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Examining the effect of forest certification on timber harvest best management practice implementation

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ABSTRACT

Forest certification programs are voluntary initiatives emphasizing sustainable forestry and harvest practices. Compliance with certification standards is enforced through third-party audits. One requirement of most forest certification systems is the use of best management practices during harvesting activities. These practices are designed to mitigate potential negative outcomes of forest management and timber harvesting activities. Best management practice implementation has been found to have a variety of positive outcomes on water quality and other resources. However, information relating forest certification to implementation of best management practices and environmental outcomes on certified versus noncertified lands is scant. Here, we examine the role of third-party certification as it contributes to enhanced forest stewardship via implementation of voluntary best management practices. Our study adds to the limited body of research comparing sustainability practices and outcomes on certified vs. noncertified lands. In alignment with previous research on the topic, our study suggests that adherence to best management practices is better on certified versus noncertified forests. Our findings also suggest that for large public agency ownerships, organizationally driven factors beyond forest certification (e.g. institutional policy and trained staff) influence the use of best management practices during timber harvests.

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Introduction

Forest certification programs are voluntary initiatives that emphasize sustainable forestry and harvesting practices and can provide a market advantage for some participants to capture a price premium for certified wood products. Compliance with certification standards is enforced through third-party audits. One requirement of forest certification systems (e.g. American Tree Farm System (ATFS), Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSC)) and for private landowners who sell wood to mills that are certified to the SFI Fiber Sourcing Standard is that best management practices be followed during harvesting activities. In 2017, approximately 38.4 million hectares or roughly 13% of forests in the United States were certified under at least one of these certification systems (Alvarez 2019).

Developed at the state-level, best management practices, also known as forest management guidelines and hereafter referred to as FMGs, are practices designed to mitigate negative externalities during forest management and timber harvesting activities (Kilgore and Blinn 2004). Most first-generation timber harvest FMGs were state-led water quality control strategies to reduce nonpoint source pollution (Warrington et al. 2017). Today, many states' FMGs not only address adverse impacts related to water pollution through sediment movement but also include practices that address other timber harvesting issues such as loss of wildlife habitat, impacts to cultural resources, and changes in visual quality (Archey 2004; Ice et al. 2010). Nearly all states have developed FMGs, which vary among states with respect to the resources they address, types of harvesting practices promoted, and the way they are implemented (Blinn and Kilgore 2001; Cristan et al. 2016).

Adherence to FMGs during harvesting activities has been found to have a variety of positive outcomes on water quality and other resources. Enhanced outcomes include a reduction in water quality impacts by more than 90% compared to harvesting activities prior to the development of FMGs (Ice 2004) as well as reduced erosion, stream temperature impacts, stream nutrient loads, and benefits to macroinvertebrate populations (Cristan et al. 2016). Certification programs further support sustainable forestry and harvesting practices through FMG training requirements for loggers (Schilling et al. 2020). While certified forest lands are to be managed to high standards of sustainably and adherence to FMGs, we were interested in determining whether the converse is true, namely whether uncertified lands are not managed according to FMGs supporting site-level forest sustainability. Little research has been done to address this question. To address this information gap, we explored how rates of FMG implementation during a commercial timber harvest differ when comparing certified to noncertified lands. We did so through a Minnesota case study, where adherence to its voluntary FMGs is a requirement of forest certification programs.

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Background

Research to evaluate the impact of certification programs on sustainable forestry outcomes has proceeded in several different directions. This includes:

- Evaluations of changes to forest practices and processes that managers/forestry companies must make to meet certification standards (e.g. Cubbage et al. 2003; Newsom et al. 2006; Moore et al. 2012).
- Comparisons of changes to forest practices and processes *between* different certification standards (e.g. Moore et al. 2012).
- The role of fiber sourcing certification standards on sustainable forestry practices (e.g. Simpson et al. 2011; Dwivedi et al. 2018; Kadam et al. 2021).
- Comparisons of FMG implementation and other metrics between certified and noncertified harvested stands (e.g. Hagan et al. 2005; Foster et al. 2008; Simpson et al. 2011).
- Forest managers' perspectives on effectiveness, benefits, challenges and desired modifications to certification programs (e.g. Tikina et al. 2012; George et al. 2022).

Research has shown that enrolling in a certification program can result in the need for substantial changes in forestry practices to initially meet certification standards (Cubbage et al. 2003; Newsom et al. 2006; Moore et al. 2012) and to achieve continuous improvement in sustainability as recommended by periodic audits. In a comparison of FSC and SFI certification standards on university and state forest lands in North Carolina, Cubbage et al. (2003) reported that meeting FSC standards required managers to implement more forest management changes to address future stand conditions and biodiversity protection, while meeting SFI standards required more record-keeping, better adherence to FMGs, and enhanced environmental management systems but little in the way of forest management changes. Examples of changes related to FMGs that were required to meet SFI certification standards included enhanced FMG record-keeping, improving roads to meet FMG standards, and the development of FMG and road inspection methods (Cubbage et al. 2003). Moore et al. (2012) found that, on average, a firm needed to make 13–14 changes in its practices to obtain certification, including implementation of FMGs. While Moore et al. (2012) found no statistically significant difference in the number of changes required when comparing SFI to FSC certification standards, many differences in the specific changes needed under each standard were identified. In addition to examining the changes in forestry practices that forest owners in the United States seeking FSC certification needed to make, Newsom et al. (2006) found that operations in states with mandatory FMGs had fewer changes that needed to be made when seeking certification as opposed to operations in states with voluntary FMGs. Studies of this nature (e.g. identifying changes that entities seeking certification must enact) provide an indication of practice improvements that an entity makes relative to its pre-certified condition but do not provide a direct comparative analysis of whether post-harvest conditions are different/better, or whether FMGs are more likely to be followed on certified versus noncertified forest harvests.

A different way in which certification can influence sustainable forestry practices is through mill certification and fiber sourcing standards. Mills can choose to be certified to SFI standards, which requires them to source wood from suppliers (i.e. loggers) who participate in SFI endorsed logger training education programs, among other things. The fiber sourcing standard allows certified mills to obtain wood from certified and noncertified land, which is particularly relevant to family forest land which has low rates of certification. Simpson et al. (2011) found higher rates of FMG implementation on wood delivered to an SFI mill versus a mill that was not an SFI member (96% implementation versus 86%) in East Texas. Dwivedi et al. (2018) found water quality FMG implementation rates were slightly higher (2%) on harvested sites in Georgia within the sourcing radius of mills certified to the SFI Fiber Sourcing Standard than those outside of the sourcing radius. The SFI Fiber Sourcing Standard requires that water quality FMGs must be followed during harvesting operations. Kadam et al. (2021) found that FMG implementation rates were higher for loggers who had participated in an SFI-approved logger education program than loggers who had not, illustrating that fiber sourcing certification programs are an important element in achieving sustainable forestry practices across the landscape even in the absence of land itself being certified.

Research that has directly examined the impact of forest certification programs by comparing the environmental and sustainability practices and outcomes of harvests on certified versus noncertified lands is scant, however. Hagan et al. (2005) examined the relationship between certification and biodiversity practices over a mix of public and private landowner types, finding that land certified to either SFI or FSC standards had stronger biodiversity practices related to habitat management, rare species management, and late successional forest management than noncertified land. No difference was found in this study in biodiversity scores when comparing FSC to SFI certified lands. In a comparison of stands harvested under FSC standards to noncertified harvested stands on nonindustrial private forest owner (NIPF) land in Vermont, Foster et al. (2008) found similar timber values, aboveground carbon storage values, and live tree structure on the certified and noncertified harvest sites, but greater residual coarse woody debris on the certified harvest sites. In an FMG field monitoring program in Texas, Simpson et al. (2011) documented that FMG implementation across multiple ownership types was higher on properties certified to the ATFS (97%) than on eligible noncertified lands (88%). When broken out by individual landowner type, overall rates of BMP implementation ranged from a low of 88% for family forest owners to 98% for public forest ownerships, although statistical tests of difference were not performed (Simpson et al. 2011)

We were interested in testing whether third-party certification contributes to enhanced forest stewardship as measured by adherence to voluntary FMGs. Our research adds to the limited body of research that directly compares the

sustainability practices and outcomes of certified to noncertified lands by comparing rates of FMG implementation on harvests across a broad range of different land ownership groups in Minnesota using field-based FMG monitoring data.

Materials and methods

Minnesota's forest management guidelines

FMGs were developed by the Minnesota Forest Resources Council to mitigate negative outcomes potentially associated with timber harvest on water quality, wildlife, soil productivity, cultural resources, biodiversity, visual quality, and other forest resources, and to support sustainable management of Minnesota's forests (MFRC 2022). FMGs address water quality concerns through practices such as filter strip implementation, use of riparian management zones (RMZs), road and skid trail design and management, erosion control structures, landing placement and footprint, slash management, and minimizing wetland impacts (e.g. crossings, sedimentation and rutting). Forest soil, wildlife and biodiversity concerns are addressed through practices like leave tree/clump, slash management, coarse woody debris and snag retention, RMZ management, identification and management to retain important microsite habitats like vernal pools protected by leave tree clumps, or areas harboring threatened or endangered species. Visual quality guidelines follow Minnesota Department of Natural Resources (MNDNR) standards published in the early 1990s. While implementation of FMGs is voluntary by statute, their use is mandated by policy for timber harvests on state, federal, and some county lands. FMG implementation is only truly voluntary on private timberland in Minnesota (Total Private = 3.17 million hectares, Private Industrial = 445,000 hectares, NIPF = 2,725,000 hectares). Of all private industrial timberland in Minnesota, about 28% is certified.

Minnesota's FMG monitoring program

Our analysis of FMG implementation uses data collected by Minnesota's guideline monitoring program (GMP). Since 2000, the MNDNR, in collaboration with the Minnesota Forest Resources Council, has conducted field assessments of approximately 1,300 recently harvested forest areas to determine the extent to which forest landowners, managers and loggers are applying the state's voluntary FMGs. The GMP uses Landsat satellite imagery to identify recently harvested sites that are potential candidates for FMG field monitoring. All harvest sites greater than 1 hectare where more than 20% canopy change was detected since the last image qualifies as candidates for field monitoring. A selection of sites proportionate to forest ownership is then made for further investigation and sampling. Summertime access presents a logistical prerequisite to field monitoring, thus wintertime access only sites on hydric soils (swamps and bogs) are almost certainly under sampled. Forest ownership and relationship to general soil moisture conditions (physiography) in Minnesota are detailed in Table 1.

Once sites are identified, the forest landowner and/or manager is contacted to verify that a harvest occurred within the target dates (1–2 years), the harvest was completed, the harvest is not a preliminary action associated with land conversion, and to secure permission to access the site. Methods used to contact forest landowners have varied over time and include contact via phone, mail, or e-mail by the GMP forester; contact via phone or in person by an MNDNR private land forester; or through cooperation with local Soil and Water Conservation Districts. Once contacted, landowners are sent a survey requesting information about the timber harvest (e.g. management planning, harvesting practices used, season of harvest, management objectives). The level of detail included in the private landowner survey has varied over the years, trending toward a simplified set of questions a larger portion of private landowners are able to answer.

FMG field monitoring consists of taking and recording detailed measurements of key features in and adjacent to the harvest area. Monitored features include but are not limited to the extent and location of streams and wetlands, leave tree retention, roads and landings, RMZs, filter strips, and condition of surface water or wetlands crossings and approaches. Over 700 unique kinds of observations could be made on particularly complex harvest sites. Field monitoring is carried out by independent contractors between May/June and September each year, depending on the timing of variable spring weather. Contractors are required to meet expertise and educational background criteria related to forest management and operations, soil science, wetland identification, watershed management, plant/tree identification, forest measurement, and aerial image interpretation and to complete calibration training with GMP staff prior to the start of field monitoring. Between 10% and 20% of the sites monitored are randomly selected and subsequently reviewed on-site by GMP staff to evaluate monitoring consistency and compliance with the monitoring protocols. Any deviations from prescribed monitoring protocols are corrected, and contractors are required to evaluate and correct any similar issues found across all sites monitored. While all sites are reviewed in-office by

Table 1. Minnesota forest land ownership and general physiographic distribution (MNDNR - Division of Forestry 2019; USDA Forest Service, Forest Inventory and Analysis Program 2022).

Ownership Type	Percent	Hectares	Xeric	Mesic	Hydric
County	16%	1,144,481	0.9%	70.7%	28.1%
Federal	12%	858,361	4.0%	75.3%	20.5%
Corporate	7%	500,710	1.7%[a]	82.4%[a]	15.7%[a]
NIPF	42%	3,004,262			
State	23%	1,645,191	0.8%	51.9%	47.0%
Total	**100%**	**7,153,006**	**1.7%**	**72.2%**	**25.8%**

[a]USDA Forest Inventory and Analysis (FIA) groups corporate, NIPF, and other privately owned lands into a single category for public reporting.

Table 2. Monitoring site distribution by year and ownership category with comparison to FIA harvest removals (2009–2018) (USDA Forest Service, Forest Inventory and Analysis Program 2022).

Year	County	Federal	Corporate	NIPF	State	Total Sites
2009	19	6	11	28	24	**88**
2011	20	6	11	20	27	**84**
2014	28	12	4	30	19	**93**
2015	29	11	6	10	23	**79**
2016	16	0	1	35	28	**80**
2017	21	1	15	25	37	**99**
2018	18	5	7	30	23	**83**
Total	**151**	**41**	**55**	**178**	**181**	**606**
% of Sample	**24.9%**	**6.8%**	**9.1%**	**29.4%**	**29.9%**	**100%**
FIA Removals	**24.5%**	**4.7%**	**43.6%**		**27.2%**	**100%**

[a]USDA Forest Inventory and Analysis (FIA) groups corporate, NIPF, and other privately owned lands into a single category for public reporting.

GMP staff for consistency and completeness of contractor data collection, due to the complexity of the monitoring survey, a small number of incomplete responses can still be found in the final data. The FMG field monitoring protocols are more 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 2018 and include 606 timber harvests distributed across all ownerships: county, federal, corporate, NIPF, and state (Table 2). Ownership categories are broadly defined as follows: ***county*** - all lands owned or managed by a county; ***federal*** - all lands owned by the USDA-Forest Service (other federal lands could be monitored but were not observed during our period of interest); ***corporate*** - all lands owned by forest industry, corporations, Timber Investment Management Organizations (TIMO), and Real Estate Investment Trusts (REIT); ***NIPF*** - all privately owned forest land not included in the corporate category and tribal lands; ***state*** - all lands owned or managed by the state. The slight disparity between the number of sites monitored and FIA estimates of harvest removals by ownership class seen in Table 2 is due to two factors: lower frequency of harvest on NIPF lands and denial of access to monitor some NIPF harvests. Overall sample size was maintained by slightly oversampling federal, state, and corporate harvests.

Each monitored site provided a set of responses relevant to the implementation criteria assessed here. Note that not all respondents provided complete answers to all survey questions. The metrics used to assess the implementation of various FMGs are described by Rossman et al. (2016, 2018), Wilson and Slesak (2020) and Wilson et al. (2021). Brief descriptions of the specific FMGs we examined are contained in Table 3. FMGs were selected for evaluation based on relevance to water quality, forest soils, and biological or cultural legacies, as well as the presence of sufficient observations to support assessment.

Certified versus noncertified forests

Minnesota's forest landowners were classified into two groups according to whether they held an FSC and/or SFI certificate or not. Certified ownerships include the MNDNR (state forest lands), ten county land departments, and industrial and corporate forest owners (including TIMOs and REITs). Noncertified ownerships include Minnesota's two national forests (Chippewa and Superior), five county land departments, and NIPF owners. Minnesota forest owners enrolled in the American Tree Farm System (ATFS) are not certified, as the state's ATFS committee chose not to certify its ATFS forests (Beyer 2022). FMG compliance rates were compared for forest landowners certified under FSC and/or SFI standards to those forest owners who were not certified. Note that we are not differentiating or comparing between the FSC and SFI standards because they both have the same requirements with regard to following FMGs during a harvest.

Statistical tests

Two separate statistical tests were used to assess the significance of any differences observed in FMG implementation among the treatment/ownership groups. For categorical outcomes where a particular FMG was either implemented or not implemented, Fisher's Exact test (Fisher 1922) was applied. For FMG implementation measured on count or continuous scales, the Wilcoxon Rank Sum test (Wilcoxon 1945) was used to assess potential differences in outcomes assuming non-parametric 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 the influence of the treatment factors in a second way. All statistical tests were performed within the R Computing and Statistical Environment (R Core Team 2019).

Due to the relatively small effect sizes seen for most FMG metrics assessed, we followed the advice of Di Stefano (2001) and reduced the likelihood of Type II error (likelihood of failing to reject the null hypothesis when a difference actually exists) by increasing the critical α level used in our tests of significance to 0.10 ($\alpha = 0.05$ being the standard). In effect, while this means we will stand a 1 in 10 chances of incorrectly rejecting the null hypothesis, it also means that our chances of making a Type II error will fall from 31% to 21% assuming small effect sizes ($w = 0.1$). From the standpoint of forest management decision-making, this means we would prefer to err on the side of caution, given the potential cost (financial and/or environmental) associated with making incorrect decisions about the efficacy of certification in promoting FMG implementation.

Results

Certified versus noncertified forests

Significant differences were found among 11 of the 26 FMGs evaluated (Table 4). Compared to noncertified forests, certified

Table 3. Minnesota's forest management guidelines (FMGs) evaluated[a].

Forest Management Guideline (FMG) Metric	Summary Description
Infrastructure not developed in filter strips	Filter strips are managed without encroachment of any infrastructure such as roads, skid trails or landings.
Landing not located in filter strip	Landings are not developed within a filter strip.
Road not constructed within filter strip	New roads are not developed within a filter strip.
Avoid erosion within filter strip	Filter strips are managed to avoid erosion within the buffer.
Less than 5% exposed mineral soil in filter strip	Filter strips are managed with less than 5% exposed mineral soil distributed (not concentrated) throughout the filter strip.
No repeated rutting in filter strip	Repeated rutting is avoided within the filter strip.
No sediment reaching water body	Filter strips are observed for indications of failure (sediment reaching a water body) and the volume of any sedimentation is recorded.
% Infrastructure compliance	Infrastructure should compose a small proportion of the harvest area (1-3% depending on harvest size).
% Road infrastructure	Percent of harvest area in road infrastructure.
% Landing infrastructure	Percent of harvest area in landing infrastructure.
Water diversions & erosion control structures	Water diversions and erosion control structures are installed where needed (slope dependent) to prevent concentration of runoff and sediment transport. The volume of any erosion present is also measured.
No avoidable water body crossings	Unnecessary crossings of wetlands and water bodies are avoided whenever possible.
Avoid repeated rutting (Upland)	Repeated rutting >15 cm deep is avoided throughout the upland harvest area. Harvest operations should be managed to avoid rutting whenever possible.
Avoid rutting of all resources on site	Repeated rutting >15 cm deep is avoided throughout the entire harvest area (uplands, lowlands, special resource areas). Harvest operations should be managed to avoid rutting whenever possible.
Rutting severity (% of rutted feature affected)	Rutting severity is measured as the average percent of each rutted feature affected.
Riparian management zone compliance	Riparian management zones are managed (at minimum) to the specified average width and basal area (depending on water body size and type).
Riparian management zone width	Average width of the RMZ measured for three representative transects.
Riparian management zone residual basal area	Average basal area for forested portions of the RMZ measured for three representative transects.
% Leave tree clumps (for even-age harvests)	Percent of site retained in leave tree clumps (at least 5% of site retained in clumps with >15 cm average dbh, minimum of 18.4 sq. meters/hectare basal area).
Leave trees scattered (for even-age harvests)	Average per hectare number of scattered leave trees (≥15 cm dbh) retained. (15-30 recommended).
Leave tree compliance (Net)	Weighted average leave tree compliance including scattered and clumped trees.
Snag compliance	Four to eight large snags per hectare are recommended.
Slash management compliance	Slash is relatively evenly distributed across the harvest site.
Coarse woody debris compliance	Two to five pieces of coarse woody debris (>15 cm dia. and > 1.8 meters long) are retained per hectare.
Cultural resources check	Owner, logger, or forester checked reports and site for presence of cultural resources prior to harvest
Endangered, threatened species (ETS) check	Owner, logger, or forester checked reports and site for presence of ETS 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.

forests were significantly less likely to have exposed mineral soil or infrastructure (e.g. roads or landings) located within filter strips, water crossings in areas that could have been avoided, severe rutting (high percentage of feature affected) and were more likely to be in compliance with the recommended portion of the harvest area devoted to infrastructure. Certified lands were significantly more likely to have water diversions and erosion control structures correctly installed, wider RMZs, slash management practices consistent with FMGs, and preharvest checks conducted for the presence of cultural resources and endangered and threatened species. Counter to what we would have expected, certified forests had significantly higher overall rates of repeated rutting in the general harvest area (all features) than noncertified forests, but with significantly less severity. It is important to note that the percent of sites in each group for this metric differed by less than 1% (4.7% of certified sites rutted vs. 3.9% for noncertified sites).

Certification influence excluding NIPF ownerships

Given the considerable variability that exists among the ownership groups we examined in the above comparison with respect to the amount of forest land owned and the level of professional expertise available to carry out land management activities, we reran our analysis after removing NIPF ownerships. We felt including only those forest owners that have some level of organizational structure and professional staff overseeing the management of their forest lands could provide more focused insight on the role forest certification has in promoting good stewardship practices as expressed in the state's FMGs on more comparable types of land ownerships.

Table 5 contains the results of this comparison after FMG monitoring records on NIPF sites were removed, which still shows significantly different FMG implementation rates among the two groups across eight FMGs. Specifically, harvest sites located on certified forests were significantly less likely to locate harvest roads and landings in filter strips and have a greater proportion of harvest sites impacted by repeated rutting than noncertified forests. Certified forests also had more scattered leave trees per hectare and a larger portion of the harvest area devoted to roads (Certified (mean) = 1.16% vs. Not Certified (mean) 0.87%). They were also more likely to have water diversion and erosion control structures correctly installed, a higher amount of residual basal area within the RMZ, and preharvest checks for the presence of cultural resources and endangered and threatened species than noncertified harvests.

Table 4. Comparison of FMG implementation on harvest sites with and without certification on all Minnesota forest lands. Percentages indicate correct use of FMG.

Forest Management Guideline (FMG) Metric	N	Single or Dual Certification	No Certification	p-value
Infrastructure not developed in filter strips	2,927	82.4%	79.3%	0.0378[a]
Landing not located in filter strip	869	67.0%	61.9%	0.1325
Road not constructed within filter strip	661	84.6%	86.0%	0.6570
No erosion within filter strip	581	96.5%	97.5%	0.6287
No exposed mineral soil in filter strip	585	97.3%	91.4%	0.0023[a]
No repeated rutting in filter strip	2,141	98.4%	98.9%	0.3538
No sediment reaching water body	3,031	99.6%	99.3%	0.3247
% Infrastructure compliance	600	62.0%	68.8%	0.0999[a]
Water diversions & erosion control structures	2,711	82.2%	72.7%	0.0000[a]
No avoidable water body crossings	3,022	92.0%	89.5%	0.0197[a]
No repeated rutting (Upland)	595	99.1%	98.4%	0.4627
Avoid rutting of all resources on site	11,437	95.3%	96.1%	0.0363[a]
Riparian management zone compliance	288	71.4%	66.7%	0.4367
Leave tree compliance (Net)	524	71.6%	71.1%	0.9221
Snag compliance	524	78.4%	82.1%	0.3205
Slash management compliance	855	71.9%	61.9%	0.0024[a]
Coarse woody debris compliance	589	96.8%	96.7%	1.000
Cultural resources check	436	95.9%	50.0%	0.0000[a]
Endangered, threatened species check	439	97.6%	51.3%	0.0000[a]
Observed % road infrastructure[b]	600	1.2%	1.0%	0.2701
Observed % landing infrastructure[b]	600	2.2%	2.4%	0.6845
Observed rutting severity (% of rutted feature affected)[b]	464	10.0%	20.0%	0.0004[a]
Observed riparian management zone width[b,c]	201	55.5	43.5	0.0438[a]
Observed riparian management zone residual basal area[b,d]	201	13.8	10.4	0.2229
Observed % of harvest in leave tree clumps[b]	524	9.3%	7.1%	0.1366
Observed leave trees per hectare scattered[b]	524	25.7	28.2	0.0811

[a] $p \leq 0.10$ or ≤ 0.05 for Wilcoxon Rank Sum Test.
[b] Wilcoxon Rank Sum Test (critical $p = 0.05$).
[c] meters.
[d] meters^2.

Table 5. Comparison of FMG implementation on harvest sites with and without certification (NIPF lands excluded). Percentages indicate correct use of FMG.

Forest Management Guideline (FMG) Metric	N	Single or Dual Certification	No Certification	p-value
Infrastructure not developed in filter strips	2,190	82.4%	78.1%	0.0436[a]
Landing not located in filter strip	595	67.0%	49.1%	0.0005[a]
Road not constructed within filter strip	458	84.6%	72.5%	0.0232[a]
No erosion within filter strip	391	96.5%	100.0%	0.3773
No exposed mineral soil in filter strip	388	97.3%	100.0%	0.6115
No repeated rutting in filter strip	1,493	98.4%	99.3%	0.4046
No sediment reaching water body	2,211	99.6%	99.5%	0.6974
% Infrastructure compliance	422	65.3%	65.3%	0.6019
Water diversions & erosion control structures	2,057	82.2%	74.2%	0.0005[a]
No avoidable water body crossings	2,205	92.0%	91.4%	0.6860
No repeated rutting (Upland)	417	99.1%	98.6%	0.5383
Avoid rutting of all resources on site	8,333	95.3%	95.6%	0.6398
Riparian management zone compliance	223	71.4%	74.5%	0.7305
Leave tree compliance (Net)	373	71.6%	64.2%	0.2403
Snag compliance	373	78.4%	74.6%	0.5179
Slash management compliance	608	71.9%	71.7%	1.0000
Coarse woody debris compliance	410	96.8%	98.6%	0.7004
Cultural resources check	355	95.9%	82.5%	0.0006[a]
Endangered, threatened species check	353	97.6%	87.5%	0.0052[a]
Observed % toad infrastructure[b]	422	1.16%	0.87%	0.0646
Observed % landing infrastructure[b]	422	2.23%	1.95%	0.1515
Observed rutting severity (% of rutted feature affected)[b]	363	10.0%	25.0%	0.0001[a]
Observed riparian management zone width[b,c]	152	182	150	0.8232
Observed riparian management zone residual basal area[b,d]	152	60	40	0.0058[a]
Observed % of harvest in leave tree clumps[b]	373	9.3%	7.6%	0.5000
Observed leave trees per hectare scattered[b]	373	10.4	7.4	0.0910

[a] $p \leq 0.10$ or ≤ 0.05 for Wilcoxon Rank Sum Test.
[b] Wilcoxon Rank Sum Test (critical $p = 0.05$).
[c] feet.
[d] ft^2.

Certified versus noncertified forests: an analysis of two public agencies

Our final analysis examined how forest certification affected FMG implementation on forest lands managed by the MNDNR and the USDA Forest Service. The MNDNR manages nearly 1.6 million hectares of forest land (1.1 million hectares of commercial timberland), whereas Minnesota's two national forests, the Chippewa and Superior, collectively manage

approximately 728,000 hectares of timberland. Both organizations have multiple use mandate, multi-disciplinary staff to implement land management activities, and robust planning processes and policies that guide the management of their forests. The MNDNR is dual certified under FSC and SFI, whereas the two national forests are not certified under any system. Thus, comparing these two ownerships that are similar in several important organizational respects and scale may provide a more direct assessment of how forest certification influences the application of good stewardship practices as reflected in the state's FMGs.

Table 6 contains the results of comparing FMG implementation on Minnesota's two national forests to MNDNR lands. Implementation of FMGs differed statistically among the two agencies in only one regard; rutting was more prevalent on DNR lands (whose lands are dual certified) than on noncertified national forest lands (i.e. 4.9% vs. 2.2%, respectively). In all other respects, there were no statistically significant differences in FMG implementation across harvest sites associated with these two public forest land management organizations.

Discussion

Our analysis found that FMG implementation rates for certified and noncertified forests varied, depending on which ownership groups were examined and whether and how ownerships were grouped together for comparison purposes. The largest number of significant differences in FMG implementation occurred when all forest ownerships were included. The analysis used the largest sample sizes and found significant differences among 11 of the 26 FMGs we evaluated, suggesting that adherence to FMGs is better on certified versus noncertified forests. Our findings are consistent with those of Hagan et al. (2005) and Simpson et al. (2011) in that when landowner types are lumped together and comparisons of certified to uncertified ownerships are made, better implementations of some FMGs are exhibited by certified ownerships.

As our analysis progressed from including all certified and noncertified MN forest lands to those of increasingly more similar and complex organizational structures (but also using smaller sample sizes), not only did the number of significant differences in FMG implementation go down, but in some instances the magnitude of the differences in FMG implementation rates did as well. For example, when all forest lands were compared, differences in compliance rates among certified and noncertified forests for cultural resources and endangered and threatened species checks were 46.9% and 46.3%, respectively. Compliance rate differences for these two FMGs decreased to 13.4% and 10.1% when NIPF lands were excluded, and no significant differences in the use of these two FMGs were found among the MNDNR and USDA-Forest Service, arguably the state's two most complex and organizationally similar forest management organizations.

Our analysis suggests that forest certification can influence FMG implementation but is likely just one of the several factors. When we compare large public land ownerships (MNDNR vs. national forests) we find essentially no difference in FMG implementation, suggesting that certification is not a necessary driver or factor for adhering to sustainability standards, which makes sense on public lands that have various laws and planning processes they adhere to. More likely, the amount and diversity of discipline expertise among

Table 6. Comparison of FMG implementation on harvest sites with and without certification on state (MNDNR) and federal (Superior and Chippewa national forest) lands. Percentages indicate correct use of FMG.

Forest Management Guideline (FMG) Metric	N	Dual Certified (State)	Not Certified (Federal)	p-value
Infrastructure not developed in filter strips	1,072	81.7%	82.0%	1.0000
Landing not located in filter strip	279	59.7%	58.3%	0.8727
Road not constructed within filter strip	206	79.8%	84.8%	0.6340
No erosion within filter strip	1,072	99.7%	100.0%	1.0000
No exposed mineral soil in filter strip	1,072	100.0%	100.0%	1.0000
No repeated rutting in filter strip	671	97.5%	100.0%	0.1462
No sediment reaching water body	853	99.6%	100.0%	1.0000
% Infrastructure compliance	217	61.9%	70.7%	0.3682
Water diversions & erosion control structures	986	86.3%	88.6%	0.4636
No avoidable water body crossings	1,019	91.9%	88.2%	0.1347
No repeated rutting (Upland)	214	99.4%	97.5%	0.3396
Avoid rutting of all resources on site	4050	95.3%	97.9%	0.0014[a]
Riparian management zone compliance	94	72.6%	85.7%	0.2636
Leave tree compliance (Net)	196	73.6%	73.0%	1.0000
Snag compliance	196	83.0%	81.1%	0.8105
Slash management compliance	312	72.5%	69.2%	0.6430
Coarse woody debris compliance	217	97.2%	100.0%	0.5870
Cultural resources check	190	95.5%	100.0%	0.6071
Endangered, threatened species check	186	96.7%	100.0%	0.5878
Observed % road infrastructure[b]	217	1.2%	1.0%	0.1037
Observed % landing infrastructure[b]	217	2.5%	2.0%	0.1142
Observed rutting severity (% of rutted feature affected)[b]	159	10.0%	7.5%	0.1611
Observed riparian management zone width[b,c]	68	54.8	44.8	0.1267
Observed riparian management zone residual basal area[b,d]	68	13.9	10.1	0.1153
Observed % of harvest in leave tree clumps[b]	196	10.5%	8.0%	0.6118
Observed leave trees per hectare scattered[b]	196	10.6	9.8	0.8268

[a] $p \leq 0.10$ or ≤ 0.05 for Wilcoxon Rank Sum Test.
[b] Wilcoxon Rank Sum Test (critical $p = 0.05$).
[c] meters.
[d] meters^2.

professional staff to carry out land management actions, importance and complexity of the forest planning process used, laws and policies governing forest use and management, and public awareness/oversight of land management activities have as much influence on FMG use as forest certification, possibly more. In other words, compliance with voluntary FMGs is likely for those forest ownerships that embody the characteristics described above even if their forest land is not certified (e.g. Forest Service). The opposite can also be true; adherence to FMGs can be found among those ownerships without these organizational characteristics since FMG compliance is a requirement to be certified. Future research will focus on the relative efficacy of certification and organizational factors in promoting FMG implementation.

Our results also suggest that lumping ownership types which have very different organizational structures, objectives, and professional expertise may be masking or obscuring the influence certification has on FMG implementation across different ownership types. We did not have certification information for the NIPF sites used in our study to be able to evaluate their influence on FMG implementation on NIPF harvests. Even if we had this information, the number of certified NIPF harvest sites we would have been able to use in our analysis would have been very small. Future research that compares FMG compliance on certified to noncertified NIPF lands would be an important information gap to fill, as Simpson et al. (2011) found the lowest implementation rates of FMGs among this landowner group.

Tables 4–6 indicate generally widespread FMG implementation across forest ownerships. In Minnesota, more than 20 years of FMG use and FMG training programs to loggers and natural resource managers have contributed to the elevated use of FMGs across all ownerships. Further, the existence of a strong organizational commitment within many public agencies and private entities aimed at implementation of FMGs means that the guidelines are effectively only voluntary for private ownerships.

Because overall implementation rates are generally high across all ownerships, substantial differences are only seen for a small subset of guidelines: ETS species checks, cultural resource checks, slash management, use of water diversion and erosion control structures, avoidance of water body crossings, and several guidelines associated with filter strip management. While limited in scope, these guidelines are important to forest and water quality sustainability. It can be argued these areas where significant differences are observed encompass an array of primary concerns which originally spurred the development of FMGs. In this context, observed differences in implementation rates may be highly informative to our understanding of the relative influences of certification on overall forest sustainability. A number of differences in FMG implementation were documented between certified and noncertified lands. The fact that fewer differences were found when NIPF lands (subject only to voluntary implementation) were excluded from the comparison may indicate that FMG use is more homogeneous on public ownerships. Indeed, when comparing implementation rates between two large agencies (state and federal) with similar levels of policy commitment and professional staff supporting guideline implementation, significant differences in implementation almost disappear. Differences in implementation related to institutional policy and availability of professionally trained staff, may also be highly informative to our understanding of factors contributing to forest sustainability.

Even though our analysis suggests the role that forest certification plays in promoting good forest stewardship practices diminishes with increasing organizational complexity, forest certification provides the most tangible way for forest landowners to demonstrate a commitment to sustainable forestry principles. It provides one (possibly the only) way of demonstrating to stakeholders (customers) and the broader public the owner's commitment to sustainable forestry principles and continuous improvement as assessed by independent third-party audits. This is very important to organizations where stakeholders and/or the general public lack confidence in the owner's commitment to these principles (Lähtinen et al. 2016; George et al. 2022). As was found by George et al. (2022) in a study of forest managers in the northeastern United States, gaining social license (reputation) to practice forestry was viewed as the most important reason to obtain certification.

Conclusions

This study is the first of its kind to take an in-depth examination of the relationship between forest certification and a forest owner's use of FMGs across a range of forest ownership groupings. It documented higher implementation rates on certified forests for nearly half of the FMGs we evaluated when all certified and noncertified MN forest lands were considered. This relationship became more tenuous as our analyses progressed from including all forest owners to only those that are increasingly similar and complex organizationally, finding both the number of significant differences in FMG implementation and often the magnitude of the differences in FMG implementation rates decreasing. When the state's two largest and organizationally most complex forest owners were compared, one whose forest land was dual certified under FSC and SFI and the other not certified, essentially no difference in FMG implementation was documented. Our findings suggest that for these ownerships, other organizationally driven factors beyond forest certification influence the agency's use of FMGs during timber harvesting operations.

Our analysis focused on just one requirement of forest certification, namely the application of a state's timber harvesting best management practices. Other certification standards such as adherence to applicable laws, rules, and policies; respecting Indigenous People's rights; and providing adequate community and stakeholder consultation, are also important indicators of a forest management system committed to the principles of responsible forest stewardship. Comparisons of rates of implementation of these standards between certified and noncertified ownerships would add new insight into additional roles that forest certification may play with respect to sustainable forestry practices.

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