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Residual Timber Values within Piedmont Streamside Management Zones of Different Widths and Harvest Levels

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Forested streamside management zones (SMZs) provide numerous societal benefits including protection of water quality and enhancement of in-stream and riparian habitats. However, values of residual timber in SMZs are often ignored, yet maintenance of unnecessarily wide SMZs can potentially reduce merchantable timber. Therefore, forestland owners, managers, and logging contractors are interested in determining minimum SMZ widths and stocking levels that can effectively maintain water quality while minimizing residual SMZ stand values. A larger SMZ efficacy study evaluated the efficacy of 7.6-m SMZs with no thinning, 15.2-m SMZs with no thinning, 15.2-m SMZs with thinning, and 30.2-m SMZs without thinning within 16 operational clearcuts. All SMZs widths provided effective sediment control (Lakel et al. 2010). The substudy presented here evaluated residual values in the SMZs of the larger study. Analyses examined immediate values associated with foregoing removal of SMZ timber and provide insight into future SMZ management issues. Across 16 harvested tracts, SMZs accounted for approximately 12% of the total harvest area with an average SMZ residual timber value of $1,064.78/ha. This study supports the financial benefits of partial harvests within the SMZs that remove higher value trees as typically recommended or permitted by best management practice guidelines. However, partial harvests may promote less valuable shade-tolerant species. Results also indicated that almost one-half of the SMZs had notable wind and/or ice damage within 2 years of installation. Financial analysis including opportunities for a tax credit indicate that longer term management of SMZs may be financially feasible if valuable products continue to be thinned from these stands along with rotational harvesting of the adjacent upland stands. Overall, results indicate that society and landowner short-term goals for typical southern Piedmont sites can generally be achieved by leaving 15.2-m SMZs and thinning the stands where practical.

Keywords: best management practices, riparian forests, streamside management zone costs

Forested streamside management zones (SMZs) are riparian areas within managed forests that are often maintained primarily for the protection of water quality and secondarily for wildlife benefits (Broadmeadow and Nisbet 2004, Lee et al. 2004). Water quality benefits associated with SMZs include sediment retention (Lowrance et al. 1986, White et al. 2007), nutrient retention and cycling (Daniels and Gilliam 1996, Secoges et al. 2013), reduction of thermal pollution (Beschta 1997), and increased stream channel stability (Fraser et al. 2012). Riparian zones may benefit wildlife by maintaining older habitats, forested corridors (Wigley and Roberts 1994), inputs of coarse and particulate woody debris to streams (De Steven and Lowrance 2011), and diversity of habitats within stream channels (Castelle et al. 1994, Blinn and Kilgore 2001). It is widely accepted that SMZs positively affect water quality in and around headwater streams where forestland management activities often occur (Aust and Blinn 2004, Ice 2004, Anderson and Lockaby 2011a); however, relatively few studies have examined the efficacy and efficiency of various SMZ widths (Richardson et al. 2012) or considered the financial implications of SMZ maintenance for forest landowners (Cubbage 2004, Hickey and Doran 2004).

Recent reviews of research for forestry best management practices (BMPs) across the southeastern United States generally conclude that SMZs are the single most effective BMP for protection of water quality (Aust and Blinn 2004, Ice 2004, Anderson and Lockaby 2011b). Studies have also indicated that practices such as roads, skid trails, and firelines, which compromise the integrity of the SMZ, can lead to decreased water quality (Keim and Schoenholtz 1999, Aust et al. 2011, Secoges et al. 2013, Wear et al. 2013). Keim and

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This article uses metric units; the applicable conversion factors are: centimeters (cm): 1 cm = 0.39 in.; meters (m): 1 m = 3.3 ft; square meters (m^2): 1 m^2 = 10.8 ft2; hectares (ha): 1 ha = 2.47 ac; kilometers (km): 1 km = 0.6 mi.

Schoenholtz (1999) evaluated different harvest disturbance levels within SMZs and found elevated levels of total suspended sediment in streams having SMZs with unrestricted traffic in the SMZ. Conversely, Aust et al. (2012) found that harvesting within riparian areas increased herbaceous vegetation and enhanced sediment trapping. Lakel et al. (2010) evaluated the effects of four different widths of SMZs ranging from 7.6 to 30.4 m and included an evaluation of thinning for the recommended SMZ width of 15.2 m. This study concluded that all SMZ widths provided effective sediment control (86–97% efficiencies). Subsequently, Secoges et al. (2013) conducted a follow-up study on the same SMZs to evaluate nitrogen retention by SMZs when adjacent plantations were fertilized. This study concluded that the 15.2-m SMZ without thinning and the 30.4-m SMZ without thinning were the more effective SMZs. Vaidya et al. (2008) evaluated the water quality effects of SMZs of 20 m, 20 m with select cut, and 30 m with select cut. Their analyses indicated that the 30-m select cut SMZ was most effective for protection of water quality and that partial harvests decreased water quality for SMZs of 20 m width. Clinton (2011) evaluated total suspended solids on harvest sites having no SMZs, 10-m SMZs, and 30-m SMZs and found that 10-m-wide SMZs adequately protected streams from total suspended sediment, stream nutrients, and temperature. Sanders and McBroom (2013) compared the effects of partial harvests in a 15-m-wide SMZ versus no SMZ and found that the SMZ with partial harvest provided a 10 times improvement in water quality.

Rivenbark and Jackson (2004) examined the causes of SMZ failures where surface water flow with suspended sediments penetrated the SMZ and entered the stream channel on 30 SMZs below harvested and site prepared sites. The majority of SMZ failures and increased sediment loads in streams were caused by existing gullies and swales or inadequate water control on roads and skid trails. This research identified one SMZ failure for approximately every 20 harvested acres. The authors suggested that SMZ widths of 30.2 m could be overwhelmed by these circumstances. Ward and Jackson (2004) examined the sediment trapping within swales leading to SMZs and concluded that the SMZs trapped 71–99% of the sediment and that SMZs were a critical BMP for protection of water quality. Fraser et al. (2012) compared the sediment trapping of 6-m-wide SMZs versus 12- to 21-m-wide SMZs on the same watersheds over a 34-year period. Although the original 6-m SMZs were found to be insufficient, the 12- to 21-m SMZs provided adequate water quality protection. The researchers also pointed out the importance of better water control on roads and improved stream crossings compared with the original 6-m SMZs.

The research indicates that some levels of disturbances within SMZs are acceptable and also indicates that disturbances can cause problems when the activities concentrate water movement to the streams or compromise the integrity of the litter layer. In terms of water quality, results for partially harvested SMZs are uneven, but several studies have indicated that partial harvests offer significant landowner incentives for maintaining SMZs. Forestry BMP guidelines vary across the eastern United States with regard to riparian management and SMZ specifications (Blinn and Kilgore 2001, Lee et al. 2004). Typically, SMZ specifications provide recommendations for the levels of partial harvests that are recommended within the SMZs to allow landowners to harvest a portion of the merchantable timber of the SMZs (Blinn and Kilgore 2001). Hickey and Doran (2004) emphasized the importance of recommending SMZ widths that will actually be implemented by landowners in states having voluntary BMPs.

The costs of leaving timber along streams can be substantial for landowners, loggers, and timber buyers (Shaffer et al. 1998, Kluender et al. 2000, Cubbage 2004, Lakel et al. 2006) because a significant amount of acreage and timber volume may be withheld from commercial management. Research has shown that partial harvests within SMZs can be acceptable from a water quality standpoint (Kiem and Schoenholtz 1999, Sheridan et al. 1999, Carroll et al. 2004, Lakel et al. 2010), and partial harvests allow landowners to recapture some portion of the SMZ value, thereby making the practice of leaving SMZs more attractive to landowners (Cubbage 2004, Hickey and Doran 2004, LeDoux 2006). LeDoux (2006) estimated the opportunity costs for landowners leaving SMZs to be between $378/ha to $1,652/ha. Cost varied by logging technology species composition and product class. Lickwar et al. (1992) estimated the costs of SMZs and concluded that that SMZ costs were potentially minor costs, but this study assumed that a majority of the timber within SMZs would be removed by partial harvests. Cubbage (2004) reviewed the costs of SMZ across the South and concluded that SMZ costs were minimal so long as partial harvest allowed removal of the majority of valuable timber. Cubbage also cautioned that such removals were allowed based on the assumption that minimal soil disturbances would occur and that SMZ disturbances would become increasingly more difficult as mechanized felling and grapple skidding continue to replace chainsaw felling and cable skidders.

In addition to the need to minimize traffic disturbances within SMZs, partial harvests within SMZs may present some silvicultural challenges. The partial harvests favor regeneration of shade-intolerant to intermediate shade-tolerant species (Wigley and Roberts 1994), which may have lower commercial values. Furthermore, SMZs may have additional losses due to wind (Fredericksen et al. 1993) and ice damage (Bragg et al. 2003) because the relatively exposed SMZ stands can be affected by inclement conditions.

Overall, the literature supports the importance of SMZs and the financial advantages for partial harvests within these zones to minimize SMZ costs to landowners. The overall goals of this study were to examine the potential short-term residual values associated with leaving different widths and harvest levels of SMZs and to evaluate the longer term consequences of using partial harvests within the SMZs.

Methods

Site Descriptions

The study watersheds are located in and around Buckingham County in central Virginia (37°32′57″ N latitude and 78°43′28″ W longitude) (Figure 1). This area is the western part of the Piedmont Plateau directly east of the Blue Ridge Mountains and is within the James River and Chesapeake Bay Watersheds (177 km west) (Figure 1). The James River flows west to east through the central Piedmont approximately 16 km to the north of the study area. The typical elevation of the surrounding area ranges from 150 to 365 m above mean sea level. January maximum and minimum temperatures average 8.3 and −2.8° C, respectively. July maximum and minimum average temperatures are 30.3 and 18.0° C, respectively (US Department of Agriculture [USDA] Natural Resources Conservation Service 2004).

Soils are typically highly eroded, often shallow ultisols with argillic horizons overlain by shallow Ap horizons. As a result of past

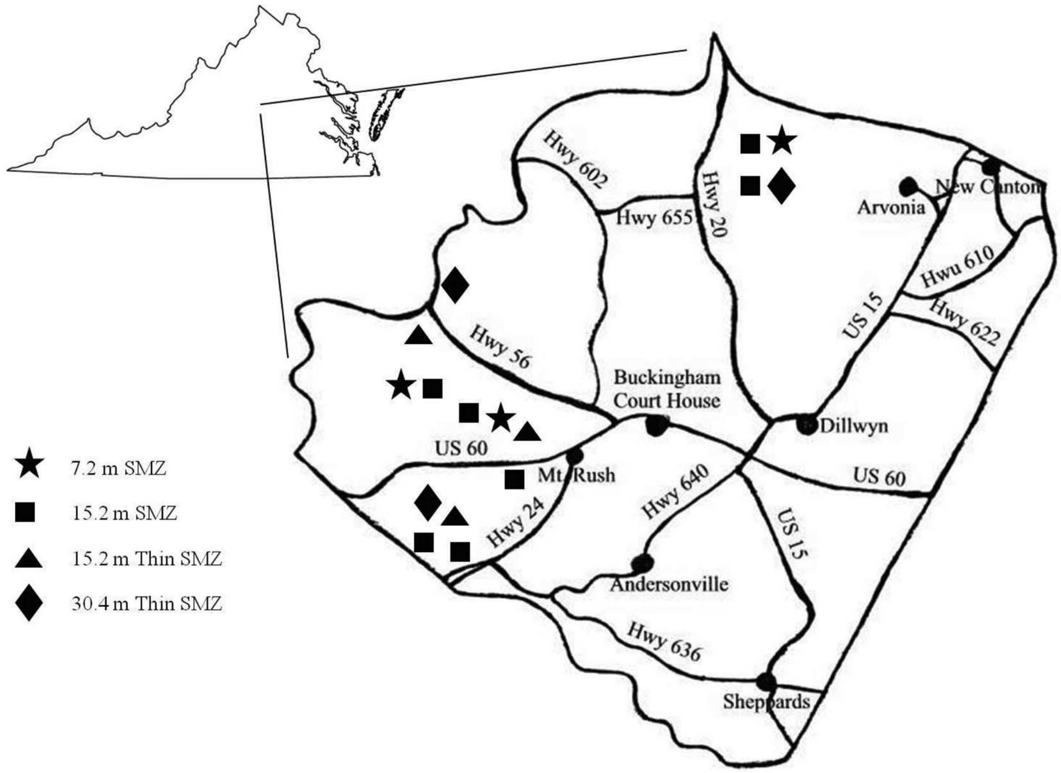

Figure 1. Map of the SMZ study sites in Buckingham County Virginia.

agricultural practices and associated soil erosion, very little organic matter remains in the Ap horizon, and alluvial E horizons are generally minor or absent. Soil textures are generally clay to clay loam with significant coarse fragments (USDA Natural Resources Conservation Service 2004). Common upland soil series include Spears Mountain silt loam (fine, mixed, semiactive, mesic, Typic Hapludults), Fairystone channery loam (clayey-skeletal, parasesquic, mesic, Typic Hapludults), and Bugley channery silt loam (loamy-skeletal, mixed, semiactive, mesic Lithic Dystrudepts). Common riparian soils include Hatboro loam (fine-loamy, mixed, active, nonacid, mesic Fluvaquentic Endoaquepts) and Delanco gravelly loam (fine-skeletal, mixed, semiactive, mesic Aquic Hapludults).

Past land use in this area was dominated by intensive and erosive agricultural practices from the mid-1700s to the late-1800s. Most of the southern Piedmont's farmland was highly degraded due to agricultural erosion and consequently abandoned (Van Lear et al. 2004). After agricultural abandonment, the old-fields were typically dominated by old-field Virginia pine stands followed by succession to natural pine and upland hardwood forests dominated by various oak species (*Quercus* spp.), red maple (*Acer rubrum),* hickories (*Carya* spp.), Virginia pine (*Pinus virginiana*), and shortleaf pine (*Pinus echinata*). Riparian areas were dominated by red maple, river birch (*Betula nigra*), sycamore (*Platanus occidentalis*), elms (*Ulmus* spp.), alder (*Alnus rugosa*), black willow (*Salix nigra*), and yellow poplar (*Liriodendron tulipifera*) (Gemborys 1974). Many of these second-growth forests were subsequently harvested at least once during the 1900s. During the late 1950s to early 1960, these lands were converted to loblolly pine (*Pinus taeda*) plantations. The stands harvested during the establishment of this study were typically the second plantation rotation. Additional site details are provided by Lakel (2008), Lakel et al. (2006, 2010), and Secoges et al. (2013).

Table 1. Stands, blocks, treatments, and harvest area relating to the study layout and data analysis for study SMZs in the Virginia Piedmont.

Stand	Block	SMZ treatment	Harvest area (ha)
1	1	15.2-m SMZ thin	8.1
2	1	15.2-m SMZ	5.7
3	1	30.4-m SMZ	11.7
4	1	15.2-m SMZ	6.5
5	2	15.2-m SMZ	14.6
6	2	7.6-m SMZ	7.7
7	2	15.2-m SMZ thin	12.6
8	2	30.4-m SMZ	4.1
9	3	15.2-m SMZ thin	41.7
10	3	7.6-m SMZ	72.1
11	3	15.2-m SMZ	45.3
12	3	15.2-m SMZ	70.4
13	4	7.6-m SMZ	52.6
14	4	15.2-m SMZ	20.6
15	4	30.4-m SMZ	31.2
16	4	15.2-m SMZ	23.9

SMZ Treatment Installation

In 2001, 16 first-order streams/riparian areas and associated forested watersheds on industrially managed loblolly pine plantations were selected (Easterbrook et al. 2003) (Table 1). All harvests were operational clearcuts on MeadWestvaco Corporation properties and were between 4.1 and 72.1 ha in size, with an average size of 26.8 ha, and stands were approximately 25 years old. Sideslopes were between 15 and 40% and were managed as loblolly pine plantations (Lakel et al. 2010). The 16 study watersheds were blocked according to site proximity, local geology, and watershed size (Table 1). Treatment SMZs were marked before harvests. Between fall 2003 and spring 2004, the 16 plantations were clearcut harvested using feller bunchers and rubber-tired skidders. The operational harvests were used to create four SMZ treatments, which were installed unequally across four blocks due to some operational errors and miscommunication with loggers (Figure 1). Within each of the 16 watersheds, the SMZ treatments were established on each side of the stream channel as 7.6-m SMZs with no thinning (7.6-m SMZ) ($n = 3$), 15.2-m SMZ width with no thinning (15.2-m SMZ) ($n = 7$), 15.2-m SMZ width with 30–50% basal area thinning (15.2-m SMZ thin) ($n = 3$), and 30.4-m SMZ width with no thinning (30.4-m SMZ) ($n = 3$). The 15.2-m thin treatment represents the current SMZ standard in Virginia. The 15.2-m SMZ represents another common practice in the state for which the logger simply does not harvest within the SMZ. The 7.6- and 30.4-m SMZ treatments represent 1/2 and 2 times current width recommendations, respectively. The unequal replication across the four blocks was managed by analyzing the study as an incomplete block design and using adjusted least squares means (Ott and Longnecker 2008).

Measurement of Residual Timber in SMZs

The residual timber within the SMZs was inventoried on a systematic spacing (Avery and Burkhart 1994), which entailed location of sample plots on a 60 × 60-m grid system in the office using aerial photographs of the SMZ treatments. Subsequently, ⅕0-ha fixed radius sample plots were established on the previously determined locations in the SMZs. Within each sample plot, hardwood stems ≥10 cm and pine stems ≥7.6 cm were recorded by species. For each stem, commercial product class, dbh, and merchantable height (Avery and Burkhart 1994) were determined. Stems damaged by storm effects (e.g., wind, snow, and/or ice) were recorded where the damages (bent, broken, or downed) would obviously prevent the tree from surviving or being merchantable.

Commercial product classes were defined according to regional commercial products used by local timber buyers. Pine sawtimber (PST) dbhs were ≥29.5 cm (11.6 in.) with a 15.2-cm (6 in.) minimum merchantable top diameter. Pine chip-n-saw (CNS) dbhs were between 22.9 cm (9 in.) and 29.5 cm (11.6 in.) with a 15.2-cm (6-in.) minimum merchantable top diameter. Pine pulpwood (PPW) dbhs were ≥14.2 cm (5.6 in.) with minimum merchantable top diameters of ≥7.6 cm (3 in.). Hardwood sawtimber (HST) dbhs were 29.5 cm (11.6 in.) with minimum merchantable top diameters of ≥25.4 cm (10 in.). Hardwood pulpwood (HPW) dbhs were ≥14.2 cm (5.6 in.) with minimum merchantable top diameters of ≥10.1 cm (4 in.). After determination of the quality and quantity of timber, SMZ values per tract and per ha were determined based on average market values in the Piedmont region as provided by Timber Mart-South in 2011. Net present values (NPVs) of the residual SMZs were calculated similarly to Goodnow et al. (2008), who examined the effects of ice damage on residual stand values for loblolly pine plantations in the Virginia Piedmont.

Data Analyses

Data were analyzed using a combination of Excel spreadsheets, TwoDog cruising software, and the SAS system. Analyses of variance for the SMZ treatments were conducted as an incomplete block design (Table 1) (Ott and Longnecker 2008) having at least three replications of the four treatments. The Tukey-Kramer adjusted least squares means separation test was used to determine differences among treatments (Table 3) (Steele et al. 1997). For both analysis of variance and mean separation, an α level of ≤0.10 was used.

Table 2. Area, percent harvest, and value of SMZ residual value by stand and treatment for the SMZ study in Buckingham County, Virginia.

SMZ treatment	Stand no.	SMZ area (ha)	Harvest % in SMZ	SMZ value ($/ha)	Total SMZ value ($)
7.6-m SMZ	6	0.5	6.2	1,231.69	615.85
	10	0.8	1.1	1,254.69	1,003.75
	14	2.0	9.7	2,495.34	4,990.68*
15.2-m SMZ	2	1.5	26.3	306.18	459.27
	4	1.1	16.9	135.99	149.59
	5	0.9	6.1	3,128.87	2,815.98
	11	3.4	7.5	1,598.78	5,435.85*
	14	1.9	9.2	1,308.11	2,485.41
	13	1.6	3.0	1,894.86	3,031.78
	16	1.3	5.4	2,526.98	3,285.07
15.2-m SMZ thin	1	1.0	12.3	390.98	390.98
	7	5.2	41.3	764.54	3,975.61*
	9	1.6	3.8	1,452.92	2,324.67
30.4-m SMZ	3	1.5	12.8	590.94	886.41
	8	1.8	43.9	758.80	1,365.84
	15	2.5	8.0	3,087.96	7,719.90*

*Maximum value for a particular treatment.

Results and Discussion

Residual timber values in the 16 individual SMZs ranged from as little as $135.99/ha to $3,128.87/ha with a median value of between $1,254.69/ha and $1,308.11/ha (Table 2). The area within the SMZ averaged 1.8 ha and 13.3% of the total harvest area. For larger clearcuts, the percentage within SMZs tended to decrease, whereas SMZ represented >40% of the harvest area for two stands having <13 ha in the harvest. Pine products included loblolly, Virginia, and shortleaf species, whereas hardwood products were primarily chestnut oak (*Quercus prinus*), white oak (*Quercus alba*), yellow poplar, and red maple. There were no significant differences between the SMZ treatments per ha values (Table 3) for any of the categories, and all values are reasonable for lower grade stands of mixed hardwood and pine on these eroded sites in the upper Piedmont of Virginia. These riparian stands were generally dominated by hardwood products by volume with a notable southern pine component. The commercial thinning performed for the 15.2-m

Table 3. Least squares means of SMZ residual stand values by SMZ treatment and product class.

SMZ treatment	Basal area ($m^2\ ha^{-1}$)	Stand density (trees ha^{-1})	PST	Pine CNS	HST	HPW	PPW	Value ($/ha)
			....	....	(tonnes ha^{-1})	....	....	
7.6-m SMZ	19.4a	407.3a	7.4a	3.0a	64.4a	31.5a	2.7a	1,293.78a
15.2-m SMZ	16.3a	351.5a	15.9a	25.5a	39.7a	37.5a	16.5a	1,568.94a
15.2-m thin	13.1a	287.8a	4.4a	9.0a	51.8a	5.1a	6.9a	1,210.79a
30.4-m SMZ	15.9a	335.9a	15.3a	7.9a	49.3a	47.1a	16.5a	1,476.81a

Least squares means were adjusted with the Tukey-Kramer mean separation test to account for the incomplete replication of treatments.
For each column, lowercase letters indicate statistical significance among the four treatment least squares means. In these cases, there are no differences.

SMZ thins was generally light (<50% of original basal area removed) and only the highest value trees were harvested. This type of thinning is often referred to as "selective cutting" or "high grading" according to Smith (1986) because only higher grade and value products were harvested and species and products of lesser value were left behind. The long-term effect of this type of thinning could make future management of SMZ stands very difficult because of a lack of commercially valuable products in future harvests. The contractors involved were already reluctant to thin SMZs owing to a combination of environmental concerns and lack of value in the stands. In many cases, the timber was dominated by low-value hardwoods with dense midstories and understories, which made thinning of any type impractical unless larger trees were encountered. Thinning consistency varied considerably among the thinned SMZs, leading to greater variability within thinned treatments. The stand values per unit area are relatively low for industrially managed stands due largely to a previous lack of management along streams. Few opportunities existed for wide-scale thinning in many stands, and contractors were forced to select from sporadically available timber from the thinned treatment stands. *P* values between treatments ranged from 0.80 to 0.96 using the Tukey-Kramer adjustment mean separation test.

There is great variability between stands with regard to value per ha and total stand value (Table 2). Values ranged from <$200/ha for stands dominated by smaller hardwood pulpwood to >$7,000/ha for better stands of pine and hardwood sawtimber. The stand per ha values ranged from $615.85 to $4,990.68 for the 7.6-m SMZ, from $459.27 to $3,285.07 for the 15.2-m SMZ, from $390.98 to $2,324.67 for the 15.2-m thinned SMZ, and from $886.41 to $7,719.90 for the 30.4-m SMZ. These large ranges indicate large variability among the experimental units (SMZs) regardless of the treatment applied.

Table 3 shows that there were no significant differences between the treatments even when thinning was involved. These data show that the 7.6-m SMZ with no thinning and the 15.2-m thinned SMZ had apparently lower overall values per ha (1,293.78 and 1,210.79 $/ha, respectively) than the 15.2-m unthinned and the 30.4-m unthinned SMZs (1,568.94 and 1,476.81 $/ha, respectively), but there were no differences between these values at the 0.10 level. This finding indicates that the thinned stands were not thinned heavily enough to have a significant impact on residual stand values compared with those for the unthinned treatments. Table 3 also indicates that the 7.6-m unthinned SMZs had had relatively high basal area and density values, which may indicate smaller, less valuable products closer to the streams. The lack of statistical significance is apparently due to the nonuniform nature of all the SMZ stands and the large variability of the SMZ stand timber volumes and values typically encountered as well as the low-intensity thinning that took place.

Local per unit prices were developed using a combination of the Timber Mart-South report and contact with local forestry consultants. Prices applied were $175 per million board feet (MBF) for PST, $100 per MBF for CNS, $15 per cord for PPW, $11 per cord for HPW, and $100 per MBF for mixed HST. Overall, HST quality was poor, which caused lower values. Mean values for PST are much higher in stands that were not thinned, but the differences were not significant at the $\alpha = 0.10$ level (Table 3). These residual values may indicate that loggers had a propensity to remove PST where possible and leave lower grade products behind.

Data indicate that the residual species composition is potentially suitable to justify future removals of more valuable timber when the next rotation of pine in the adjacent uplands reaches rotation age in approximately 29 years (Table 4). These removals would probably target ample supplies of oak and yellow poplar along with the remaining pine products, which will be larger and more valuable at that time. This next rotation could potentially remove >50% of the value from all stands if harvesting techniques were to specifically target SMZ timber. This type of management would remove much of the shade-intolerant species, which are currently the most valuable (oaks, poplar, and pine), over the next two rotations and would probably lead to stands dominated by the generally less commercially valuable intermediate shade-tolerant and shade-tolerant species (Smith 1986) such as red maple, American beech (*Fagus grandifolia*), and various hickory species that are shown to be abundant in these stands (Table 4). Given that markets change over time, this may not be a critical factor in future rotational harvests. Wadl (2008) evaluated the understory species within these stands and found less merchantable species such as red maple, blackgum (*Nyssa sylvatica*), pignut hickory (*Carya glabra*), and mountain laurel (*Kalmia latifolia*) within all SMZ treatments. Continuation of selective harvests and thinning within these SMZs will probably increase the dominance of intermediate shade-tolerant to shade-tolerant species over time. The relatively small areas within the SMZs and the anticipated dominance of intermediate shade-tolerant to shade-tolerant hardwoods suggest that future SMZ management will be challenging and is an area for which silvicultural options should be examined. Under current SMZ partial harvest regimes, SMZ stands will potentially have even lower market value and fewer management options. This geographic region has few merchantable shade-tolerant species; thus, silvicultural options may be more restrictive than in other regions of the country.

Another concern among landowners in Virginia with regard to SMZ maintenance, health, and value is the likelihood of these stands being damaged by storms and pests after the adjacent timber stand is harvested, and these narrow strips are exposed to wind, ice,

Table 4. Overstory species shade tolerance and average density composition of SMZs in the Buckingham County study.

Product class	Species	Shade tolerance	Stand density (stems ha^{-1})	SE
Sawtimber	Loblolly pine	Intolerant	48.8	7.36
	White oak	Intermediate	13.1	3.38
	Yellow poplar	Intolerant	11.5	4.89
	Chestnut oak	Intermediate	4.2	1.40
	Red maple	Intermediate	3.5	2.10
	Virginia pine	Intolerant	1.8	1.31
	Southern red oak	Intermediate-intolerant	1.7	1.04
	Blackgum	Intolerant	1.0	1.04
	White ash	Intolerant-intermediate	0.9	0.64
	Pignut hickory	Intermediate-Tolerant	0.5	0.41
	American beech	Very tolerant	0.4	0.39
Pulpwood	Red maple	Intermediate	57.6	7.14
	Yellow poplar	Intolerant	52.6	9.10
	Loblolly pine	Intolerant	46.2	9.31
	Chestnut oak	Intermediate	31.4	6.44
	White oak	Intermediate	26.8	5.38
	Virginia pine	Intolerant	15.2	4.74
	Southern red oak	Intermediate-intolerant	11.3	2.22
	Pignut hickory	Intermediate-tolerant	7.4	3.11
	American beech	Very tolerant	7.3	2.35
	Black cherry	Intolerant	4.8	2.27
	River birch	Intolerant	1.0	0.99
	Eastern white pine	Intermediate	0.6	0.41

Overstory species shade tolerance data are from the USDA Forest Service (1965).

Table 5. Assessment of 7 of 16 SMZs having significant timber damage due to ice and wind storms in the first 2 years after harvest in the Virginia Piedmont.

Stand	Treatment	Species damaged	Products	Value ($/ha)	Value (%)
5	15.2-m SMZ	Loblolly pine	PST, CNS, PPW	301.81	22.5
6	7.6-m SMZ	Loblolly pine	PST, CNS,PPW	328.93	30.7
7	15.2-m SMZ thinned	Loblolly pine	CNS, PPW	115.10	31.7
8	30.4-m SMZ	Loblolly pine	CNS, PPW	114.86	66.1
9	15.2-m SMZ thinned	Loblolly pine	CNS	151.65	40.4
10	7.6-m SMZ	Loblolly pine	CNS	253.67	39.4
14	15.2-m SMZ	Loblolly pine	PPW	11.11	2.8

and snow (Fredericksen et al. 1993). The upper Piedmont of Virginia is frequently affected by freezing rain and wet snow events in the winter, and significant stand damage can occur (Goodnow et al. 2008). Damage to SMZ stands was recorded and quantified during the timber inventory process (Table 5), which revealed that 7 of the 16 stands (44%) had received notable climatic damage within 2 years of SMZ establishment.

Storm damage was evenly distributed among the different SMZ treatments, and no treatment was entirely immune to damage (Table 5). Perhaps because of the somewhat random climatic incidents of ice and wind, thinned and narrow stands were not damaged any more frequently than wider SMZs, and no treatment was more damaged by weather. However, the only species that experienced storm damage was loblolly pine. It is common for loblolly pine to succumb to storm damage in this part of Virginia due largely to its inability to resist bending, breakage, and throw during periods of ice accumulation (Muntz 1947, Shepard 1975, Amateis and Burkhart 1996, Aubrey et al. 2007). It is important to note that one ice storm, which occurred in February 2007, was particularly damaging to the pine stands in this part of the county.

Seven of 16 stands had some damage, and 5 of 16 had at least $100/ha lost to damage. Some stands lost as much as 66% of the remaining value to storm damage because many of the trees lost were higher value products (CNS and PST) (Table 5). It is also important to note that 9 of 16 stands had no storm damage during the same postharvest period, but that period was only 2 years.

The 2000 Virginia General Assembly enacted the Virginia Riparian Buffer Tax Credit (§58.1-339.10 and §58.1-439.12), which offers Virginia timberland owners a tax credit for 25% of the commercial value of timber left in a riparian buffer during and after timber harvest up to $17,500.00 per harvest. This credit is available to individuals, S-corporations, partnerships, and limited liability corporations. Estates and trusts are not eligible for this tax credit. The eligible landowner must own land where timber is being harvested, the harvested portion must abut a perennial or intermittent waterway as defined by the most current US Geological Survey topographical map, and the landowner must have a stewardship plan for the property. Partial harvesting up to 50% of the timber in the buffer does not negate eligibility, but the tax credit value is based on the value left behind in the buffer. The landowner also must forgo future timber harvesting in the riparian buffer for a period of 15 years regardless of changes in landownership (M. Poirot, Virginia Department of Forestry, pers. comm., Dec. 10, 2011). Since 2000, 264 tracts were eligible for tax credits totaling $1,516,420 in tax savings with an average tax savings of $5,744.02 per application. This tax relief program gives landowners an opportunity to recover some lost revenue directly through a Virginia state income tax credit for the year of the timber harvest and can be carried over for a period of up to 5 tax years if unused during the initial tax year.

Given these tax credit opportunities for Virginia timberland owners, it may be useful to evaluate NPV estimates for the upland stands managed with a typical uneven-aged southern pine silviculture approach and also for the SMZ stands managed in an uneven-aged approach where approximately 50% of the SMZ timber value will be extracted at every rotation final harvest for the adjacent upland stand. Using standard discounting methods for a typical pine even-aged rotation in central Virginia and typical harvest volumes and values as described by local procurement and consulting foresters (Jeffrey Watts, Hancock Forest Management, pers. comm., Dec. 15, 2011), we calculated NPVs for the upland even-aged stands with average site quality. Even-aged rotation in this area typically includes burn and plant site preparation with a single thinning at about 17 years and a clearcut final harvest at about 29 years. Site preparation costs in the analysis were based on those reported by Barlow and Duboise (2011).

Our calculated NPV values for the upland even-aged stands ranged between $469.30 and $519.17/ha using an 8% discount rate and approximate site index of 60–65 ft at 25 years. It is important to reiterate that these estimates were obtained by local professional foresters with extensive experience with southern pine management in Virginia (Greg Scheerer, MeadWestvaco Corporation, pers. comm., Dec. 13, 2011). These calculated values are reasonable compared with values reported by Goodnow et al. (2008) for stands in Central Virginia that were modeled with TRULOB.

It was more difficult to calculate NPVs for SMZ stands that would probably be thinned for a variety of products every 29 years when the adjacent upland stand is being harvested. Without the benefit of an appropriate model to estimate harvest products and volumes for the SMZs through multiple rotations, we assumed that 50% of the likely total available products and volumes at rotation would be harvested again in a thinning at age 29 and discounted that value along with the estimated value of the 25% tax credit for the residual value left behind. The calculated NPV for the thinned SMZ was $278.34/ha and the NPV for the tax credit value was $69.58/ha for a total regime NPV of $347.92/ha for the uneven-aged SMZ stand with the 8% discount rate. The NPV for this scenario is considerably less than that for the even-aged scenario, and this is often to be expected (Henderson 2008) because of the much lesser value removed at rotation as well as several other complicating factors (Baker et al. 1996, Cafferata and Kemperer 2000), but the tax credit certainly makes a measurable difference when the timber is cut if it is considered additional timber income in the calculation. It is also important that any landowner must have a state tax burden to benefit from the tax credit, and the total credit can be spread across the following 5 tax years.

Given that the tax credit is available to timberland owners in Virginia and that value could be considered additional timber income from the SMZ stands, it is apparent that the cost of leaving

SMZs for water quality protection may not be unacceptable to all landowners particularly if the nontimber benefits of SMZs such as water quality and wildlife habitat are assigned a monetary or intrinsic value by the landowner. Further economic analysis of SMZs as timber-producing stands is beyond the scope of this article, but this limited analysis reveals that the current market value of timber left in an SMZ is not necessarily lost with proper management. It should also encourage landowners to consider leaving SMZs as a BMP at recommended specifications for their state even if BMPs in that state are currently voluntary.

Conclusions

For these 16 SMZs, treatments did not have a large impact on residual SMZ values on a per ha basis. Several factors probably contributed to the lack of differences. The existing SMZs tended to have small but valuable quantities of pine volume existing toward the outer edges of the SMZs, but the interior SMZs were dominated by relatively low-value hardwood. Future commercial removals from these stands are potentially economically viable as a continued thinning or high-grading scenario along with the period rotational harvesting of the surrounding upland pine stands. Under this regime, it is anticipated that an increase in shade-tolerant species such as red maple and American beech, which are already common in the understories and overstories of these stands, will occur. Such species have little current market value, yet they can maintain the general effectiveness of the SMZ for water quality protection and both are valuable wildlife species.

These findings are the opposite of those of Sharp (2003), who worked in similar SMZ treatments in the Allegheny Plateau region of West Virginia and concluded that desirable species could continue to be present within the SMZ. The major difference is that Sharp was working in northern hardwood stands having a significant sugar maple component. The desirable shade-tolerant sugar maple is far more likely to regenerate after selective harvesting and is much more valuable commercially than the shade-tolerant species in these Piedmont study sites.

It is also important to note that the landowner in this scenario voluntarily removed 24.1 ha (59.5 acres) of productive timberland across 16 managed stands from more intensive even-aged management for the protection of water quality and some added wildlife habitat and aesthetic values. This management option required that approximately $37,688 of residual timber be left across the 16 stands with uncertain opportunities to be managed for future revenues. Further financial analysis indicates that maintaining a longer term SMZ thinning policy may help landowners enjoy all the benefits of SMZ maintenance without losing future values if valuable timber can continue to be removed from the SMZs over time. The tax credit program in Virginia is just one tool to encourage proactive SMZ management in the future. Policy makers should be cognizant of potential burdens to landowners for the benefit of society and look for additional opportunities to encourage such responsible stewardship.

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