Assessing the opportunity cost of implementing streamside management zone guidelines in eastern hardwood forests

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Abstract

Forest landowners, managers, loggers, land-use planners, and other decision/policy makers need to understand the opportunity cost associated with different levels of allowable management and required/voluntary protection in streamside management zones (SMZs). Four different logging technologies, two mature hardwood stands, three levels of streamside zone protection, and a simulation model were used to assess the opportunity costs. Results from this assessment suggest that protection costs can range from \$153/acre to \$669/acre depending on the level of protection desired, the logging technology used to harvest the timber, and the species composition of the tract. Results suggest that annual capital recovery costs by protection option range from \$6.18/acre/year to \$27.00/acre/year depending on the combination of stand, logging technology, and protection option. Results suggest that the highest opportunity costs for a given level of protection are driven by a combination of high value species mix stands and low cost logging technologies. The results should be valuable to loggers, planners, and decision/policy makers involved with streamside management zone protection.

Streams, wetlands, and wet areas are among our most valuable natural areas. From an ecological/biological perspective, forested wetlands are among the most productive wildlife habitat on the continent (Kentucky Dept. of Fish and Wildlife Resources 1990). In addition to providing habitat for a wide range of game and non-game wildlife species, these areas also are considered among the most productive sites for high-quality wood products. Protection of forested wetlands and streamside management zones (SMZs) is a priority with most state and federal conservation agencies (Blinn et al. 2001). Best management practices (BMPs) have been adopted in many states to protect water quality and other resources. A popular Internet website (USABMP 2004) allows easy access to BMPs and SMZ information on a state-by-state basis. The guidelines for locating haul roads, skid trails, log landings, stream crossings, and harvesting in SMZs are fairly consistent among states (Huyler and LeDoux 1995, Shaffer et al. 1998, Vasievich and Edgar 1998). For example, the recommended BMP options for most SMZs include no harvesting activities in 50- to 150-foot buffer strip widths adjacent to the SMZ and/or allowances for allowing up to 50 percent removal of the basal area/volume of standing trees leaving an evenly distributed/spaced stand to protect the stream/wetland (LeDoux et al. 1990, Phillips et al. 2000). The standing timber left in SMZs represents a substantial opportunity cost to landowners (Shaffer and Aust 1993, Kilgore and Blinn 2003, LeDoux and Whitman 2006). The opportunity costs are influenced by the species mix in the stand, the level of protection desired, and by the logging technology used (Peters and LeDoux 1984, LeDoux 2004). In this article, we evaluate the impact of alternative protection level options, the species mix in the stand, and the logging technology used on the opportunity costs associated with different levels of allowable management and desired/voluntary protection in SMZs.

Methods

Stand data

The two stands selected for this study were similar in age (120 yr), stems/acre, average DBH, volume, and acreage. One stand represents a medium- to low-value species mix consisting predominantly of yellow-poplar (*Liriodendron tulipifera* L.) with some red maple (*Acer rubrum* L.), black cherry (*Prunus serotina* Ehrh.), and sycamore (*Plantanus occidentalis* L.). This stand has 94 trees/acre, average DBH of 17.94 inches, and a merchantable volume of 4697.62 ft^3/acre. The stand table is shown in **Table 1.** The second stand represents medium- to high-value mixed hardwood species consisting of

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Table 1. — Stand table for the yellow-poplar stand at age 120 years.

Tree species	Midpoint of 2-inch DBH class					
	14 in	16 in	18 in	20 in	22 in	Total
	(trees/acre)					
Black cherry	2	--	--	--	--	2
Red maple	6	--	--	--	--	6
Sycamore	3	--	--	--	--	3
Yellow-poplar	17	19	24	6	17	83
Total	28	19	24	6	17	94

yellow-poplar, American beech (*Fagus grandifolia* Ehrh.), shagbark hickory (*Carya ovata* (Mill.)), black cherry, red maple, cucumber tree (*Magnolia acuminata* L.), sugar maple (*Acer saccharum* Marsh.), red oak (*Quercus rubra* L.), white oak (*Quercus alba* L.), and hemlock (*Tsuga canadensis* (L.) carr.). This stand has 90 trees/acre, average DBH of 18.27 inches, and a merchantable volume of 4872.75 ft^3/acre. The stand table is shown in **Table 2.** These stands were selected because of comparability, available detailed tree measurements, and they represent a relatively low- and high-value species mix level, respectively. These stands are representative of typical stands in the eastern hardwood region. Both stands were subjected to the same even-aged silvicultural treatment, harvesting all merchantable timber.

Logging technology evaluated

Four logging systems were used in this simulation (**Table 3**). These logging technologies were selected because of robust time and motion study data available for each, and they represent contemporary methods being used by loggers to harvest eastern hardwood stands. Machine capacities were matched to the size of logs to be removed. Machine configurations are ranked by their operating cost per unit produced (for option 1), with the Ecologger I[1] cable yarder being the most expensive and the Timbco 425 feller-buncher with the Valmet forwarder being the least expensive. The operating cost per unit produced for logging technology combinations C and D are very similar, but they reflect different on-the-ground operating conditions since logging technology D is mechanized.

Models used

Two computer software models were used in this research. The first model, ECOST (LeDoux 1985) estimated the stump-to-mill logging costs for the logging technology configurations evaluated (**Table 3**). ECOST is a microcomputer program used to estimate the stump-to-mill costs of cable logging, conventional ground-based skidding, cut-to-length, feller-buncher applications, forwarding, and several small farm tractors for logging eastern hardwoods. Stand data were input into ECOST to develop simulated estimates of the stump-to-mill costs; all costs are in 2004 dollars and reflect new equipment.

The second model, MANAGE-PC (LeDoux 1986), a microcomputer program, provided the volume yield and volume/product estimates. MANAGE-PC integrates harvesting technology, silvicultural treatments, market prices, and economics continuously over the life of the stand. The simulation is a combination of discrete and stochastic subroutines. Individual subroutines model harvesting activities, silvicultural treatments, growth and yield projections, market prices, and discounted present net worth (PNW) economic analysis. The model can be used to develop optimal management guidelines for eastern hardwoods. Stand data were entered into MANAGE-PC to provide volume/product yield estimates/acre. The average delivered prices for sawlogs and pulpwood (**Table 4**) were obtained from Forest Products Price Bulletins (Ohio Agri. Stat. Serv. 2002, Pennsylvania State Univ. 2003, Tennessee Div. of Forestry 2003).

SMZ protection options

The location of the stands was modeled identically such that they were located on both sides of a wet area that included 15 acres adjacent to a live stream. The harvesting plan was removal of timber from both sides of the stream to a landing on a truck haul road while simultaneously protecting the stream and adjacent wetlands. The wet areas were defined as areas that are periodically moist and potentially flooded, but which dry up during periods of low rainfall, allowing trees and other vegetation to grow on the site.

SMZ protection options evaluated include: 1) no protection, harvest all 68 acres; 2) leaving the wet area as a buffer zone on both sides of the stream and not removing any wood from this 15-acre zone; 3) leaving a buffer zone on both sides of the stream, but selecting some timber from within the buffer zones (approximately 50% of the volume) and allowing trafficking activity within the buffer zones.

Results

SMZ protection option 1 provides the least protection to the wet area and stream but results in the most revenue to the landowner and the highest utilization of wood in the stands (**Tables 5** and **6**). This option provides net returns ranging from $1,382 to $2,043 per acre for the low-value yellow-poplar stand depending on the logging technology used to harvest the stand (**Table 5**). Option 1 returns net values ranging from $2,389 to $3,050 per acre for the high-value mixed hardwood stand (**Table 6**). The difference in net value returns in this case range from $1,004 to $1,026/acre (net value differences are calculated by subtracting **Table 5** net revenues of protection option 1 from the comparable values in **Table 6**) depending on the logging methods used and reflect the difference in the value of the tree species in the two stands. Higher value trees bring higher values when delivered to sawmills. The differences in net revenue to the landowner range from $59 to $661 per acre for the yellow-poplar stand and range from $40 to $661 per acre for the mixed hardwood stand.

Option 2, which leaves a portion of the stand as a buffer strip, removes less wood (ranging from 1,036 to 1,075 ft^3/acre, for the yellow-poplar and mixed hardwood stand, respectively) and results in protection costs ranging from $304 to $449 per acre for the yellow-poplar stand depending on the logging methods used (**Table 5**). Option 2 results in protection costs per acre ranging from $527 to $669 for the mixed hardwood stand depending on the logging technology used (**Table 6**). The differences in protection cost between stands for all logging systems in this option ranges from $220 to $227 per acre (differences in protection costs are calculated

[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader and does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Table 2. — Stand table for the mixed hardwood stand at age 120 years.

Tree species	Midpoint of 2-inch DBH class											
	8 in	10 in	12 in	14 in	16 in	18 in	20 in	22 in	24 in	26 in	28 in	Total
	(trees/acre)											
Black cherry	--	3	--	--	2	--	--	--	2	--	--	7
Shagbark hickory	--	2	--	--	--	--	--	--	--	--	--	2
Red maple	--	--	--	2	--	--	--	--	--	--	--	2
Red oak	--	--	--	4	2	4	--	--	--	--	--	10
White oak	--	--	--	2	1	4	--	--	--	--	--	7
Cucumber tree	--	--	--	2	--	--	--	--	--	--	--	2
Hemlock	--	--	--	--	2	--	--	--	--	--	2	4
Yellow-poplar	--	--	--	4	8	4	--	--	--	--	--	16
American beech	--	--	--	2	2	4	2	--	2	--	--	12
Sugar maple	2	--	2	4	--	6	4	4	--	6	--	28
Total	2	5	2	20	17	22	6	4	4	6	2	90

Table 3. — Logging technology machine configurations used to simulate the harvest of the 68-acre tracts.

Logging technology	Description	Cost/unit	
		Yellow-poplar stand	Mixed hardwood stand
		($/ft^3)	
A	Chainsaw felling with Ecologger I cable yarder	0.59	0.58
B	Timbco 445 cut-to-length harvester with Valmet forwarder	0.50	0.49
C	Chainsaw felling with John Deere 640 cable skidder	0.46	0.46
D	Timbco 425 feller buncher with Valmet forwarder and chainsaw limbing, bucking, and topping	0.45	0.45

Table 4. — Delivered prices for sawlogs and fuelwood/pulpwood by species.

Species	Product			
	Large[a] high-quality sawlogs	Medium[b] size and quality sawlogs	Small[c] low-quality sawlogs	Fuelwood[d]/ pulpwood
	($/MBF)			($/cord)
Sugar maple	319	242	136	40
Red maple	251	192	131	40
Sycamore	280	176	125	40
American beech	280	176	125	40
White oak	408	279	138	40
Yellow-poplar	280	176	125	40
Red oak	561	397	225	40
Cucumber tree	280	176	125	40
Shagbark hickory	168	145	131	40
Hemlock	150	150	150	40
Black cherry	280	176	125	40

[a]Minimum small-end diameter ≥ 13 inches, length ≥ 10 feet.
[b]Minimum small-end diameter ≥ 11 inches, length ≥ 8 feet.
[c]Minimum small-end diameter ≥ 10 inches, length ≥ 8 feet.
[d]89 ft^3/cord, minimum small-end diameter ≥ 4.0 inches that will not make large, medium, or small sawlogs.

by subtracting **Table 5** protection costs for protection option 2 from comparable values in **Table 6**) and is attributable to the difference in value of the tree species involved. The differences in net revenue loss returns to the landowner for this protection option range from $47 per acre ($1,594 – $1,547) to $516 per acre ($1,594 – $1,078) for the yellow-poplar stand and range from $35 per acre ($2,381 – $2,346) to $519 per acre ($2,381 – $1,862) for the mixed hardwood stand depending on the logging technology used. This difference in net revenue to the landowner is attributable to the logging technology used to harvest the stands.

Protection option 3 removes 518 ft^3/acre more volume than option 2 for the yellow-poplar stand (**Table 5**) and 538 ft^3/acre more merchantable wood than option 2 for the mixed hardwood stand (**Table 6**). This extra removal of volume results in lower protection costs for the yellow-poplar stand (range of $153 to $226 per acre) compared to protection costs for the mixed hardwood stand (range of $264 to $333 per acre) depending on the logging technology employed. Net revenues to the landowner are increased in the range of $151 to $223 per acre and $263 to $336 per acre for the yellow-poplar and mixed hardwood stand depending on the logging systems used, respectively. These decreases in protection costs/acre and increases in net revenue/acre are attributable to the impact of harvesting more wood from within the buffer strips.

Revenue reductions attributed to SMZ protection occur only once at the beginning of the rotation. However, SMZ protection benefits accrue throughout the next rotation. To compare future costs and benefits, a capital recovery factor can be calculated to convert revenue reductions to a series of uniform annual costs that begin at the time of harvest and extend through the next rotation. The annual costs shown in **Tables 5** and **6** have net present values equal to the revenue reductions estimated for pro-

Table 5. — Costs and revenues by protection option treatment for the simulated harvest of a 68-acre yellow-poplar tract at rotation age of 120 years by logging technology.

Protection option	Volume removed	Logging technology	Logging cost	Revenue		Protection cost[a]	Capital recovery cost
				Gross	Net		
	(ft^3/acre)		($/acre)				($/acre/year)[b]
1	4,698	A	2,769	4,151	1,382	--	--
		B	2,329		1,822	--	--
		C	2,167		1,984	--	--
		D	2,108		2,043	--	--
2	3,662	A	2,158	3,236	1,078	304	12.27
		B	1,815		1,421	401	16.19
		C	1,689		1,547	437	17.64
		D	1,642		1,594	449	18.12
3	4,180	A	2,464	3,693	1,229	153	6.18
		B	2,072		1,621	201	8.11
		C	1,928		1,765	219	8.84
		D	1,876		1,817	226	9.12

[a]Difference in net revenue from option 1.
[b]Future series of end-of-period payments that will exactly recover a present capital sum with a real interest rate of 4 percent.

Table 6. — Costs and revenues by protection option treatment for the simulated harvest of a 68-acre mixed hardwood tract at rotation age of 120 years by logging technology.

Protection option	Volume removed	Logging technology	Logging cost	Revenue		Protection cost[a]	Capital recovery cost
				Gross	Net		
	(ft^3/acre)		($/acre)				($/acre/yr)[b]
1	4,873	A	2,844	5,233	2,389	--	--
		B	2,407		2,826	--	--
		C	2,223		3,010	--	--
		D	2,183		3,050	--	--
2	3,798	A	2,217	4,079	1,862	527	21.27
		B	1,876		2,203	623	25.15
		C	1,733		2,346	664	26.80
		D	1,698		2,381	669	27.00
3	4,336	A	2,531	4,656	2,125	264	10.66
		B	2,142		2,514	312	12.59
		C	1,978		2,678	332	13.40
		D	1,939		2,717	333	13.44

[a]Difference in net revenue from option 1.
[b]Future series of end-of-period payments that will exactly recover a present capital sum with a real interest rate of 4 percent.

tection options 2 and 3. These annual capital recovery costs by protection option range from $6.18/acre/year to $18.12/acre/year for the yellow-poplar stand (**Table 5**) and range from $10.66/acre/year to $27.00/acre/year for the mixed hardwood stand (**Table 6**) at a real interest rate of 4 percent. Although the annual capital recovery costs are uniformly equal, there is a possibility of changing annual accrued benefits over time. Attempting to model changing annual accrued benefits over time is beyond the scope of this paper. Another way to think of these capital recovery costs is that tangible monetary benefits would have to accrue yearly per acre by protection option to fully recover the upfront cost of implementing the respective protection/harvesting technology/stand option combination. Yet another way to look at these capital recovery costs is that these are the costs/losses that a landowner could/should use for tax accounting purposes. An alternative way to interpret these costs is that this is the monetary benefit value required to protect water quality on a yearly basis. Regardless of how these capital costs are interpreted, these results demonstrate that harvesting revenue forgone to protect SMZs can represent sizeable annual opportunity costs to the landowner against which future benefits to society must be weighed.

Considerations for managers

For the landowners, protection costs increase and net revenues decrease when BMP guidelines call for more SMZ protection. Protection costs are affected by the species mix of the stands, the level of protection desired, and the relative cost of the logging technology used. Generally, higher value species mixes result in higher net returns to the landowner but also higher per-acre protection costs. Increasing levels of protection that require that no wood or that very little wood be removed will increase protection costs and result in lower net returns to the landowner. As the cost of logging technology increases, the net return to the landowner decreases and the protection costs decrease, due largely to the fact that more expensive logging methods consume most of the stand's gross monetary value as part of their operating cost.

Landowners may gain additional financial benefits by scheduling future entries into the SMZs. Additionally, landowners may elect to remove high value trees selectively from within the SMZ at initial harvest, followed by one or two future entries to remove additional trees. Landowners may wish to consider alternative buffer strip widths. Landowners also may wish to use these SMZs for purposes of structural retention, thus allowing the SMZs to provide multiple benefits.

This research considers only the value of the timber left in SMZs as the opportunity cost. In this study, we did not address the physical/ecological impacts of the simulated treatments. Clearly, leaving SMZs provides an array of other benefits to society. Future benefits will accrue not only to water quality but to wildlife, fisheries, aesthetics, and biodiversity, which are beyond the scope of this paper.

We evaluated four logging technologies, actual data from two stands, and three protection options. Our results suggest that the costs to the landowners and the benefits that must accrue over time to offset these costs can be substantial.

Ultimately, the landowners and managers must determine the appropriate balance point between protection level and capital recovery costs. The level of required riparian protection will vary between ownerships and even within different landscapes on a single ownership. Managers should take into consideration state and local laws and BMPs, certification requirements, and their long-term management strategies for maintaining and protecting fisheries and wildlife. To provide the maximum protection, landowners should use the highest level of protection possible and the logging technology/wood utilization mix that will meet harvesting and protection goals.

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