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Planning and Professional Assistance as Factors Influencing Private Forest Landowner Best Management Practice Implementation

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Abstract

Virtually all states have developed best management practices (BMPs) to mitigate potential adverse effects associated with timber harvesting. This study examined how BMP implementation on Minnesota's family forest lands varied according to whether the land had a forest management plan, the timber sale was administered by a forester, or a written timber harvesting contract was used. Analysis of field monitoring data from 174 commercial timber harvesting sites on family forest lands found that BMP implementation is only modestly influenced by a forest management plan, supervising forester, or timber harvesting contract. Supervision of a forester had the greatest influence, with six guidelines implemented differently. In contrast, differences were found for just two BMPs with a forest management plan and only one with a written timber harvesting contract. When timber sales were administered by a forester, forest management guidelines generally related to management of the land-water interface were implemented to a higher standard, with significant increases observed for avoidance of infrastructure in filter strips, use of water diversion and erosion control structures, avoiding unnecessary wetland and waterbody crossings, and slash management. Higher timber utilization efficiency (within leave tree guidelines) was also found when a professional forester supervised the timber sale.

Study Implications: We examine how BMP implementation on family forest lands varies with three types of supervisory and planning assistance: a forest management plan for the property, sale administration by a professional forester, and a written timber harvesting contract. Field monitoring data from 174 commercial timber harvests on family forest lands indicate that BMP implementation is only modestly influenced by any single form of assistance. Supervision by a forester had the greatest influence, increasing use of four guidelines related to management of the land-water interface. Results may help to inform best practices for landowner assistance and planning.

Keywords: non-industrial private forest (NIPF), family forest owner, timber harvest, water quality, best management practices

A variety of tools have been developed to promote stewardship on private forests in the United States. Among the most prominent are best management practices (BMPs). Developed by states and tailored to their specific forest resource conditions, silvicultural treatments, and timber harvesting practices, BMPs are a suite of actions to help mitigate negative externalities that can be associated with timber harvesting and forest management activities. This

includes soil erosion, water quality degradation, loss of wildlife habitat, or change in visual quality. Nearly all states have developed BMPs (sometimes referred to as forest management guidelines [FMGs]), which vary among states with respect to the resources they address (e.g., water quality, wildlife habitat), types of harvesting practices promoted (e.g., management of riparian areas), and the way they are implemented (voluntary, regulatory) (Blinn and Kilgore, 2001, Cristan et al., 2016). Most timber harvest BMPs were developed as state-led water quality control strategies to reduce nonpoint source pollution under the Clean Water Act, with additional priorities addressed as a byproduct of the focus on reducing runoff, erosion, and loss of riparian areas (Warrington et al. 2017).

Landowners often learn about their state's timber harvesting BMPs through the development of a forest management (stewardship) plan, a conversation with a forester, or in preparing a written contract when formalizing the details of a commercial timber sale on their property. In other instances, the training and expertise of a logger may be the sole means through which BMPs are implemented. Because most loggers in Minnesota are members of the Minnesota Logger Education Program (MLEP) with formal training in FMGs, this probably affects how FMGs are understood and implemented for sites considered in this study. Nonetheless, we were interested in evaluating whether a landowner's exposure and engagement with management planning and assistance are associated with how a state's BMPs are applied. Using Minnesota as a case study, our objective was to assess whether the types of practices called for in their BMPs are applied differently by three cohorts of family forest owners: (1) those with and without a forest management plan, (2) those with and without forester supervision of their timber harvest, and (3) those with and without a written timber harvesting contract. The research will add to the scant literature on how various forms of private forest planning and professional forestry assistance influence BMP implementation.

Background

Research has sought to identify factors that may influence BMP implementation during timber harvests on family forest land, but the findings have been sparse and inconsistent. This inconsistency is likely due in part to substantial variation in BMP recommendations among states and jurisdictions, variability in how BMP implementation is monitored and reported, and large variation among harvest sites in the applicability of BMPs designed to address specific environmental risk factors. Nevertheless, several factors have been investigated, including the influence of management plans (e.g., VanBrakle et al., 2013), forest landowner assistance program participation (e.g., Maker et al., 2014), BMP language incorporated into timber sale contracts and plans (e.g., Carraway et al., 2000), and connections and interactions with forestry professionals (e.g., Knoot and Rickenbach, 2011).

Forest management plans (also referred to as stewardship plans) have long been promoted by consulting and public agency foresters as a means of encouraging family forest owners to intentionally plan for the long-term management and stewardship of their land (Egan et al., 2001, Kilgore et al., 2007). Forest management plans are also the cornerstone of many private forest landowner assistance programs, such as the Forest Stewardship Program (https://www.dnr.state.mn.us/foreststewardship/index.html). Much attention has been focused on encouraging and incentivizing family forest owners to obtain a forest management plan by the research and extension communities, but state and federal forestry programs also play a role. Previous research has often documented a positive association between forest management plans and forest landowner management and conservation behaviors and intentions. For example, family forest owners with a forest management plan are more likely to conduct or have the intention to conduct a commercial timber harvest than those without a plan (e.g., Esseks and Moulton 2000; Egan et al. 2001; Kilgore, et al. 2015; Silver et al. 2015). Having a management plan has also been found to be positively associated with other forest land management behaviors such as treating invasive plants (Clarke et al. 2019), wildfire risk reduction activities (Jarrett et al., 2009, Floress et al., 2019), and undertaking wildlife habitat improvement projects (Buffum et al., 2014, Kilgore et al., 2015).

Yet little empirical research has examined the relationship between the presence of a forest management plan and the extent to which a landowner's timber harvesting or forest management actions are consistent with those called for in their state's BMPs. VanBrakle et al. (2013) examined timber harvesting practices on family forest lands in the New York City watershed, finding some differences in how voluntary water quality BMPs were applied based on whether a forest management plan for the property existed. Specifically, BMP evaluation scores for properties with management plans were significantly better in two of six BMP categories: skid trails and forest roads.

Several studies have compared BMP implementation rates and success for landowners who are enrolled in various forest landowner assistance programs versus non-enrollees. These programs generally require a management or stewardship plan, so program enrollment may be a proxy for the influence of having a management plan on BMP implementation. Maker et al. (2014) found that properties enrolled in the Vermont forestland property tax program (Use Value Appraisal Forestland Tax Program), which requires owners to have a forest management plan, had higher implementation of BMPs related to skid trails and water diversion devices. Knoot and Rickenbach (2011) explored the relationship between participation in Wisconsin's state forest property tax program and BMP implementation. Their study found that enrollees in the tax program, which requires enrollees to have a management plan, were slightly more likely to implement harvesting BMPs than non-enrollees. Provencher et al. (2007), however, found that mean BMP compliance was greater on lands that were not enrolled in the Forest Stewardship Program (requires a management plan) as compared with enrolled lands.

Another factor that has been explored as a potential influence on whether or how well BMPs are implemented on family forest lands is the involvement of forestry professionals in overseeing a commercial timber harvest. As suggested by VanBrakle et al. (2013), foresters can play an important role in educating forest landowners about BMPs and serving as an intermediary with loggers around BMP implementation. Egan (1999) examined whether the involvement of a professional forester on timber harvests on family forest lands in West Virginia was associated with BMP compliance, finding that forester involvement resulted in higher BMP compliance but did not guarantee compliance. Maker et al. (2014), however, found that timber harvests administered by a forester were not found to have higher rates of BMP implementation in Vermont.

Interactions and relationships between forest landowners and other forestry professionals have also been found to influence BMP adoption. Munsell et al. (2006) found that a family forest owner's decision to implement BMPs was most influenced by their awareness of organizations promoting them, concluding that extension personnel, through their relationship-building and educational programming, influence BMP adoption among family forest owners. Knoot and Rickenbach (2011) found that forest owners who had a larger social network, particularly in terms of the number of forestry experts, as well as higher social network heterogeneity (e.g., greater diversity of forestry information sources), were more likely to implement water quality BMPs.

A third factor that can influence the use of BMPs is a written timber harvesting contract. This document is often prepared by a professional forester and can be a legally binding agreement with respect to several important aspects of the timber harvest such as its financial considerations, liability assignments, methods of timber harvest, and the use of BMPs (e.g., Coats and Miller, 1981, Szydzik and Gunter, 1993, MLEP, 2021). Forestry certification programs such as the Sustainable Forestry Initiative require the inclusion of BMP language and compliance in timber sale contracts (Sustainable Forestry Initiative, 2015). Very few studies have investigated the relationship between BMP implementation and the use of a written timber harvesting contract. In a study by Egan (1999), no statistically significant relationship was found between BMP compliance scores and inclusion of language about BMPs in the timber harvest contract. However, Carraway et al. (2000) found that logger familiarity with BMPs was positively associated with BMP compliance as was the inclusion of BMP language in timber sale contracts. In Minnesota, logger education, including training in timber harvest BMPs, is an important component of forest certification and the enhanced market access provided by such oversight.

Our research examines the influence of these three types of planning and assistance for family forest owners (forest management plan, forester oversight of a timber harvest, written timber harvesting contract) on BMP implementation. In the process, we add to the limited and sometimes contradictory literature on whether these interactions are positively associated with higher rates of BMP implementation or greater BMP compliance by family forest landowners. Specifically, we examined how having a forest management plan, management of the harvest by a professional forester, or use of a written timber harvesting contract influenced BMP implementation in Minnesota. Minnesota's forestry BMPs, termed Timber Harvesting and Forest Management Guidelines, were published by the Minnesota Forest Resources Council in 1998. The state's FMGs are voluntary and describe a suite of practices designed to mitigate harvest-related impacts on water quality, wildlife, soil productivity, cultural resources, biodiversity, visual quality, and other forest resources (MFRC 1999).

Methods

Our analysis of FMG implementation was conducted using data collected from the state's

guideline monitoring program (GMP). Since 2000, the Minnesota Department of Natural Resources, in collaboration with the Minnesota Forest Resources Council, has conducted field assessments of recently harvested forest areas to determine the extent to which forest landowners are applying the state's FMGs. The GMP uses Landsat satellite imagery to identify recently harvested sites to be considered for field monitoring. All sites where >20% canopy change on at least 2.5 acres is detected qualified as a candidate for field monitoring. Landowner or manager contact is subsequently attempted to verify that harvest occurred within the target dates and harvest was completed and to secure permission to access the site. Methods used for contacting landowners have varied over time, relying on one or more of the following: contact via phone, mail, or email by the GMP forester, contact via phone or in person by a Minnesota Department of Natural Resources private lands forester, or contact via phone or in person by cooperators within local Soil and Water Conservation Districts. Once contacted, landowners are sent a survey that requests information about the timber harvest (e.g., harvesting practices used, season of harvest, management objectives). The level of detail included in the nonindustrial private forest (NIPF) landowner survey has also varied over the years, trending towards a simplified set of questions more NIPF landowners are able to answer. One set of questions common to the NIPF surveys used across all years of the GMP asks landowners whether the property has a written forest management (stewardship) plan, whether a professional forester administered the timber sale, and whether a written timber harvesting contract was used (MNDNR 2018).

FMG field monitoring is carried out by independent contractors between June and September. The contractors are required to meet several expertise and educational background criteria and complete calibration training with GMP staff before the start of field monitoring. Field monitoring consists of taking and recording detailed measurements of key features in and adjacent to the harvest area, such as the extent and location of leave trees, roads and landings, riparian management zones (RMZs), filter strips, and surface water and wetlands crossings (92% wetland, 8% stream crossings) (MN DNR 2018). Approximately 10%–20% of the sites monitored are randomly selected and subsequently reviewed on-site by GMP staff to evaluate consistency and compliance with the monitoring protocols. All sites are reviewed in-office by GMP staff for consistency and completeness of contractor data collection. The FMG field monitoring protocols are fully described by Rossman et al. (2016, 2018), Wilson and Slesak (2020) and Wilson et al. (2021). The field monitoring and landowner survey data used in this study were collected from 2009 to 2020 and include 174 timber harvests on the state's family forest lands (Figure 1). Each of these 174 sites (25% of total sites monitored) provided a complete set of responses relevant to one or more of the stewardship planning or assistance categories assessed here. Note that not all respondents provided complete answers to all survey questions. Metrics used to assess implementation of various BMPs are outlined in Table 1 and are more fully described by Rossman et al. (2016, 2018), Wilson and Slesak (2020) and Wilson et al. (2021).

Three separate statistical tests were used to assess the significance of any differences observed in BMP implementation among the treatment groups. For categorical outcomes where a particular BMP was either implemented or not implemented, the Pearson chi-square test (Pearson 1900) with Yates' correction for continuity (Yates 1934) was initially used to develop a chi-square statistic related to the number of "Yes" and "No" observations for each partition of the treatment group (planning/ supervision/ contract either used or not used). The chi-square statistic was then compared against the chi-square distribution to determine significance and *P*-values ($\alpha = 0.05$). For some comparisons, the outcome was close to significance but not definitive. In those cases, the Fisher exact test (Fisher 1922) was also applied, and *P*-values determined at the $\alpha = 0.05$ level were reported. For BMP implementation measured on count or continuous scales, the Wilcoxon rank sum test (Wilcoxon 1945) was used to assess potential differences in outcomes assuming nonparametric distribution of ranked implementation values. We also provide a comparison of compliance (sometimes combining two or more practices) with a select set of FMGs to assess influence of the treatment factors (e.g., planning, supervision, and/or contract) in a second way. All statistical tests were performed within the R Computing and Statistical Environment (R Core Team 2019).

Results

FMG Application

Guidelines recommend development of a written forest management plan for the property, timber harvest supervision by a professional forester, and use of a timber harvest contract. Conformance to these recommendations among the 174 harvests assessed is outlined in Table 2.

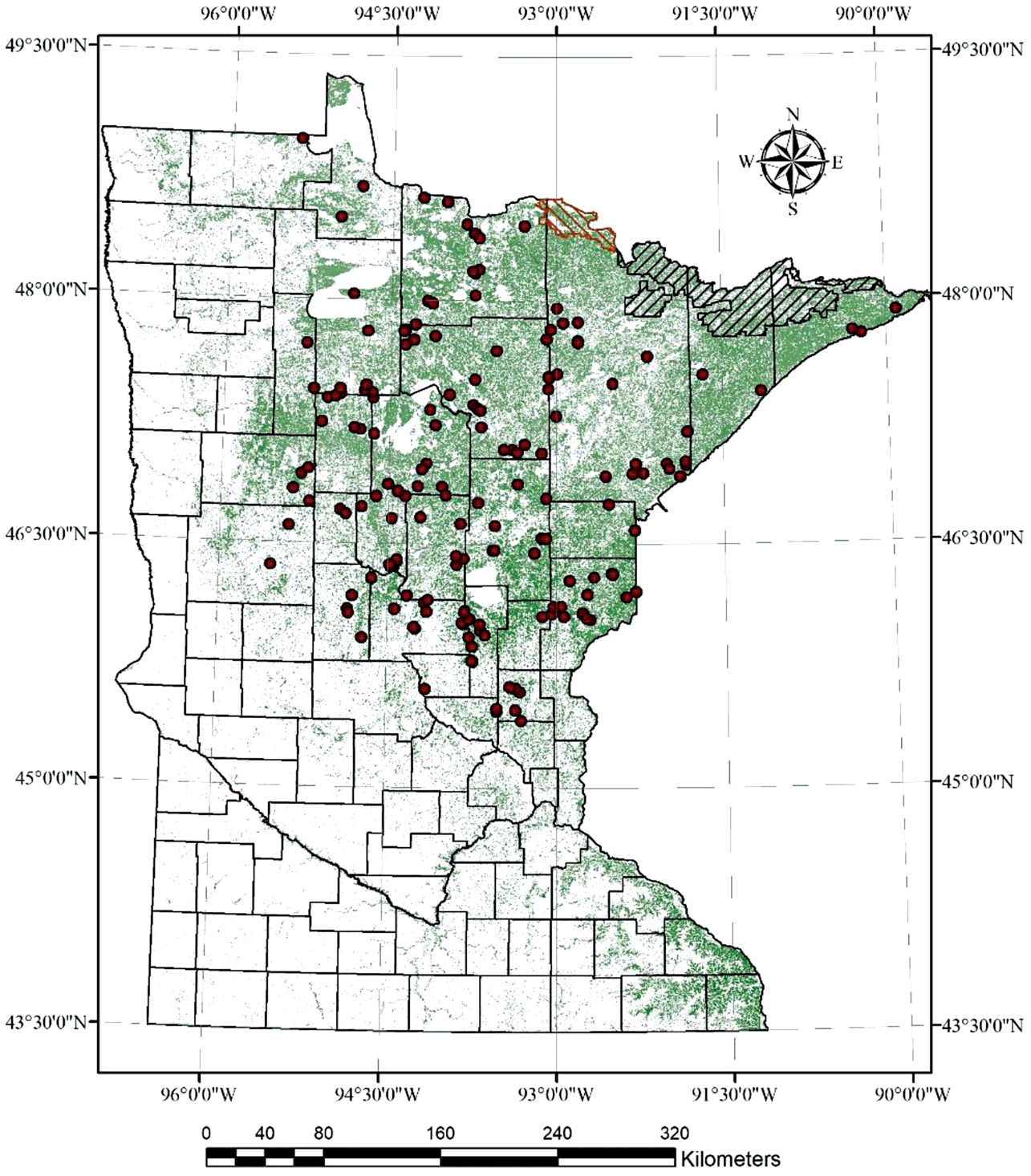

Figure 1. Location of forest management guideline monitoring on recently harvested family forest lands, 2009–2020. For reference, the Boundary Waters Canoe Area and Wilderness and Voyageurs National Park are shown in black and brown crosshatch, respectively.

Management Plan Influence

Family forest owners who had a forest management plan prepared for their property (78 of 153 responses) were also more likely to have a forester supervise their timber harvesting operation (93 of 157 responses) and use a written contract when conducting a commercial timber harvest (72 of 155 responses) (Table 3). Eighty-three percent of the harvests located on a property with

Table 1. Metrics used to evaluate Minnesota's forest management guideline implementation.

Forest management guideline	Metric
Infrastructure development in filter strips	Percent of filter strips managed according to recommendations
Soil exposure in the filter strip	Percent of filter strips managed without concentration of mineral soil exposed in the filter strip
Road and landing infrastructure	Percent of harvest area in roads and landings (evaluated separately below)
Sedimentation reaching water body	Percent of observations[a] where sedimentation is not reaching a wetland or waterbody
Water diversions and erosion control structures	Percent of water diversions and erosion control structures correctly installed
Water body crossings	Percent of unnecessary crossings of wetlands and other waterbodies avoided (ex., going around instead of through a wetland, single crossing instead of many, choice of stable location with low percent slope for stream crossings)
Rutting occurrence	Percent of sites with repeated rutting > 6" deep in the upland portion of the harvest site
Rutting severity	Average percent of feature(s) rutted when rutting is present
Riparian management zone (RMZ) width	Mean RMZ width (feet)
Riparian management zone residual basal area	Mean RMZ residual basal area (ft^2/acre) where partial harvesting occurred
Leave trees clumped	Percent of site acres retained in leave tree clumps
Leave trees scattered	Number of leave trees per acre ≥ 6 in. dbh
Snags	Number of snags left standing per acre
Slash management	Percent of sites where slash was retained and distributed across the harvest site
Coarse woody debris	Number of dead logs > 12 in. dbh and > 6 ft. per acre
Cultural resources	Owner, logger, or forester checked reports for cultural resources prior to harvest
Endangered, threatened species	Owner, logger, or forester checked reports for endangered and threatened species prior to harvest

[a]Includes observations of filter strips, landings, steep slopes, water quality segments, cultural resource areas, and other features potentially prone to erosion.

a forest management plan were supervised by a forester. However, the percentage of timber sales overseen by a forester decreased to 34% when a forest management plan had not been prepared for the property. Over three-fourths of the family forest owners with a forest management plan (77%) also had a written contract to guide their timber harvest. In contrast, only 16% of properties without a forest management plan used a timber harvesting contract.

When family forest owners were differentiated according to whether their property had a forest management plan, both cohorts implemented most FMGs in a consistent matter. The only two FMGs where there was a statistically significant difference in application based on whether the property had a forest management plan was the percent of water diversions and erosion control structures that were correctly installed and percent of mineral soil exposed in a filter strip (Table 3). For those landowners who had a forest management plan for their property, water diversion and erosion control structures were correctly installed 74% of the time compared with 67% of those structures correctly installed when the property didn't have a forest management plan. Ninety-seven percent of the timber harvesting occurring on family forest lands having a forest management plan did not have mineral soil exposed in filter strips. However, minimization of mineral soil in filter strips was found to be 99% for timber sales on family forest lands lacking a forest management plan. Although statistically significant, the occurrence of filter strips with exposed mineral soil differs by only 2% between treatment groups.

Table 2. Differential conformance to management planning and assistance recommendations.

	Harvest contract		
Management plan	Yes	No	No response
No plan	12	63	0
No response	0	21	0
Yes, a written plan	60	18	0
	Professional supervision		
Management plan	Yes	No	No response
No plan	25	49	1
No response	3	2	16
Yes, a written plan	65	13	0
	Professional supervision		
Harvest contract	Yes	No	No response
No contract	35	51	16
Yes, a written contract	58	13	1

Forester Oversight Influence

Family forest owners who acquired the services of a forester to supervise their timber sale were much more likely to use a written timber harvesting contract, as well as have a forest management plan prepared for their property (Table 3). Two-thirds of the harvest sites that were supervised by a forester also had a written timber harvesting contract, whereas only 21% of harvests conducted without the oversight of a forester had a written contract. Nearly three-fourths (72%) of the timber sales supervised by a forester were located on parcels where the owner had acquired a forest management plan. The likelihood of having a forest management plan for the property dropped to 21% when the timber sale was conducted without the supervision of a forester.

Although many of the FMGs were applied in a similar manner regardless of whether a forester administered the timber sale, statistically significant differences in FMG implementation were found in six areas (Table 3). Three of these FMGs (avoiding infrastructure [i.e., roads, skid trails, landings] in filter strips, correctly installing water diversions and erosion control structures, avoiding unnecessary water crossings), are intended to protect water quality during a timber harvest. Eighty-six percent of the timber sales supervised by a forester avoided having infrastructure located in filter strips whereas 77% of harvests did so when a forester was not involved in overseeing the timber sale. Ninety percent of the timber sales that were adjacent to water avoided unnecessary crossings of wetlands and other waterbodies when the sale was supervised by a forester. However, the percent of unnecessary wetland and other waterbody crossings that were avoided decreased to 81% when a forester was not involved in administering the timber sale. The biggest difference in implementing water quality FMGs as a function of whether a forester was involved in the timber sale was in the installation of water diversion and erosion control structures. When a forester supervised the timber sale, nearly four in five (78%) of the water diversion and erosion control structures were correctly installed. Yet, when no forester was present, the installation of these structures was done correctly only 58% of the time.

When a family forest owner secured the services of a forester to administer a timber sale, the area within the timber sale in leave tree clumps was significantly smaller than timber sales where a forester was not involved. Timber sales supervised by a forester had 5.1% of the sale area in leave tree clumps, whereas those sales without the involvement of a forester had nearly twice the area (9.7%) retained in leave tree clumps. Slash management was also related to forester involvement in a timber sale. Approximately two-thirds (65%) of the timber sales overseen by a forester retained and distributed the unmerchantable limbs and tops across the harvest site. This percentage decreased to 46% when a forester was not involved in the timber sale. Finally, road infrastructure tended to compose a slightly larger percentage of the harvest area on sites supervised by a professional forester compared with unsupervised sites. Although statistically significant, the actual difference is quite small (1.1% and 1.0%, respectively).

Timber Harvest Contract Influence

Most family forest owners who had a written contract to guide their timber harvesting operation also had a forest management plan prepared for their land and had engaged the services of a forester to administer their timber sale (83% and 82%, respectively) (Table 3). In contrast, when a written timber harvesting contract was not used, only 38% of the timber sales were overseen by a forester and only 22% of the properties had a forest management plan.

With respect to FMG implementation, family forest owners who had a written timber harvest contract were nearly indistinguishable from those who did not use one (Table 3). The only statistically significant difference in how FMGs were implemented was mineral soil exposure in filter strips. Specifically, the percent of filter strips managed without a concentration of mineral soil exposed was somewhat higher when landowners did not use a written contract for their timber harvesting operation. Only 1%

Table 3. Implementation of Minnesota's forest management guidelines on family forest land based on the presence or absence of a forest management plan, use of a forester to supervise the timber sale, and use of a written timber harvesting contract.

	Forest management plan for property			
Forest management guideline	N	Yes	No	*P*-value
Written forest management plan	NA	NA	NA	NA
Timber sale supervised by forester	152	83%	34%	<0.01
Written timber harvesting contract	153	77%	16%	<0.01
Avoid infrastructure in filter strips[a]	679	82%	83%	0.20
Minimize exposed soil in filter strip[a]	679	97%	99%	0.02
Sediment reaching water body (filter strip)[a]	705	99%	99%	0.47
% Road infrastructure[b]	153	1.1%	1.0%	0.31
% Landing infrastructure[b]	153	2.4%	2.6%	0.54
Water diversions & erosion control structures[a]	558	74%	67%	0.04
Water body crossings	640	87%	85%	0.57
Rutting presence[a]	142	3%	2%	1.00
Rutting severity[b]	82	15%	8%	0.19
Riparian management zone width	43	128	147	0.60
Riparian management zone residual basal area[b]	34	15	31	0.25
Leave trees clumped[b]	31	5.4	7.1	0.56
Leave trees scattered[b]	140	16	13	0.37
Snags	135	2.4	3.0	0.31
Slash management[a]	214	59%	50%	0.12
Coarse woody debris	135	27	24	0.44
Cultural resources	105	1.9%	1.9%	1.00
Endangered, threatened species	81	20%	17%	0.74
Size of harvest area (acres)[b]	173	32.3	30.7	0.80
	Timber sale supervised by forester			
Forest management guideline	N	Yes	No	*P*-value
Written forest management plan	152	72%	21%	<0.01
Timber sale supervised by forester	NA	NA	NA	NA
Written timber harvesting contract	150	66%	21%	<0.01
Avoid infrastructure in filter strips[a]	670	86%	77%	<0.01
Minimize exposed soil in filter strip[a]	670	97%	95%	0.39
Sediment reaching water body (filter strip)[a]	729	99%	99%	1.00
% Road infrastructure[b]	157	1.1%	1.0%	0.01
% Landing infrastructure[b]	157	2.6%	2.6%	0.48
Water diversions & erosion control structures[a]	607	78%	58%	<0.01
Water body crossings	664	90%	81%	<0.01
Rutting presence[a]	157	0%	5%	0.07
Rutting severity[b]	91	10%	15%	0.15
Riparian management zone width	45	98	159	0.07
Riparian management zone residual basal area[b]	35	30	22	0.08
Leave trees clumped[b]	35	5.1	9.7	0.03
Leave trees scattered[b]	155	15	13	0.73
Snags	139	2.5	2.8	0.52
Slash management[a]	221	65%	46%	0.01
Coarse woody debris	139	26	25	0.85
Cultural resources	109	0.0%	4.3%	0.36
Endangered, threatened species	80	20%	18%	0.83
Size of harvest area (acres)[b]	157	33.5	27.2	0.32

Table 3. Continued

Forest management guideline	N	Written timber harvesting contract: Yes	No	*P*-value
Written forest management plan	149	83%	22%	<0.01
Timber sale supervised by forester	150	82%	38%	<0.01
Written timber harvesting contract	NA	NA	NA	NA
Avoid infrastructure in filter strips[a]	739	82%	83%	0.71
Minimize exposed soil in filter strip[a]	739	97%	99%	<0.01
Sediment reaching water body (filter strip)[a]	796	99%	99%	1.00
% Road infrastructure[b]	174	1.0%	1.1%	0.98
% Landing infrastructure[b]	174	2.7%	2.3	0.24
Water diversions & erosion control structures[a]	668	67%	73%	0.95
Water body crossings	731	87%	86%	0.65
Rutting presence[a]	174	1%	2%	1.00
Rutting severity[b]	99	20%	10%	0.10
Riparian management zone width	42	44	46	0.87
Riparian management zone residual basal area[b]	22	35	29	0.78
Leave trees clumped[b]	38	5.4	7.4	0.59
Leave trees scattered[b]	172	16	12	0.86
Snags	137	2.6	2.7	0.79
Slash management[a]	245	61%	52%	0.09
Coarse woody debris	137	25	25	0.99
Cultural resources	108	0.0%	3.0%	0.60
Endangered, threatened species	87	18%	18%	0.96
Size of harvest area (acres)[b]	151	32.2	29.3	0.64

[a] Fisher's exact test
[b]Wilcoxon rank sum test
P-values are from chi-square tests unless otherwise noted.

of the timber harvests associated with these owners had mineral soil exposed in the areas immediately adjacent to wetlands or waterbodies. In contrast, 3% of the timber harvests on family forest land had mineral soil exposed in filter strips when the owner used a written timber harvest contract.

FMG Compliance

Table 4 describes the recommended practice or outcome associated with each of Minnesota's FMGs. These recommendations are used by GMP staff to evaluate the extent to which FMG implementation conforms to the desired practice for that guideline. We compared the actual practices observed on each harvest site to these recommendations to evaluate compliance with the FMGs as well as FMG compliance as a function of whether the landowner had a forest management plan, engaged the services of a forester to oversee the timber sale, or used a written timber harvesting contract.

Table 5 indicates overall compliance with FMGs across the family forest owner sites and features[1] (N) evaluated. Overall, compliance with FMGs on the assessed properties in this study is highly variable. The majority (9 of 14) of the FMGs were implemented to conform to the performance standard associated with that FMG at least 80% of the time. Three others (installation of water diversion and erosion control structures, appropriate width and basal area in RMZs, distributing slash across the harvest site) conformed to the recommendation for that guideline between 56% and 70% of the time. The two FMGs where compliance was significantly less than 50% are checks for endangered or threatened species and cultural resources (9% and 1% compliance, respectively). However, when endangered or threatened species and cultural resources were

[1] Multiple observations were taken per site for certain features that that had multiple occurrences (e.g., water diversion and erosion control structures) or when repeated measurements were taken for a specific FMG (e.g., sedimentation reaching water body).

Table 4. Description of Minnesota forest management guideline recommendations.

Forest management guideline	Recommendation
Infrastructure development in filter strips	Avoid development of landings, roads, and skid trails within the filter strip
Soil exposure in filter strips	Keep mineral soil exposure in filter strips to < 5% aerial extent. Avoid concentrated soil exposure
Road and landing infrastructure[a]	Limit road and landing infrastructure to 1 acre or 5% of harvest area, depending on harvest area size
Sedimentation reaching water body	Avoid sedimentation into wetlands and waterbodies from areas of exposed soil and/or erosion
Water diversions and erosion control structures	Install at all stream and wetland crossings, when slope is > 2%, and sedimentation in water and wetlands is possible
Water body crossings	Minimize the number of water body crossings
Rutting avoidance[b]	Minimize rutting during harvest and cease operations if conditions conducive to extensive rutting
Riparian management zones (RMZs)[c]	50–165 ft. minimum depending on waterbody designation; retain at least 60 ft^2 per acre basal area
Leave tree retention[d]	Retain 6–12 scattered leave trees per acre or ≥ 5% of the total harvest area in clumps
Snags	Retain all snags possible to promote habitat structure after harvesting
Slash management	Retain at least 1/3 of all slash and scatter across the site when possible
Coarse woody debris	Limit disturbance of all CWD (dead logs > 12 in. dbh and > 6 ft.); create 2–5 dead logs/acre across the harvest site if less than that amount is present; create ≥ 4 dead logs/acre when harvesting in RMZ if less than that amount is present
Cultural resources[e]	Check inventory reports for presence of cultural resources; sites protected with present
Endangered, threatened species[e]	Check inventory reports for presence of endangered and threatened species; habitat or features (e.g., nests) protected when present

[a]Compliance based on combined road and landing acreage.
[b]Combined rutting occurrence and severity.
[c]Compliance based on achievement of greater than 95% of the recommended RMZ width and basal area.
[d]Combined compliance depending on whether leave trees were clumped or scattered. Includes RMZ leave trees as clumps.
[e]Determined from landowner self-reporting on the pre-site questionnaire.

found, actions taken to ensure their protection was very high (i.e., 67% and 100% respectively). Logging operators protected cultural resources on the two sites where they were present and protected the habitat or other important features two-thirds of the time when endangered or threatened species were found within or immediately adjacent to the harvest area.

Overall, few significant differences in FMG compliance were observed aside from slash management practices and those FMGs directed at the land-water interface specifically to protect the integrity of riparian areas and minimize soil movement. For some of these FMGs, although differences in compliance rates are statistically significant between cohorts, the differences are minimal. For example, nearly full compliance with the FMG to minimize soil exposure in filter strips was achieved by those with and without a forest management plan or written timber harvest contract (97% versus 99% in both cases). Similarly, although compliance with the FMG to avoid unnecessary crossings was significantly different among landowners who did/did not use a forester to supervise their timber sale, compliance rates among both cohorts was relatively high (90% and 81%, respectively). However, large differences in compliance are evident for some FMGs, the majority of which are associated with whether a forester supervised the timber sale. For example, compliance rates associated with correctly installing water diversion and erosion control

Table 5. Forest management guideline compliance for 174 family forest owned harvest sites.

Forest management guideline (FMG)	N (sites/features)	Percent compliance
Coarse woody debris	174	99%
Sedimentation reaching water body	694	99%
Soil exposure in filter strips	739	98%
Leave tree retention	151	94%
Snags	159	87%
Water body crossings	731	86%
Infrastructure development in filter strips	739	82%
Road and landing infrastructure	148	82%
Rutting avoidance	174	81%
Water diversions and erosion control structures	668	70%
Riparian management zones	67	64%
Slash management	174	56%
Endangered, threatened species (checked/protected)	174/6	9%/67%
Cultural resources (checked/protected)	174/2	1%/100%
Size of harvest area (Mean/SD)[a]	174	31/37 acres

[a]Total sample includes 5,340 acres.

structures differed by as much as 20% depending on whether a forester was involved in administering the timber sale (78% versus 58%, respectively) and how slash was managed (65% compliance if a forester was used, 46% compliance if a forester was not used). The other FMG with a large difference in compliance is how RMZs were managed. Conformance with the RMZ width and basal area recommendations varied by over 30% depending on whether a forest management plan had been prepared for the property (79% and 48%, respectively) and whether a written timber harvesting contract was used (79% with and 45% without).

Discussion

The study documented how different family forest owner planning tools and professional assistance influence the application of a broad range of Minnesota's FMGs designed to protect the integrity of forest systems when a commercial timber harvest is undertaken. We did so by examining whether and to what degree the FMGs are implemented, depending on whether the landowner acquired a forest management plan for the property, engaged the services of a forester to administer the timber sale, or used a written contract to formalize various parameters of the timber harvest. Overall, we found that FMG implementation was only modestly influenced by these three interventions. Of the three, the presence of a forester when a timber sale was conducted was found to have the most influence, with six FMGs implemented differently when a forester was involved, compared with different FMG implementation rates for just two FMGs when a forest management plan was used and only one when the landowner had a written timber harvesting contract.

With respect to the differential rates of FMG implementation when a forester was involved, some of the findings may be explained by the forester's perspective or motivation with respect to that guideline. For example, timber sales supervised by a forester had 5.1% of the sale area in leave tree clumps, whereas timber sales without the involvement of a forester had nearly twice the area (9.7%) retained in leave tree clumps. This finding may be explained in part by how foresters are sometimes compensated by private landowners for their work administering a timber sale: as a percent of the timber sale's value. If compensated in this manner, foresters would have an incentive to capture as much of the merchantable volume of a timber sale as practical while still meeting guidelines. Slash management practices also varied as a function of whether a forester was present. Nearly two-thirds of the timber sales overseen by a forester followed the FMG to retain and distribute the unmerchantable limbs and tops across the harvest site, but this percentage decreased to 46% when a forester was not involved in the timber sale. One possible explanation for the large difference in FMG implementation could be the forester's awareness of and sensitivity to the visual and silvicultural concerns arising from large piles of slash. Silvicultural training, awareness of soil conditions and sensitivity to wildlife habitat issues may provide good explanations for differential implementation of these or other FMGs. Alternatively, the operational expense of redistributing

slash or installing erosion control practices, for example, may be a disincentive to recommended practices when supervision and/or contract language do not require them.

One statistically significant difference in BMP implementation that seems counterintuitive is that family forest owners with a forest management plan protected mineral soil in filter strips less frequently than landowners who did not have a forest management plan. Although the difference was only 2% (97% mineral soil protection on lands with a forest management plan and 99% protection when no plan existed), it was the opposite of what we expected. However, this finding may not be substantive given confounding factors like variable road construction or implementation of erosion control practices among the highly correlated treatment factors we evaluated.

Our findings are largely consistent with others who have examined various factors that influence BMP implementation. As did VanBrakle et al. (2013), we found that Minnesota landowners who had a forest management plan also implemented some BMPs more frequently, although the specific BMPs in each study were different. Our findings were also largely consistent with Egan (1999), who found no statistical relationship between BMP implementation and a landowner's use of a timber harvesting contract. By comparison, we found that only the BMP addressing filter strip soil exposure was differentially implemented when a timber harvesting contract was used. With respect to the influence a forester has on BMP implementation, previous research that examined this relationship reached different conclusions. We found that implementation rates for several BMPs were different when a forester supervised a family forest owner's timber sale.

The study documented that compliance with FMGs that are voluntarily implemented on Minnesota's family forest lands is highly variable. The majority of the FMGs we evaluated were implemented to the performance standard set by the state >80% of the time. Many of these FMGs are intended to protect water resources and their associated features. The voluntary compliance is encouraging, considering that forest management plans, forester supervision, and timber harvesting contracts did not have a substantial influence on the use of most FMGs. FMG compliance is still extremely low (< 10%) with respect to checking for the presence of endangered or threatened species or cultural resources before a timber harvest begins. However, even with this low implementation rate, when endangered or threatened species or cultural resources are found on-site, they are generally protected (100% of the time for cultural resources, 67% for endangered or threatened species).

We found that FMG compliance rates were only modestly influenced according to whether the landowner had acquired a forest management plan, employed a forester to supervise the timber sale, or used a written timber harvesting contract. The presence of a forester appears to have the greatest influence on whether an FMG is implemented to the recommended guideline standard, as significant increases in compliance were observed with four FMGs (avoid infrastructure in filter strips, correctly install water diversions and erosion control structures, avoid unnecessary water crossings, and distribute slash across the harvest site). The compliance rates for only two FMGs (minimize exposed soil in filter strips and riparian zone management) were significantly different if the landowner had a forest management plan or used a written timber harvesting contract. Additionally, it appears the form of landowner intervention matters when targeting specific FMGs. The FMGs whose compliance rates increased when a forester was involved are different than improvements in FMG compliance when the landowner had a forest management plan or used a written timber harvesting contract. The extensive training opportunities available to Minnesota foresters for correct application of FMGs combined with their periodic on-site presence during a timber sale are likely reasons for this difference.

Conclusions

To our knowledge, the study is the first to conduct a comparative analysis of how three different forms of landowner intervention (forest management plan, forester supervision of a timber sale, written timber harvesting contract) influence BMP implementation. Our analysis demonstrates that implementation and compliance rates for the majority of BMPs are not meaningfully influenced by any of these three interventions. Of the three, the influence of having a forester on site when a timber harvest is conducted had the greatest impact on whether and how the BMP is implemented. Our results should not be interpreted, however, to suggest that having a management plan or professional interaction during a timber harvest are not beneficial in achieving land stewardship goals and outcomes. Rather, our results suggest that

other factors individually or in combination may be driving BMP implementation. Existing requirements that loggers attend FMG training to maintain their membership in the MLEP program may partially explain similarities among treatment groups found in this study. Virtually all Minnesota logging businesses are MLEP members, in support of common forest certification standards, so it is highly unlikely that any of the loggers who operated on our study sites have not attended an FMG training session. In states where logger training is less common or largely absent, forest management plans, supervision by a forester, and use of a contract could potentially be expected to produce different levels of impact on FMG outcomes. Future research to explore the influence or association of additional factors on BMP implementation, such participation in certification systems or landowner, forester, and logger knowledge and attitudes towards BMPs, could enhance our understanding of what factors motivate implementation of forest stewardship practices.

Our findings support the value of information and training directed at service foresters about the importance of incorporating BMPs into forest management plans, timber harvesting contracts, and other planning tools. This is especially relevant given the improved levels of implementation on harvests overseen by a professional forester for some FMGs. Even so, it appears that additional information (e.g., webinars, online resources, targeted marketing) and assistance or incentives directed at both family forest owners and foresters working with those landowners may be needed to achieve higher rates of BMP implementation for some practices.

It should be noted that the GMP data used in our analyses only includes data on family forest lands whose owner gave permission to allow field monitoring. This nonrandom sampling design could impart upward bias on rates of FMG implementation and compliance. However, although landowners had to opt in to be part of this database, many of the FMGs on these lands were not implemented or, when they were, fell short of the performance standard associated with the FMG. Although this suggests our data were not limited just to landowners committed to implementing the FMGs, readers need to keep these dimensions of our study in mind when interpreting our results. Substantial additional research aimed at characterizing, in demographic terms, both the pool of private woodland owners and the pool of private woodland owners engaged in active management will be needed to shed further light on the question of how representative our sample was.

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