A METHOD FOR QUANTIFYING AND COMPARING THE COSTS AND BENEFITS OF ALTERNATIVE RIPARIAN ZONE BUFFER WIDTHS

Chris B. LeDoux and Ethel Wilkerson[1]

Abstract.—We developed a method that can be used to quantify the opportunity costs and ecological benefits of implementing alternative streamside management zones/buffer zone widths. The opportunity costs are computed based on the net value of the timber left behind in the buffer zone, the stump-to-mill logging costs for the logging technology that would have been used to harvest the timber, the prevailing pond values of logs delivered to the sawmills or processing plants, and the time value of money. By conducting a comprehensive review of the published scientific literature, we quantified the ecological benefits for select riparian functions based on their ability to protect against post-harvest changes. The riparian functions considered in this study were recruitment and supply of coarse woody debris, shade and temperature maintenance, sediment filtering, protection and maintenance of aquatic communities, and the protection and maintenance of habitat for riparian associated bird communities. The results can be compared using graphical displays and the principles of benefit/cost analysis. The method can be used by loggers, managers, and decision- and policy-makers to understand the costs and benefits of implementing alternative buffer zone widths to protect riparian functions.

INTRODUCTION

Riparian areas protect water quality and aquatic communities by reducing the amount of sediment entering the stream channel (Castelle and Johnson 2000), shading the stream channel from solar radiation (Brown and Krygier 1967), supplying organic material for food (Allan 1995), contributing woody material that increases the hydraulic and structural complexity of the stream channel (Hilderbrand and others 1997), and providing habitat for aquatic and terrestrial organisms (Bisson and others 1987). From an ecological perspective, riparian areas are among the most productive wildlife habitat on the continent (Kentucky Dept. of Fish and Wildlife Resour. 1990). Removal of riparian vegetation during forestry operations has been shown to increase the sediment load in the stream (Davies and Nelson 1994), increase water temperature (Brown and Krygier 1967), and change the food supply and/or habitat conditions(Hawkins and others 1982, Hanowski and others 2002), all of which alters the aquatic and riparian communities. Streams, wetlands, and riparian areas are among our most ecologically valuable natural areas. Leaving buffer strips adjacent to waterways can effectively reduce the water quality concerns associated with timber harvesting, agricultural production (e.g., Maisonneuve and Rioux 2001, Allan 2004, Schultz and others 2004, Schulte and others 2006), and lakeshore development (Kramer and others 2006).

The protection of riparian areas is a top priority for most state and federal conservation agencies (Blinn and others 2001). Protection of riparian areas is achieved by establishing streamside management zones (SMZs) adjacent to waterways and by adopting guidelines for locating haul roads, skid trails, log landings, and stream crossings (best management practices or BMPs). Recommendations for SMZs and BMPs vary

[1]Industrial Engineer (CBL), Northern Research Station, USDA Forest Service, 180 Canfield Street, Morgantown, WV 26505; and Headwaters Stream Project Manager (EW), Manomet Center for Conservation Sciences, 14 Maine Street, Brunswick, ME 04011. CBL is corresponding author: to contact, call (304)285-1572 or email at cledoux@fs.fed.us.

among states (Huyler and LeDoux 1995, Shaffer and others 1998, Vasievich and Edgar 1998, Blinn and Kilgore 2001, Williams and others 2004). An Internet website (Timbersource.com/bmp/html) allows easy access to BMPs and SMZ management information on a state-by-state basis. For example, the recommended BMP for most SMZs include no harvesting activities in 15 to 45 m buffer strips adjacent to the waterway and/or allowances for up to 50-percent removal of the basal area/volume of standing trees leaving an evenly distributed/spaced stand to protect the stream and wetland (LeDoux and others 1990, Phillips and others 2000). Recommendations also vary among National Forests; for example, the Mark Twain uses riparian management zones (RMZs) and watershed protection zones (WPZs). The WPZ extends 30.48 meters (horizontal distance) on either side of the channel. Some activities are prohibited in the WPZ, such as log landings, road and skid trail construction, and the construction of wildlife ponds. Timber harvesting is allowed, but trees cannot be cut within 7.62 meters of the stream channel unless necessary to move the area towards the desired condition, or to facilitate designated crossings (Personal Communication, Charly Studyvin). By contrast, the Green Mountain and Finger Lakes National Forests use 7.62-m equipment-free zones on either side of the channel. Although logging equipment is prohibited in these strips, trees may be cut in them but must be winched out (Personal communication, Christopher Casey).

In addition to providing habitat for a wide range of game and nongame wildlife species, and providing a host of ecological services, riparian areas are some of the best sites for producing high-quality wood products. The unharvested timber left in SMZs can represent a substantial opportunity cost (Shaffer and Aust 1993, Kilgore and Blinn 2003, LeDoux 2006). The opportunity costs are influenced by the species mix in the stand, the logging technology used, the level of riparian protection desired (Peters and LeDoux 1984, LeDoux 2006), the stream network to be protected (Ice and others 2006), and the proportion of isolated SMZ units within a watershed (Olsen and others 1987, University of Washington 2003).

OBJECTIVES

Simultaneous economic and environmental assessments have been reported, addressing the consequences of alternative fuel management strategies (Mason and others 2003) and the layout and administration of fuel removal projects (Hauck and others 2005). Companion papers address the opportunity costs/capital recovery cost of managing for old growth forest conditions (LeDoux 2004), of alternative patch retention treatments (LeDoux and Whitman 2006), and of implementing streamside management guidelines in Eastern hardwoods (LeDoux 2006, Li and others 2006). In this paper, our objective was to document a method that can be used to quantify and compare the opportunity costs and ecological benefits of implementing alternative streamside management zones/buffer zone widths. This is the first attempt at modeling opportunity costs and ecological benefits for riparian areas in forested regions. Land managers are more likely to implement buffer zones if they understand the costs and benefits of doing so.

METHODS

Stand Data

The best data to use for this method are data on stands that are representative of the riparian area to be protected. Ideally, individual tree or cruise lists will be developed for the stands in question. The next step is to determine the economic rotation length that would apply to these riparian stands. A robust method for determining the optimal economic rotation is to use one of many growth and yield models to project growth of the stand to its optimal economic rotation. This approach yeilds the present net worth (PNW) for the optimal rotation, which is a necessary component for this method.

Logging System

The next step is to determine the type of logging technology that could be used to harvest the timber in these stands. The portion of the stands in the riparian zone to be protected will likely not be harvested, but the method requires the logging cost information to determine the net value of the timber in the SMZ. Once the logging technology is defined, then we can estimate the logging costs involved. Traditionally, time study data are used to compute logging costs. A more robust, user-friendly approach is to use stump-to-mill logging cost estimation software (LeDoux 1985).

Pond Values

The delivered prices for sawlogs and pulpwood can be obtained from forest product bulletins posted on the internet by individual companies or by universities. Alternatively, more accurate information on log prices can be obtained by contacting the wood-consuming industry located within a 30.48-m radius of the riparian area to be protected and requesting their price sheets. Most sawmills or timber procurers are more than willing to provide contemporary log and pulpwood price information upon request. The log and pulpwood price information along with the stand data is used to compute the gross dollar value of the timber to be left in the SMZ. The logging costs are then subtracted from the gross value to arrive at the net value of the timber left in the protection of the SMZ. The opportunity and capital recovery costs are then computed for each protection option. Pond values represent the cost side of the equation in this method, capturing the value lost by leaving timber standing in the riparian corridor.

Riparian Functions

The ecological functions and values of riparian zones are numerous and range from stabilizing near-stream soil (Castelle and Johnson 2000) to providing travel corridors for large terrestrial mammals (Klapproth and Johnson 2000). Riparian zones also have important social and culture value and can be important areas for recreation and community interaction (e.g., Cole and Marion 1988, Globster and Westphal 1998, Ryan and Walker 2004, Colby and Smith-Incer 2005). Quantifying the range of physical and biological functions and values that occur within riparian areas would be a daunting task. For this method, the focus should be on the processes and biota that are easily measurable and strictly dependent on and/or unique to riparian zones. In an application of this method (LeDoux and Wilkerson 2006), we limited the various functions of the modeled riparian forests to the following five categories: 1) coarse woody debris supply; 2) shade/temperature maintenance; 3) sediment filtering; 4) maintenance of aquatic communities (macroinvertebrates and periphyton); and 5) maintenance of riparian bird habitat (riparian associated passerines).

A literature review would be conducted to identify studies examining the riparian function of interest. Studies with SMZ widths similar to those in the planned project but that do not correspond exactly to the above ecological categories should be placed in the most logical category, while studies with large discrepancies in SMZ width or those using experimental design should be excluded from the review. Research results on the ecological assessment of SMZs may not exist in adequate quantities from a single region of the United States. To complete the analysis, one must focus on literature from the appropriate region of the country, but as data are limited it is desirable to include studies from other regions. The evaluation of SMZ protection options is limited to the published scientific results in the contemporary literature.

Table 1.—SMZ protection scores for different SMZ widths for protecting against post-harvest changes in riparian functions for 2nd to 4th order streams (from LeDoux and Wilkerson 2006)

	Width				
Riparian Function	No SMZ	15 m	30 m	45 m	References
Coarse woody debris	0[a]	1	2	3	Murphy and Koski 1989, Harmon and others 1986, McDade and others 1990, Robinson and Beschta 1990, Van Sickle 2000, May and Gresswell 2003.
Shade/ temperature maintenance	0	2	3	3	Burton and Likens 1973, Moring 1975, Brown and Krygier 1967, Rishel and others 1982, Lynch and others 1984, Lynch and others 1985, Noel and others 1986, Beschta and others 1987, Budd and others 1987, Caldwell and others 1991, Kochenderfer and Edwards 1991, Davies and Nelson 1994, Jackson and others 2001, Kiffney and others 2003, Wilkerson and others 2006
Sediment filtering	0	2	2	3	Karr and Schlosser 1977, Moring 1982, Lynch and others 1985, Davies and Nelson 1994, Jackson and others 2001
Aquatic communities (macroin-vertebrates and periphyton)	0	2	3	3	Newbold and others 1980, Noel and others 1986, Davies and Nelson 1994, Hetrick and others 1998, Kiffney and others 2003, Wilkerson and others, in reviewb
Riparian bird communities (riparian-associated passerines)	0	2	3	3	Triquet and others 1990, Whitaker and Montevecchi 1999, Pearson and Manuwal 2001
Total Score	0	9	13	15	
Percent SMZ effectiveness	0%	60%	87%	100%	

[a]Scoring: 0) Does not protect riparian function; 1) Results in moderate post-harvest changes in riparian function; 2) Results in small post-harvest changes in riparian function; 3) Completely protects against measurable changes in riparian function

Ranking/Scoring System

For each SMZ width the next step is to assess the capacity of the SMZ to protect against post-harvest changes for each of the categories of riparian function based on the following criterion:

- (score =0) the SMZ does not protect the component, resulting in large post-harvest changes
- (score =1) SMZ results in moderate post-harvest changes
- (score =2) SMZ results in small post-harvest changes
- (score =3) SMZ protects against major changes in the component

Scores are determined by comparing the magnitude of expected changes with and without the SMZ of that width. The statistical significance of post-harvest changes found in the studies reviewed gives a good indication of protection. Based upon this scoring method, each SMZ width is given a numerical score (0-3) for each of the five categories of riparian function. An overall score for each SMZ width is calculated by summing the score of each category of riparian function (Table 1). The overall scores have a minimum value of 0 and a maximum value of 15. To calculate the SMZ protection score, the overall score is then converted into a percentage with 0 percent representing no protection of riparian functions (value of 0) and

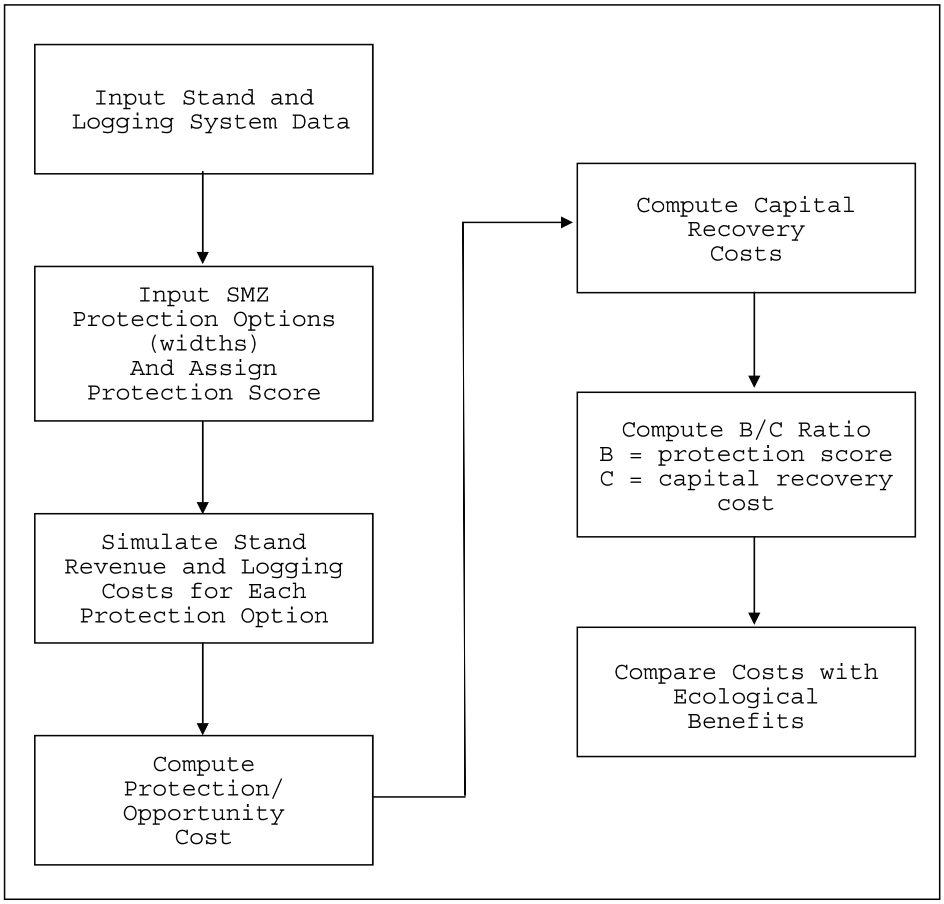

Figure 1.—Design flow diagram.

100 percent representing complete protection against measurable changes in riparian functions, creating conditions similar to undisturbed riparian areas (value of 15).

SMZ Protection Options

The stands are then modeled for computer analysis considering any assumptions necessary. SMZ protection options that could be evaluated include:
no protection

- unharvested 15-m SMZ on both sides of the stream
- unharvested 30-m SMZ on both sides of the stream
- unharvested 45-m SMZ on both sides of the stream
- a partial harvest of alternative SMZ widths on both sides of the stream with alternative percentages of the timber volume removed from the SMZ (Li and others 2006).

Although most RMZ guidelines call for removing some volume (Blinn and Kilgore 2004), users can evaluate the opportunity costs and ecological benefits for more restrictive treatments, such as not allowing any wood to be removed from within the SMZ.

Sample Application

The general procedure is shown in the flow diagram in Figure 1. In order to illustrate how this method works, we borrow data and results from LeDoux and Wilkerson 2006 and from LeDoux and Wilkerson

2007. In the example we considered two stands, four logging technologies, five riparian functions, and four SMZ protection options. In this example we use the published scientific data that are currently available. We interpolate estimates between known discrete data points for the five riparian functions and SMZ protection options. For example, Figure 2 assumes that the relationship between capital recovery cost and SMZ protection score is linear. We fit curves to the four data points from Table 3. We then compute the slopes between the data points for comparison. We realize that the available data are not complete or in the most desirable format for the type of integration we are conducting in this research. We make these assumptions and interpolate between known discrete data points in order to complete the research. As more refined data become available, they will be incorporated into the analysis. In some cases we simply do not have data available. Thus we interpolate or simulate values between known data points. Although this approach is not as robust as using observed values, it does help understand the opportunity cost and ecological tradeoffs involved in using alternative buffer zone widths. Table 1 shows the protection scores and percent SMZ effectiveness for five riparian functions and four SMZ protection options. Table 2 shows the logging system configurations used in the example.

For evaluation, decisionmaking, and policy analysis, the costs and benefits of implementing alternative buffer zone widths can be compared using graphic displays (Figs. 2 and 3), benefit/cost ratios (Table 3), or the change in SMZ protection scores versus capital recovery costs (Fig. 2) between simulated buffer widths. For example, Figure 3a and 3b show that gross and net revenue by stand and logging technology decrease as wider buffer zones are implemented. Gross and net revenues also decrease as more expensive logging technology is used (logging technology A versus logging technologies C and D). The curves in Figure 2 show that although the capital recovery costs increase in a linear fashion, the SMZ protection score levels off in a nonlinear fashion, suggesting that the protection score decreases as wider buffer zones are implemented. The benefit/cost ratios shown in Table 3 suggest that as wider buffer zones are used, the ratio of ecological benefit to the cost differential required to obtain that benefit decreases with stand tree species composition, logging technology, and SMZ protection score. Figure 2 also shows change with respect to SMZ protection score and capital recovery cost between simulated buffer zone width points. For example, the slope between buffer zone width of zero and 15 m is 5.89, suggesting that the ecological benefit is responding aggressively as buffer zone widths go from no buffer zone (width=0) to buffer zones that are 15 m wide. The slope between 15-m and 30-m widths is 2.65, implying that the ecological benefit of going from 15- to 30-m widths is decreasing compared to going from 0 to 15-m widths. The slope between 30- and 45-m widths is 1.28, much smaller than the previous two slopes. Going from 30- to 45-m widths appears to provide marginal benefits in comparison to 15- and 30-m widths.

CONSIDERATIONS FOR MANAGERS

There is no question that land managers and owners need to protect water quality and riparian area functions when considering forest operations adjacent to or within such areas by using buffer zones. However, it is clear that leaving trees of value within these buffer zones can represent a substantial financial loss in the short and long term to the landowners. A desirable outcome would be to strike a balance where riparian functions and areas are protected and monetary losses are minimized. The method documented in this paper could be used to arrive at these balance points or to understand the tradeoffs involved in implementing alternative buffer zone widths. Using these methods will not solve all the problems and challenges of selecting the correct buffer zone widths, but it can provide information that integrates the short- and long-term costs and ecological benefits of the alternatives, information that can help managers

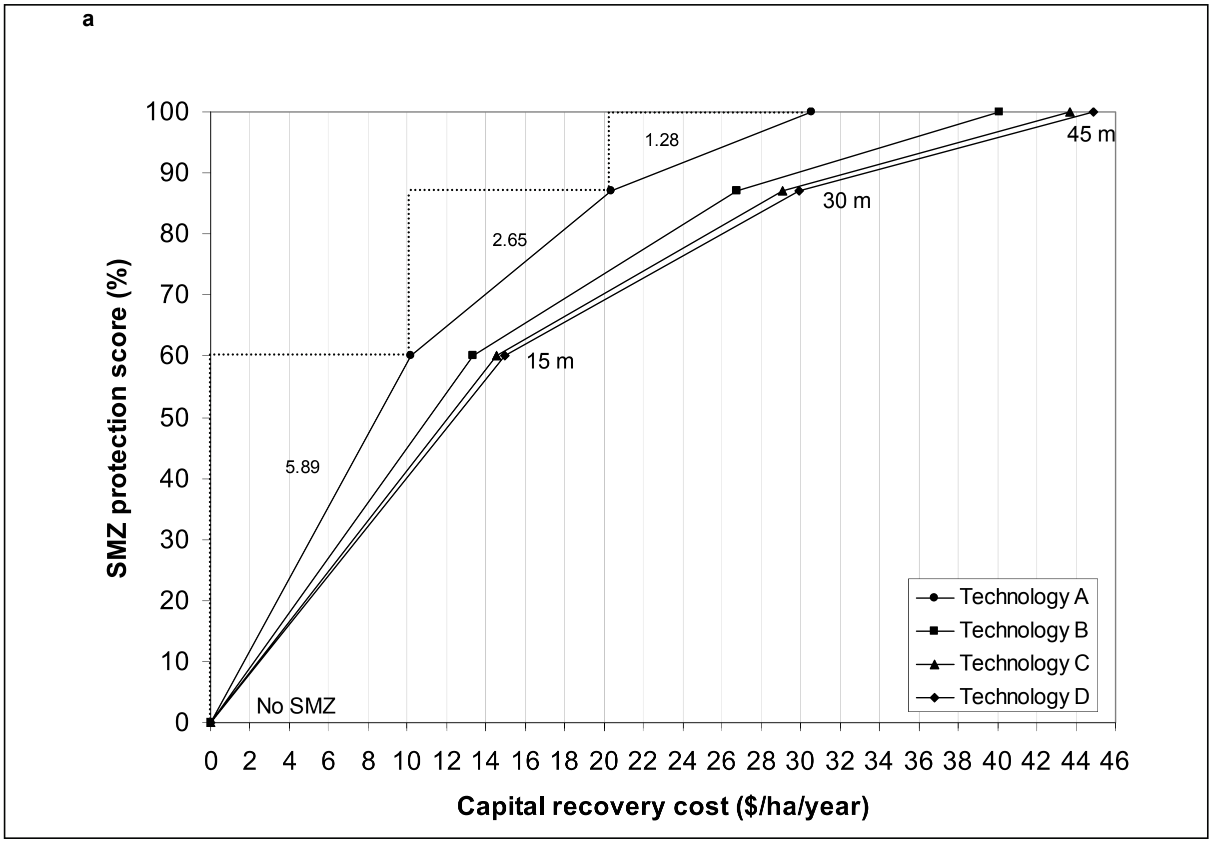

Figure 2.—SMZ protection scores compared with capital recovery costs for the (a) yellow-poplar stand under the four harvesting technologies. Symbols and lines represent different logging systems. SMZ protection scores are labeled on corresponding SMZ width (See Table 2 for description of technologies used) (from LeDoux and Wilkerson 2007).

Table 2.—Logging system configurations and costs used to simulate the harvest of the 27.5-ha tracts (from LeDoux and Wilkerson 2006)

		Cost/unit ($/m^3)	
Logging technology	Description	Yellow-poplar stand	Mixed hardwood stand
A	Chainsaw felling with Ecologger I cable yarder	20.83	20.47
B	Timbco 445 Cut-to-length harvester with Valmet forwarder	17.65	17.30
C	Chainsaw felling with John Deere 640 cable skidder	16.24	16.24
D	Timbco 425 feller buncher with Valmet forwarder	15.88	15.88

make better decisions. An additional topic to consider is landowners' acceptance of different land management practices on their land, and in riparian buffer zones specifically. Landowners' attitudes and views on management practices will influence what they are willing to implement on their land regardless of some of the economic implications (Schrader 1995, Kline and others 2000, Shindler and others 2002).

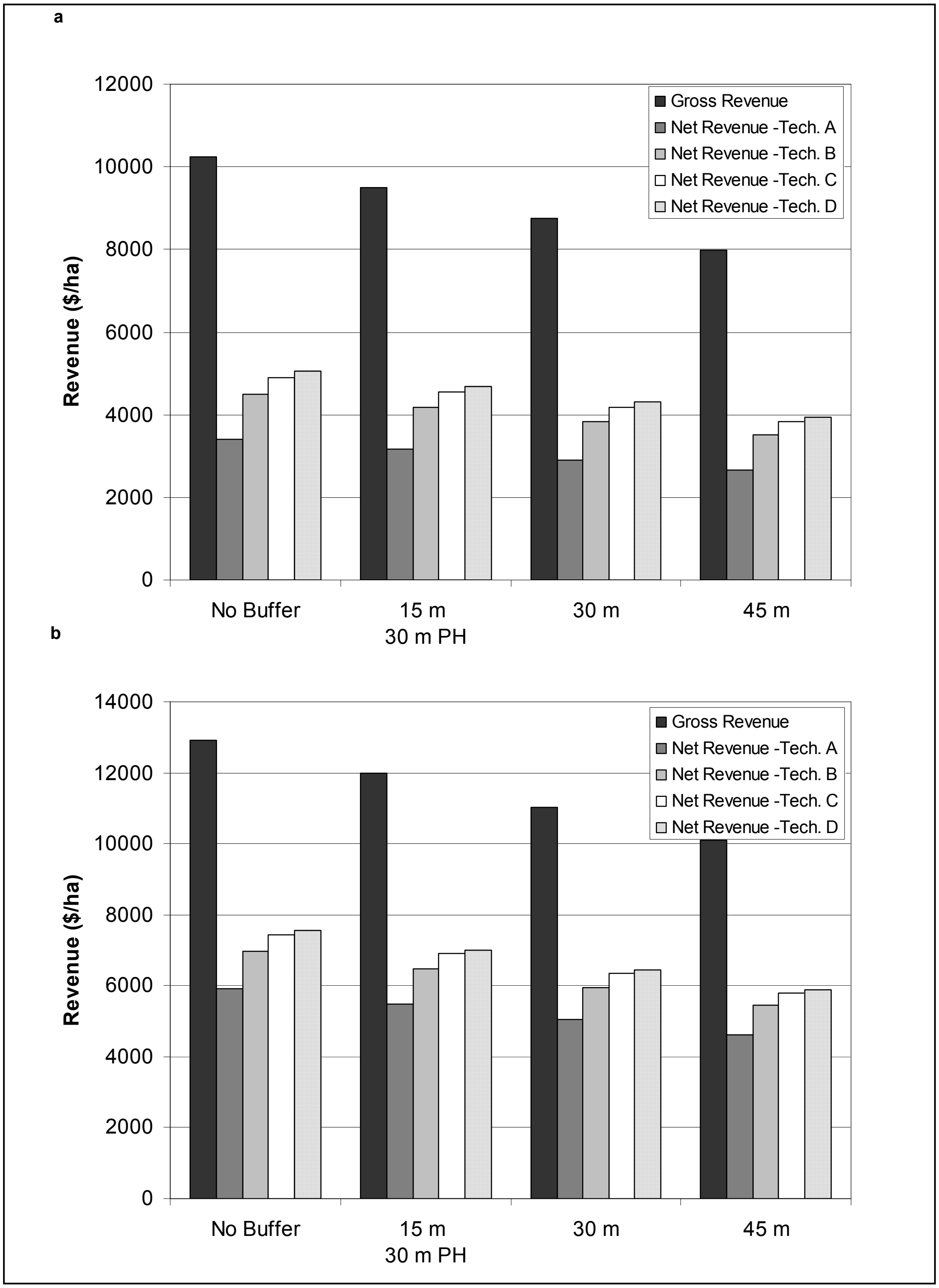

Figure 3.—Gross and net revenues for different levels of SMZ protection for (a) yellow-poplar and (b) mixed hardwood stands under the four harvesting technologies (PH=partial harvest, see Table 2 for description of technologies used) (from LeDoux and Wilkerson 2006).

Table 3.—SMZ protection scores, capital recovery costs, and benefit/cost (B/C) ratio by logging technology and stand type (from LeDoux and Wilkerson 2007)

	Yellow-poplar		Mixed Hardwood	
SMZ Protection Score	Capital Recovery Cost	B/C Ratio	Capital Recovery Cost	B/C Ratio
- - - %- - -	- -$/ha/yr- -		- -$/ha/yr- -	
		Technology A		
0	0.00	0.00	0.00	0.00
60	10.18	5.89	17.44	3.44
87	20.36	4.27	34.88	2.49
100	30.54	3.27	52.32	1.91
		Technology B		
0	0.00	0.00	0.00	0.00
60	13.37	4.49	20.66	2.90
87	26.74	3.25	41.32	2.11
100	40.11	2.49	61.98	1.61
		Technology C		
0	0.00	0.00	0.00	0.00
60	14.55	4.12	22.04	2.72
87	29.10	2.99	44.08	1.97
100	43.65	2.29	66.12	1.51
		Technology D		
0	0.00	0.00	0.00	0.00
60	14.95	4.01	22.34	2.69
87	29.90	2.91	44.68	1.95
100	44.85	2.23	67.02	1.49

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