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policy

Working Woods: A Case Study of Sustainable Forest Management on Vermont Family Forests

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Families own 35% of US forestland and 67% of Vermont forestland. Sustainable management of their woodlots could provide social and economic benefits for generations. We examined sustainable forest management across four counties in Vermont by evaluating the use of silvicultural practices and best management practices on 59 recently harvested, family-owned properties with at least 25 acres of timberland. We explored relationships between management practices and Vermont's Use Value Appraisal Forestland Tax Program (UVA), one of Vermont's primary forest management policy instruments. We found positive correlations between UVA enrollment and sustainable management practices and determined that UVA may be partly responsible for the increased application of silviculture in the study area compared with that in other parts of the Northeast. Even so, UVA's limited adoption and the overall prevalence of nonsilvicultural harvesting practices demonstrate that policy alone is not achieving widespread sustainable forest management among family forest owners in Vermont.

Keywords: sustainable forest management, silviculture, best management practices, Use Value Appraisal, Current Use Program, general

Families own 35% of forestland in the United States—more than any other type of owner (Butler 2008). In Vermont, forestland owned by the public and industry is not widespread, and families control some 67% of forestland (Butler 2008). Their collective management decisions play a dominant role in shaping the forested landscape. The use of sustainable practices on family forestland could maximize the social and economic benefits for generations in the form of jobs, recreation, revenue from forest products, clean water, and many other nonmarket goods and services. Exploitative timber harvesting in the absence of management could pollute water, adversely affect recreation potential, and reduce the yield and quality of forest products, thereby diminishing the potential benefits to local communities (Berlick et al. 2002).

Sustainable forest management, which we define as the application of appropriate silvicultural techniques and best management practices (BMPs), has had mixed success in the United States. Although additional progress could be made to limit soil disturbance and stream sedimentation during forest management activities (Schuler and Briggs 2000), for example, forest operations account for only 3% of the nation's nonpoint source pollution (US Environmental Protection Agency 1991). That is some nine times less than other land uses per unit area (US Environmental Protection Agency 1991), in part because of successful adoption of BMP. On the other hand, timber harvesting on family forests rarely follows silvicultural guidelines, especially in the Northeast (Fajvan et al. 1998, Munsell et al. 2009), which threatens long-term forest productivity. The effects of nonsilvicultural practices are being felt in the marketplace too, as sawmills are reporting decreased log quality and lower per log volumes (Anderson and Germain 2007).

Working toward sustainable management on family forests can be difficult, in part because landowners' motivations and management goals vary considerably (Butler 2008), making it hard for public and private natural resource managers to communicate effectively with them (Butler et al. 2007). As a result, much effort has been put into understanding, categorizing, and reaching this category of landowners (Butler et al. 2007). Still more research is needed to empirically link landowners' decisions and other factors to management outcomes and impacts on the landscape. For example, do policy

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Figure 1. Map of the four-county study area in northern Vermont.

instruments intended to promote sustainable forest management lead to changes on the ground?

In this study, we gain a detailed understanding of harvest outcomes on family forestlands by focusing on a substate, four-county region in northern Vermont. In addition to quantifying the extent to which sustainable forest management is practiced in the area, this approach allows us to examine relationships between sustainable forest management and enrollment in Vermont's current use program, the Use Value Appraisal Forestland Tax Program (UVA), which is partly intended to promote the use of BMPs and appropriate silvicultural practices on family forests.

Encouraging sustainable management is a secondary goal of UVA, which is primarily intended to limit development on working lands by relieving tax burdens (Vermont Department of Forests, Parks, and Recreation [VT FPR] 2010). The requirements of UVA are thought to promote sustainable forest management because enrolled properties (41% eligible land enrolled) must be managed according to silvicultural plans and all management activities must follow BMP guidelines (VT FPR 2010). County foresters periodically inspect enrolled properties to ensure that these conditions are met.

However, empirical evidence to support the connection between UVA and sustainable forest management is still somewhat limited. In 1990, enrolled properties were shown to have significantly less harvest-related soil erosion than unenrolled properties (Newton et al. 1990). Sendak and Dennis (2006) reported significantly higher preharvest timber volumes and stem diameters on enrolled versus unenrolled stands. The same study also reported enrolled properties growing higher quality white pine (*Pinus strobus*) timber, although this was not the case for other species. Here, we present a more detailed portrayal of UVA's relationship to sustainable forest management by comparing silviculture and BMP use on enrolled and unenrolled properties and by exploring the effects of using a forest management plan (a UVA requirement) and employing a forester to administer harvesting (not required). These last two variables shed light on decisionmaking dynamics common to current use programs that affect the use of sustainable forest management.

We quantify sustainable forest management using BMPs and silvicultural guidelines. BMPs, also called acceptable management practices in Vermont, are a set of management protocols that vary little from state to state and have been shown to protect water quality, soil structure, and site nutrients from the effects of logging (Edwards and Williard 2010). BMP use is not mandatory in Vermont per se, but if BMPs are not used in a logging operation in which sediment, petroleum products, woody debris, or other pollutants are discharged into surface waters, landowners and loggers can be held liable (VT FPR 2010). Although BMP use is important for maintaining soil and site productivity, silviculture use is necessary to sustain the production of any resources dependent on forest vegetative communities.

Methods

We evaluated sustainable forest management on family-owned properties across four counties in northern Vermont (Figure 1). A range of socioeconomic characteristics and relatively homogeneous land cover dominated by forestland characterize this study area. Chittenden County is more populous, with a partially urbanized land base and relatively little timber harvesting, Essex County is sparsely populated with high levels of timber harvesting, especially in its southern half, and Washington and Caledonia Counties have populations and wood markets that rank somewhere between those of Chittenden and Essex Counties (Anderson et al. 2011, US Department of the Interior, Census Office 2011). Median annual household incomes range from >$60,000 in Chittenden County in the west to $34,400 in Essex County in the east (US

Management and Policy Implications

As in other areas of the United States, Vermont's family forests are often managed without attention to long-term productivity. Although our study documented that approximately 40% of the sampled harvests exhibited evidence of use of acceptable silvicultural practices, this level of silviculture may not be enough to meet the state's goal of "production and use of resources to meet the needs of present generations without compromising the needs of future generations" (Vermont Department of Forests, Parks, and Recreation 2010, p. 23). Greater efforts are needed in Vermont and elsewhere to promote sustainable forest management. Vermont's Use Value Appraisal Forestland Tax Program (UVA) is strongly correlated with evidence of sustainable forest management and is probably increasing the use of sustainable practices on enrolled properties. The findings related to UVA will be useful to policymakers in Vermont and elsewhere, who must assess the efficacy and efficiency of such programs. In addition, an evaluation of a current use program's impact will help land managers assess its value for individual landowners. Ultimately, it seems that states will best achieve widespread sustainable forest management by preserving and enhancing the capacity of existing programs such as UVA, while finding additional ways to enable sustainable management on properties outside the influence of such programs.

Table 1. Total number of towns in each study area county and number of towns included in the study based on availability of GIS data.

County	Total towns	Towns studied
Chittenden	19	19
Washington	20	19
Caledonia	17	7
Essex	19	8
Total	75	53

Department of the Interior, Census Office 2011). Forests throughout the study area are a mix of northern hardwood and spruce-fir-northern hardwood formations (Thompson and Sorenson 2005).

Properties with ≥25 acres of timberland are considered manageable under UVA guidelines. A sample frame of family forest properties meeting this requirement was developed by performing a geospatial analysis of land cover data, cadastral data, and property boundaries in a geographic information system (GIS). Towns without useable GIS parcel data were omitted from the study (Table 1). For this study, we also needed confirmation from the landowner that the property had received a timber harvest in the last 5 years (2005–2010) and permission to conduct a field survey of their forest. We sent two waves of response card mailers to the owners of potentially eligible properties and asked them to respond if they met the above criteria.

Mailers were sent to 2,144 landowners. Of these, 113 landowners eligible for the study responded, along with 22 ineligible landowners. The response rate is difficult to determine because timber harvests are not tracked in the state; consequently, we do not know the percentage of the 2,144 landowners who conducted a harvest in the past 5 years. However, Butler (2008) reported that of Vermont family forest owners with ≥25 acres of land, 42% harvested wood within a 5-year period, including nonsawtimber harvests. This suggests that <900 of the mailers reached eligible landowners, depending on what portion of harvests include sawtimber, providing an estimated response rate of 13%. Because we needed landowner permission to examine harvest areas, the sample was self-selected by participants, allowing the potential for nonresponse bias. Landowners engaged in active management and comfortable with researchers collecting data on their properties were probably more likely to respond, for example, and results should be interpreted accordingly. We were, however, unable to find evidence of bias. Unpaired, unequal variance *t*-tests showed no significant differences in silviculture or BMP scores between early and late respondents, suggesting that sustainable forest management is used similarly on sampled and unsampled harvests (after Lindner et al. 2001). In addition, the same test failed to find significant differences between our sample's mean preharvest basal area and the mean basal area of all private, accessible timberland across the study area (after US Department of Agriculture [USDA] Forest Service 2010), suggesting that sampled forests were representative of the study area.

Because of time limitations, a simple random sample of 59 of the 113 responding property owners was selected, and their properties were visited between the months of May and August 2010. No owner had more than one eligible property in the sample. Each property owner was asked questions about recent harvesting to determine whether harvests were conversions to nonforest uses, whether their property was enrolled in UVA, and whether they had a forest management plan and/or had a forester administer the most recent harvest.

Researchers used a systematic grid of 1/10-acre fixed-area plots within the harvested area of each property to determine pre- and postharvest species composition, basal area, quadratic stand diameter, and postharvest percentage of acceptable growing stock. Preharvest basal area and quadratic stand diameters were calculated by converting stump diameters to dbh using species-specific equations developed for the Northeast (Westfall 2010). A minimum of 10 plots were established on each property except when harvested areas were too small, in which case as many plots were established as would fit without spacing the plot centers closer than two chains (132 ft) from one another. On sufficiently large harvested areas, as many plots were established as needed so that, with 95% confidence, the estimate of the mean basal area was within 20% of the true mean. Grid dimensions varied from property to property and were chosen to ensure that the sample represented the whole of each harvested area. Starting plots were located at random distances and directions from predetermined starting points.

Plot data were used to classify the application of silviculture on each property using a decision tree modified from Fajvan et al. (1998) (Figure 2). Modifications were made to account for study area forest cover types. Stocking levels and designation of high-value species were determined for the harvested area of each property based on cover type and available stocking guides. In northern hardwood and mixed-wood cover types, hard maple (*Acer saccharum*), black cherry (*Prunus serotina*), red oak (*Quercus rubra*), and yellow birch (*Betula alleghaniensis*) were considered desirable because of their timber value in Vermont (Center for Northern Woodlands Education 2009). Red maple (*Acer rubrum*) also ranks as one of the more valuable species but was not included because its stumpage price was much lower relative to those of other high-value species (Center for Northern Woodlands Education 2009). In addition to the hardwood species, white pine was considered desirable in the mixed-wood cover type because of its high growth potential and commercial value (Howard 1985). In black spruce/cedar and hemlock/spruce/fir cover types, hemlock (*Tsuga canadensis*), tamarack (*Larix laricina*), and spruce species (*Picea mariana* and *Picea rubens*) were considered desirable. Hardwoods were not considered desirable in these cover types because the aim of management of spruce/fir forests is often to promote continued dominance of softwood species (Frank and Bjorkbom 1973). Balsam fir (*Abies balsamea*) was not considered desirable because it is shorter lived than other softwoods and often removed at financial maturity during thinning operations, before stands are ready for regeneration (Frank and Bjorkbom 1973). White pine and red pine (*Pinus resinosa*) were considered desirable in those respective cover types.

Stocking was determined based on cover type using the best available relative density equations or graphic stocking guides (Philbrook et al. 1973, Benzie 1977, Leak et al. 1986, Stout 1990, Solomon and Zhang 2002). Preharvest stands at or above the B-line (the minimum recommended stocking for full site utilization) were considered fully or overstocked before the harvest (Frank and Bjorkbom 1973, Philbrook et al. 1973, Benzie 1977, Leak et al. 1986, Marquis et al. 1992). Otherwise, they were considered understocked. Higher preharvest relative densities are often recommended for thinning to ensure that enough timber is present for operable harvests, but as long as preharvest stands meet the above guidelines, stocking is considered sufficient to make full use of the growing space. Postharvest stocking at or

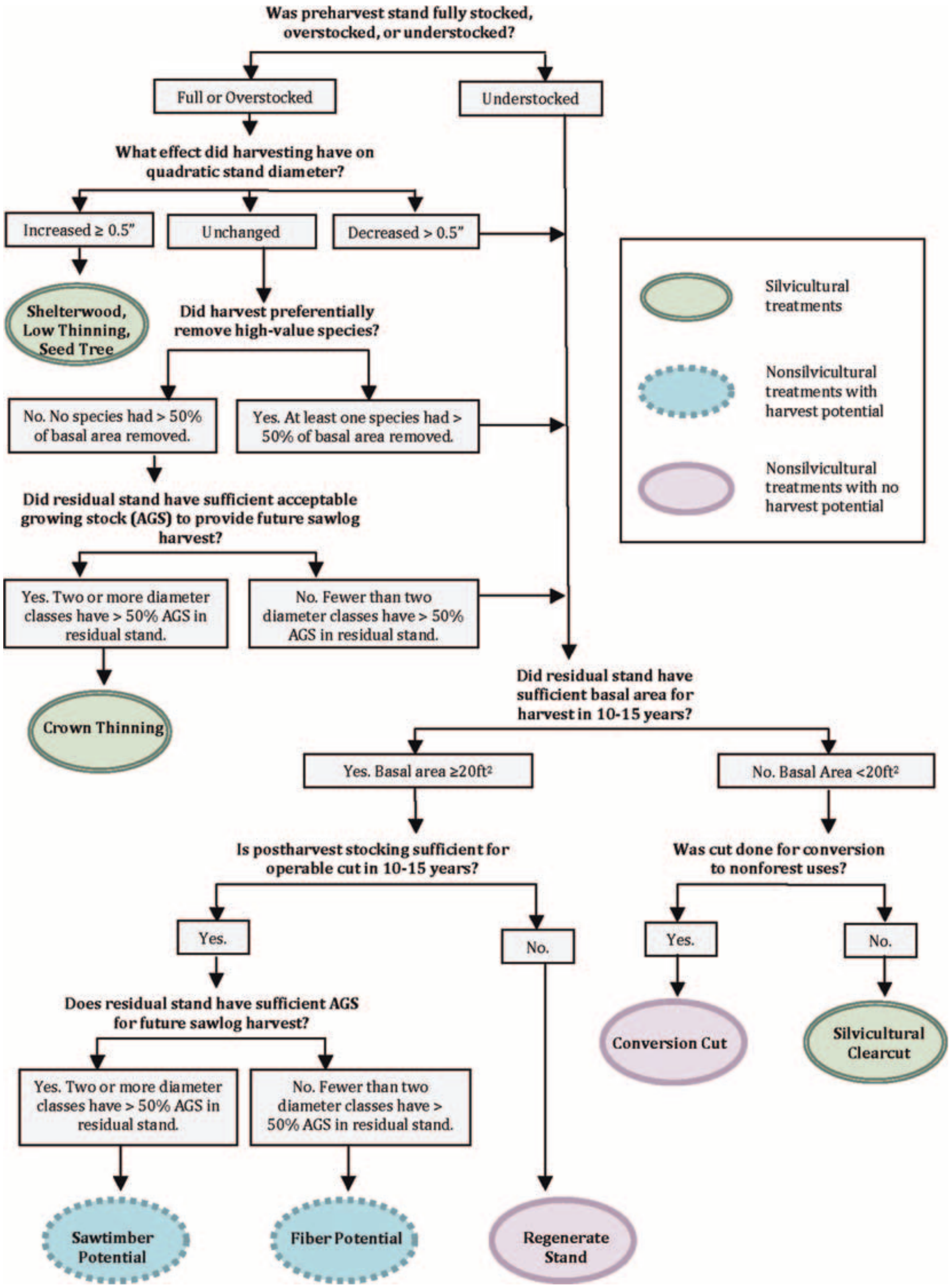

Figure 2. Decision chart for classifying harvests on single-cohort stands (modified from Fajvan et al. 1998). Stocking levels and desirable species are determined based on forest type.

above the C-line, which is the lower limit of stocking necessary to reach the B-line in 10 years on an average site, was considered sufficient for operable cuts in 10–15 years (Frank and Bjorkbom 1973, Philbrook et al. 1973, Benzie 1977, Marquis et al. 1992, Fajvan et al. 1998).

Each harvest was assigned a silviculture score using methodology modified from Munsell et al. (2008) (Figure 3). Stocking and the percentage of high-value species were determined for each property based on the forest cover type. The recent harvest activity was rated based on a silvicultural score on a continuous scale ranging from 0 to 1, where 0 indicates no evidence of the application of silvicultural practices and 1 indicates strong evidence of a silvicultural harvest. We used silvicultural classifications for descriptive purposes and numeric scores for hypothesis testing related to independent variables. Both silvicultural assessment methods were designed for use in forests dominated by a single age class. Harvest areas in uneven-aged and two-aged stands were not analyzed.

In addition to silvicultural classification

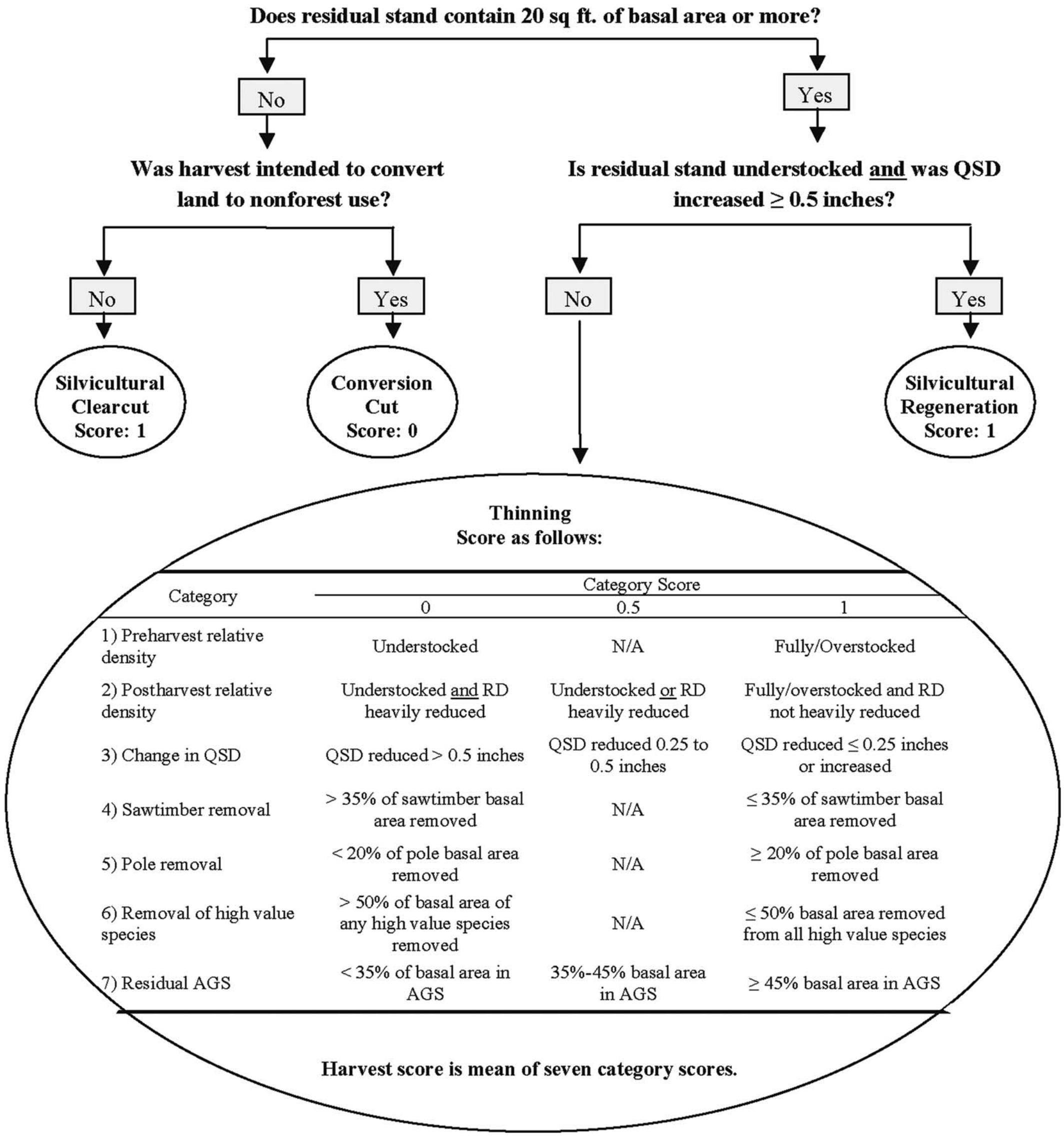

Figure 3. System for scoring harvests in single-cohort stands based on implementation of appropriate silvicultural techniques. Scores of 0 indicate nonsilvicultural harvests and scores of 1 indicate carefully implemented silvicultural harvests (modified from Munsell et al. 2008). Stocking levels and desirable species are determined based on forest type. N/A, not applicable; RD, relative density; QSD, quadratic stand diameter; AGS, acceptable growing stock.

and scoring, we evaluated BMP use by point sampling sections of skid trails where they crossed plot sampling gridlines and by assessing all log landings and forest roads on each harvest. Data collection and BMP evaluation were done using methodology developed by Munsell et al. (2006) and VanBrakle et al. (2013). The methodology assigns separate scores for each of six BMP categories on a given harvest area, but because of a lack of replication in one category (forest road stream crossings), we are reporting results from the following five categories: (1) log landings, (2) skid trails, (3) skid trail stream crossings, (4) forest roads, and (5) water diversion devices. For hypothesis testing, only categories 1, 2, and 5 were used because small sample sizes in categories 3 and 4 yielded comparisons with low power that were not meaningful. BMP scores are continuous and are on a scale of 0 to 3 (Snedecor and Cochran 1980), where 0 indicates that BMPs related to each category were not applied, 1 indicates that BMPs were applied with major deviations, 2 indicates that BMPs were applied with minor deviations, and 3 indicates that BMPs were correctly applied and functional at the time of the visit.

Unpaired, unequal variance *t*-tests were used to test for associations between each of the sustainable forest management categories (silviculture and three categories of BMP implementation) and UVA enrollment and between the four sustainable forest management categories and forester harvest administration. This statistical design was replicated from previous studies with similarly collected and distributed data (Munsell et al. 2006, VanBrakle et al. 2013). Management plan use was almost perfectly congruent with UVA enrollment, so it was not analyzed independently. All hypothesis tests were considered statistically significant with a type I error probability of $\alpha = 0.05$.

Results

Sampled harvest areas occurred in multiple forest cover types (Figure 4). One harvest, representing 1.7% of the sampled harvest area, had an uneven-aged stand

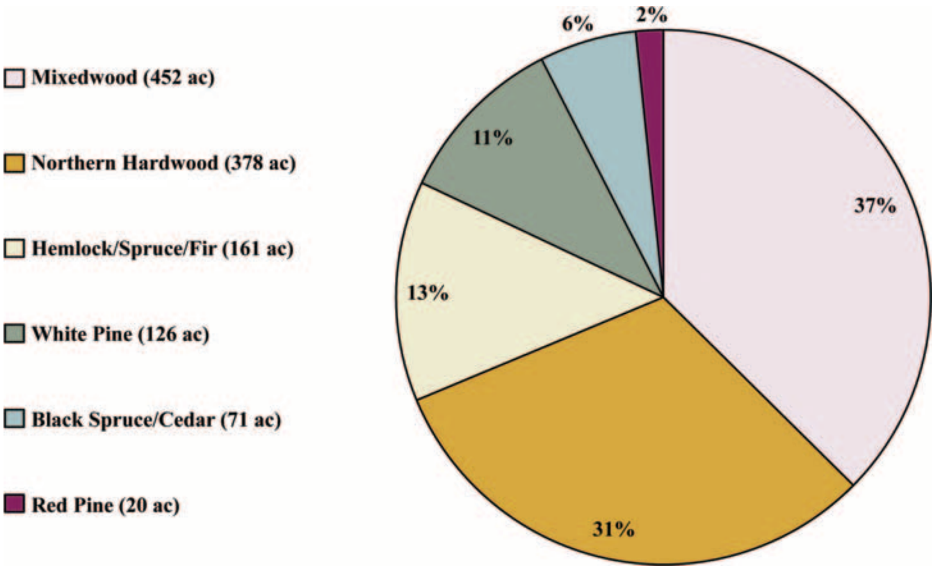

Figure 4. Forest cover types of sample harvests by acreage.

Table 2. Pre- and postharvest values for sample harvest area characteristics (n = 59).

Harvest area characteristic	Preharvest	Postharvest
Total basal area ($ft^2\ ac^{-1}$)	152 (9)	99 (10)
Poletimber basal area ($ft^2\ ac^{-1}$)	42 (5)	32 (4)
Sawtimber basal area ($ft^2\ ac^{-1}$)	101 (11)	59 (10)
Quadratic stand diameter (in.)	8.2 (0.5)	7.2 (0.6)
Trees per acre	472 (58)	377 (58)

Values are means (95% confidence intervals).

Table 3. BMP scores by category for harvests in the study area.

BMP category	n	Mean score	95% confidence interval for mean score
Landings	57	2.65	2.53–2.77
Skid trails	57	2.24	2.11–2.36
Skid trail stream crossings	14	1.70	1.32–2.07
Forest roads	15	2.56	2.23–2.88
Water diversion devices	57	1.04	0.84–1.23

Scores are on a scale from 0 to 3, with 0 indicating no implementation of BMPs, 1 indicating implementation with major deviations, 2 indicating implementation with minor deviations, and 3 indicating proper implementation of BMPs (after Munsell et al. 2006).

structure, and another harvest, representing 1.2% of sampled harvest area, was confirmed as two-aged using qualitative observation and analysis of diameter distributions. The remaining sampled harvest areas were dominated by a single age class. With 95% confidence, the mean harvested property in the study area was 110 (±28) acres, whereas the mean harvest area was 21 (±5) acres. Pre- and postharvest stand characteristics are reported in Table 2.

UVA enrollment on harvested properties was high across the study area. Seventy-four percent of the sampled harvest area is managed under UVA, even though only 41% of eligible forestland in the state is enrolled (Vermont Department of Taxes 2013). It is possible that enrollment is not spatially homogeneous across the state, with relatively higher enrollments in the study area, but this is difficult to evaluate without detailed statewide UVA data, which were not available to us. However, it is also possible that owners of enrolled parcels were more likely to be included in the sample frame because of a higher incidence of timber harvesting on enrolled properties. UVA requires recurring timber harvesting on all enrolled forestland parcels, at intervals determined for each property using silvicultural guidelines, whereas only 54% of all Vermont family forest owners have ever engaged in harvesting activities (Butler 2008). Data from 1988 show that only 16% of eligible timberland in Vermont was enrolled in UVA that year (Sendak and Huyler 1994), even though 32% of harvesting occurred on enrolled land (Newton et al. 1990). In our sample, all 43 enrolled properties had forest management plans, as is required, whereas only 1 of the 16 unenrolled properties had a plan. In addition, a forester administered the harvest on only 1 of the unenrolled properties, whereas 27 of the 43 enrolled properties had forester administration of the harvest.

Estimates of mean BMP scores for harvests in the study area are presented in Table 3. Landing, skid trail, and forest road scores show that on the average Vermont harvest operation, BMPs in those categories were applied with only minor deviations. BMPs related to skid trail stream crossings, on the other hand, were generally applied with minor to major deviations, and those related to water diversion devices were applied with major deviations. UVA enrolled properties scored significantly higher in the application of skid trail and water diversion device-related BMPs than unenrolled properties (Table 4). In the case of landing-related BMPs, enrolled and unenrolled properties both scored consistently high. Harvest administration by a forester was not significantly associated with BMP implementation for any category (Table 5).

In terms of vegetation management, some 40% of the sampled area was managed according to silvicultural guidelines as determined by the decision tree methodology (Figures 5 and 6). We classified 42% of the harvest area as nonsilvicultural with some potential for future timber harvesting within the next 15 years. The remaining 18% was classified as nonsilvicultural with no near-term harvest potential. Nearly one in every six of the operations that were classified as silvicultural (14% of all harvested area) was a regeneration harvest: we observed two silvicultural clearcuts, one shelterwood cut, and one seed-tree cut. Silviculture scores were significantly higher on UVA-enrolled properties than on unenrolled properties (Table 4), although forester harvest administration was not significantly associated with silviculture implementation (Table 5).

Discussion

The use of sustainable forest management in northern Vermont is comparable in many ways to that in other areas of the Northeast. In the New York City Water-

Table 4. Comparison of sustainable forest management scores between UVA-enrolled and unenrolled properties.

Category	UVA enrolled	n	Mean score	P value
Silviculture	Yes	41	0.68	0.01
	No	16	0.50	
Landing BMPs	Yes	41	2.72	0.12
	No	16	2.48	
Skid trail BMPs	Yes	42	2.33	0.01
	No	15	1.97	
Water diversion device BMPs	Yes	42	1.18	0.01
	No	15	0.65	

Unpaired, unequal variance t-tests test the null hypotheses that scores on enrolled properties do not differ from those on unenrolled properties.

Table 5. Comparison of sustainable forest management scores between harvests administered by and not administered by a forester.

Category	Forester administered	n	Mean score	P value
Silviculture	Yes	28	0.65	0.60
	No	29	0.62	
Landing BMPs	Yes	28	2.72	0.27
	No	29	2.59	
Skid trail BMPs	Yes	27	2.27	0.61
	No	30	2.20	
Water diversion device BMPs	Yes	27	0.99	0.63
	No	30	1.08	

Unpaired, unequal variance t-tests test the null hypotheses that scores on harvests with a forester do not differ from those on harvests without a forester.

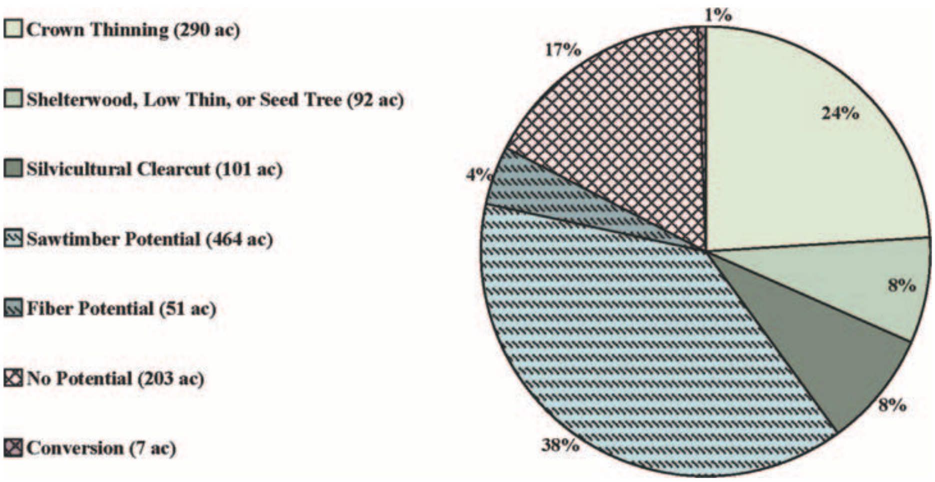

Figure 5. Silvicultural classifications of sample harvests by area. Classifications were made using a decision tree (Figure 2; modified from Fajvan et al. 1998) for single-cohort stands (n = 57). Unhatched green classifications are silvicultural, dashed blue classifications are nonsilvicultural with harvest potential, and cross-hatched pink classifications are nonsilvicultural without harvest potential.

shed, VanBrakle et al. (2013) reported that landing and skid trail BMPs were implemented with minor deviations, whereas stream crossing recommendations were implemented with moderate deviations, and water diversion device recommendations were rarely implemented at all. A statewide BMP assessment in New York (Schuler and Briggs 2000) found that application of water diversion device-related BMPs was consistently lower than that of other BMPs and identified stream crossings as the primary source of negative water quality impacts on logging jobs. Lack of BMP implementation around stream crossings and water diversion devices also stands out in our results, suggesting that efforts to improve BMP use in the region will be most effective by focusing on these deficiencies. The use of BMPs has improved significantly over the past three decades in states with and without mandates. Outreach and education efforts by government and nongovernment organizations have generally been successful in this regard. Our study supports the conclusion that the most pressing issue now is the effectiveness of BMP implementation (Loehle et al. 2014).

Northern Vermont also displays a predominance of nonsilvicultural vegetation management on family forests, although not to the degree reported in studies from other states. In our study area, some 40% of sawtimber harvests complied with silvicultural guides as we applied them. This result compares with about 20% in West Virginia (Fajvan et al. 1998) and 2% in the New York City Watershed (Munsell et al. 2009). We classified 11% of harvests in the study area as exploitative to the point of precluding further harvesting in the current rotation, compared with 31% in West Virginia (Fajvan et al. 1998) and 42% in the New York City Watershed (Munsell et al. 2009). Furthermore, we were encouraged to find regeneration harvests in our sample, whereas such harvests have rarely been observed in other northeast studies (Munsell et al. 2009). Their use in Vermont is an indication that landowners and managers are concerned with future stand conditions and with the long-term potential to produce another forest crop.

It is important to recall that our sample was self-selected by landowners, and there is a potential for bias in the results. If owners of sustainably managed forests participated in the study disproportionally, for example, the results could depict greater implementation of silvicultural practices and BMPs than actually exists. Nonetheless, all studies requiring landowner permission (including Fajvan et al. 1998 and Munsell et al. 2009) suffer from this potential bias, and there is no reason to believe it would be higher in Vermont than elsewhere. Although absolute levels of silviculture and BMP implementation should be interpreted cautiously, comparisons between studies of this type or between groups of properties within this study are legitimate.

Results pertaining to UVA are a cause for optimism regarding use of sustainable forest management. UVA-enrolled properties scored significantly higher in skid trail and water diversion device BMPs and in sil-

Figure 6. Four year old crown thinning in a white pine stand, as classified by the decision tree developed for this study.

viculture. Preferential enrollment in the program by conservation-minded landowners probably accounts for some of those differences, although it has not been demonstrated directly. Dennis and Sendak (1992) found a positive correlation between UVA enrollment and landowner education level, demonstrating preferential enrollment by landowners with higher levels of education, but they also reported no correlation between enrollment and landowner occupation or ownership tenure. Sendak and Dennis (1989) observed similar site quality and forest stand characteristics on enrolled and unenrolled properties, suggesting that decisions to enroll are not largely affected by forest attributes. Given these observations, it is likely that UVA is altering landowners' behavior in favor of sustainable forest management. Research in the program's early years documented its capacity to change landowners' actions by showing that because of program requirements, 40% of participants worked with a forester for the first time when enrolling and 75% began using management plans at the time of enrollment (Brighton 1988).

Nationwide, landowners tend to like preferential tax programs such as UVA more than other forest management incentive programs, but foresters providing management assistance see them as having limited success in promoting sustainable forest management (Greene et al. 2007). It is important to note that many of the current use programs with high enrollment (i.e., New Hampshire with 60%) are primarily focused on maintaining open space, with varying levels of attention to sustainable forest management. For instance, only about half of the nation's preferential tax programs require a forest management plan and not all management plan requirements are strict enough to prompt landowners to hire foresters or even follow through on silvicultural work plans (Butler et al. 2011). UVA is an example of a program with strict requirements monitored by county foresters, through site visits, which may account for its success in promoting sustainable forest management on enrolled properties. VanBrakle et al. (2013) supported this premise, reporting higher BMP implementation associated with harvests under the strict rules of the New York Forest Tax Law management plans compared with performance under the voluntary plans sponsored by the Watershed Forestry Program. In the case of New York, the strict forest tax law results in good performance but low enrollment (9%). The combination of a strict management plan and direct forester contact appears to yield the best results on the ground. In their review of the USDA Forest Service's Forest Steward Program, Butler et al. (2014) reported that direct one-on-one contact with a forester was more effective than a federally subsidized management plan without concrete requirements.

The role of the forester cannot be examined in isolation but rather as part of the "forest management triangle" that includes the logger and landowner. Based on our results, forester involvement in harvest administration alone had no effect on BMP or silviculture implementation. When working with a landowner enrolled in a current use program to promote sustainable forest management, the forester provides the critical expertise to develop a management plan. The actual implementation of silviculture and BMPs requires professional loggers who carry out the plan. Again, forester involvement only during the harvest does not appear sufficient to achieve high-quality BMP and silvicultural outcomes. Loggers well versed in BMPs and silviculture are often participants in logger certification programs, such as Vermont's Logger Education to Advance Professionalism (LEAP), which seeks to give loggers the tools to implement sustainable forest management (Egan 2012). LEAP loggers may be increasing the use of silviculture and BMPs in Vermont. However, a lower incidence of sustainable management on forests not enrolled in UVA (and therefore not subject to closer scrutiny) provides some evidence that loggers are not solely responsible for implementing sustainable practices. We maintain that the best results occur when all three sides of the forest management triangle are working together to achieve landowner objectives through a management plan.

Although UVA appears to be successfully promoting silviculture and BMPs on enrolled properties, its impact is limited by its reach. Only 41% of eligible land is enrolled in the program, although the percentage of actively managed land is higher than that because all enrolled properties are actively managed. Enrollment could possibly be increased by making program requirements less stringent, but those changes would likely decrease UVA's effectiveness in encouraging sustainable forest management. Reducing the minimum acreage for enrollment could also increase the amount of enrolled land in the state, although it would be politically difficult because it could mean reducing property tax income for the state or transferring more of the tax burden to unenrolled landowners. Concerns about UVA's financial impact cause program reform to be reconsidered in state government almost yearly; for example, a recently overturned bill would have changed the penalties for owners withdrawing from the program. Pushes for these types of changes are fueled by fears that developers are temporarily "parking" land in UVA to save taxes, without a real commitment to provide long-term resource productivity.

Other public incentive and outreach programs that support sustainable forest management appear to be limited in their reach as well. Over a recent 5-year period, only 26% of Vermont family forestland owners received advice or information about their forests and only 6% of these owners have ever participated in a state- or federal-sponsored cost share program related to forest management (Butler 2008). A majority of Vermont's family forests are outside the direct influence of public programs. It seems that voluntary policy instruments can only go so far to ensure the widespread use of sustainable forest management.

Efforts to engage landowners and affect lands outside the reach of state and federal policy might benefit from taking a local focus. Even within our study area, differences in land use, timber markets, and landowner characteristics are substantial. Landscape-scale efforts (at the town or county level, for example) are better able to account for these unique cultural and ecological attributes and might prove effective in increasing sustainable forest management if they were more widely implemented. The Northern Forest Center,[1] with offices in Maine and New Hampshire, represents one example of a Northern Forest approach with a local flavor. The Center specifically taps research projects funded by the Northern States Research Cooperative focused on the Northern Forest region (such as this study) and uses the results to reach out to landowners and other stakeholders to promote a viable forest-based economy.

Closer examination of existing local initiatives would allow researchers and policymakers to better assess their effectiveness at increasing sustainable forest management. If local efforts do show potential, state and local governments might benefit by allocating resources to supporting those endeavors. A similar mechanism is used by the state for land use planning under Vermont's Act 250, whereby the state provides planning and technical assistance to individual towns and municipalities through regional planning commissions. Under the system, towns are able to make land-use planning decisions tailored to their specific situations, while taking advantage of additional resources not included in local budgets (Sanford and Stroud 1997).

Conclusions

General trends in sustainable forest management on family forests as reported by landowners are known for much of the eastern United States, but this case study in Northern Vermont shows significant local variability in those trends. More frequent use of silvicultural practices in our study area compared with those in other areas of the eastern United States, for example, may be partly due to the influence of the state's current use tax program, which seems to be improving silviculture and BMP performance in the region. Still, like other eastern states that have been studied, Vermont does not exhibit widespread use of sustainable forest management.

Increasing sustainable forest management in the study area appears to depend on two complementary efforts. First, existing programs such as UVA will need to be maintained. Ensuring consistent program requirements is one of the best ways to increase the impact of financial incentive programs such as UVA (Greene et al. 2007) and should preserve the advances already made by such programs. Second, although efforts are commonly focused on boosting enrollment in existing programs, we believe that more effective ways of reaching forestland owners outside the lure and influence of UVA and similar programs must be developed. The majority of family forestland in the area is not enrolled, and timber harvesting in these forests generally seems to occur in the absence of management planning and forester involvement, leading to less sustainable practices. Expansion of local and county-based programs coordinated with state and federal incentives provides a logical next step to address local conditions and potentially reach a population that seems consistently resistant to enrollment in initiatives like UVA.

Endnote

1. For more information on the Northern Forest Center, see www.northernforest.org.

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