



Agency Field Forester Perceptions of Changing Winter Weather Conditions and Their Impacts on Timber Sale Management During Frozen Ground Conditions in Northern Minnesota

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Received: 21 November 2024 / Accepted: 23 February 2025 / Published online: 17 March 2025
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Abstract

Focus group meetings with Minnesota field foresters were conducted to obtain their observations on how winter weather conditions have changed, and how these changes have impacted their work during the winter logging season over the course of their career. Foresters stated warmer winter temperatures and precipitation changes have generally led to less conducive conditions for winter harvesting. They indicated changing winter weather has substantially affected their work administering timber sales during the frozen ground logging season. This includes spending more time interacting with loggers and more frequent site visits to active logging operations, which has increased the stress level they experience during the winter logging season and reduced time for other job activities. Foresters stated non-weather factors are also affecting frozen ground harvesting such as poor timber markets and larger, heavier, and more productive logging equipment. Several tools, metrics, education, and training opportunities were identified that would help foresters address the challenges they face administering their organization's timber sale program during the winter logging season.

Keywords Timber sale administration · Climate · Timber harvesting · Field foresters · Winter logging · Focus groups

Study Implications Increasing winter temperatures and unpredictable precipitation patterns have created less conducive conditions for frozen ground timber harvesting in northern latitude states. Field foresters working in these areas are being impacted by the changing climate in several important ways, most notably in administering their organization's timber sale program. This includes spending more time interacting with loggers and making more frequent site visits to active logging operations, which has added more job-related stress. Additionally, foresters are concerned that the shorter and less predictable winter logging season is adversely affecting forest conditions both at the harvest site and across the broader forest landscape.

Extended author information available on the last page of the article

Introduction

Minnesota's forests are an important driver of the state's economy, with wood products manufacturing representing the state's fifth largest manufacturing sector. This industry annually consumes nearly 6 million tonnes of wood for the production of pulp and paper (55%), lumber (21%), engineered wood products such as oriented strand board (15%), and wood energy (9%) (De Pellegrin et al. 2024). Approximately 71% of the state's mechanized timber harvesting is done using conventional harvesting systems (i.e., feller-buncher, skidder), with the remaining accomplished using a cut-to-length harvester-forwarder system (27%) and chainsaw (2%). (Blinn and Nolle 2023).¹

Changing climatic conditions are having a pronounced impact on forest resources and the economic contributions they provide (Hermosilla et al. 2024). Research has found that increasing temperature and atmospheric CO₂ and changing precipitation patterns are affecting forest soil health (Raison and Khanna 2011), the extent and severity of wildfires (Flannigan et al. 2000), forest hydrology (Sun et al. 2024), and the extent (Yang et al. 2019) and composition (Bugmann and Pfister 2000) of forest ecosystems.

Research has documented that the effects of increasing atmospheric temperature in the northern latitude areas of the United States are more pronounced in the winter than summer. For example, in northern Minnesota, the average minimum winter temperature has increased 0.33°C per decade since 1895, more than 15 times faster than average daily summer high temperature. Additionally, the frequency of extreme low winter temperature events (−37° C) in the state has decreased 90 percent in the last half-century (MN DNR, 2025). An increase in wintertime temperature and decreased frequency of very cold temperature events can reduce the snowpack in northern latitude forests, leading to warmer soils and decreased frost depth.

Logging is often conducted during frozen soil conditions in many northern latitude forests to protect the soil, vegetation and roots from equipment operation on wet and sensitive sites that are susceptible to compaction, rutting and erosion (Contosta et al. 2019). In Minnesota, for example, approximately 53 percent of the timber is harvested during the winter (Blinn and Nolle 2023). An increase in wintertime temperature and decreased frequency of very cold temperature events can reduce the snowpack in northern latitude forests, leading to warmer soils and decreased frost depth that can, in turn, adversely impact winter logging operations (Lehtonen et al. 2019; Kilgore et al. 2024).

Field foresters have extensive knowledge of the forests they are responsible for managing and hands-on experience administering timber sales during the frozen ground harvesting season. The latter includes: 1) implementing a resource management planning process to identify stands where commercial timber harvesting is needed to accomplish silvicultural objectives; 2) preparing a tract for harvest that involves conducting an on-site timber appraisal, marking timber sale boundaries, identifying the location of harvest infrastructure (e.g., access roads, landings, skid trails),

¹ Percentages represent the percent of total annual harvest volume.

and specifying timber harvesting guidelines and other regulations to be used during harvest; 3) offering tracts for sale through public auction; and 4) overseeing active timber harvesting operations. As such, these individuals are an important source of information to better understand how changing winter weather conditions may be affecting winter logging operations and their responsibilities in overseeing these operations.

Few studies have explored foresters' perspectives and experiences in administering winter timber sales amid changing winter conditions. Rittenhouse and Rissman (2015) interviewed individuals in different professional capacities (including foresters) with knowledge of frozen ground logging in northern Wisconsin to better understand how forestry operations are affected by weather and frozen ground conditions. However, we were unable to find any research describing how foresters' responsibilities related to managing their organization's timber sale program during frozen ground conditions may have changed over time in response to changing winter weather conditions.

To address this information gap, we conducted focus groups with experienced northern Minnesota public agency field foresters. Our goal was to obtain their observations and perspectives about changing winter weather conditions over the course of their career, how these changes have affected their work as timber sale program administrators during the winter logging season, the issues and challenges they are dealing with, and strategies they are employing as a result of these changes in winter weather. To our knowledge, this study is the first to document these observations and perspectives and adds to our understanding of how changing winter weather conditions may be affecting winter logging operations in northern latitude forests of the United States.

Materials and Methods

Focus Groups

Data were collected through focus groups with northern Minnesota public agency field foresters. Focus groups are guided conversations commonly used in qualitative research to collect in-depth, rich narrative responses from study subjects (Krueger and Casey 2000). A feature and strength of the focus group approach is that it allows for dialogue between study subjects that can lead to additional insights and ideas through the group interaction.

The questions that guided the focus group discussion were developed by the study team based on a review of the literature and knowledge of Minnesota field forester winter timber sale activities. After the study team drafted and iteratively discussed several rounds of potential focus group questions, a finalized list of questions was created (Table 1). A short questionnaire was also developed to obtain background data on the foresters who participated in the focus groups. The authors' institutional review board reviewed and approved the questionnaire protocol.

Focus group participant recruitment was purposeful, as is the convention recommended by Krueger and Casey (2000), to ensure that study participants have

Table 1 Focus group questions

1. Looking back over the many years that you have been designing and administering timber sales in Minnesota, what, if any, weather-related changes have you observed during the winter, frozen ground logging season?
2. Have these weather-related changes impacted how you plan and design timber sales that will be operable during the winter logging season and, if so, describe the impacts you've experienced?
3. In response to any weather-related changes and impacts, what, if any, modifications have you made in the planning, design, and administration of your timber sales that will be operable during the winter logging season?
4. Have you observed any nonweather-related changes that have had a positive or negative impact on planning, designing and administering timber sales in Minnesota during the winter logging season?
5. Has the frequency or nature of your interactions with loggers changed over time regarding winter logging season operations and, if so, in what way?
6. Are there post-harvest site or landscape-level conditions that have changed due to winter-weather related changes and, if so, which ones and in what way?
7. What, if any, additional training and resources have been provided or you wish were available to help you more effectively plan, design, and provide on-site administration of winter only timber sales?
8. Have winter weather-related changes impacted the planning, design and administration of your timber sales beyond just the winter logging season and, if so, what are they and what changes have you made to address these impacts?

the desired experiences and perspectives. Focus group participant recruitment was based on employment directories provided by the MN Department of Natural Resources' (MN DNR) Division of Forestry and 15 Minnesota county land departments. State and county-administered forests comprise 39% of the state's 15.8 million acres of timberland and 62% of the timber volume harvested per year (De Pellegrin et al. 2024). Only field foresters and forestry technicians (hereafter 'foresters') with at least 15 years of field timber sale administration experience in northern Minnesota were considered as potential focus group participants. We focused on 'experienced' foresters because of their field-based observations of winter conditions and operations over many years.

Sixty-five foresters were invited to participate in one of the six focus groups, 33 of which agreed to participate. The six focus groups were held in May 2024. Each focus group contained a mix of MN DNR and county foresters. Focus groups ranged from four to seven participants. Each one-hour focus group was audio-recorded using Zoom with the permission of the participants.

Thirty of the 33 participating foresters completed a short, on-line questionnaire administered at the end of each focus group meeting. Descriptive information from the survey of focus group participants is contained in Table 2. On average, the foresters who completed the survey had 22.5 years of experience administering timber sales, had administered 31 timber sales during the last three years, and 70 percent of them had more than half of their timber sales designed for winter harvest operations.

Data Analysis

The audio-recorded focus groups were automatically transcribed via Zoom. One researcher led all six focus groups, while the other two observed. The data were

Table 2 Summary of attributes of field forester focus group participants who completed the on-line questionnaire

Respondents ¹		Years Administering Timber Sales			Timber Sales Administered During the Last 3 Years ²	Percent of Timber Sales Designed for Winter Operations in the Last 3 Years ³			
MN	County	Mean	Max	Min		< 25%	25–50%	51–75%	> 76%
DNR									
17 (3)	13 (2)	22.5	36	15	31	7	23	37	33

¹ number of forestry technicians are in ()² mean number of timber sales administered³ percent of respondents

inductively analyzed using open coding to identify and analyze patterns in qualitative data consistent with thematic analysis procedures (Holton 1973; Braun and Clarke 2006). The study team used an iterative process to identify and refine emergent codes, themes, and subthemes in the data. In the first step, all three researchers read the transcript and listened to the recording of one focus group and individually identified themes.

After a discussion among the study team, a consensus set of themes emerged. In the second coding phase, each of the researchers listened to/read the transcript from one additional focus group using the consensus set of themes to determine whether coverage of all the major concepts was captured by the current set of themes. Sub-themes were also developed in this coding phase. In a second study team discussion, themes and sub-themes were discussed and refined. All researchers then reviewed the remaining four focus groups with the consensus themes and sub-themes to determine whether additional themes or sub-themes were needed. In a final coding step, one of the researchers analyzed the full set of focus groups with the themes and sub-themes, resulting in a modest number of refinements.

Direct quotes are used to illustrate the major themes and subthemes that emerged from the focus groups. The selected quotes highlight either shared perspectives among participants or different aspects of a common theme or subtheme (Krueger and Casey 2000). A code is included at the end of each quote to indicate whether the comment was attributed to a state (S) or county (C) field forester and whether the individual was a forester (F) or forestry technician (T). For example, [CT] indicates the quote came from a county forestry technician.

Results

Perceptions of Changing Winter Weather Conditions

Focus group participants shared their perceptions about changing winter weather conditions they have observed since the beginning of their forestry careers related to two main themes.

Temperature

Participants generally perceive that nighttime temperatures are not as cold today as they were earlier in their career. As described by one forester, *“It seems like the nightly lows in the heart of winter don’t just seem to get as cold as they would before. Those really cold nights...it just doesn’t seem like that happens as often.”* [SF]. Foresters also indicated that the onset of cold winter temperatures were starting later in the winter and that consistently below-freezing temperatures were less reliable. Additionally, foresters stated that they are not seeing extended stretches of very cold temperatures. One forester described their sentiment this way, *“Those good cold spells that we usually get in the heart of the winter in January don’t seem to be happening. You can’t count on a week or two of 20 below (-29 C) anymore.”* [CF].

Precipitation Changes

Foresters shared several perspectives regarding winter precipitation. Some felt that snowfall has decreased in the years they have worked as foresters. However, the more common perception was of greater variability and/or less reliability in the amount of snowfall. One forester said, *“We’re all over the place with snow. There are some years where there’s no snow... there are other years where there’s so much snow that the ground can’t freeze.”* [SF]. The foresters also talked about winter rain events, which they felt was a new phenomenon. As one forester described it, *“Very seldom did you have a bad winter. Rain in the wintertime, these warm winters...that kind of stuff just wasn’t there.”* [CT].

Weather Impacts on Winter Logging Season

Focus group participants generally agreed that changes in weather conditions have delayed the start of the winter logging season. Many foresters referenced late November as a historical benchmark when winter logging infrastructure development began in their area. They believed in recent years the date where the ground can support the development of winter roads and landings has been delayed a month or more. As one forester put it, *“Early on, we were starting to think about plowing or putting in roads or infrastructure for winter harvest when the deer season ended in November and hoped they were operating by the third week in December. But now it seems like logging starts close to the first of January.”* [CF]. Many also felt spring breakup, that period towards the end of the winter logging season when frozen ground conditions are beginning to deteriorate, is starting earlier and extending over more days than it used to. Taken together, the vast majority of foresters concluded the length of the winter logging season is getting more compressed since the time they started their career, as illustrated in the following comment, *“I would say from the 1990s until now, we’ve lost a month of wintertime to freeze down sales.”* [CF].

Several foresters believe the predictability of the winter logging season has changed over time, noting that winter has become less consistent in recent years. They feel this inconsistency pertains not only to the start and end of the winter

logging season, but also to the dependability of having frozen ground conditions throughout the winter logging season. The following comment by one forester is illustrative of this sentiment, *“Year to year, I don’t think winter logging is as consistent as it was 15 years ago.”* [SF]. A major point of discussion among foresters regarding how changing weather conditions have impacted the winter logging season was in regard to the timing of the first significant snowfall and the onset of cold temperatures. Many remarked how they used to be able to freeze down their access roads to lowland timber sales before the winter’s first big snow event. In recent years, however, the timing of the first large snowfall and cold weather has been reversed. Foresters stated that they are more frequently getting a large amount of snow before the ground starts freezing than in the past. Additionally, they stated the milder winter temperatures in recent years have made it much more difficult for the soil to stay frozen once there is a lot of snow on the ground. One forester described the sentiment of focus group participants this way, *“You’ve basically got one chance. If we get a lot of snow right away, it’s over for the winter.”* [SF].

Winter Weather Impacts to Timber Sale Program Management

Focus group participants described a variety of ways in which winter weather conditions since they began working in the field have affected their timber sale program management activities.

Timber Sale Planning

Foresters stated that changing winter weather conditions have had minimal to no effect on the timber tracts selected for harvest. They indicated tracts are selected for harvest through their agency’s resource management planning process to accomplish specific silvicultural objectives, often a year or more ahead of time, and that changing winter weather has not influenced which stands are selected. Forester comments indicative of this sentiment include, *“We haven’t really changed what we’re doing. We have our target goals of acres that we want to treat.”* [ST] and *“I don’t plan ahead because of the weather any differently.”* [CF].

Timber Sale Design

Foresters had varied opinions on the degree to which changing winter weather has influenced how they design timber sales that can only be operated on when the ground is frozen. A few stated there has been no impact. As one forester put it, *“I just let the resource dictate the design.”* [CF]. Yet, most focus group participants described several changes they have made in how timber sales are designed in response to warmer winters. Many commented that the boundaries of their timber sales are now more likely to avoid low areas where frozen ground conditions are often tenuous. One forester summarized this sentiment this way, *“I’ve been more conservative of where my lines go. Now I may make my buffers a little wider.”* [SF]. Focus group participants also described how they are giving loggers more flexibility

in wet areas that are part of a timber sale. As one forester put it, *“If we’ve got some wetland or adjacent lowland inclusions in an upland sale, we’re more flexible to just let them leave it. Especially if it means that coming back will trash the ground and there’s not a lot of volume.”* [CF].

Several focus group participants commented on how they are now giving more attention to the placement of reserve areas (i.e., areas within the sale boundary where timber harvesting is prohibited) and site infrastructure within the sale boundary and how loggers should access the site. *“One of the things we’ve been trying to do is better placement of the reserves to avoid a bottleneck for access so we don’t travel over the same spot over and over again. Open a little bit of territory to get the equipment in seems to be making some difference.”* [SF].

Foresters also noted they have been more intentional about combining lowland and upland stands in a timber sale. The term ‘punishment sales’ was used by several focus group participants. A punishment sale is a timber sale that contains lowland timber along with timber located on well-drained, upland soil. They stated loggers historically did not like these sales because of the low volume and/or quality timber that is often associated with these lowland areas. However, changing winter weather conditions have made these sales more attractive to many loggers. As one forester described the practice, *“When I first started, sometimes we would put those punishment sales, sales with low volume, with a really good sale. Loggers didn’t like that, because that’s how we were selling the bad sales. Now, I’m told by loggers it’s actually a good thing to have some of those sales because they like to have something close by they can harvest, something they can make money on and at the same time they can have equipment trying to freeze down the other low volume, lowland sale.”* [CF].

Yet not all foresters shared this sentiment. Some stated they are reluctant to combine upland and lowland timber into a single timber sale out of concern loggers do not want to buy a sale that includes lowland areas and/or they will not be able to harvest the lowland timber. As stated by one forester, *“When it comes to putting sales together, we might second guess throwing in those smaller adjacent stands that are in lowland because chances are it’ll make the stand less sellable. They won’t want to come back for that lowland piece if they’re able to cut the upland during non-frozen conditions.”* [SF].

Foresters said they are giving loggers more flexibility on the low ground timber within a timber sale than they have in the past. One strategy that was repeatedly mentioned was breaking the timber sale into distinct blocks. One forester described the practice this way, *“We’ve been cutting some sales into two different cutting blocks now, so basically making it like two sales. They can come in and only pay for half of the sale that can be accessed during dry conditions when it’s not frozen and then save the lowland stuff for the next year or even the year after that when it does freeze.”* [SF]. Foresters also mentioned they are now more frequently making the timber located on the wet portions of the timber sale an optional purchase. By doing so, this allows the sale purchaser the option to buy the timber if ground conditions allow it to be harvested without having to pay for the timber upfront when the tract is purchased.

Timber Sale Administration

Foresters discussed several ways in which the administration of timber sales has changed in response to changing winter weather conditions over the course of their career. Numerous focus group participants stated they are granting extensions to their timber sale permits more frequently than in the past. One forester characterized the practice this way, *“In 7 out of 11 last years, we’ve offered free frozen ground extensions to our 3-year permits.”* [ST]. Others commented that due to the high likelihood of having to grant extensions to timber sale permits due to poor winter logging conditions, they now automatically extend the length of a winter-access timber sale permit. *“Any winter access sale is going to be an extra year in length. So instead of the standard three years, it’s going to be a 4-year permit, just so we can give the loggers an extra year to try to get in there because of the weather patterns.”* [SF].

Foresters reported they are spending more time than they used to interacting with loggers on the harvest site prior to when harvesting begins. This often involves walking the site with the logger to point out concerns such as potentially difficult areas to operate in and mitigation measures to minimize rutting and soil compaction problems. Others mentioned they will often suggest how the logger might operate the sale if it appears frozen ground conditions are not ideal, as stated by this forester. *“When I open up a sale that’s winter and it’s not looking like it’s going to freeze up anytime soon, I encourage them to fell in advance and let it sit for a while and not forward or skid that area right away...stay on the high ground and let that stuff sit a little longer.”* [ST].

We also asked foresters about whether/how the frequency and nature of their communication with loggers is different in response to changing winter weather conditions. Most agreed they interact more with loggers during winter logging today than when they first started working. As stated by one forester, *“When I first started, you’d have a winter sale and it would be totally frozen ground. I’d say, ‘Go ahead, there really isn’t much to worry about with the ground disturbance.’ And now, it’s ...a lot more discussions with the logger. There’s a lot more communication on a typical winter sale.”* [CT]. Others commented that challenging ground conditions during winter require the forester and logger to work in partnership more closely than they have in the past. *“Loggers and foresters need to work together as a team and make sure that we’re doing a good job. When we have marginal sites, we have to work together and be willing to try this, but we have to make sure that we’re willing to shut down if we run into issues. You need good communication...be upfront with them.”* [ST].

In addition to communicating more frequently during the winter logging season, foresters talked about how changing winter weather has required them to be at active logging operations more frequently than in the past. As stated by one forester, *“I think there’s much more supervision going on, especially when we have a soft winter. You may have to go there every day.”* [ST]. Others described how the timing of when they visit logging sites has changed in response to warmer winter weather conditions. One example included the following, *“I like to go out in the afternoon and check them just because it’s going to be a little warmer. Sometimes when you*

go out in the early morning, you can't see the impacts because there might be fresh snow. So going out later in the day allows me to see if there's a difference as the day goes on." [SF].

Foresters talked about how having greater interaction with loggers and more frequent site visits to active logging job has impacted their work schedule. For many, it means frequently working outside normal business hours, as described by this forester, *"I've always told [loggers] that if they have questions, call me anytime between 7 a.m. and 8 p.m., even if it's on a Saturday if they're not sure of what to do. I always made myself available."* [ST]. Others stated they are helping loggers in ways they never did before, such as this participant, *"If I know a road is going to be a problem, I'll get my snowmobile out of the back of my truck and pack the road to help start that process of freezing down. I've done that numerous times."* [SF].

Foresters also described how the additional hours they work during the winter logging season is reducing the time they have for their other core responsibilities such as forest inventory and resource assessment. As one individual put it, *"When you have active logging jobs to administer, everything else takes a back seat."* [CF]. Focus group participants talked about the need to be organized, strategic, and innovative to make sure they are not neglecting their other work responsibilities due to the increased workload during the winter logging season. One forester stated it this way, *"Yeah, it's gotta give somewhere. We only work 40 h a week. So yeah, you know less time setting up sales. However, you figure out how to cut corners, you know. Maybe use more natural boundaries where you can. And it's really helped."* [CF].

Several focus group participants commented on the need to be more flexible when overseeing winter logging operations than they were in the past, given the more dynamic and uncertain ground conditions during the winter logging season. As one forester put it, *"We're being more flexible. If a logger wants to try something and I don't think it's unreasonable, I'm going to tell him to try it. And if it works, it's good for them and good for us. If it doesn't work, they're going to have to pick up and move somewhere else."* [CF].

Foresters also described how loggers have adapted to changing winter weather conditions. For example, loggers are doing more work at night to capitalize on colder temperatures and ground conditions more suitable to harvesting operations. One forester commented, *"I've had multiple loggers switch when they're operating. They'd be trucking and hauling in the middle of the night and then quitting like around 9 or 10 the next morning."* [SF]. Foresters have also observed loggers more frequently putting wood mats, wood chips, and slash on roads, skid trails, and landings to extend late season roads and reduce ground compaction and rutting.

Foresters talked about how they can sometimes feel a lack of organizational support for actions they may want to implement on the ground, in part because loggers are increasingly well-connected politically to agency administration, industry and local legislators. One forester described the lack of support this way, *"The ability to be supported by [agency] leadership and to actually halt an operation has dwindled. There could be an issue in the woods, and you have to*

shut someone down or you have a conversation with them and they don't like the direction it's headed. The issue sometimes gets to [my administration] before I get back to the office." [SF].

Foresters also described how the level of stress they are experiencing has increased in recent years due to poorer winter logging conditions. One focus group participant summarized it this way, *"There's a lot more stress than there used to be. Sales get put off and extended, so loggers have a backlog of sales to always catch up on. Everybody's working lots of hours and 7 days a week."* [CF]. Several also mentioned that most of the logging in their area has to be conducted when the ground is frozen, and that heavy reliance on winter logging increases pressure and stress on both foresters and loggers. *"The logging in this area is done in the winter...that's the season. There's more money and more wood moving in a shorter time span, so it's certainly ratcheted everything up...there's absolutely more conflict on the administration side, as a result of that. There's the business pressure and then the environmental pressure...it all ramps up."* [SF]. One forester summed up the increased stress he feels during the winter logging season this way, *"When it comes to administering winter timber sales, I buy a big bottle of Advil because it creates more headaches."* [CF].

Site and Landscape-Level Impacts

Foresters were asked to describe how changing winter weather conditions may be impacting individual logging sites, as well as broader changes across the forested landscape.

Site Impacts

Many focus group participants noted that soil compaction and/or rutting were occurring more frequently today during winter logging operations than in the past. Others noted that the period of concern when rutting is noted has expanded to the entire winter, whereas it used to be just early and late winter when frost quality is less certain. As described by one forester, *"I've been noticing more rutting. Things that would normally happen early and late. We're running into those issues all winter."* [CT].

Foresters also described a range of adverse effects on post-harvest tree regeneration. One forester summarized the impact on regeneration this way, *"When we had no frost, you can go back to some of those sales now and still see the ruts. The rutting and compaction have definitely impacted regeneration."* [ST]. Several foresters also noted that increased compaction and/or rutting during winter has reduced aspen regeneration where vegetative reproduction through root suckers is common. A few foresters described warmer winter weather as having minimal impact to even a positive impact on post-harvest regeneration.

Many foresters stated that as logging equipment becomes larger over time, it often causes site-level impacts to infrastructure. One described the impacts this way, *“The equipment they’re buying is definitely getting bigger and the footprint that they want, like the landing size, is also getting bigger. We want to keep it as small as possible, so we’re trying to accommodate their equipment to some degree.”* [CF]. Yet some focus group participants stated they have not observed a change in site impacts over time, attributing the lack of impact to the loggers they work with. As described by one forester, *“Not seeing much with post-harvest changes. We explain to loggers what we’re looking for and how they can help us do that management. They do a pretty good job of incorporating those ideas into their harvest methods.”* [SF]. Equipment options that made harvesting operations lighter on the land were also identified by several as a reason for the lack of site impacts, *“More loggers are getting [skidders with] flotation tires and, you know, they have processors and forwarders with tracks. They can do more without rutting.”* [CF].

Landscape-Level Impacts

Foresters stated that when a tract of timber that is offered for sale goes unsold, management objectives (e.g., improve forest health and wildlife habitat, provide income) may not be met. They noted the tracts that are most likely to go unsold are those that have poor markets for their wood, require frozen ground harvest conditions, and/or substantial winter road development costs. Herbivory can also impact a timber stand’s ability to regenerate during winters when snow cover is minimal, especially on young pine plantations in areas with high deer density. Similarly, insects can increase mortality within a timber stand, thus reducing harvest volume. Several foresters described the challenges managing black spruce stands infested with dwarf mistletoe (*Arceuthobium pusillum* Peck). One participant described the challenge this way, *“I try to manage stands that have mistletoe back into production. If a winter road is required, then they are likely not going to sell.”* [SF].

Providing a diversity of habitat across a landscape is important for managing wildlife. Foresters expressed concerns about how changing winter weather conditions were affecting the distribution of age classes across the landscape. One focus group participant summarized the challenge this way, *“When nothing gets cut for five years due to poor winter weather and then there’s finally a good winter, all of it gets cut in one year. That makes it tough to manage for different age class structures.”* [SF].

Impact on Summer Logging Operations

Foresters described how weather-induced changes to the winter logging season has affected summer logging operations. In contrast to summer access timber sales that can be harvested year-round, many northern Minnesota timber sales are commonly assigned to winter-only operations due to their soil type, access

limitations, or concerns about impacts to endangered and special concern species. Some foresters indicated that loggers are now frequently cutting more of their summer wood inventory in the winter when their frozen ground sales are not accessible or operable. This can cause a spillover effect for a logger's summer operations as they need to purchase more timber sales to replace the ones that allowed them to keep operating during the winter. The combined increased demand for and limited availability of summer access timber for purchase makes these tracts more expensive, as noted by one forester who said, *"I think they're overpaying for summer wood now which has always been a premium, anyway."* [SF]. Focus group participants described how their agencies are trying to accommodate this increased demand for timber sales that can be harvested year-round. As an example, the MN DNR held a special timber sale auction in 2024 that consisted entirely of summer access timber tracts. All but four of the 29 tracts sold, with 13 tracts bid up more than 100% and two bid up more than 200% above their appraised price (MN DNR [2024](#)).

Strategies to Address Issues and Impacts

Foresters were queried about strategies that would be helpful in addressing the challenges and impacts they face in administering their organization's timber sale program, in light of the changing winter weather conditions they are observing. The strategies they offered were centered on two themes.

Tools and Metrics

One topic of discussion related to tools or metrics that could be helpful to foresters as they design and administer winter timber sales. Specifically, foresters talked about the need for an instrument or quantifiable guidelines that could determine when rutting would occur as a function of soil type and frost depth. One forester described the need this way, *"I've said for a long time that I wish we had a soil probe and we had standardized numbers that said this situation will result in rutting."* [SF]. With respect to guidelines, foresters characterized the need for quantifiable guidelines to determine how many inches of frost are needed to support specific equipment operating on certain soil types. *"Instead of telling loggers there's not enough frost based on my gut feeling, it'd be nice to have something to reference."* [CF].

Education and Training

Perspectives were shared about the need for field-based information exchanges between foresters and loggers so each can better understand the range of winter weather impacts on winter logging activities, as well as leverage each group's knowledge to identify new or creative ways to access and harvest winter-only sites. One participant suggested the information exchange this way, *"A workshop where foresters and loggers can go out to sites together to discuss why a site is laid out the way it is, and loggers should have input in those conversations."* [CF]. Others indicated loggers and foresters should

conduct audits of recently-completed timber sales together. In addition to suggestions for forester-logger information exchanges, recommendations were also made about peer-information sharing activities among foresters to exchange knowledge, strategies, and best practices. One forester described the interaction this way, “*If we have issues, we get our staff together and go look at the site to discuss it and get on the same page of determining what is acceptable and what isn’t. [CF].*” Foresters emphasized the importance that experience with winter sales in different conditions imparts and the value in sharing that experience among peers. One participant summarized it this way, “*Working with other foresters...having them tell us their stories and sharing their experiences and dealing with difficult situations.*” [ST].

Discussion

Perceptions and Empirical Data

The field foresters who participated in this study described how winter weather conditions have changed over the course of their career, and how these changes have impacted the winter logging season and their responsibilities in administering their agency’s timber sale program. With regard to changing winter weather, all of the participants described warmer winters, with several benchmarking their observations to minimum nightly temperature because of its importance in increasing the frost depth needed to access and harvest lowland species. Figure 1 shows how the

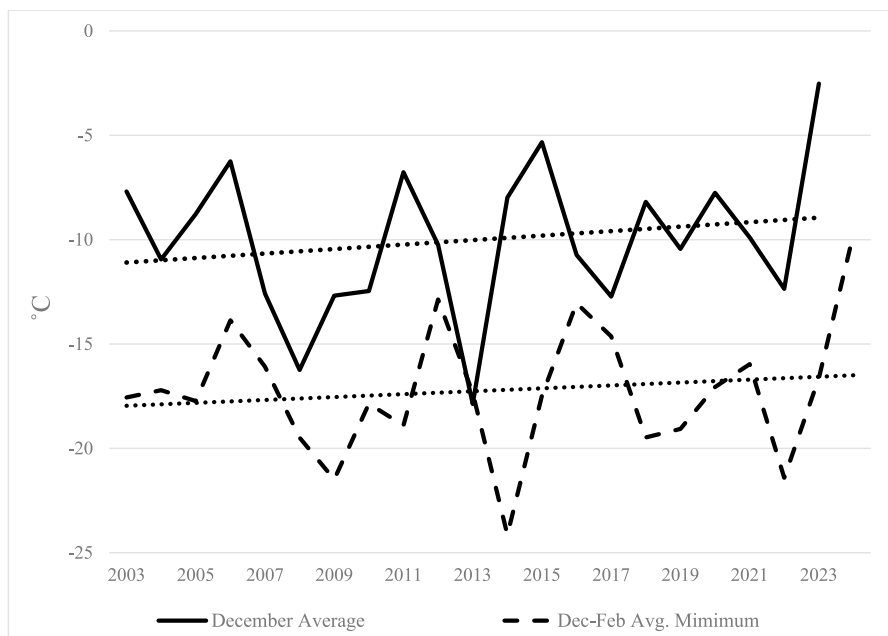


Fig. 1 Northern Minnesota average December temperature (upper) and average December-February minimum temperature (lower). The dotted lines represent trend lines. (MN DNR 2025)

average minimum December–February temperature in northern Minnesota has changed from 2003–2023, the period that approximates the average number of years our focus group participants had been administering timber sales. Their observations are confirmed by this data, which shows the average minimum temperature increasing at a rate of 0.69°C per decade (MN DNR 2025).

Foresters also described how the winter logging season seemed to be starting later than it did earlier in their career. They felt the temperature at the start of winter was not as cold as it used to be, delaying the time when loggers could begin accessing and harvesting their winter timber sales. Figure 1 shows the average temperature in December in northern Minnesota from 2003–2024. While the average December temperature has fluctuated from year to year (also reported by several focus group participants), the long-term trend was an increase of more than 0.83°C per decade (MN DNR 2025), supporting their sentiment that the start of the winter logging season has been delayed. In years where deep snow precedes the arrival of cold temperatures, the start of the winter logging season can be further delayed.

Foresters also talked about how the number of days conducive to winter logging has been decreasing over time. A proxy metric for the winter logging season length is the number of days when northern Minnesota roads are subject to increased load limits for hauling. The MN Department of Transportation (MN DOT) increases winter load limits when it forecasts extended freezing temperature and removes these additional limits when the agency's cumulative thawing index forecasts a period of extended daily thawing (MN DOT 2025). Figure 2 shows the number of days when the winter seasonal load limit has been in effect in northern Minnesota since the

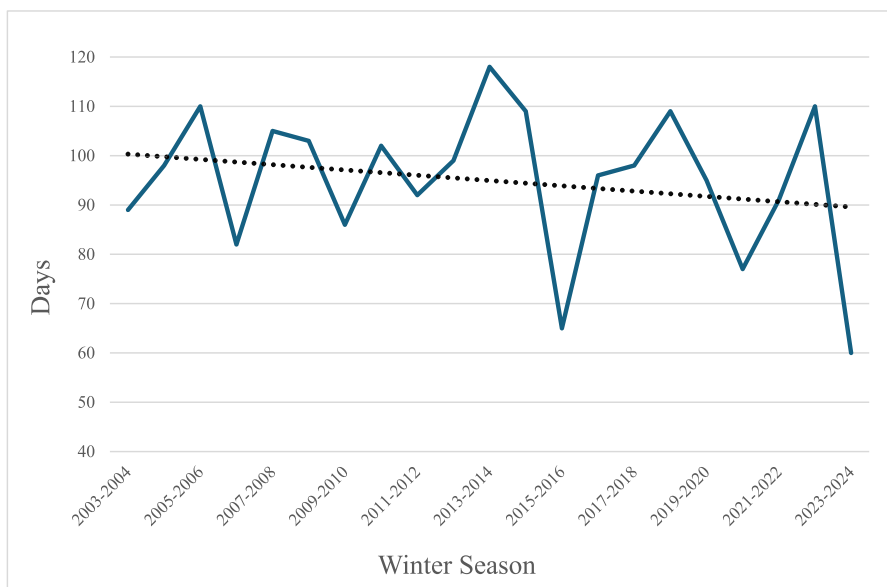


Fig. 2 Number of days of when the winter seasonal load limit is in effect in the MN Department of Transportation's Northern Region from the 2003–2004 to 2023–2024 winter seasons. The dotted line represent a trend line. (MN DNR 2025)

2003–04 winter season. This data shows that over the last two decades, the number of days with increased winter road limits has decreased an estimated ten days, again confirming the observations made by the field foresters who participated in our study.

While regional temperature and precipitation data provide useful information about changing conditions over a wide area, they may not be detailed enough for foresters making site-specific decisions where differences in soil texture, landscape and hydrology, frost depth, logging equipment characteristics, etc. influence site impacts. Toot et al. (2024) provided considerations for planning, and practices that may be useful for protection of natural resources and continued forest operations in the changing climate.

Foresters identified the need for a tool or quantifiable guidelines to predict rutting based on soil type and forest depth, helping them assess operability under site-specific conditions. Nash et al. (2020) suggest pounding a frost probe (a 1.3 cm steel rod with one end sharpened to a 30-degree cone) or rebar into frozen soil to determine the depth of the frozen zone. The depth of that zone is determined by pounding the probe into the soil until it breaks through the frozen zone. Distributing a minimum of 30 sample points across the planned travel areas should provide a reliable sample (Stone 2002).

There is little available data on the bearing strength of frozen soils to support specific equipment on soils in northern Minnesota. While Stone (2002) suggested minimum frost depths for mineral soils ranging from 7.5 cm for small equipment to 15 cm for large equipment, equipment has increased in size since that study was published. Lehtonen et al. (2019) reported that 20 cm of frozen soil was sufficient to support cut-to-length harvesters on peat soils. Nash et al. (2020) provided examples of frost and/or snow depth standards to mitigate impacts from winter logging in four national forests.

Comparing Field Forester and Logger Perspectives

We compare our findings to results of a companion study of northern Minnesota logging business owners and their perceptions about changing winter weather conditions and how these changes have impacted winter logging operations (Kilgore et al. 2024). The questions asked of the focus group participants in both studies were designed to assess whether and the extent to which they had observed weather-related changes during the winter logging season over time and how these changes have impacted winter logging operations. Beyond these observations, the focus with field foresters was on how their observed changes have affected their responsibilities in administering their agency's timber sale program during the frozen ground harvest season. With logging business owners, the focus was on how their observed changes have affected their winter business operations. The similar nature of these two studies with respect to their subject matter and geographic scope provided an excellent opportunity to identify and describe important similarities and differences between the observations of foresters and loggers.

All foresters and most loggers acknowledged that they had observed weather-related changes during the winter logging season with cold temperatures beginning

later after the first large snowfall, with winter rain being more common today. A few loggers, however, did not perceive these trends, indicating a lack of any observed change in winter weather patterns over time or that any changes they had observed were short-term and cyclical.

Individuals in both groups indicated the length of the winter logging season has become shorter due to the lack of frost buildup in the soil before the first snowfall that has delayed the start of winter operations. Foresters and loggers also noted how nonweather-related changes had affected their work. For example, both groups indicated the size, weight, and productivity of logging equipment had increased over time and that dual tires and tracks are used more commonly today to reduce ground pressure and rutting while enhancing the opportunity to keep working on unfrozen soils. Both groups also reported an increase in the use of slash and wood mats to reduce compaction and rutting.

Foresters and loggers similarly reported several other nonweather-related changes impacting winter logging operations, although the changes each described were specific to their work. Loggers reported their winter timber sales require more time and effort today to construct and maintain access. They also mentioned the portfolio of their winter timber sales was changing by purchasing more total sales and/or summer sales to harvest during winter, buying sales that require less access development, and focusing their procurement on timber sales that better align with their equipment characteristics. Loggers further noted that their winter timber sales are smaller in size and have more regulations. Limited workforce availability also constrained the ability of some businesses to increase their production during the winter.

Foresters, in contrast, cited poor markets, especially for some lowland species that are primarily harvested during the winter, as the primary nonweather-related concern that is limiting their ability to manage those species. Foresters also noted that the increased productivity of logging equipment required them to visit active operations more frequently than in the past. They stated the additional time they spend administering active logging operations, combined with a shorter winter logging season and poorer winter logging conditions, have increased the level of job-related stress they are experiencing.

One area where foresters and loggers saw things differently was regarding the need to be more flexible in light of changing winter weather. Both foresters and loggers saw themselves as flexible and willing to try new approaches or techniques to deal with suboptimal winter logging conditions. Many foresters also described how loggers have been flexible and innovative considering these conditions. Yet, loggers did not mention that they perceived foresters similarly being flexible or innovative, especially when it involved the decision to shut down a logging operation over concerns about soil compaction and rutting.

Conclusions

This study is the first to document how the timber sale program responsibilities of public foresters working in northern latitude parts of the United States have changed in response to warmer temperatures and less predictable precipitation during the

winter logging season. Focus group participants described a range of challenges that they are experiencing when administering winter harvest sales in light of climatic, economic, policy, and other changes. While the authors are not aware of any statewide data that has assessed whether changing winter conditions may have impacted silviculture on Minnesota's public lands, study participants perceive that the increased difficulty in conducting winter harvests is affecting the forest landscape within their management area in several ways including through unmet silvicultural and forest health goals, increased rutting and compaction, and impacts to regeneration. The foresters who participated in the focus groups also described a range of strategies that they are undertaking to assist them in more effectively addressing the challenges they face in administering their organization's timber sale program. Through increased flexibility and adaptation to the changing conditions, both foresters and loggers are striving to meet both silvicultural and harvest volume goals. Future research could explore how changing winter weather conditions influences other points in the wood supply chain of northern latitude forests as well as how winter harvesting operations and sales administration may need to continue to adapt if winter temperature and precipitation events continue to evolve. As one focus group participant said, *"We're going to have to be versatile for whatever else comes in the future."* [CF].

Acknowledgements Funding for this study was provided, in part, by the Minnesota Agricultural Experiment Station through projects MIN-42-103 and MIN-42-117.

The findings and conclusions in this publication are those of the author(s) and should not be construed to represent any official USDA or US Government determination or policy.

Author contributions Dr. Kilgore assisted in developing the study methodology and focus group questionnaire, co-led focus group participant recruitment, led all focus group meetings, led data coding and analysis, and led manuscript drafting.

Dr. Blinn assisted in developing the study methodology and focus group questionnaire, co-led focus group participant recruitment, participated in all focus group meetings, assisted in data coding and analysis, and participated in manuscript drafting.

Dr. Snyder assisted in developing the study methodology and focus group questionnaire, participated in all focus group meetings, assisted in data coding and analysis, and participated in manuscript drafting.

Data availability Due to an agreement of confidentiality provided by the authors to the individuals who participated in this study, the data underlying this article is not available.

Declarations

Ethics approval The authors acknowledge that in conducting the research described in this manuscript, they have followed the rules of good scientific practice as specified by the *Journal of Forestry*.

Conflicts of interest The authors have no relevant conflicts or competing financial or non-financial interests to disclose.

Research involving human participants approval The University of Minnesota's Institutional Review Board reviewed the list of questions used by the authors to guide the discussion of focus group participants and determined it was exempt from further review.

References

- Blinn, Charles R., and David A. Nolle. 2023. Status of the Minnesota Logging Sector in 2021. Staff Paper 268. USA: Department of Forest Resources, University of Minnesota. 113 p. <https://hdl.handle.net/11299/257129>. Accessed 8 Nov 2024.
- Braun, Virginia, and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3 (2): 77–101. <https://doi.org/10.1191/1478088706qp0630a>.
- Bugmann, Harald, and Christian Pfister. 2000. Impacts of interannual climate variability on past and future forest composition. *Regional Environmental Change* 1: 112–125. <https://doi.org/10.1007/s101130000015>.
- Contosta, Alexandria R., Nora J. Casson, Sarah Garlick, Sarah Nelson, Matthew P. Ayres, Elizabeth A. Burakowski, John Campbell, Irena Creed Catherine. Eimers, Celia Evans, Ivan Fernandez, Colin Fuss Thomas, Huntington, Kaizad Patel, Rebecca Sanders-DeMott, Kyongho Son, Pamela Temple, and Casey Thornbrugh. 2019. Northern forest winters have lost cold, snowy conditions that are important for ecosystems and human communities. *Ecological Applications* 29 (7): e01974. <https://doi.org/10.1002/eap.1974>.
- De Pellegrin Irene, Jeremy Fauskee, Scott Burns, and Donald Deckard. Minnesota's Forest Resources 2020. Department of Natural Resources; Division of Forestry. 99 p. <https://files.dnr.state.mn.us/forestry/um/forest-resources-report-2020.pdf>. Accessed 3 Jan 2025.
- Flannigan, Michael D., Brian J. Stocks, and B. Mike Wotton. 2000. Climate change and forest fires. *Science of the Total Environment* 262 (3): 221–229. [https://doi.org/10.1016/S0048-9697\(00\)00524-6](https://doi.org/10.1016/S0048-9697(00)00524-6).
- Hermosilla, Toxmin, Michael A. Wulder, Joanne C. White, Nicholas C. Coops, Christopher W. Bator, and Gordie W. Hobart. 2024. Characterizing long-term tree species dynamics in Canada's forested ecosystems using annual time series remote sensing data. *Forest Ecology and Management* 572: 122313. <https://doi.org/10.1016/j.foreco.2024.122313>.
- Holton, Gerald. 1973. *Thematic origins of scientific thought: Kepler to Einstein*, 504. USA: Harvard University Press.
- Kilgore, Michael A., Charles R. Blinn, and Stephanie A. Snyder. 2024. Perceptions of and adaptation to changing winter weather by logging business owners in northern Minnesota USA. *International Journal of Forest Engineering*. pp.1–10. <https://doi.org/10.1080/14942119.2024.2339553>.
- Krueger, Richard A., and Mary A. Casey. 2000. Focus groups: A practical guide for applied research. 3rd Edition. Sage Publications, Thousand Oaks, CA. 215 pages. <https://doi.org/10.17169/fqs-3.4.791>.
- Lehtonen, Ilari, Ari Venäläinen, Matti Kämäräinen, Antti Asikainen, Juha Laitila, Perttu Anttila, and Heli Peltola. 2019. projected decrease in wintertime bearing capacity of different forest and soil types in Finland under a warming climate. *Hydrology and Earth System Sciences* 23 (3): 1611–1631. <https://doi.org/10.5194/hess-23-1611-2019>.
- Minnesota DNR. 2024. Timber sales. [accessed 2024 Oct 31]. <https://www.dnr.state.mn.us/forestry/timber-sales/index.html>.
- Minnesota DNR. 2025. Climate trends. Minnesota Department of Natural Resources. USA. [accessed 2025 Jan 2]. https://www.dnr.state.mn.us/climate/climate_change_info/climate-trends.html.
- Minnesota DOT. 2025. Seasonal load limits. [accessed 2025 Jan 2]. <https://www.dot.state.mn.us/loadlimits/>.
- Nash, M., Napper, C., Page-Dumroese, D., Alger, R., Wagenbrenner, J., Tirocke, J., Amman, A., Courtney, A., Griesl, J. 2020. Winter logging for mechanical harvesting and fuel treatment operations. 2025–2806-NTDP. Washington, DC: USDA Forest Service, National Technology and Development Program. 40 p. <https://research.fs.usda.gov/treesearch/62108>. Accessed 13 Feb 2025.
- Raison, R. John., and Partap K. Khanna. 2011. Possible impacts of climate change on forest soil health. In *Soil Health and Climate Change*, 257–285. Berlin, Heidelberg: Springer, Berlin Heidelberg.
- Rittenhouse, Chadwick D., and Adena R. Rissman. 2015. Changes in winter conditions impact forest management in north temperate forests. *Journal of Environmental Management* 149: 157–167. <https://doi.org/10.1016/j.jenvman.2014.10.010>.
- Stone, Douglas M. 2002. Logging options to minimize soil disturbance in the northern Lake States. *Northern Journal of Applied Forestry* 19 (3): 115–121. <https://doi.org/10.1093/njaf/19.3.115>.
- Sun, Ge, Krishna Tiwari, Lu Hao, Devendra Amatya, Nig Liu, and Conghe Song. 2024. Climate change and forest hydrology in future forests. In *Future Forests* pp. 95–124. Elsevier. <https://doi.org/10.1016/B978-0-323-90430-8.00003-4>.

- Toot, R., Handler, S., Shannon, P.D., Amman, A., Blinn, C., Butler-Leopold, P., Shakun, J., Janowiak, M.K. [in press]. 2024. Climate change considerations for forest operations in northern forests. Gen. Tech. Rep. NRS-223. Madison, WI: USDA Forest Service, Northern Research Station. 39 p. <https://doi.org/10.2737/NRS-GTR-223>.
- Yang, Qinli, Heng Zhang, Wanshan Peng, Yaoyao Lan, Shasha Luo, Junming Shao, Dongzi Chen, and Guoqing Wang. 2019. Assessing climate impact on forest cover in areas undergoing substantial land cover change using landsat imagery. *Science of the Total Environment* 659: 732–745. <https://doi.org/10.1016/j.scitotenv.2018.12.290>.

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