Financial Assessment of Future Stand Conditions Required to Recover the Opportunity Costs of a North Louisiana Streamside Management Zone

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Abstract

Understanding the costs that residual habitat spaces carry into future rotations can provide managers more complete information when financially assessing timber management options that often extend for many decades. This case study assessed a streamside management zone's (SMZ) opportunity costs for a timber harvest site in north Louisiana. Timber removal occurred in summer 2018 by clearcut. A wooded buffer extending 50 feet on each side of a streambank and totaling 7.52 acres was retained; partial harvesting of pine timber was allowed. A timber inventory revealed that 99.6 tons per acre of standing hardwoods resided within the SMZ. Excluding noncommercial species placed its current present value (opportunity cost) at $1,803. Two future active management scenarios, ''controlled'' and ''intensive,'' were modeled over the next rotation at a 4 percent real discount rate, where price changes occurred at 0, 1, 2, 3, and 4 percent annually. Both management strategies consistently produced positive land expectation values (LEV) when SMZ opportunity costs were not included in the assessment. However, inclusion of SMZ protection under ''controlled'' management required timber price changes of 4 percent annually, while the ''intensive'' management option required timber price changes of at least 3 percent annually to return positive LEVs.

Streamside management zones (SMZ) are one component within timber harvesting best management practices (BMPs) that contribute both environmental and economic benefits. Lakel et al. (2010) found SMZs provided 97 percent watershed erosion trapping effectiveness in Virginia. The value of forested buffers in terms of valuing the land use to be retired in Alabama ranged from $0 to $1,241 per acre, or $0 to $1,984 per acre when adjusted for inflation to 2018 dollars (Basnyat et al. 2000, US Department of Labor Bureau of Labor Statistics 2019). Compliance with BMPs is voluntary in Louisiana, but penalties can be levied in many states where compliance is voluntary yet dereliction is identified (Londo 2004). Also, international certification standards in which many companies are enrolled, such as the Sustainable Forestry Initiative and Forest Stewardship Council, require installing protective zones around water bodies within timber harvest areas to safeguard fragile habitats and provide ecosystem services.

Meeting BMP requirements demands an SMZ that can serve as a vegetative buffer between a disturbed area and a water body, minimize erosion by reducing speed of runoff and filter out sediments, and provide adequate canopy to maintain current water temperature, among other requirements (Louisiana Department of Environmental Quality [LA DEQ] 2000). Louisiana's BMP manual calls for an SMZ width on either side of an intermittent stream to be 35 feet; perennial waterways less than 20 feet require a 50-foot SMZ buffer along each bank; while perennial waterways greater than 20 feet wide require a 100-foot SMZ buffer along each bank (LA DEQ 2000). Partial harvesting is

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allowed within an SMZ, given it does not compromise the SMZ's objectives (Kluender et al. 2000). This is true in Louisiana, where a silvicultural exemption can be issued for forest operations if certain criteria are met regarding a property's characteristics, e.g., ownership classification, tax declarations, past land use, timber type, timber certification, etc. (LA DEQ 2000).

Cost analyses of SMZs have primarily focused on their implementation costs along with other BMP-related structures and practices, such as installing water diversion structures, seeding, etc. (Morris et al. 2016). Forest operations putting environmental protection, erosion prevention, etc., into service was not a new concept when legally adopted as a means of maintaining and protecting water quality. Indeed, many contractors were employing at least some practices prior to their documented requirement and reported receiving net returns from their implementation, but this effect had largely faded by the mid-1990s (Blinn et al. 2001). Cubbage (2004) reviewed cost studies regarding implementing BMPs in different forest regions of the United States. Installations of SMZs carried the lowest direct costs in terms of both expenditure and as a percentage of gross revenue (Lickwar et al. 1990, cited by Cubbage 2004). Woodman and Cubbage (1994) investigated BMP installation costs in Georgia. Costs there were more expensive for private landowners and less so for forest industry landholdings. Costs for SMZs were the least for each landowner type, 3 percent of total BMP costs for forest industry and 10 percent for private landowners. Shaffer et al. (1998) found loggers' costs to install SMZs in Virginia were 4 percent of the overall median cost of BMPs.

It is tempting to conclude from the studies above that SMZs come with a low cost; tempting, but also perhaps inadequate. The responsibility of SMZs, and BMPs in general, has been misperceived as being an obligation borne solely by the logger (Londo 2004). While SMZ installation can lower logger productivity and increase unit cost (Li et al. 2006), the implementation costs are oftentimes absorbed by the landowner (Aust et al. 1996). Aust et al. (1996) found these costs, often in the form of an opportunity cost, can be greater than realized benefits. LeDoux (2006) and LeDoux and Whitman (2006) considered the opportunity costs associated with SMZs and woodland patch retention at discount rates of 4 percent each. Both studies calculated a capital recovery cost, which was a uniform annual payment that over a rotation summed to the present market value of the residual stems residing in the designated plot of land. Ledoux (2006) found capital recovery costs varied from \$6.18/acre/yr to \$27.00/acre/yr over a 120-year rotation due to timber quality, logging technology, and degree of required streamside protection. LeDoux and Whitman (2006) found capital recovery costs varied from \$5.20/acre/yr to \$12.30/acre/yr over rotation ages of 110 to 160 years for two Appalachian hardwood stands, respectively.

No study to our knowledge has considered an SMZ within the financial implications of timber growth and yield over the next rotation. A better understanding of the opportunity costs these zones carry can assist managers and landowners in determining the levels of activities the subsequent timber crop will require to achieve stated financial goals. This article intends to fill the identified literature gap using a north Louisiana forested property as a case study to assess an SMZ's opportunity costs simultaneously with other future forest management activities. Two scenarios, ''controlled'' and ''intensive'' management, were modeled over the next rotation at a 4 percent real discount rate. Price change levels included increases at 0, 1, 2, 3, and 4 percent annually.

Methods

Study property description

The study property comprised 69.66 acres and was located along the Lincoln–Union Parish line in north central Louisiana (Latitude 32.754653, Longitude 92.662702, Fig. 1). A clearcut timber harvest was conducted in summer 2018 (Fig. 2), with an SMZ consisting of 7.52 acres being retained along the branch of Cypress Creek running through the property. The soils of the harvest area were a Darley gravelly fine sandy loam and a Dubach fine sandy loam, and the SMZ's soils series was an Iuka-Dela association. Slopes ranged from 1 to 12 percent in the harvest area, while the SMZ is characterized by frequent flooding (US Department of Agriculture Natural Resources Conservation Service [USDA NRCS] 2018). The SMZ's width varied at different points along the creek, but averaged 100 feet for the property (50 feet along each bank). Limited harvesting of only pine timber occurred in the SMZ. The SMZ's soils were rated as acceptable for this to occur (USDA NRCS 2018). Loblolly pine site index was 75 feet at base age = 25 years.

Inventory methods

The SMZ was inventoried in February 2019. Rectangular plots measuring 0.05 acres were mapped equidistantly in ArcMap (Environmental Systems Research Institute 2015) beginning at one chain (66 feet) from the boundary line and downloaded to a portable tablet for field data entry prior to the inventory cruise. Species were recorded as either red oak (including southern red oak [*Quercus falcata* Michx.], water oak [*Quercus nigra* L.], willow oak [*Quercus phellos* L.], and cherrybark oak [*Quercus pagoda* Raf.]); white oak (including white oak [*Quercus alba* L.] or swamp white oak [*Quercus bicolor* Willd.]); sweetgum (*Liquidambar styraciflua* L.); and miscellaneous hardwoods (all other commercial hardwood species). All hardwood trees greater than 3 inches in diameter at breast height (DBH) were measured to the nearest tenth of an inch. Product class was entered as pulpwood (DBH below 11 in.) or sawtimber (DBH of 11 in. or greater). Trees meeting the sawtimber size requirement but of poor quality, e.g., forked, low branching, rot present, were downgraded to pulpwood. The data were merged into one dataset upon returning to the lab.

Single-entry (DBH only) timber weight tables were constructed by 2-inch diameter classes. First, total tree height was predicted using equations from VanderSchaaf and McConnell (2018) for red oak and white oak. Sweetgum and miscellaneous hardwood height-diameter equations were developed using north Louisiana US Department of Agriculture Forest Service (USDAFS) forest inventory and analysis data (USDAFS 2019). Stem cubic-foot volumes by product class were next determined from Clark and Souter (1996) using the respective DBH class and the average height predicted at that diameter. Pulpwood product volumes were calculated to a 4-inch merchantable top diameter (outside bark); sawtimber product volumes were calculated to a 9-inch merchantable top diameter (outside bark), with the stem portion between 9 and 4 inches designated as pulpwood. Species bulk densities for wood

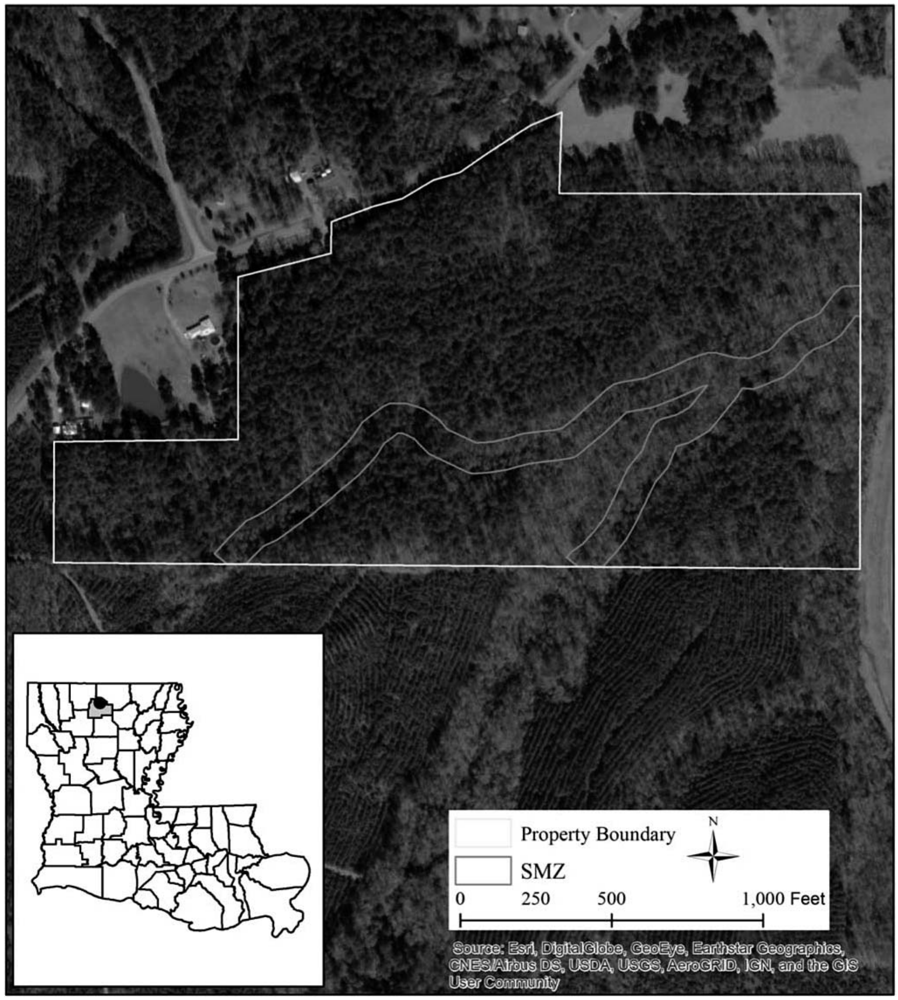

Figure 1.—Study site prior to timber removal in north central Louisiana (Latitude 32.754653, Longitude –92.662702). SMZ = streamside management zone.

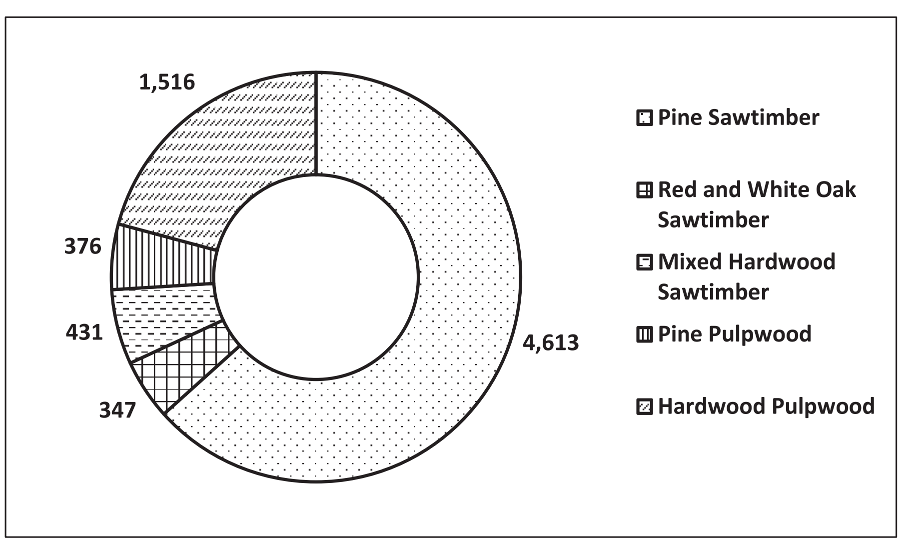

Figure 2.—Timber removals, tons, by species group and product class from the study area in summer, 2018.

and bark provided conversions of volumes to weights (Miles and Smith 2009).

Once the plot-level inventory data were stratified by DBH and weights determined by species, an expansion factor of 20 (1/0.05 = 20) was applied to obtain per acre equivalents per plot. The per acre equivalents were then averaged across all plots to yield per acre averages between species and product classes within species. Per acre totals resulted from summing across species and product classes.

Prices reflected those actually received by the landowner (Table 1). When initially inventoried, all hardwood species besides oaks were classified as miscellaneous at a price of $25/ton, including sweetgum. Our cruise identified many miscellaneous species, such as ironwood (*Carpinus caroliniana* Walt.), holly (*Ilex opaca* Ait.), or elm (*Ulmus spp.* L.), which lack commercial value in north Louisiana. Thus, miscellaneous hardwoods were included in our inventory results below, but they were excluded from economic analysis.

Future stand growth, yield, and cash flow analysis

The Cutover Loblolly Plantation Growth and Yield model (Matney 1996) was used to analyze future management scenarios on a dollar per acre basis that either excluded or included the opportunity cost of SMZ protection, where SMZ protection cost was considered its commercial timber value at time of harvest (Table 2). One scenario considered a ''controlled'' management strategy, with active yet more restrained management being practiced. The other strategy reflected a more ''intensive'' timber management plan. Thinnings occurred under each case when basal area reached 110 ft^2/acre, which was determined iteratively. Both management scenarios considered the pine timber prices listed in Table 1 under four future situations—constant prices (0% price change), fair prices (increasing at real rates of 1% annually), average prices (increasing at real rates of 2% annually), good prices (increasing at real rates of 3% annually), and optimistic prices (increasing at real rates of 4% annually). Future management costs were figured similarly (Zhang 1998) from Maggard and Barlow (2018). The landowner's alternative real rate of return (i.e., interest or discount rate) was set at a constant 4 percent. Net present values and land expectation values (LEV) were determined for each management strategy under the five future conditions for a total of 10 differing scenarios. The LEVs were calculated using Equation 1 (Straka and Bullard 1996):

$$\mathrm{LEV} = \frac{\mathrm{NPV} \times (1+i)^n}{(1+i)^n - 1} \qquad (1)$$

Table 1.—Timber prices paid in summer 2018 to the landowner in north Louisiana, $/ton.

Species	Pulpwood ($)	Chip-N-Saw ($)	Sawtimber ($)
Red oak	10	—	40
White oak	10	—	40
Miscellaneous hardwoods	10	—	25
Sweetgum	10	—	25
Pine	10	19	30

where LEV was the land expectation value, NPV was the net present value, i was the discount (interest) rate, and n was the rotation length (yr). Detailed information regarding calculations, which were performed in Microsoft Excel, can be found in the article's Appendix.

Results

SMZ inventory and value

A stand table describing per acre tree counts by species and DBH in the SMZ is provided in Table 3, and Table 4 provides a stock table on the timber inventory. Miscellaneous species, primarily ironwood, holly, and elm, along with sweetgum, predominated. Many of these trees were of smaller size, thus their designation to the smaller and lesser valued pulpwood class. Oak species comprised 21 percent of the SMZ, where 13 percent were red oak and 8 percent were white oak. In terms of tree counts, smaller, pulpwood-sized stems outnumbered the tally of larger sawtimber-sized by about 3:1, 74 to 26 percent.

Table 5 provides the timber market value of the SMZ at the time of harvest. As stated earlier, this value is inclusive only of oak species and sweetgum. The total value per acre was $1,803, which, expanded to the entire 7.52-acre area, placed its value at $13,556. Sweetgum's stock and market values become more apparent in Tables 4 and 5, where its contributions to the SMZ more than double the other species. Sweetgum sawtimber alone accounted for 59 percent of the total SMZ value. White oak timber was valued at $480 per acre, while red oak contributed $254 per acre. Sawtimber far outvalued pulpwood per acre by about 7:1. The opportunity cost carried into the next rotation by retaining hardwoods; SMZ protection, based upon market value of commercial species at harvest, was therefore $1,803 (Table 4).

Future stand growth, yield, and cash flow analysis

The ''controlled'' forest management strategy produced two timber harvests over a 35-year period, one thinning at age 19 followed by a final harvest at age 35. Per acre timber yields at age 19 were 13.3 tons of Chip-N-Saw (CNS) and 15.6 tons of pine pulpwood (PPW). Per acre timber yields at age 35 were 38.5 tons of pine sawtimber (PST), 58.8 tons of CNS, and 7.1 tons of PPW. The LEVs where SMZ protection costs were not considered were all positive, ranging from $706 per acre at constant prices to $3,073 per acre where future prices increased 4 percent annually (Fig. 3). Considering SMZ protection as an upfront cost carried over subsequent rotations reduced LEV. Where price increases were no more than 3 percent annually, LEVs were negative. The landowner would need to have an optimistic view of future timber markets for a ''controlled'' management approach to be a profitable venture.

The ''intensive'' forest management strategy produced three timber harvests over a 42-year period, two thinnings at ages 14 and 28 followed by a final harvest at age 42. Per acre timber yields at age 14 were 6.7 tons of CNS and 15.4 tons of PPW. Per acre timber yields at age 28 were 1.7 tons of PST, 30.3 tons of CNS, and 6.1 tons of PPW. Per acre timber yields at age 42 were 56.9 tons of PST, 36.6 tons of CNS, and 2.0 tons of PPW. The LEVs where SMZ protection costs were not considered were all positive here as well, ranging from $559 per acre at constant prices to

Table 2.—Management scenario variables and levels considered for growth, yield, and financial analysis of a future loblolly pine plantation on the study property, where the streamside management zone's (SMZ) opportunity cost was either excluded or included.[a]

Scenario	Age (yr)	Activity	Cost ($)	Revenue ($)
''Controlled''	0	Site prep burn	−22.74	
	0	Chemical site prep	−71.74	
	0	Cutover bareroot hand planting	−59.34	
	0	Bareroot seedlings, 585 TPA	−46.80	
	0	Exclude SMZ protection cost	0.00	
	0	Include SMZ protection cost	−1,802.76	
	Annual	Taxes and custodial management	−8.00	
	19	Consulting fee	−10%[b]	
	35	Consulting fee	−10%[b]	
	Annual	Hunting lease fee		+9.00
	19	Thin		[c]
	35	Final harvest		[c]
''Intensive''	0	Site prep burn	−22.74	
	0	Chemical site prep	−71.74	
	0	Cutover container hand planting	−72.29	
	0	Container seedlings, 610 TPA	−103.70	
	0	Exclude SMZ protection cost	0.00	
	0	Include SMZ protection cost	−1,802.76	
	1	Herbaceous weed control[c]	−37.76	
	14	Hardwood control at first thin[c]	−62.12	
	Annual	Taxes and custodial management	−8.00	
	14	Consulting fee	−10%	
	28	Consulting fee	−10%	
	42	Consulting fee	−10%	
	Annual	Hunting lease fee		+9.00
	14	Thin		[c]
	28	Thin		[c]
	42	Final harvest		[c]

[a] The Cutover Loblolly Growth and Yield Model (Matney 1996) was used to model each strategy. Site prep, planting, and annual custodial management costs were obtained from Maggard and Barlow (2018). Costs are dollars per acre unless otherwise specified. Weight scaling factors (outside bark green) were set at 60 pounds per cubic foot, with one cord being 5,450 lbs. Merchantability standards were: pulpwood, 4.5 in. diameter at breast height (DBH) to a 3-in. top; Chip-N-Saw, 7.5 in. DBH to a 5-in. top; sawtimber, 12.5 in. DBH to an 8-in. top (all outside bark).

[b] Percentage of harvest value.

[c] Considered at annual pine price increases of 0, 1, 2, 3, and 4 percent (Table 1).

$3,352 per acre where future prices increased 4 percent annually (Fig. 4). Considering the $1,803 per acre to provide SMZ protection lowered LEVs to where future timber markets at average or below annual price increases would yield unacceptable return. Annual price increases of at least 3 percent were required to provide positive LEVs.

Comparing the two strategies with SMZ protection costs excluded found the ''controlled'' strategy to be the preferred management approach if future prices increased no more than 2 percent annually. Higher prices, on the other hand, favored more intense management. The more intensive management strategy was consistently favored financially when SMZ costs were included as an environmental safeguard. Even then, financial acceptance required robust future price conditions.

Table 3.—Stand table of estimated number of trees per acre within the study area's streamside management zone. Totals may not add due to rounding.

	Species (trees per acre)			
DBH (in.)[a]	Red oak	White oak	Miscellaneous hardwoods	Sweetgum
4	12	2	39	10
6	4	2	37	11
8	4	6	21	10
10	8	3	5	13
12	1	2	5	9
14	0	1	1	13
16	3	3	8	7
18	0	2	1	4
20	1	0	1	2
Totals	33	21	119	79
% of Totals	13	8	47	31

[a] DBH = diameter at breast height.

Table 4.—Stock table, tons per acre, by species and timber product class within the study area's streamside management zone. Totals may not add due to rounding.

	Product (tons per acre)			
Species	Pulpwood	Sawtimber	Totals	% of totals
Red oak	5.6	5.0	10.5	11
White oak	4.3	10.9	15.2	15
Miscellaneous hardwoods	11.2	12.2	23.4	24
Sweetgum	12.8	37.6	50.4	51
Totals	33.8	65.7	99.6	100

Table 5.—*Timber values, dollars per acre, by species and timber product class within the study area's streamside management zone. Totals may not add due to rounding.*

Species	Product ($ per acre)			% of totals
	Pulpwood	Sawtimber	Totals	
Red oak	55.64	198.59	254.23	14
White oak	43.08	437.27	480.35	27
Sweetgum	127.57	940.62	1,068.19	59
Totals	226.28	1,576.48	1,802.76	100

Discussion and Conclusions

Excluding SMZ protection costs from assessment of future rotations resulted in an expected trend regarding the landowner's consideration of a future investment in forestry. The LEV consistently increased within each management strategy with improving future prices. More conservative future scenarios favored ''controlled'' management, while the reverse was true for more prosperous circumstances that favored ''intensive'' management. Regardless, forestry was viewed favorably from this perspective.

Environmental protection costs have largely been studied in terms of the logger, since that businessperson assumes the expense of implementing BMPs to protect water quality and provide residual habitat in real time (Conrad et al. 2018). This is ultimately transferred to the landowner in the form of reduced stumpage or the mill as a higher contract rate (Kilgore and Blinn 2003, Kelly et al. 2017). Partial harvesting within SMZs alleviates some of these costs (Kluender et al. 2000). We witnessed this here, where pine timber was harvested within the SMZ. However, the cost of water quality protection goes beyond constructing water diversion structures, because a retained SMZ is where highly valued bottomland hardwood species reside.

This case study assumed the SMZ as an environmental protection cost carried by subsequent rotations, and from this viewpoint future investment in forestry was concluded to be less favorable. Including the SMZ's opportunity cost in future rotations increased costs by a factor of 4.1 for the ''controlled'' strategy and 5.2 for the ''intensive'' strategy. Per acre returns between the two future management options in this case favored an intensive approach. If generating forest-based income is the sole goal of the forest investment, management must be active and within a context of an expanding economic climate to generate financially positive outcomes.

The current economic environment contradicts the long-term trend of the South's timber industry, where hardwood timber now sells for as much or more regionally than southern pine. This could be problematic in the South, where production forestry is primarily practiced in the context of managing for southern pine. Industry consolidation, sawmill yield improvement, and an oversupply of pine was predicted to keep that species' prices below trend for several more years before a competitive log market returned to the region (Clark 2019).

Our determined SMZ environmental protection cost of $1,803 accrued by the landowner compared favorably with the inflation-adjusted $1,901 borne by Virginia Coastal Plain landowners to implement forestry BMPs at 99 percent compliance (Aust et al. 1996). LeDoux (2006) discussed whether subsequent entries into SMZs that removed mature stems in future years could help lower an SMZ's annual capital recovery cost. The SMZ's marketable timber in this case study was dominated by sweetgum, which sawmillers are reluctant to mill and dry because of its severe warping tendency (USDAFS 2010). Sweetgum markets in the study area were pulpwood, chips, pallets, and ties. Therefore, subsequent harvesting prior to the next pine plantation's first thinning was considered unlikely.

Landowner stumpage revenue for Appalachian mixed hardwoods may clarify the appropriateness of the subsequent entry prescription for LeDoux's (2006) study region over ours. Doing so required determining real equivalent annual incomes for both instances (Table 6); our study scenario was over 42 years, while LeDoux's (2006) covered 120 years. Our highest LEV result of $1,120 for intensive pine management at 4 percent price increases equated to a net present value of $900. In contrast, the inflation-adjusted

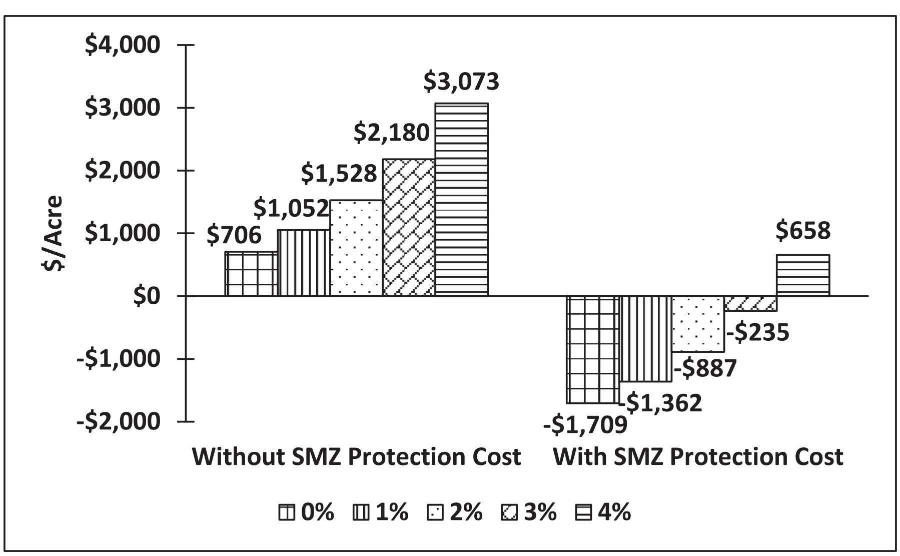

Figure 3.—Land expectation values ($ per acre) for the "controlled" management strategy under five differing expectations of future price changes. SMZ = streamside management zone.

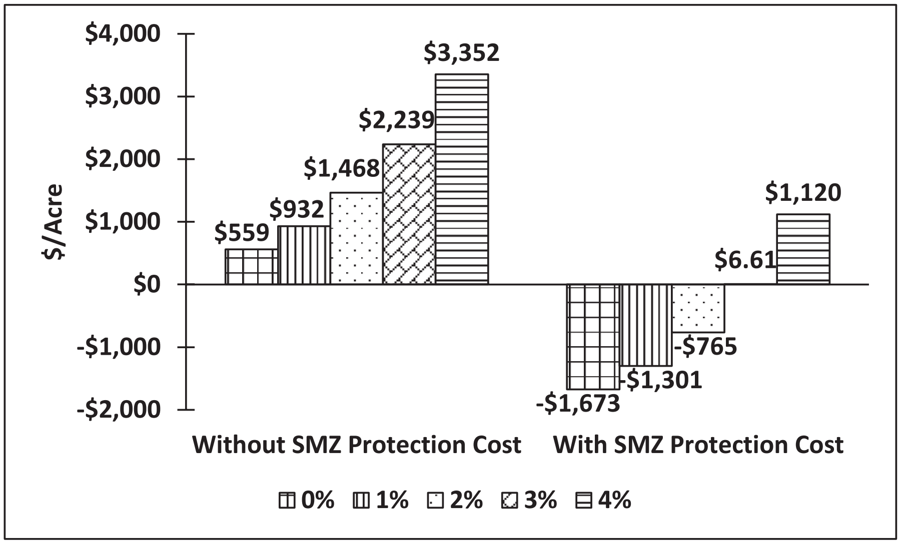

Figure 4.—Land expectation values ($ per acre) for the "intensive" management strategy under five differing expectations of future price changes. SMZ = streamside management zone.

net present value for LeDoux's (2006) study was $3,500 per acre. Real equivalent annual income per acre in our study's scenario was one-third the level of that found by LeDoux (2006), approximately $45 versus $141.

One simple explanation for this difference was that the LeDoux (2006) study was located beyond the Deep South in the Appalachian region. Typically, more highly valued hardwood species reside there as compared with the Deep South, hardwood sawtimber is of higher quality, and value is tied more to the scale and grade of the individual piece (Luppold 1997, McConnell 2017). This case study was located where weight scaling of hardwood sawtimber is the norm, industrial hardwood products are the more common output, and appearance-grade lumber typically peaks at the mid-level common grades. LeDoux's (2006) strategy could be more appropriate in certain circumstances in the Deep South where tracts possess desirable species of appropriate size and quality and hardwood markets are highly competitive.

There are multiple perspectives from which to view the opportunity costs of habitat retention (LeDoux and Whitman 2006). Monetarily, one perspective is viewing the opportunity costs as the loss of timber income at harvest. A second may be to view opportunity costs as a sunk cost associated with forest certification. A third may be to view those costs as the additional hurdle the next plantation will need to clear. Others may be perceived from the provision of ecosystem services. One is the cost of ecosystem diversity, a second may be the annual payment for water quality and soil protection, and a third might be as a carbon sequestration expenditure.

This article focused on the financial implications of SMZs over a timber rotation. Obviously, many benefits are provided from their implementation. We noted the monetary benefit received from wildlife habitat as leasing revenue. A second source of income not applicable here, but perhaps elsewhere, would be recreation and tourism from outdoor activities (e.g., camping). Sediment trapping effectiveness of SMZs in Virginia ranged from 86 to 97 percent (Lakel et al. 2010). Carbon accumulation and storage also occur within an SMZ's trees; watershed regulation provides water filtration and helps regulate water supply (Simpson et al. 2013). Benefits and costs do not necessarily accrue uniformly over time (LeDoux 2006), thus future research should address this issue.

Table 6.—Per acre equivalent annual incomes from timber production comparing the current study to LeDoux (2006).

	Study description	Net present value per acre (2018 $)[a]	Equivalent annual incomes ($)
Study site	Based upon an intensive management strategy and pine timber stumpage prices per Table 1, with prices increasing at a real annual rate of 4%. Modeled using the cutover loblolly growth and yield model (Matney 1996) at a 4% real discount rate.	904.07	44.79
Ledoux (2006)	Simulated harvest of a mixed Appalachian hardwood stand at age 120 years. Modeled using hardwood delivered prices in ECOST and MANAGE-PC at a 4% real discount rate. Machine configuration included track feller buncher, forwarder, and chainsaw for limbing, bucking, and topping.	3,504.78	141.45

[a] Ledoux's (2006) net revenue was $2,717 per acre in 2004 dollars. This was converted to 2018 dollars using the producer price index for logs, bolts, timber, pulpwood, and wood chips, WPU0851 (US Department of Labor Bureau of Labor Statistics 2019). The equivalent annual income was calculated as below, where the real discount rate was 4 percent and n was equal to either 42 for this study or 120 for Ledoux (2006): Equivalent annual income = $\frac{(0.04 \times \text{Net present value})}{(1-1.04^{-n})}$.

One implication not investigated here is the environmental and economic effects inflicted upon SMZs by weather. This includes not only severe individual events but also longer-term exposure to conditions not previously experienced by trees that resided in a fully stocked or overstocked environment. We noted several pulpwood-sized stems with broken tops, while a number of larger sawtimber-sized trees experienced uprooting. Whether either, both, or neither occurred as a circumstance of harvesting was unknown, but weather-related factors leading to merchantable volume losses of up to 30 percent one year following clearcutting were not unexpected (Ruel 1995). Recorded precipitation from August 2018 through January 2019 totaled 35.9 inches as compared with the normal expected level of 24.2 inches (National Weather Service 2019). How this affects species composition, stand stocking, and ultimately value, over time can elucidate economic and ecological responses to exogenous shocks.

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Appendix

Example calculations considering 2 percent real annual timber price increases are provided below highlighting how the land expectation values (LEV) in Figures 3 and 4 were obtained for the ''controlled'' and ''intensive'' management strategies, including whether the SMZ's timber value was excluded or included. Calculations for other scenarios followed similarly. The Cutover Loblolly Growth and Yield Model (Matney 1996) was used to model each strategy. Site preparation, planting, and annual custodial management costs found in Table 2 were obtained from Maggard and Barlow (2018). Throughout the study the real discount rate was held to 4 percent. Note the calculations in the below text and tables may not sum exactly due to rounding. All equations can be referenced in Bullard and Straka (2011).

Controlled management at 2 percent real annual timber price increases

Future timber prices were obtained by applying the compound interest formula. For example, pine sawtimber from Table 1 sold for $30/ton. The future price in 35 years under a controlled management strategy would be $60/ton by

$$\$60.00 = \$30.00 \times 1.02^{35}$$

The Cutover Loblolly Growth and Yield model (Matney 1996) predicted 38.5 tons per acre of sawtimber would reside on the property in 35 years. The future per acre revenue of pine sawtimber would be the product of future price multiplied by future yield. The future revenue would then be discounted to the present at the 4 percent discount rate over 35 years

$$\$585.44 = \frac{\$60.00 \times 38.5}{1.04^{35}}$$

Calculations of discounted present values for other future timber product revenues followed similarly, with time varying by the year of harvest. Timber revenues summed to $1,469.66. The landowner leased his property at an average annual price of $9.00 per acre. Discounting all future revenues to the present followed

$$\$167.98 = 9 \times \frac{(1 - 1.04^{-35})}{0.04}$$

In total, the per acre present value of future revenues for the controlled management strategy was $1,637.64 (Table A1).

Table A2.—Discounted cost results required to calculate land expectation value results for the "controlled" management strategy that assumed real annual timber price increases of 2 percent.[a]

		Present value ($ per acre)	
Age	Description	SMZ excluded	SMZ included
0	SMZ timber value		−1,802.76
0	Site prep and planting	−200.62	−200.62
19	Consulting	−28.26	−28.26
35	Consulting	−118.70	−118.70
Annual	Taxes and management	−149.32	−149.32
	NPV	1,140.74	−662.02
	LEV	1,527.95	−886.74

[a] SMZ = streamside management zone; NPV = net present value; LEV = land expectation value.

All costs were treated as negative values (Table A2). Site prep, seedling, and planting costs occurred at Year 0 and summed to –$200.62. The costs of annual tax and custodial management payments were based upon a value of $8.00 per acre

$$(-\$149.32) = -8 \times \frac{(1 - 1.04^{-35})}{0.04}$$

Timber consulting fees were assumed as 10 percent of timber revenues, and for this scenario occurred at Years 19 and 35. Using Year 35 as an example, per acre pine yields were predicted to be 38.5 tons of sawtimber, 58.8 tons of Chip-N-Saw, and 7.1 tons of pulpwood. Future revenues summed to $4,684.07. A 10 percent commission would cost –$468.41 at Year 35. Discounting to the present provides

$$(-\$118.70) = \frac{-\$468.41}{1.04^{35}}$$

Year 19 commission fees were calculated identically and amounted to –$28.26. In total, the present value of future costs summed to –$496.90 if the SMZ's timber value is excluded. Including the SMZ's present timber value as an opportunity cost changed total present costs to –$2,299.67.

Net present value was calculated by adding discounted (negative) future costs to discounted future revenues, both by excluding and including the SMZ's opportunity cost

$$\text{Net present value}_{\text{SMZ excluded}} = \$1,140.74 = \$1,637.64 + (-\$496.90)$$

Table A1.—Future and discounted revenue results required to calculate land expectation value for the "controlled" management strategy that assumed real annual timber price increases of 2 percent.[a]

	+2% timber price change			SMZ excluded		SMZ included	
Age (years)	Future price	Tons	Product	Future revenue	Present value ($ per acre)	Future revenue	Present value ($ per acre)
19	27.68	13.3	CNS	368.33	174.83	368.33	174.83
19	14.57	15.6	PPW	227.16	107.82	227.16	107.82
35	60.00	38.5	PST	2,310.20	585.44	2,310.20	585.44
35	38.00	58.8	CNS	2,232.53	565.76	2,232.53	565.76
35	20.00	7.1	PPW	141.34	35.82	141.34	35.82
Annual	9.00		Lease	9.00	167.98	9.00	167.98

[a] SMZ = streamside management zone; CNS = Chip-N-Saw; PPW = pine pulpwood; PST = pine sawtimber.

$$\text{Net present value}_{\text{SMZ included}} = -\$662.02 = \$1,637.64 + (-\$2,299.67)$$

LEVs were ultimately determined, because the ''controlled'' strategy occurred over a 35-year period, whereas the ''intensive'' strategy took place over 42 years (Table A2). The LEV calculations were

$$\text{LEV}_{\text{SMZ excluded}} = \$1,527.95 = \frac{\$1,140.74 \times (1.04)^{35}}{(1.04)^{35} - 1} \text{ and}$$

$$\text{LEV}_{\text{SMZ included}} = (-\$886.74) = \frac{-\$662.02 \times (1.04)^{35}}{(1.04)^{35} - 1}$$

Intensive management at 2 percent real annual timber price increases

Future timber prices were compounded to the year of harvest. For example, pine sawtimber from Table 1 sold for \$30/ton. The future price in 42 years under an intensive management strategy would be \$68.92/ton by

$$\$68.92 = \$30.00 \times 1.02^{42}$$

The Cutover Loblolly Growth and Yield model (Matney 1996) predicted 56.9 tons per acre of sawtimber would reside on the property in 42 years. The future revenue would then be discounted to the present at the 4 percent discount rate over 42 years

$$\$754.56 = \frac{\$68.92 \times 56.9}{1.04^{42}}$$

Calculations of discounted present values for other future timber product revenues followed similarly, with time varying by the year of harvest. Timber revenues summed to \$1,685.15. Discounting all future leasing revenues to the present followed

$$\$181.67 = 9 \times \frac{(1 - 1.04^{-42})}{0.04}$$

In total, the per acre present value of future revenues for the controlled management strategy was \$1,866.82 (Table A3).

All costs were treated as negative values (Table A4). Site preparation, seedling, and planting costs occurred at Year 0 for the intensive strategy and summed to –\$270.47. The costs of all annual tax and custodial management payments at \$8.00 per acre discounted to the present followed

$$(-\$161.69) = -8 \times \frac{(1 - 1.04^{-42})}{0.04}$$

Two additional costs were borne in this scenario. Herbaceous weed control occurred in Year 1, and a hardwood control occurred at Year 14. Each of these costs were assumed to appreciate at a real annual rate equal to the rate of timber price increase, which was 2 percent for this example. At 3 percent annual real timber price increases, weed and hardwood control costs would also increase at 3 percent annually, etc. Each was discounted to the present by

$$\text{Weed control} = (-\$37.03) = \frac{(-\$37.76 \times 1.02^{1})}{1.04^{1}}$$

$$\text{Hardwood control} = (-\$47.33) = \frac{(-\$62.12 \times 1.02^{14})}{1.04^{14}}$$

Timber consulting fees were assumed as 10 percent of timber revenues, and for this scenario occurred at Years

Table A4.—Discounted cost results required to calculate land expectation present value results for the "intensive" management strategy that assumed real annual timber price increases of 2 percent.[a]

		Present value ($ per acre)	
Age (years)	Description	SMZ excluded	SMZ included
0	SMZ timber value		−1,802.76
0	Site prep and planting	−270.47	−270.47
1	Weed control	−37.03	−37.03
14	Hardwood control	−47.33	−47.33
14	Consulting	−21.39	−21.39
28	Consulting	−37.04	−37.04
42	Consulting	−107.88	−107.88
Annual	Taxes and management	−161.49	−161.49
	NPV	1,184.98	−617.78
	LEV	1,467.60	−765.13

[a] SMZ = streamside management zone; NPV = net present value; LEV = land expectation value.

Table A3.—Future and discounted revenue results required to calculate land expectation value for the "intensive" management strategy that assumed real annual timber price increases of 2 percent.[a]

	+2% Timber price change			SMZ excluded		SMZ included	
Age (years)	Future price ($)	Tons	Product	Future revenue ($)	Present value ($ per acre)	Future revenue	Present value ($ per acre)
14	25.07	6.7	CNS	167.63	96.80	167.63	96.80
14	13.19	15.4	PPW	202.84	117.14	202.84	117.14
28	52.23	1.7	PST	89.78	29.94	89.78	29.94
28	33.08	30.3	CNS	1,003.95	334.79	1,003.95	334.79
28	17.41	6.1	PPW	106.88	35.64	106.88	35.64
42	68.92	56.9	PST	3,918.26	754.56	3,918.26	754.56
42	43.65	36.6	CNS	1,595.61	307.27	1,595.61	307.27
42	22.97	2.0	PPW	46.76	9.00	46.76	9.00
Annual	9.00		Lease	9.00	181.67	9.00	181.67

[a] SMZ = streamside management zone; CNS = Chip-N-Saw; PPW = pine pulpwood; PST = pine sawtimber.

14, 28, and 42. Using Year 42 as an example, per acre pine yields were predicted to be 56.9 tons of sawtimber, 36.6 tons of Chip-N-Saw, and 2.0 tons of pulpwood. Future revenues summed to $5,560.63. A 10 percent commission would cost –$556.06 at Year 42. Discounting to the present provides

$$(-\$107.08) = \frac{-\$556.06}{1.04^{42}}$$

Other commission fees were calculated identically and totaled –$165.52. In total, the present value of future costs summed to –$681.84 if the SMZ's timber value is excluded. Including the SMZ's present timber value as an opportunity cost changed total present costs to –$2,484.61.

Net present value was calculated by adding discounted (negative) future costs to discounted future revenues, both by excluding and including the SMZ's opportunity cost

$$\begin{aligned}\text{Net present value}_{\text{SMZ excluded}} &= \$1,184.98\\ &= \$1,866.82 + (-\$681.84).\end{aligned}$$

$$\begin{aligned}\text{Net present value}_{\text{SMZ included}} &= -\$617.78\\ &= \$1,866.82 + (-\$2,484.61)\end{aligned}$$

LEV provided the better criterion for evaluation because the ''controlled'' strategy occurred over a 35-year period, whereas the ''intensive'' strategy took place over 42 years (Table A4). The LEV calculations were

$$\text{LEV}_{\text{SMZ excluded}} = \$1,467.60 = \frac{\$1,184.98 \times (1.04)^{42}}{(1.04)^{42} - 1} \quad \text{and}$$

$$\text{LEV}_{\text{SMZ included}} = (-\$765.13) = \frac{-\$617.78 \times (1.04)^{42}}{(1.04)^{42} - 1}$$