS (FVS/SN), tree growth and mortality relationships are specified for regional conditions. Site index (described above) and regeneration need to be specified by the user. In the modeling scenarios, natural regeneration was supplied manually in FVS/SN after each regeneration treatment (i.e., final harvest or cutting cycle) within each management scenario. For each forest type, the composition and abundance of regeneration were determined by averaging FIA stand-level regeneration data within a forest type (see Nepal 2016).

Table 1—Distribution of forest stands used in Forest Vegetation Simulator (FVS/SN) simulations based on forest type, site quality[a], and stocking conditions[b]

Forest type	Site quality	Overstocked	Fully stocked	Understocked	Total
Sweetgum-Nuttall oak-willow oak	High (115 feet)	3	1	1	5
	Medium (99 feet)	4	8	4	16
	Low (83 feet)	6	6	1	13
Overcup-water hickory	High (115 feet)	0	0	1	1
	Medium (99 feet)	8	4	0	12
	Low (83 feet)	5	5	1	11
Sycamore-pecan-American elm	High (112 feet)	1	1	0	2
	Medium (98 feet)	0	5	1	6
	Low (83 feet)	1	1	2	4
Sugarberry-hackberry-elm-green ash	High (110 feet)	0	0	2	2
	Medium (97 feet)	3	6	5	14
	Low (84 feet)	1	12	8	21
Total stands:		32	49	26	107

[a] Site quality was determined using Forest Service Forest Inventory and Analysis (FIA) program site index and site productivity class data (see Nepal 2016). Respective site index numbers (dominant height at base age 50) are shown in parentheses above.

[b] Stocking conditions were determined based on equations used in the bottomland stocking guide developed by Goelz (1995; fig. 1) using data from Putnam and others (1960).

To constrain the broad spectrum of possible management approaches, we modeled an even-aged scenario and an uneven-aged management scenario (described below). These management scenarios were developed based on published literature and reflect different management paradigms that have been used in BLH management. Furthermore, we chose these management scenarios to capture the extremes of the management spectrum, thereby allowing interpretation at the forest level of mixed approaches that integrate elements of even- and uneven-aged management at the stand level.

In the even-aged management scenario, the existing stands (based on FIA data) were first managed to their financially optimal rotation length to achieve maximum Net Present Value (NPV), based on a management guide (table 2) developed by Goelz and Meadows (1997). Intermediate treatments (i.e., thinnings) were applied to maintain suitable stocking. This type of uniform, even-aged approach is considered economically efficient for commercially desirable hardwood species in the Southern United States (Meadows and Stanturf 1997). After final harvest, a second rotation stand was established using natural regeneration (representing the average densities and composition across the forest type) and was managed through to its financially optimal rotation length. For both rotations, thinning treatments were applied to maintain the stand between the B-line (lower limit) and 100 percent stocking (upper limit), based on the Goelz (1995) BLH stocking guide.

The uneven-aged management scenario followed a "BDq" approach implemented using single tree selection (O'Hara and Gersonde 2004). Target stand conditions for southern BLH forests under the BDq method were determined from Putnam and others (1960). Specifically, their data suggest balanced uneven-aged stand conditions for a managed BLH stand would be achieved with a residual basal area of 68 square feet per acre, maximum tree diameter of 38 inches, and a q-factor of 1.3. These target conditions provide for large trees and structural variability (by diameter class), which represent conditions which may be desirable to wildlife habitat managers (e.g., Twedt and others 2012). Cutting cycles of 5–15 years in length were evaluated to maximize NPV. Natural regeneration was supplied at each cutting cycle, allocated proportionally to the percentage of canopy opening created for regeneration. Each entry removed approximately 20 percent canopy cover, thus 20 percent of the average regeneration for the forest type was provided at each entry (Nepal 2016).

Economic Analysis

Timber yield data (pulp and sawtimber) from each FVS model simulation were valued based on historical hardwood timber price data for the period 2004–2013 for the Southeastern United States reported by TimberMart-South (table 3). Oak sawtimber was valued at $34.12 per ton, mixed-hardwood sawtimber at $24.76 per ton, and pulpwood at $8.43 per ton. Economic outcomes were determined at a 3-percent discount rate. Economic

Table 2—Decisionmaking criteria for even-aged management of BLH forests, adapted from Goelz and Meadows (1997)

Scenario	Stocking conditions	Prescription
Stand <10 years from rotation age		Plan to regenerate when appropriate
Stand >10 years from rotation age	Stocking <100 percent	
	AGS ≥C-10 line	Do nothing
	AGS <C-10 and QMD ≥16 inches	Consider regeneration
	AGS <C-20 and QMD <16 inches	Consider regeneration
	AGS ≥C-20 and stand >B-line	Consider stand Improvement
	Stand ≤B-line	Do nothing
	Stocking ≥100 percent	
	AGS >B-line	Thin stand
	AGS ≤B-line and AGS ≥C-10	Timber stand improvement
	AGS <C-10, ≥C-20 and QMD ≥16 inches	Consider regeneration
	QMD of AGS <16 inches	Timber stand improvement
	AGS ≤C-20	Consider regeneration

AGS = stocking of acceptable growing stock; QMD = quadratic mean diameter; C-10 and C-20 refer to stocking levels below the B-line.

Table 3—Average sawtimber and pulpwood stumpage prices ($ per ton) by State for the period 2004–2013

	Sawtimber ($ per ton)		Pulpwood ($ per ton)
State	Oak	Mixed-hardwood	Hardwood
Arkansas	$34.39	$24.18	$9.16
Mississippi	$32.00	$23.27	$8.29
Louisiana	$35.98	$26.82	$7.83
Average	$34.12	$24.76	$8.43

Timber price data supplied by TimberMart-South.

outcomes under the different management scenarios were estimated in terms of cumulative net present value (NPV), as defined below.

For the even-aged scenario, NPV was determined for the initial rotation of the existing stand, and land expectation value (LEV) was determined for an infinite series of identical rotations starting with the second rotation to calculate LEV (equation 1.1). Cumulative NPV (equation 1.2) for the even-aged management scenario was a summation of NPV from the existing stand and the discounted LEV for the rotations following the initial rotation (fig. 1). These metrics were calculated for a range of possible final harvest ages of the existing stand, in order to achieve the highest cumulative NPV for that stand.

$$LEV = \frac{NFV}{(1+i)^t - 1} \tag{1.1}$$

$$NPV = \frac{NTR + LEV}{(1+i)^k} \tag{1.2}$$

where

LEV = land expectation value for infinite series of identical rotations

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

t = length of rotation

k = number of years remaining in the current rotation

i = interest rate expressed as a decimal

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

NPV = cumulative net present value (monetary value of the conversion period plus *LEV* of future rotations)

For the uneven-aged management scenario, there were two component phases. The initial cutting cycles tended to produce highly variable NPVs, which stabilized over time (fig. 2). A financially optimal cutting cycle was identified for each stand once this stable (balanced uneven-aged) condition was achieved. NPV of the conversion period harvests was calculated, along with LEV (equation 1.3) for the balanced condition assuming average revenue produced in each cutting cycle as perpetual periodic revenue. Cumulative NPV (equation 1.2) for the uneven-aged management was also calculated by summing NPVs from the initial cutting cycles (i.e., conversion period) and discounted LEV of the balanced condition.

$$LEV = \frac{R}{(1+i)^t - 1} \tag{1.3}$$

where

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

R = net timber revenue received each cutting cycle from future managed forest

t = number of years in the cutting cycle

i = interest rate, expressed as a decimal

The economic tradeoffs between the approaches were assessed by annualizing the returns using an equivalent annual annuity (EAA) (equation 1.4) described by Cafferata and Kemperer (2000). The EAA of the uneven-aged scenario was subtracted from the EAA of the even-aged scenario to produce the EAA difference (equation 1.5). A positive value indicates that the even-aged scenarios outperformed the uneven-aged scenarios, while a negative value indicates that the uneven-aged management scenarios outperformed the even-aged scenarios. Furthermore, the EAA difference can be interpreted as the annualized cost (or benefit) of choosing the less economically optimal approach in $ per acre per year.

$$EAA = NPV * \text{Discount rate} \tag{1.4}$$

$$EAA \text{ Difference} = \text{Even-aged } EAA - \text{Uneven-aged } EAA \tag{1.5}$$

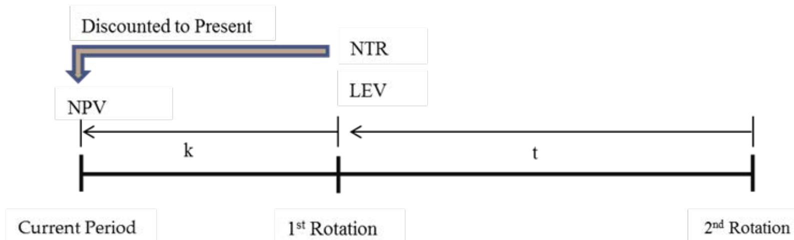

Figure 1—Timeline for cumulative NPV calculation in the even-aged scenario. Cumulative NPV combined the maximized NPV for the first rotation and highest LEV for the second rotation (both discounted to the present).

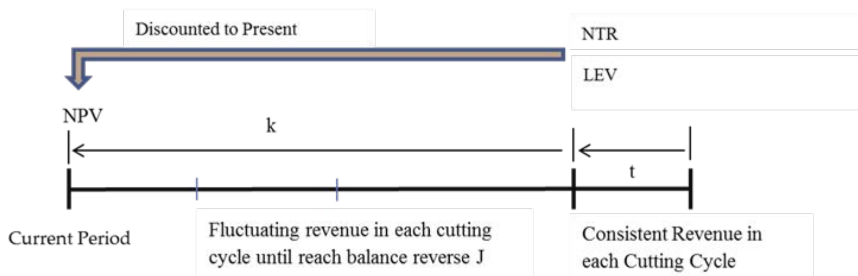

Figure 2—Timeline for cumulative NPV calculation in the uneven-aged scenario. Cumulative NPV combined the NPV for the initial cutting cycles needed to achieve a balanced uneven-aged condition and LEV for subsequent cutting cycles that generated stable revenue (both discounted to the present).

RESULTS

Even-aged Management NPV

Cumulative NPVs increased with higher initial basal area in all forest types. Among the four BLH forest types evaluated, the sweetgum-Nuttall oak-willow oak forest type produced the highest NPVs overall, ranging from approximately $1,300 per acre to $9,600 per acre. Trends for the overcup oak-water hickory and sycamore-pecan-American elm forest types were intermediate, ranging from approximately $1,300 per acre to $8,300 per acre and from approximately $1,600 per acre to $6,100 per acre, respectively. The sugarberry-hackberry-elm-green ash forest type produced lower NPVs compared to the other forest types particularly at higher initial basal areas, ranging from approximately $700 per acre to $4,500 per acre (fig. 3).

Uneven-aged Management NPV

NPVs for stands under uneven-aged management followed a similar pattern as stands under even-aged management across all forest types (fig. 4). In most cases, higher NPVs were observed for the sweetgum-Nuttall oak-willow oak forest type, and lower NPVs were observed in the sugarberry-hackberry-elm-green ash forest type. Approximate NPVs ranged from $800 per acre to $8,400 per acre for the sweetgum-Nuttall oak-willow oak forest type, $1,000 per acre to $7,200 per acre for the overcup oak-water hickory forest type, $1,200 per acre to $5,400 per acre for the sycamore-pecan-American elm forest type, and $650 per acre to $4,000 per acre for the sugarberry-hackberry-elm-green ash forest type. Similar to even-aged management scenarios, the NPV trend for the sugarberry-hackberry-elm-green ash forest type did not increase as steeply for stands with higher initial basal areas as compared to other forest types. Overall, NPVs for uneven-aged management were generally lower than in even-aged management.

EAA Tradeoff ($ per acre per year)

Across all forest types, the EAA difference increased with a larger average diameter (quadratic mean diameter, QMD) (fig. 5). Sweetgum-Nuttall oak-willow oak and overcup oak-water hickory forest types produced higher EAA differences as compared to sycamore-pecan-American elm and sugarberry-hackberry-elm-green ash forest types. Approximate EAA differences ranged from $3 per acre per year to $75 per acre per year for the sweetgum-Nuttall oak-willow oak forest type, <$1 per acre per year to $46 per acre for the overcup oak-water hickory forest type, -$2 per acre per year to $35 per acre per year for the sycamore-pecan-American elm forest type, and -$15 per acre per year to $35 per acre per year for the sugarberry-hackberry-elm-green ash forest type. Some stands with lower QMDs in the sugarberry-hackberry-elm-green ash and sycamore-pecan-American elm forest types produced higher EAA difference under uneven-aged management

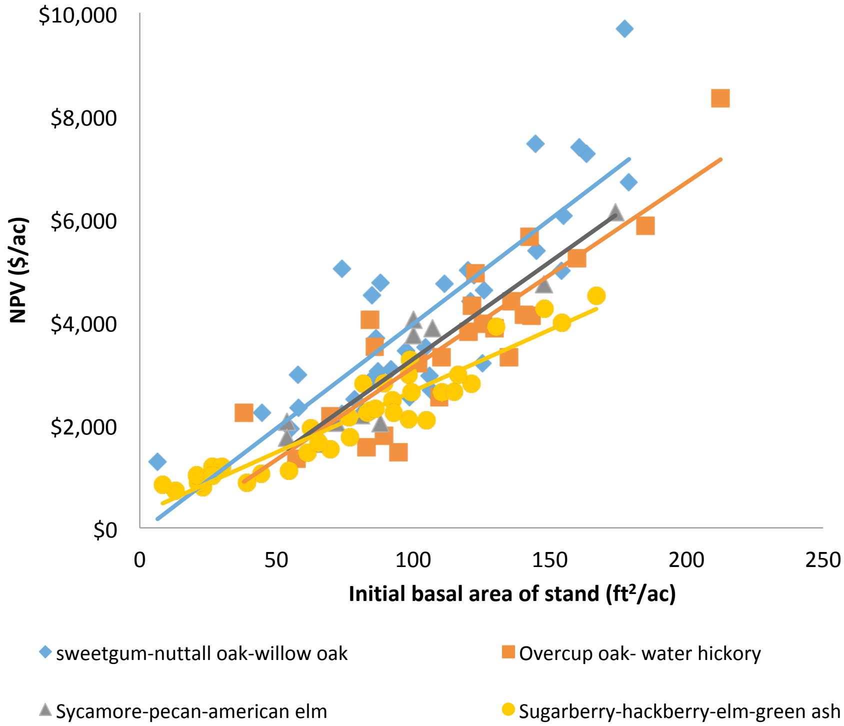

Figure 3—NPVs produced by four different forest types at a 3-percent discount rate under even-aged management.

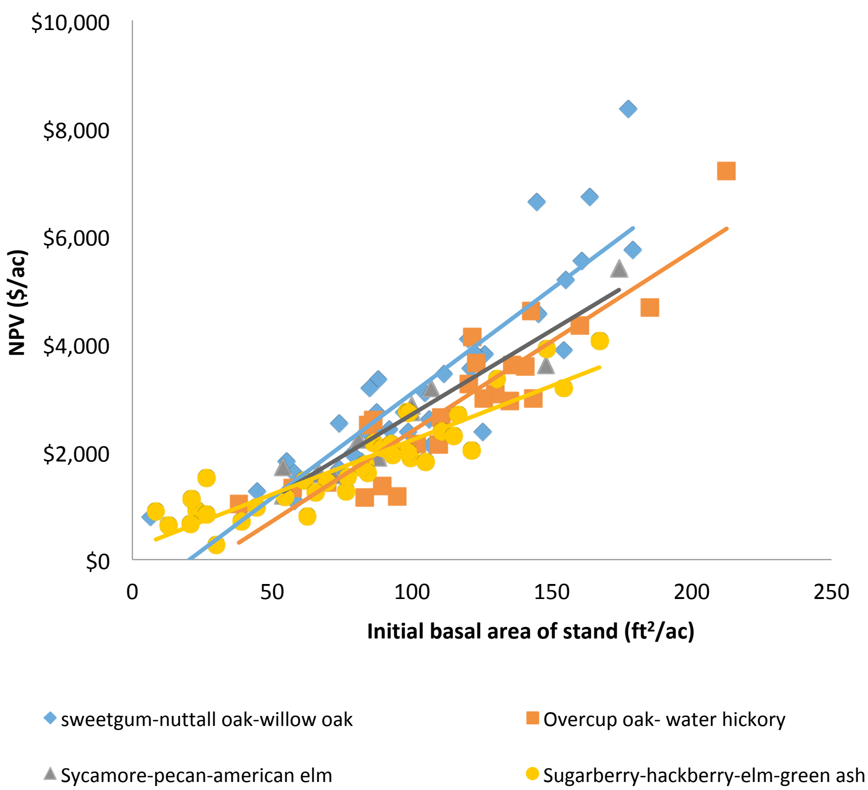

Figure 4—NPVs produced by four different forest types at a 3-percent discount rate under uneven-aged management.

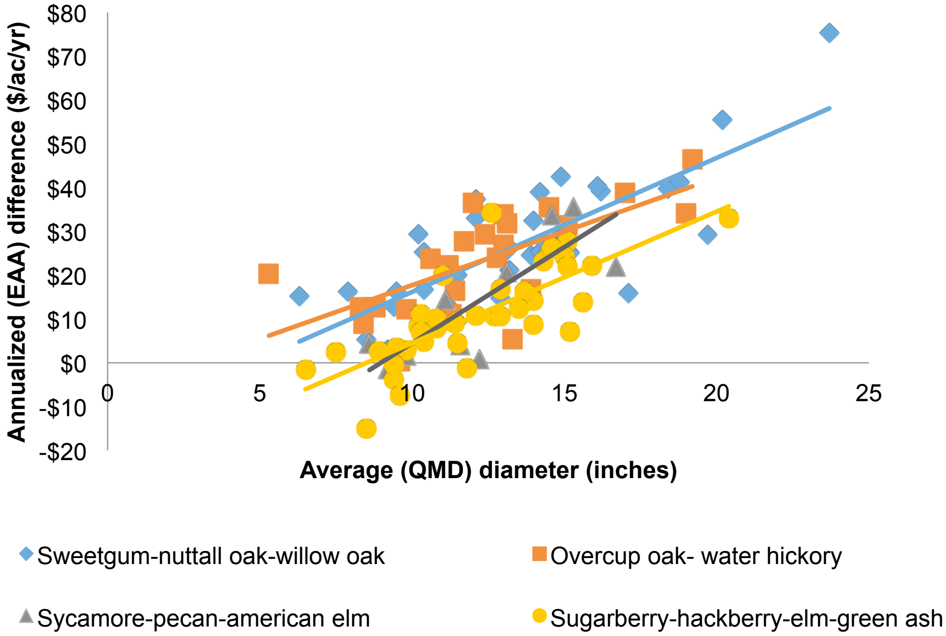

Figure 5—Tradeoff in terms of equivalent annual annuity (EAA) difference ($ per acre per year) across four forest types at a 3-percent discount rate.

(i.e., negative tradeoffs). Those stands also had lower initial basal areas.

DISCUSSION

This study aimed to quantify economic tradeoffs, specifically in terms of forgone timber revenue, between even- and uneven-aged management in bottomland hardwood forests of the LMAV. The study evaluated a wide range of initial stand conditions. Results from a total of 107 simulated stands for four different forest types in the LMAV showed that even-aged management outperformed uneven-aged management in most cases but not all. However, the magnitude of the tradeoff differed greatly depending on the initial stand conditions. NPVs increased with higher initial basal area in both even- and uneven-aged management because higher basal area stands are ready for harvest sooner in even-aged scenarios or because initial cutting cycles in uneven-aged scenarios yield higher volumes (Nepal and others 2016). The economic tradeoffs in terms of EAA difference were positively correlated with average diameter (QMD) of the initial stand and negatively correlated with the length of rotation of the existing stand in even-aged management. Stands with a higher QMD were likely to perform well under even-aged management, while moderately stocked stands with low or average QMD were likely to produce more competitive NPVs under uneven-aged management.

Among the four forest types, the sweetgum-Nuttall oak-willow oak and the overcup oak-water hickory forest types produced higher NPVs under the even-aged management scenario in all conditions. These forest types contain and produce higher volumes of higher-valued oak sawtimber resulting in higher NPVs, whereas uneven-aged scenarios produce greater volumes of lower-valued mixed hardwood sawtimber, resulting in lower NPVs (Nepal 2016). That said, several stands from the sugarberry-hackberry-elm-green ash forest type and one stand from the sycamore-pecan-American elm forest type produced higher NPVs under uneven-aged management. Conditions favorable to uneven-aged management occurred in stands of smaller-sized trees (average diameter <10 inches), conditions which were not well represented in the dataset for the oak forest types. It is possible that this more favorable performance of uneven-aged management in stands of smaller-sized trees is a more general phenomenon across forest types; unfortunately, there were limited stand-level data to assess this.

This economic analysis is based solely on valuing timber yields. Management costs were not considered, nor were price premiums for higher value products or price reductions for low quality, all of which could affect the economic performance under even- and uneven-aged management. Our analyses were based on long-term price trends and future product price dynamics could alter these outcomes. Future shifts in sawtimber values could thus alter these outcomes, either narrowing or accentuating the tradeoffs. Likewise, assumptions related to the growth and yield model, particularly regeneration and stand structural targets could affect economic tradeoffs. Sensitivity analyses have suggested that outcomes are not substantially affected by regeneration inputs (Nepal and others 2017). However, tradeoffs may be sensitive to target stand conditions prescribed in the uneven-aged BDq approach, with a higher q-factor and smaller maximum diameter limit improving the relative performance of uneven-aged management (Nepal and others 2017). Shifts in species composition will also affect economic outcomes. These aspects need further investigation. Finally, future research should also address costs associated with specific forest management practices, and non-timber values such as watershed and wildlife habitat, which are increasingly high priority concerns for BLH forests in the LMAV.

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LITERATURE CITED

Bailey, R.G. 1995. Description of the ecoregions of the United States. Miscellaneous Publication No. 1391. Washington, DC: U.S. Department of Agriculture, Forest Service. 107p.

Bowling, D.R.; Kellison, R.C. 1983. Bottomland hardwood stand development following clearcutting. Southern Journal of Applied Forestry. 7:110–116.

Cafferata, M. J. S.; Kemperer, W.D. 2000. Economic comparisons between even-aged and uneven-aged loblolly pine silvicultural systems. Tech. Bull. Research Triangle Park, NC: NCASI. 801: 1–64.

Gardiner, E.S.; Stanturf, J.A.; Schweitzer, C.J. 2004. An afforestation system for restoring bottomland hardwood forests: biomass accumulation of Nuttall oak seedlings interplanted beneath eastern cottonwood. Restoration Ecology. 12: 525–532.

Goelz, J.C.G. 1995. A stocking guide for southern hardwoods. Southern Journal of Applied Forestry. 19: 103–104.

Goelz, J.C.G.; Meadows, J.S. 1997. Stand density management of southern bottomland hardwoods. In: Meyer, D.A., ed. Proceedings of the 25th annual hardwood symposium: 25 years of hardwood silviculture – a look back and a look ahead. Cashiers, NC; Memphis, TN: National Hardwood Lumber Association: 73–82.

Hodges, J.D. 1997. Development and ecology of bottomland hardwood sites. Forest Ecology and Management. 90: 117–125.

Kellison, R.C.; Young, M.J. 1997. The bottomland hardwood forest of the southern United States. Forest Ecology and Management. 90: 101–115.

Keyser, C.E., comp. 2008 (revised November 14, 2016). Southern (SN) Variant Overview - Forest Vegetation Simulator. Internal Rep. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Forest Management Service Center. 80p.

King, S.L.; Keeland, B.D. 1999. Evaluation of reforestation in the lower Mississippi River alluvial valley. Restoration Ecology 7: 348–359.

Meadows, J. S.; Hodges, J.D. 1997. Silviculture of southern bottomland hardwoods: 25 years of change. In: Meyer, D.A., ed. Proceedings of the. 25th annual hardwood symposium; 25 years hardwood silviculture a look back a look ahead. 1997 May 7-10; Cashiers, NC. Memphis, TN: National Hardwood Lumber Associations: 1–16.

Meadows, J.S.; Stanturf, J.A. 1997. Silvicultural systems for southern bottomland hardwood forests. Forest Ecology and Management. 90: 127–140.

Nepal, S. 2016. Evaluating economic impacts of different silvicultural approaches in bottomland hardwood forests of the Lower Mississippi Alluvial Valley (LMAV). Mississippi State, MS: Mississippi State University. M.S. thesis.

Nepal, S.; Frey, B.R.; Henderson, J.E. 2017. Even- and uneven-aged management scenarios for maximizing economic return in the sweetgum-Nuttall oak-willow oak bottomland hardwood forest type in the Lower Mississippi Alluvial Valley. Proceedings of the 2017 Forest Vegetation Simulator (FVS) e-Conference.

Nepal, S.; Henderson, J.E.; Frey, B.R. [and others]. 2016. Evaluating economic impacts of different silvicultural approaches in sweetgum-Nuttall oak-willow oak bottomland hardwood forests in the Lower Mississippi Alluvial Valley. In: Frey, G.E.; Nepal, P. eds. 2016. Forest economics and policy in a changing environment: how market, policy, and climate transformations affect forests—Proceedings of the 2016 meeting of the International Society of Forest Resource Economics. e-Gen. Tech. Rep. SRS-218. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 13–21.

O'Hara, K.L.; Gersonde, R.F. 2004. Stocking control concepts in uneven-aged silviculture. Forestry. 77: 131–143.

O'Hara, K.L.; Ramage, B.S. 2013. Silviculture in an uncertain world: utilizing multi-aged management systems to integrate disturbance. Forestry. 86: 401–410.

Oswalt, S.N. 2013. Forest resources of the Lower Mississippi Alluvial Valley. Gen. Tech. Rep. SRS-177. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 29 p.

Putnam, J.; Furnival, G.; McKnight, J. 1960. Management and inventory of southern hardwoods. Agriculture Handbook No. 181. Washington, DC: U.S. Department of Agriculture. 108p.

Stanturf, J.A.; Gardiner, E.S.; Hamel, P.B. [and others]. 2000. Restoring bottomland hardwood ecosystems in the Lower Mississippi Alluvial Valley. Journal of Forestry. 98: 10–16.

Sternitzke, H.S. 1976. Impact of changing land use on Delta hardwood forests. Journal of Forestry. 74: 25–27.

Twedt, D.J. 2004. Stand development on reforested bottomlands in the Mississippi Alluvial Valley. Plant Ecology. 172: 251-263.

Twedt, D.J.; Somershoe, S.G. 2009. Bird response to prescribed silvicultural treatments in bottomland hardwood forests. The Journal of Wildlife Management. 73: 1140–1150.

Twedt, D.; Wilson, R.; Ribbeck, K. 2012. Restoration, management, and monitoring forest resource in the Mississippi Alluvial Valley: recommendations for enhancing wildlife habitat. Lower Mississippi Valley Joint Venture Forest Resource Conservation Working Group. 108 p.