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EXECUTIVE SUMMARY

The silvicultural practices applied within a given landbase are dynamic and respond to numerous social, economic, and biological drivers. Minnesota is unique in that the silvicultural practices occurring within the state have been surveyed periodically over the past two decades, allowing for an assessment of the general trends and status of practices. These assessments are also critical for examining how factors, such as the adoption of site-level guidelines or fluctuations in stumpage prices, affect the types of management employed across the landbase.

This study characterizes the status of silvicultural practices within Minnesota in 2008 and uses results from past surveys (1991 and 1996) to describe general trends in silviculture across ownerships and over time. A questionnaire regarding silvicultural practices applied in fiscal year 2008 was administered to all state, county, federal, industry, and Native American ownerships. Surveys included questions on silvicultural and harvesting practices such as regeneration practices used, extent and type of biofuels harvesting, use of site-level guidelines, and approaches to insect and disease issues. In addition, open-ended responses were collected on questions relating to general constraints most affecting the implementation of silvicultural practices.

Twenty-six respondents completed the survey with the respondent pool including 2 state, 2 federal, 14 county, 3 industrial, and 5 Native American ownerships. In addition, one nongovernmental organization involved with forest management also completed the survey. Collectively, the respondent pool ownerships covered 64% of the timberland in the state (9,865,694 out of 15,414,200 acres) and accounted for 67% of the estimated 2008 statewide harvest (1.97 million out of 2.92 million cords). The respondent harvest levels were similar to those reported during the 1996 survey; however, the statewide harvest levels were less than in 1996 (3.81 million cords). In addition, the harvest volume removed per acre of timberland in 2008 (0.20 cords) was lower than the harvest volumes in 1996 (0.25 cords).

Comparisons between 2008 and 1996 indicated that the relative intensity of silvicultural systems used had decreased, as the proportion of clearcutting (>5 acres) acres diminished and the use of patch clearcutting, seed tree, shelterwood, and single-tree and group selection systems increased. Nonetheless, clearcutting (>5 acres) was still the predominant type of silvicultural system employed across all ownerships with the average clearcut size at 29 acres. Most of the clearcut area on state, industry, and Native American lands was in clearcuts greater than 40 acres, whereas the clearcut sizes on other ownerships were more evenly distributed between clearcuts greater than 40 acres, 20 to 40 acres, 5 to 20 acres, and less than 5 acres. The percentage of clearcut areas with residuals increased slightly relative to 1996, with 80% of clearcuts >5 acres containing residuals compared to 77% in 1996. Residual trees were equally likely to be scattered individually across the site as they were to be arranged in clumps.

The amount of commercial thinning applied in 2008 within the state increased relative to 1991 and 1996 and comprised roughly 14% of the silvicultural operations on respondent ownerships. This practice was most prevalent on federal and industry lands and least

common on county lands. In contrast, the acreage of precommercial thinnings decreased relative to previous surveys, due in large part to a 59% decrease in the use of this practice on industry lands compared to 1996. Responses to open-ended questions suggested that this decrease was due, in part, to the operational constraints posed by residual trees to mechanized precommercial thinning operations.

Regeneration harvests relied primarily on natural regeneration (62,391 acres of natural seeding and sprouting); however, federal ownerships relied more heavily on artificial regeneration. Most natural regeneration was of vegetative origin (sprouts or root suckers), whereas artificial regeneration was primarily conifer species that were containerized planting stock. In comparison to 1996, the acreage of artificial regeneration increased substantially with an 84% increase in planted acres and a 78% increase in direct seeding acres (11,530 and 5,036 acres planted and directed seeded in 2008, respectively).

The prevalence of site preparation practices varied across ownerships, with the use of this practice declining considerably (47%) on industry lands relative to 1996 levels, and the application of this practice increasing on state and county lands (10 and 20%, respectively). Overall, the use of regeneration release practices increased from 1996 and was similar to the levels of application of this practice in 1991 (11,217 total acres of release treatments in 2008). The majority of release operations were manual release treatments, followed by ground-based and aerial herbicide treatments.

A total of 7,642 acres were sold as biofuels harvests across the ownerships surveyed in 2008, with the majority of that acreage on state and county lands. Biofuels harvests focused primarily on logging residues, although roundwood, submerchantable trees, and hard snags were harvested for biofuels on 20, 72, and 17% of biofuel sales, respectively. Most logging residues were largely collected from piles at landings, with only 21% of biofuels harvests involving a second entry into the stand to collect harvest residues.

Collectively, there has been a great deal of variation in the silvicultural practices applied across ownerships within the state over the last 17 years with the greatest differences existing between federal and Native American lands and the other ownerships surveyed. These differences reflect the lack of site preparation and chemical release treatments on federal and Native American lands and the correspondingly high level of mechanical manual release on these lands relative to other ownerships. In addition, federal ownerships have increasingly relied on artificial versus natural regeneration; a trend not observed on other ownerships.

With the exception of federal and Native American lands, the silvicultural practices among ownerships have shifted back towards those recorded in the initial survey in 1991. This shift is primarily due to higher levels of site preparation treatments used on county and state lands, accompanied by an increase in the acreage of release treatments. Collectively, these changes indicate an increased intensity of management related to the establishment of conifer species on the landscape. Nonetheless, these efforts are currently facing considerable obstacles due to increased herbivory of planted conifer seedlings, as indicated by the mention of this issue by numerous respondents. Future surveys will be

able to assess the impact of this issue on silvicultural practices, as well as the challenges posed by exotic and invasive species, changing climatic regimes, the emerging use of wood residue for energy wood, and budget constraints.

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Introduction

The silvicultural practices and systems being used within a forested landbase are reflective of a multitude of factors ranging from economic conditions, biological constraints, and political and social mandates (Bengston 1994). As a result, the types and ways in which silviculture is applied within a given region is dynamic over time. Moreover, recent global emphasis on forest certification programs and the use of site-level forest management guidelines has created a new suite of challenges and opportunities that silvicultural practices need to adapt to and work within. These programs and guidelines encourage the use of sustainable silvicultural practices. However, tracking the impact of these and other factors on the actual on-the-ground implementation of silviculture is challenging without periodic assessments of the status of such practices within a given region (Newsom et al. 2005).

Minnesota is relatively unique in that the status and trends of silvicultural practices have been periodically surveyed since the early 1990s (Jaakko Pöyry Consulting, Inc. 1992, Puettmann et al. 1998). These surveys have proven useful in assessing the influence of various factors on practices. For example, trends in the late 1990s indicated an increase in the levels of residual trees left on harvested areas, likely in response to concerns expressed during the early 1990s over the ecological impacts of forest harvesting (Puettmann and Ek 1999). In addition, increases in pulpwood stumpage prices during this period led to an intensification of practices, particularly on industrial landholdings, in which thinning and site preparation treatments increased. These and other insights from these surveys have been invaluable for informing policy initiatives and forest management within the state.

Since the last survey of silvicultural practices was administered in 1996, several important factors have emerged that have presumably influenced the way in which forests are managed within Minnesota and beyond. For example, Minnesota adopted a series of site-level guidelines in 1999 that are designed to promote sustainable management practices through provisions for the retention of habitat features such as leave (live) trees within clearcut harvest areas, as well as use of riparian buffers (MFRC 1999, 2007). Renewed interest in the use of forest-derived feedstocks for supplying bioenergy facilities in the region has also developed since the last survey was conducted (Becker et al. *in press*). Another important factor potentially affecting silvicultural practices has been the increasing use of ecological classification systems and geospatial data (i.e., geographic information systems) for forest management planning and implementation. In addition, the recent reduction in housing starts has had a significant impact on the region, reducing stumpage prices and the demand for raw materials, decreasing statewide harvest levels and increasing harvest levels on public lands (Jacobson 2008, Deckard 2009). Within the logging industry, there has been an increase in mechanization and a decrease in the number of small operations (Powers 2004). Finally, forest ownership patterns have changed with several large industrial ownerships converting to timber investment management organizations (TIMOs) and real estate investment trusts (REITs), as well as the emergence of nongovernmental organizations (NGO) forest owners, such as the Nature Conservancy. Collectively, these changes have important ramifications for the ways in which silviculture is practiced across the landscape; however, no formal long-

term evaluations on the impacts of these and other factors exists for Minnesota or other portions of North America. As such, the objectives of this study were to characterize the general trends in silvicultural practices from 1991-2008, as well as to summarize the current status of silviculture within the state.

Methods

In the spring of 2009, a survey of the silvicultural and forest management practices used in the 2008 fiscal year was developed, approved by the Institutional Review Board at the University of Minnesota, and administered (Appendix A). Overall, questions followed the same pattern and subject matter of the 1996 (Puettmann et al. 1998) and 1991 surveys (Jaakko Pöyry Consulting, Inc. 1992). The surveys consisted of sections to develop background knowledge on respondents, silvicultural practices, and open-ended questions. Questions from previous surveys were modified based on recommendations from previous investigators (Puettmann et al. 1998) and new questions were developed to assess current issues in forest management, such as the harvesting of biomass for bioenergy production and the use of site-level guidelines in riparian areas. During the development stage, a draft of the new survey was reviewed by various personnel within the Minnesota Department of Natural Resources (MN DNR). Based on comments from those reviews, revisions were made to the survey to assure clarity.

The survey was administered following the Dillman method (Dillman 2000) and used a web-based collection system provided by SurveyMonkey (Gordon 2002). Distribution was conducted via email to the respondents, which collectively made up a large proportion of forest resource land ownership in the state (2 national, 2 state, 14 county, 3 forest industry, 1 nongovernmental organization, and 5 Native American reservations). Contact information for respondents was collected from directories of county and state employees, as well as through conversations with Minnesota Forest Industries, Inc., and representatives for the US Bureau of Indian Affairs. Note the forest industry category included TIMOs, REITs, and traditional forest industry organizations. The survey was also sent to the listserv for the Minnesota Association of Consulting Foresters to include an assessment of silviculture practices on nonindustrial private forests (NIPF).

Survey recipients received an email message (Appendix B) containing information about the web-based survey one day prior to receiving a link to the on-line survey. This email explained the general nature of the questions being asked and that participation was entirely voluntary. Participants were informed that all of the information they provided would be confidential. In addition to the web-based survey, an electronic copy of the survey and a glossary of silvicultural terms (Appendix A) were sent through email to each survey respondent to facilitate survey completion.

Tracking of respondents was performed to allow for follow-up emails and phone calls. Follow-up emails were sent to nonrespondents three and six weeks after the initial survey invitation. Follow-up phone calls were made to no-response as well as incomplete response participants eight weeks following the initial invitation.

Statewide estimates of silvicultural practices were derived following the approach outlined in Puettmann and Ek (1999). In short, this approach expanded respondent acreages in silvicultural systems using an expansion factor based on the reported statewide harvest levels divided by the respondent reported harvests (2,924,500 cords/ 1,973,290 cords = 1.48). Note the statewide harvest level used was an estimate, as final mill survey numbers had not been received at the completion of the study. Thus, the reported statewide harvest level here was the midpoint of the range of estimates to date, i.e., the midpoint between 2,807,000–3,042,000 cords (Jacobson 2008). Only silvicultural systems data were expanded statewide, as data on other silvicultural activities, such as site preparation and timber stand improvement, were deemed less accurate. Unless otherwise noted, all results represent data reported by respondents, not statewide estimates. Nonetheless, the acreages reported for these activities allow for a general assessment of the trends and activity associated with a given practice. For all summaries of silvicultural practices presented, acres treated at the ownership level (i.e., county, federal, industry, Native American, and state) are used as the unit of analysis, unless otherwise noted.

Due to the use of somewhat different survey methodologies in 1991, we chose to focus on presenting the results of the 2008 survey as observations and discussing general trends based on the 1991, 1996, and 2008 surveys without statistical comparisons. Nonetheless, nonmetric multidimensional scaling was used to graphically examine general patterns in silvicultural practices among ownerships and over time within the state. These ordination analyses focused exclusively on variables collected for each survey year and were performed within PC-ORD Version 5.13 (McCune and Mefford 2006).

Results and Discussion

Twenty-six respondents completed the questionnaire. These respondents represented 100% of state and federal land (MN DNR Division of Forestry and USDA Forest Service, respectively); 100% of county, 100% of industrial, and 84% of Native American ownerships (n=2, 2, 14, 3, and 5, respectively). In addition, one NGO involved with forest management activities also completed the survey (Appendix C). These levels of participation are very similar to the 1996 survey, with the exception of county and Native American ownerships. In particular, our current survey includes two more county and two fewer Native American ownerships than the 1996 survey (Puettmann and Ek 1999). The lack of responses from consulting foresters precluded the inclusion of the NIPF ownership category within our summary.

Respondent ownerships covered a total of 9,865,694 acres (Table 1), which is approximately 64% of the 15,414,200 acres of timberland in the state (Miles and Heinzen 2008). Total harvest volumes from the ownerships represented by survey respondents was 1.97 million cords (Table 1), which is 67% of the 2008 estimated statewide harvest of 2.92 million cords (Jacobson 2008). These respondent harvest levels are similar to those reported during the 1996 survey (1.97 million cords; Puettmann and Ek 1999, Table 1); however, the statewide harvest levels for 2008 are less than in 1996 (3.81 million cords; Puettmann and Ek 1999, Table 1) and are likely reflective of a sharp decline in housing markets and the closure and market-related downtime of several mills beginning

in 2006 (Deckard 2009). Correspondingly, the harvest volume removed per acre of timberland in 2008 (0.20 cords) was lower than the harvest volumes in 1996 (0.25 cords; Table 1).

Silvicultural systems

Overall, the relative intensity of the silvicultural systems used decreased from 1996 to 2008, as the proportion of clearcutting (>5 acres) acres diminished and patch clearcutting, seed tree, shelterwood, and single-tree and group selection systems increased (Table 2). This decrease in intensity was also evident in the average volume removed per acre which declined from 19.8 cords/acre in 1996 to 15.8 cords/acre in 2008 (Table 1). Although there was a lower proportion of clearcutting (>5 acres) in 2008 relative to past surveys (85, 89, and 69% of silvicultural systems used in 1991, 1996, and 2008, respectively) clearcutting-based silvicultural systems were still the predominant type of silvicultural system employed for all ownerships (Table 2). The approximate average clearcut size (acreage within a harvest or sale block) was 29 acres and the average partial cut was 25 acres, with both values quite similar to the 1996 survey (24 and 27 acres, respectively; Puettmann and Ek 1999, Table 1). These values are also consistent with the average harvest site size reported by Dahlman (2008) from timber sale monitoring efforts in the state from 2004-2006 (25 acre average harvest site size).

The distribution of acreage within different clearcut sizes varied across ownerships (Table 3). Much of the clearcut area on state (53%), industry (58%), and Native American (65%) lands was in clearcuts greater than 40 acres, whereas clearcut sizes were relatively evenly distributed between clearcuts greater than 40 acres, 20 to 40 acres, and 5 to 20 acres on federal lands. Similarly, clearcut sizes on county lands were well-distributed across each size class, with the greatest percentage in clearcuts less than 5 acres (i.e., patch clearcutting; Table 3). Compared to 1996, the distribution of clearcut sizes across ownerships suggest an increase in clearcut size on state lands and a general decrease in size on most other ownerships (Tables 3 and 4). The increased clearcut sizes on state lands may be reflective of efforts to maintain large open areas for wildlife management purposes. In addition, the overall increase in average clearcut size may be driven by objectives to restore large patch sizes to the landscape (cf. White and Host 2008), as indicated by some respondent comments (Appendix D, Question 1). The increase may also be associated with a desire to increase operational efficiency.

Thinning

There was an increased emphasis on commercial thinning relative to the 1996 and 1991 surveys, with this practice comprising 14% of the silvicultural operations on the ownerships sampled (Tables 3, 4, and 5). Thinning was particularly prevalent on federal (31%) and industry lands (26%) and was least common on county lands (4%). Some respondents indicated that thinned acres included the use of variable density thinning treatments highlighting the use of these treatments to restore stand-level structural and environmental heterogeneity (Carey 2003). The increase in commercial thinning may be due, in part, to an increased number of cut-to-length (CTL) operations (Powers 2004), which help facilitate thinning operations. The observed increased emphasis on commercial thinnings was not accompanied by a concomitant increase in precommercial

thinnings, as the acreage in this practice decreased from the 1996 survey (1,444 ac, compared to 3,055 acres in 1996; Tables 6 and 7). This decrease is largely due to a reduced level of precommercial thinning on industry lands (59% decrease from 1996), which accounted for 90% of precommercial thinning activities in the 1996 survey (Table 7). Comments made by industry respondents to the 2008 survey indicated that this decrease in precommercial thinning was due, in part, to the operational constraints posed by residual trees to mechanized precommercial thinning operations (Appendix D, Question 2). It may also be related to the overall increase in mechanization level within the logging force reported by Powers (2004), which generally has associated with it higher fixed and operating costs than manual systems.

Regeneration

The total acreage regenerated during 2008 (92,513 acres, Table 3) was less than the total number of acres on which regeneration harvests took place (i.e., total acreage in regeneration methods, 105,198 acres, Table 2). This difference in acres regenerated and regeneration harvests is likely due to the fact that regeneration activities (e.g., planting) recorded in 2008 were largely related to regeneration harvests occurring in 2007. As with 1996, most regeneration harvests in 2008 relied on natural regeneration (62,391 acres of natural seeding and sprouting, Tables 6 and 7); however, federal ownerships relied more heavily on artificial regeneration (68% of their total regeneration efforts). Natural regeneration across ownerships was largely composed of sprouts or root suckers (94% of area with natural regeneration; Table 6); whereas artificial regeneration was primarily conifer species (98% of planted area) that were containerized planting stock (71% of planted seedlings).

Overall, the acreage of artificial regeneration increased substantially from 1996 to 2008, with a 84% increase in planted acres and a 78% increase in seeded acres (Tables 6 and 7). In addition, underplanting increased 32% from 1996 (1,957 and 2,584 acres in 1996 and 2008, respectively). These increases in planting were due in part to an increased emphasis on restoring conifer species to areas of the landbase where it was once historically prominent, particularly on federal lands (Appendix D, Question 1; Stone et al. 2001). In contrast to the use of other planting stock, the use of hybrid poplar cuttings decreased considerably from 1996 (80%) and was only applied on Native American ownerships (Tables 6 and 7). Despite the low application of this practice on the forest ownerships sampled in this survey, planting of hybrid poplar remains a relatively common practice on agricultural lands within the state (Andy David and Dean Current, personal communication).

Site preparation

The total acreage of site preparation was 12,632 (Table 6), which was a decline of 9% from 1996 (Table 7). The acres treated with chemical, mechanical, and prescribed burning declined 22, 0.2, and 33%, respectively, compared to 1996 levels (Tables 6 and 7). This overall decrease in site preparation was largely due to a 47% reduction in the acreage treated on industry lands, as acreages treated on state and county lands actually increased 10 and 20%, respectively, compared to the 1996 surveys (Tables 6 and 7). A decline in prescribed burning was also observed between the 1991 and 1996 surveys

(Tables 7 and 8); that decrease was attributed to drier conditions during the 1996 burning season (Puettmann and Ek 1999). The continued decline in the use of prescribed burning within the current survey suggests a broader trend of decreasing application of this practice for site preparation. This decrease is presumably due to the logistical and administrative challenges associated with using prescribed burns to prepare a site for regeneration relative to other methods (Nyland 2007).

Release

The use of regeneration release treatments increased 26% from 1996 and was similar to levels of application of this practice in 1991 (Tables 6, 7, and 8). In contrast to 1996, mechanical release treatments were the most common technique used in 2008, followed by ground-based and aerial chemical treatments (Tables 6 and 7). Interestingly, the total acreage on which chemical release treatments were applied was similar to 1996; however, the use of aerial treatments declined significantly in 2008 (50% versus 25% of total acreage of chemical release in 1996 and 2008, respectively; Tables 6 and 7). This decrease likely reflects the logistical difficulties for aerial operations posed by residual trees, which are increasingly being left within harvested areas to meet site-level guidelines (Table 9) and to serve as sources of natural regeneration in silvicultural systems based on partial harvesting. This decrease in acres treated aerially may also reflect the record high fuel prices during 2008.

Clearcut with residuals and riparian management zones

A primary finding of the 1996 survey was the increasing retention of residual trees on clearcut areas relative to the 1991 survey (77 and 44% of clearcut areas in 1996 and 1991, respectively; Tables 4 and 5), which likely reflected an increased awareness of aesthetic and biodiversity considerations in managed forests (Puettmann and Ek 1999). Since the last silviculture survey, formal site-level statewide guidelines have been developed that include recommendations for retaining residuals within clearcut areas (MFRC 1999, 2007). Those guidelines offer two options, scattered or clumped.

The percentage of clearcut areas with residuals in 2008 increased slightly relative to 1996, with 80% of clearcuts >5 acres containing residuals (Table 9). Interestingly, this amount is much greater than observed in a 2004-2006 survey of harvest sites for site-level guideline compliance (47.3%, Dahlman 2008); however, it is fairly consistent with what was reported by landowners and resource managers in terms of their use of clearcutting with residuals during 2004-2006 (69.2%, Dahlman 2008). The difference in values reported in the silviculture survey versus what was observed in the field by Dahlman (2008) is reflective of differences in survey methodology, as our numbers reflect all clearcuts with any number of residual trees, regardless of whether or not they met site-level guidelines for leave tree retention. In contrast, the numbers reported by Dahlman (2008) only include those acres with six or more scattered individual leave (live) trees per acre or 5% of the clearcut harvest area in leave-tree clumps at least ¼ acre in size; criterion based on the state site-level guidelines (MFRC 1999, 2007). Although the levels of retention reported by most 2008 silviculture survey respondents largely met or exceeded state-level guidelines, some ownerships were classifying sites with three trees/acre as a clearcut with residuals (Table 9).

As with the 1996 survey, most residuals (84%) retained on a site were alive at the time of harvesting (Table 9). Note snags are not considered leave trees in the context of meeting site-level guidelines (MFRC 1999, 2007). Residual trees were equally likely to be scattered individually across the site (50%) as they were to be arranged in clumps (50%), which differs from 1996 when residuals were largely scattered (67% of acres with residuals; Puettmann and Ek 1999). The increased usage of clumped arrangements may reflect the operational efficiency of this spatial pattern versus dispersed trees, as well as the ecological benefits provided by clumps in maintaining interior forest conditions within harvest areas (Aubry et al. 2009). Most commonly, the criteria indicated in open-ended comments regarding the selection of residual trees was their value as wildlife habitat, followed by species, merchantability, and windfirmness.

In addition to the development of formal leave-tree guidelines, the site-level guidelines for the state of Minnesota also include recommended buffer widths and residual basal areas to maintain the functionality of water bodies within and adjacent to harvest areas (MFRC 1999, 2007). We did not ask about specific guidelines being applied within riparian management zones (RMZs) across ownerships; however, we included a question regarding the level of harvesting occurring within these areas. Harvesting is allowed within RMZs under the current guidelines and is often critical to restoring and maintaining forest cover within these areas. The level of activity within RMZs ranged from no harvesting to harvesting occurring within more than 60% of RMZs (average of 32%), highlighting the tremendous variation in the approach to managing these areas across the state (Table 9). The greatest levels of activity within RMZs occurred on forest industry (65%), state (54%), and county (40%) lands (Table 9).

Other issues

The distribution of harvesting activities across seasons was similar to the 1996 survey, with most harvesting operations occurring in winter (58%), followed by summer (15%), fall (13%), and spring (4%). For the current survey, several (5) respondents did not report slash disposal practices due to lack of bookkeeping on these practices; however, the relative proportions of slash removal practices can be compared to ascertain general trends. As with the 1996 survey (note this was not recorded in 1991), the majority of slash was left on-site, either through delimbing trees within the stand or through backhauling slash onto the site from landings (Tables 6 and 7). The 1996 survey did not specifically ask about the use of backhauling practices for slash; however, the prevalence of this practice in 2008 may be due in part to site-level guidelines recommending the retention of slash scattered across the site to maintain site productivity and habitat features (MFRC 1999, 2007). The amount of slash piling was much lower in 2008 (3,204 versus 8,232 acres in 1996, Tables 6 and 7), whereas, the proportion of sites in which slash was removed via whole-tree skidding increased from 11 to 19% between the 1996 and 2008 surveys (Tables 6 and 7). This increase may reflect the increased level of mechanization reported by Powers (2004) with less chainsaw felling and cable skidding and more use of feller-bunchers and grapple skidders, a greater amount of biofuels harvests occurring within the state (see below), and the efficiency of conventional harvesting systems in recovering biofuels from branches and tops (Robertson et al. 2008).

The use of woody biomass as a feedstock for bionergy has emerged as a prominent issue in the Lake States since the last silviculture survey (Becker et al. in press). A total of 7,642 acres were sold specifically as biofuels harvests in 2008, with the majority of that acreage on state and county lands and to a lesser extent on industry and Native American ownerships (Table 10). This acreage is likely an underestimate of the total amount of sales involving biofuels, as this information is not recorded separately on timber sale documents for all agencies. Biofuels harvests focused primarily on logging residues, although roundwood, submerchantable trees, and hard snags were harvested for biofuels on 20, 72, and 17% of biofuel sales, respectively (Table 10). Although logging residues were largely collected from piles at landings, 21% of biofuels harvests involved a second entry into the stand to collect harvest residues.

Forest insects and diseases are increasingly causing economic losses to forest ecosystems in the Lake States and a diversity of approaches is being employed to minimize these losses across the ownerships surveyed. Silvicultural practices applied to address common and emerging forest health issues included promotion of mixed species stands, thinning treatments, and clearcutting (Table 11). Much of the pruning recorded for state and federal lands was related to pathological pruning efforts to minimize the occurrence of white pine blister rust (Table 6). Beyond these forest health issues, most respondents indicated that deer and other animal damage to seedlings was a major constraint to regenerating conifer species, particularly jack, red, and white pine and northern white cedar (Appendix D, Question 3). Problems with regenerating paper birch were noted due to winter harvesting operations which are not creating adequate seedbed conditions for this species, such as exposed mineral soil (Appendix D, Question 3).

Long-term trends in silvicultural practices

Collectively, there has been a great deal of variation in the silvicultural practices applied across ownerships within the state over the last 17 years (Figure 1). In particular, the silvicultural practices applied on each ownership type have been relatively distinct, with the greatest differences existing between federal and Native American lands and the other ownerships surveyed. This was illustrated by the general separation of points for each ownership type over time in the ordination of silvicultural practices, which explained 88.1% of the variation in the raw data (NMS ordination, final stress=5.69, final instability=0.000001). Most of the variation in silvicultural practices was explained by Axis 1, which represented a gradient from (a) ownerships and time periods with higher harvest volumes, greater levels of site preparation (particularly ground-based chemical means), and a higher reliance on natural regeneration in the positive portion of Axis 1 to (b) ownerships and time periods with lower harvest levels, less site preparation, and a greater reliance on artificial relative to natural regeneration in the positive portion. The distribution of ownerships and time periods along Axis 2, which explained 26.8% of the variation, generally ranged from (c) ownerships with a high reliance on manual mechanical release, greater levels of pruning, and overall higher amount of timber stand improvement applied in the positive portion to (d) ownerships and time periods with lower levels of these practices in the negative portion.

Based on the distribution of ownerships and time periods in ordination space, several general ownership-based and temporal trends emerge. A primary factor differentiating the silvicultural practices applied among ownerships is the lower amounts of site preparation and chemical release applied on federal and Native American lands relative to other ownerships (Figure 1). This pattern reflects, in part, the adoption of a no herbicide policy on USDA Forest Service lands in the Lake Sates that was enacted in 1990. Correspondingly, the greatest levels of application for mechanical manual release treatments are on federal lands (Figure 1, Table 6).

An additional distinguishing factor among ownerships is the increasing reliance on artificial versus natural regeneration on federal lands relative to other ownerships (Figure 1). As discussed above, this increase in planting on federal lands is reflective of efforts to restore conifers to areas that have become dominated by aspen systems. Although similar efforts are occurring on portions of state, county, and industry lands, these ownerships continue to rely primarily on aspen suckers for regeneration (Table 6). Interestingly, federal ownerships were the only lands on which the acreage of release treatments exceeded planted acreages, highlighting the intensity at which these restoration efforts are being pursued (Table 6).

With the exception of federal and Native American lands, the silvicultural practices among ownerships have shifted back towards those recorded in the initial survey in 1991 (Figure 1). This shift is primarily due to higher levels of site preparation treatments used on county and state lands in 2008 relative to 1996, accompanied by an increase in the acreage of release treatments, which now are at levels similar to those applied in 1991 (Tables 6, 7 and 8). In addition, artificial regeneration efforts, which declined 19% from 1991 to 1996, were 46% greater in 2008 than those acres reported in 1991 (Tables 6, 7, and 8). Collectively, these changes indicate an increased intensity of management related to the establishment of conifer species on the landscape; presumably in areas where these species were once historically dominant (Schulte et al. 2007). Nonetheless, these efforts are currently facing considerable obstacles due to increased herbivory of planted conifer seedlings, as indicated by the mention of this issue by numerous respondents (Appendix D, Question 3).

Along with the increased attention towards establishing conifer species, ownerships have continued to increasingly rely on silvicultural systems that retain residual trees, both in clearcuts, as well as part of regeneration methods, such as shelterwood and selection systems. This increase reflects both the adherence to site-level guidelines, as mandated by forest certification systems, as well as an increasing focus towards biodiversity and aesthetic considerations within managed areas. While the increases in these practices provide numerous positive ecological benefits (Franklin et al. 1997), the greater presence of residual trees has also hindered the use of certain silvicultural treatments, such as precommercial thinning, on certain ownerships (Appendix D, Question 2). The shift from aerial to ground-based chemical treatments is also likely a reflection of the logistical challenges posed by the presence of residuals within harvest areas.

A final significant change occurring over time has been the lower level of investment in early stand treatments on industry lands, particularly related to site preparation, release, and precommercial thinnings. These decreases likely reflect a change in the composition of the industrial ownerships since the last survey, as two of the larger industrial forest ownerships from the 1996 survey are now a TIMO and REIT (one each). As indicated by several of the industry respondent comments, the lower stumpage prices and costs of these treatments have made it challenging to justify these treatments to investors (Appendix D, Questions 1 and 4). Nonetheless, the application of commercial thinning treatments on industry lands increased 94% compared to the 1996 survey—highlighting the increased application of commercially viable intermediate treatments on these ownerships (Tables 6 and 7). These trends are also likely reflective of an increased number of CTL operations within the state (Powers 2004; see *Thinning* section above).

Conclusions

Differences in management philosophy between ownerships, as well as changes in social perceptions and biological and economic conditions related to forest management have resulted in a diversity of silvicultural practices across ownerships and over time within the state of Minnesota. For example, many of the differences between ownerships reflect differences in management approach, such as the lack of herbicide use on federal lands and the application of precommercial thinning treatments almost exclusively on industry lands. In contrast, broad changes in management philosophy over time, including the desire to increase the amount of conifer species on the landscape, adoption of certification systems, the increased usage of partial harvesting systems, and the availability of more mechanized harvesting operations have lead to changes in silvicultural practices observed across all ownerships. Beyond changes in management approach and philosophy, changes in economic conditions related to stumpage prices and shifts in ownership priorities over time have reduced the levels of investment in early stand treatments, whereas the application of commercial intermediate treatments has increased considerably across the state over time. This variability in silvicultural approach over time and across ownerships has maintained a diversity of forest conditions and silvicultural systems across Minnesota's forested landbase and the practices currently used will need to further adapt to the challenges posed by exotic and invasive species, changing climatic regimes, the emerging use of wood residue for energy wood, budget constraints, as well as increasing herbivory levels on seedlings.

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Table 1. Summary of 1996 and 2008 silvicultural survey response for acreage and volume harvested. Data for 1996 survey are from Puettmann and Ek (1999).

	2008 Survey				1996 Survey			
			Range				Range	
Variable	No. of respondents	Reported	Minimum	Maximum	No. of respondents	Reported	Minimum	Maximum
Timberland (acres)	26	9,865,694	4,258	4,500,000	25	7,720,204	5,400	2,600,00
Total volume harvested (cords)	26	1,973,289	1,873	783,240	25	1,965,164	1,474	533,000
Fuelwood (cords)	26	10,080	50	3,400	25	63,468	50	20,000
Average clearcut (acres)	26	29	10	135	25	24	6	50
Average partial cut (acres)	22	25	12	49	21	27	3	200
Total area in silvicultural systems (acres)	26	125,234	241	41,000	25	99,297	126	41,546
Cords harvested/acres timberland		0.20				0.25		
Cords harvested/acres timber sale		15.8				19.8		

Table 2. Reported silviculture survey results and statewide estimates for Minnesota, 2008, 1996, and 1991.

	Survey results			Statewide estimate[1]		
Variable	2008	1996	1991	2008	1996	1991
Ownership, harvesting, and regeneration						
Timberland ownership (acres)	9,865,694	7,720,204	7,848,031	14,988,700	14,723,200	14,723,200
Total volume harvested (cords)	1,973,290	1,965,164	1,858,849	2,924,500	3,810,000	3,530,000
Harvesting operations (acres)	88,985	99,297	90,128	134,209	192,514	171,155
Natural regeneration (acres)	62,391	69,220	64,428	83,272	134,202	122,350
Artificial regeneration (acres)	39,989	16,566	20,563	46,985	32,178	39,050
Acres by silvicultural system and thinning (% of acres)						
Clearcut (>5 acres) with or w/out residuals	86,523(69)	84,567 (85)	80,214 (89)	128,167 (69)	163,956 (85)	152,328 (89)
Patch clearcut	11,385 (9)	727 (1)	1,803 (2)	17,331(9)	1,409 (1)	3,434 (2)
Strip clearcut	0 (0)	234 (0)	901 (1)	0 (0)	454 (0)	1,711 (1)
Seed tree	1,974 (2)	1,356 (1)	0 (0)	3,002 (2)	2,629 (1)	0 (0)
Shelterwood	2,830 (2)	789 (1)	0 (0)	4,303 (2)	1,530 (1)	0 (0)
Selection (group and single-tree)	4,712 (4)	1,022 (1)	1,802 (2)	7,164 (4)	1,981 (1)	3,422 (2)
Thinning	17,809 (14)	10,602 (11)	5,408 (6)	27,044 (14)	20,555 (11)	10,270 (6)

[1] Statewide estimates were derived by multiplying the respondent silvicultural system acreages by an expansion factor based on the reported statewide harvest level divided by the sum of the respondent reported harvests. This approach expanded respondent acreages in silvicultural systems using an expansion factor based on the reported statewide harvest levels divided by the respondent reported harvests (2,924,500 cords/ 1,973,290 cords = 1.48). Note the statewide harvest level used was an estimate, as final mill survey numbers had not been received at the completion of our study. Thus the reported statewide harvest level here was the midpoint of the range of estimates to date, i.e., the midpoint between 2,807,000 – 3,042,000 cords (Jacobson 2008).

Table 3. Reported harvesting activities by ownership within Minnesota in 2008. Data represent 64% of all timberland in Minnesota. Nonindustrial private forests were not surveyed. Note *n* = number of responses for each given variable.

		Ownership category				
Variable	**Survey total**	**State**	**County**	**Federal**	**Forest Industry**	**Native American**
Ownership, harvesting, and regeneration						
Area of ownership (acres) *n*=26	9,856,994	4,500,000	2,551,145	1,624,573	737,701	443,575
Total volume harvested (cords) *n*=26	1,983,370	783,240	640,952	168,724	335,266	55,188
Area with logging operation (acres) *n*=25	88,985	41,000	27,025	5,649	13,461	1,850
Natural regeneration area (acres) *n*=23	62,391	26,117	23,426	1,766	5,114	1660
Artificial regeneration area (acres) *n*=23	32,776	21,307	9,651	4,324	4,584	436
Acres by silvicultural systems and thinnings by ownership (% of acres)						
Clearcutting >40 acres *n*=23	52,870 (42)	30,385 (53)	10,904 (26)	1,522 (18)	8,220 (58)	1,839 (65)
Clearcutting 20-40 acres *n*=23	21,299 (17)	9,611 (17)	8,848 (21)	1,133 (13)	1,305 (9)	402 (14)
Clearcutting 6-19 acres *n*=23	12,356 (10)	4,505 (8)	5,943 (14)	1,423 (17)	127 (1)	358 (13)
Patch clearcutting *n*=23	11,386 (9)	0 (0)	11,334 (27)	2 (0)	0	50 (2)
Strip clearcutting *n*=24	0 (0)	0 (0)	0 (0)	0	0	0
Seed tree *n*=25	1,974 (2)	1,311 (2)	354 (1)	208 (2)	91 (1)	10 (<1)
Shelterwood *n*=25	2,830 (2)	1,008 (2)	310 (1)	1,283 (15)	219 (2)	10 (<1)
Single-tree selection *n*=25	2,218 (2)	366 (1)	1,294 (3)	0	558 (4)	0
Group selection *n*=26	2,542 (2)	963 (2)	1,381 (3)	198 (2)	0	0
Thinning *n*=26	17,740 (14)	9,272 (16)	1,892 (4)	2,644 (31)	3,755 (26)	177 (6)

Table 4. Reported harvesting activities by ownership within Minnesota in 1996. Data represent 50% of all timberland in Minnesota and are from Puettmann and Ek (1999). Nonindustrial private forests were not surveyed.

		Ownership category				
Variable	**Survey total**	**State**	**County**	**Federal**	**Forest Industry**	**Native American**
Ownership, harvesting, and regeneration						
Area of ownership (acres)	7,720,204	2,605,400	2,543,909	1,206,147	838,000	526,748
Total volume harvested (cords)	1,965,164	554,094	618,427	324,580	360,181	107,882
Area with logging operation (acres)	99,297	41,914	26,883	15,106	9,839	5,555
Natural regeneration area (acres)	69,220	22,080	21,851	11,488	8,777	5,024
Artificial regeneration area (acres)	18,880	8,145	3,089	3,140	3,572	934
Acres by silvicultural systems and thinnings by ownership (% of acres)						
Clearcutting >40 acres	23,149 (23)	5,270 (12)	8,157 (30)	1,625 (11)	6,114 (62)	1,983 (36)
Clearcutting 20-40 acres	42,189 (43)	24,000 (57)	7,377 (27)	6,907 (46)	2,107 (21)	1,798 (32)
Clearcutting 6-19 acres	19,229 (19)	5,118 (12)	7,852 (29)	4,195 (28)	1,318 (13)	746 (13)
Patch clearcutting	727 (1)	0 (0)	246 (1)	0 (0)	50 (1)	431 (8)
Strip clearcutting	234 (0)	0 (0)	184 (1)	0 (0)	0 (0)	50 (1)
Seed tree	1,356 (1)	494 (1)	817 (3)	0 (0)	0 (0)	45 (1)
Shelterwood	789 (1)	62 (0)	546 (2)	181 (1)	0 (0)	0 (0)
Single-tree selection	612 (1)	93 (0)	339 (1)	0 (0)	30 (0)	150 (3)
Group selection	410 (0)	347 (1)	0 (0)	0 (0)	0 (0)	63 (1)
Thinning	10,602 (11)	6,530 (16)	1,365 (5)	2,198 (15)	220 (2)	289 (5)

Table 5. Reported harvesting activities by ownership within Minnesota in 1991. Data represent 50% of all timberland in Minnesota and are from Jaakko Pöyry Consulting, Inc. (1992). Nonindustrial private forests were not surveyed.

		Ownership category				
Variable	**Survey total**	**State**	**County**	**Federal**	**Forest Industry**	**Native American**
Ownership, harvesting, and regeneration						
Area of ownership (acres)	7,848,031	2,584,400	2,226,506	1,705,000	834,479	498,046
Total volume harvested (cords)	1,858,849	685,900	553,071	344,000	214,635	86,692
Area with logging operation (acres)	90,128	30,861	26,395	17,296	11,148	4,428
Natural regeneration area (acres)	64,428	19,760	20,594	13,113	7,559	3,402
Artificial regeneration area (acres)	20,563	9,465	5,128	2,724	2,765	481
Acres by silvicultural systems and thinnings by ownership (% of acres)						
Clearcutting > 5 acres						
without residuals	50	52	56	0	91	83
with residuals	39	36	30	91	1	0
Patch clearcutting	2	3	5	0	0	0
Strip clearcutting	1	2	2	0	0	1
Seed tree	0	0	1	0	0	0
Shelterwood	0	1	0	0	1	1
Selection systems	2	2	5	0	0	0
Thinning	6	5	3	8	7	15

Table 6. Reported acres of silvicultural practices by ownership within Minnesota in 2008. Data represent 64% of all timberland in Minnesota. Nonindustrial private forests were not surveyed. *n*=number of responses for each given variable.

		Area by ownership category (acres)				
Practice	Survey total	State	County	Federal	Forest Industry	Native American
Regeneration						
Planting (total) *n*=23	21,174	7,211	5,525	3,418	4,584	436
Underplanting *n*=22	2,584	691	143	0	1,650	100
Direct seeding *n*=23	8,948	7,048	1,447	453	0	0
Cuttings (e.g., hybrid poplar) *n*=23	70	0	0	0	0	70
Natural regeneration, from sprouts *n*=26	58,533	26,000	24,404	1,766	5,214	1149
Natural regeneration, from seed *n*=26	3,858	117	1,880	0	1,350	511
Total	92,513	40,376	33,256	5,637	11,148	2,096
Site preparation						
Chemical-aerial *n*=23	466	90	100	0	112	164
Chemical-ground *n*=23	3,711	1,763	1,370	0	510	68
Prescribed burning *n*=23	260	38	0	0	0	222
Mechanical (scarification, etc.) *n*=24	8,195	3,343	2,102	190	2,056	504
Total	12,632	5,234	3,572	190	2,678	958
Timber stand improvement						
Chemical release-aerial *n*=21	1,908	689	1,055	0	164	0
Chemical release-ground *n*=21	5,562	709	3,094	0	1,691	68
Hack and squirt release *n*=21	0	0	0	0	0	0
Mechanical/manual release *n*=21	7,645	2,187	37	4,410	965	46
Precommercial thinning *n*=21	1,444	0	116	0	1,121	207
Residual stem felling *n*=21	388	0	0	368	0	20
Pruning *n*=21	978	205	0	715	0	58
Underburning *n*=21	161	0	0	78	0	83
Total	17,782	3,790	4,302	5,571	3,941	482
Slash disposal						
Untreated, left on site *n*=21	9,330	-	6,409	1,964	387	570
Piled or windrowed *n*=21	3,204	-	1,343	831	100	930
Removed (whole tree skidding) *n*=21	4,387	-	3,827	0	300	260
Backhauled onto site *n*=21	7,830	-	5,130	0	2,700	0
Total	24,751	-	16,709	2,795	3,487	1,760
Salvage logging *n*=21	210	-	146	64	0	0

Table 7. Reported acres of silvicultural practices by ownership within Minnesota in 1996**.** Data represent 50% of all timberland in Minnesota and are from Puettmann and Ek (1999). Nonindustrial private forests were not surveyed.

		Area by ownership category (acres)				
Practice	Survey total	State	County	Federal	Forest Industry	Native American
Regeneration						
Planting (total)	11,530	4,061	2,118	1,739	2,958	654
Underplanting	1,957	500	72	1,305	0	80
Direct seeding	5,036	3,584	899	96	257	200
Cuttings (e.g., hybrid poplar)	357	0	0	0	357	0
Natural regeneration, from sprouts	62,374	18,080	20,062	11,438	8,300	4,494
Natural regeneration, from seed	6,846	4,000	1,789	50	477	530
Total	86,143	30,225	24,940	14,628	12,349	5,958
Site preparation						
Chemical-aerial	2,251	748	243	0	1,260	0
Chemical-ground	3,099	1,040	999	0	1,060	0
Prescribed burning	388	147	19	150	0	72
Mechanical (scarification, etc.)	8,212	2,781	1,133	1,050	2,764	484
Total	13,950	4,716	2,394	1,200	5,084	556
Timber stand improvement						
Chemical release-aerial	3,184	767	574	0	1,843	0
Chemical release-ground	3,138	677	961	0	1,500	0
Hack and squirt release	100	100	0	0	0	0
Mechanical/manual release	4,795	1,133	316	2,685	50	611
Precommercial thinning	3,055	100	40	0	2,751	164
Residual stem felling	361	300	45	6	0	10
Pruning	339	10	66	33	200	30
Underburning	135	0	0	113	0	22
Total	15,107	3,087	2,002	2,837	6,344	827
Slash disposal						
Untreated, left on site	62,801	20,000	24,771	8,800	5,120	4,110
Piled or windrowed	8,232	2,500	1,945	3,500	200	87
Removed (whole tree skidding)	9,223	2,688	1,634	2,201	2,450	250
Total	80,256	25,188	28,350	14,501	7,770	4

Table 8. Reported acres of silvicultural practices by ownership within Minnesota in 1991. Data represent 50% of all timberland in Minnesota and are from Jaakko Pöyry Consulting, Inc. (1992). Nonindustrial private forests were not surveyed.

		Area by ownership category (acres)				
Practice	Survey total	State	County	Federal	Forest Industry	Native American
Regeneration						
Planting	14,600	4,750	4,948	1,979	2,442	481
Direct seeding	5,963	4,715	180	745	323	0
Natural regeneration	64,428	19,760	20,594	13,113	7,559	3,402
Total	84,991	29,225	25,722	15,837	10,324	3,883
Site preparation						
Chemical-aerial	456	402	0	0	54	0
Chemical-ground	2,962	1,402	1,369	0	191	0
Prescribed burning	1,237	825	120	192	100	0
Mechanical (scarification, etc.)	9,619	3,553	1,360	2,431	1,831	444
Mechanical with band spraying	932	0	0	0	932	0
Total	15,206	6,182	2,849	1,623	3,108	444
Timber stand improvement						
Chemical release-aerial	5,252	535	2,715	0	2,002	0
Chemical release-ground	3,914	675	1,877	0	1,362	0
Hack and squirt release	20	20	0	0	0	0
Mechanical/manual release	5,506	808	455	3,782	53	408
Precommercial thinning	1,444	427	164	60	203	590
Residual stem felling	9,001	570	271	7,686	474	0
Pruning	201	150	28	13	10	0
Slash disposal (burn brush piles)	91	50	41	0	0	0
Total	25,428	3,225	5,550	11,541	4,104	998

Table 9. Reported harvesting activities related to clearcut sites with residuals and riparian management zones by ownership category within Minnesota in 2008.

Variable	Survey total	State	County	Federal	Forest Industry	Native American
Minimum no. of residuals to qualify as clearcut w/residuals	-	6 trees/acre or 5% of harvest area	3-10 trees/acre	8 trees/acre or 22.5 ft^2/acre	6 trees/acres or 5% of harvest area	30 ft^2/acre
Residuals, acres (% of acres)						
Clearcut >5 acres	86,525 (69)	44,501 (77)	25,694 (61)	4,077 (48)	9,652 (68)	2,599 (62)
Clearcut >5 acres with residuals	69,254 (80)	34,680 (78)	21,996 (86)	1,921 (47)	8,364 (87)	2,293 (88)
Percent residuals alive	84	85	77	83	93	81
Percent acres with residuals scattered	50	50	55	60	10	77
Percent riparian zones w/ harvesting activity	32	54	40	3	65	0

Table 10. Summary of biofuels harvests reported within Minnesota in 2008. Harvest levels are likely an underestimate, as not all agencies recorded biofuels harvests separately from roundwood harvests. Percentages represent proportion of harvests.

		Ownership category				
Variable	Survey total	State	County	Federal	Forest Industry	Native American
Number of respondents	15	1	7	2	1	4
Total acres of biofuel harvests	7,642	5,467	1,675	0	300	200
Percent of biofuels removed on second entry	21	25	58	-	0	0
Percent of biofuel harvests where roundwood was sold as biofuel	20	25	36	-	10	10
Location of slash before collection						
Windrows	0	0	0	-	0	0
Piles at landing	75	50	60	-	100	90
Scattered	3	0	0	-	0	10
Percent of biofuel harvests for which:						
Sub-merchantable materials were harvested	72	75	65	-	75	-
Hard snags were harvested	17	15	2	-	50	0

Table 11. Forest health issues affecting Minnesota forests and most common silvicultural practices listed by survey respondents for addressing these issues. Numbers in parentheses correspond to number of times a given practice was identified by respondents.

Forest health issue	Silvicultural practice
white pine blister rust	promotion of mixed species (5) sanitation cuttings (5) improved growing stock (4)
emerald ash borer	promotion of mixed species (3) thinning (2)
gypsy moth	promotion of mixed species (4) thinning (1)
oak wilt	sanitation cuttings (1) promotion of mixed species (1)
bark beetles	slash removal (10) thinning (4) promotion of mixed species (4) clearcutting (4)
Sirococcus/Diplodia	clearcutting (5) promotion of mixed species (2)
Hypoxylon	clearcutting (10) salvage harvests (2)
spruce budworm	thinning (3) clearcutting (3) salvage harvests (2)
two-lined chestnut borer	salvage harvests (3) thinning (2) promotion of mixed species (2)
ash decline	clearcutting (4) thinning (1) salvage harvests (1) promotion of mixed species (1)
dwarf mistletoe	clear-cutting (6) sanitation cuttings (3)
eastern larch beetle	clear-cutting (4) salvage harvests (2)
white pine weevil	promotion of mixed species (1)
root and butt rot	clear-cutting (2) sanitation cuttings (1) promotion of mixed species (1) slash removal (1) pathological rotation age (1)

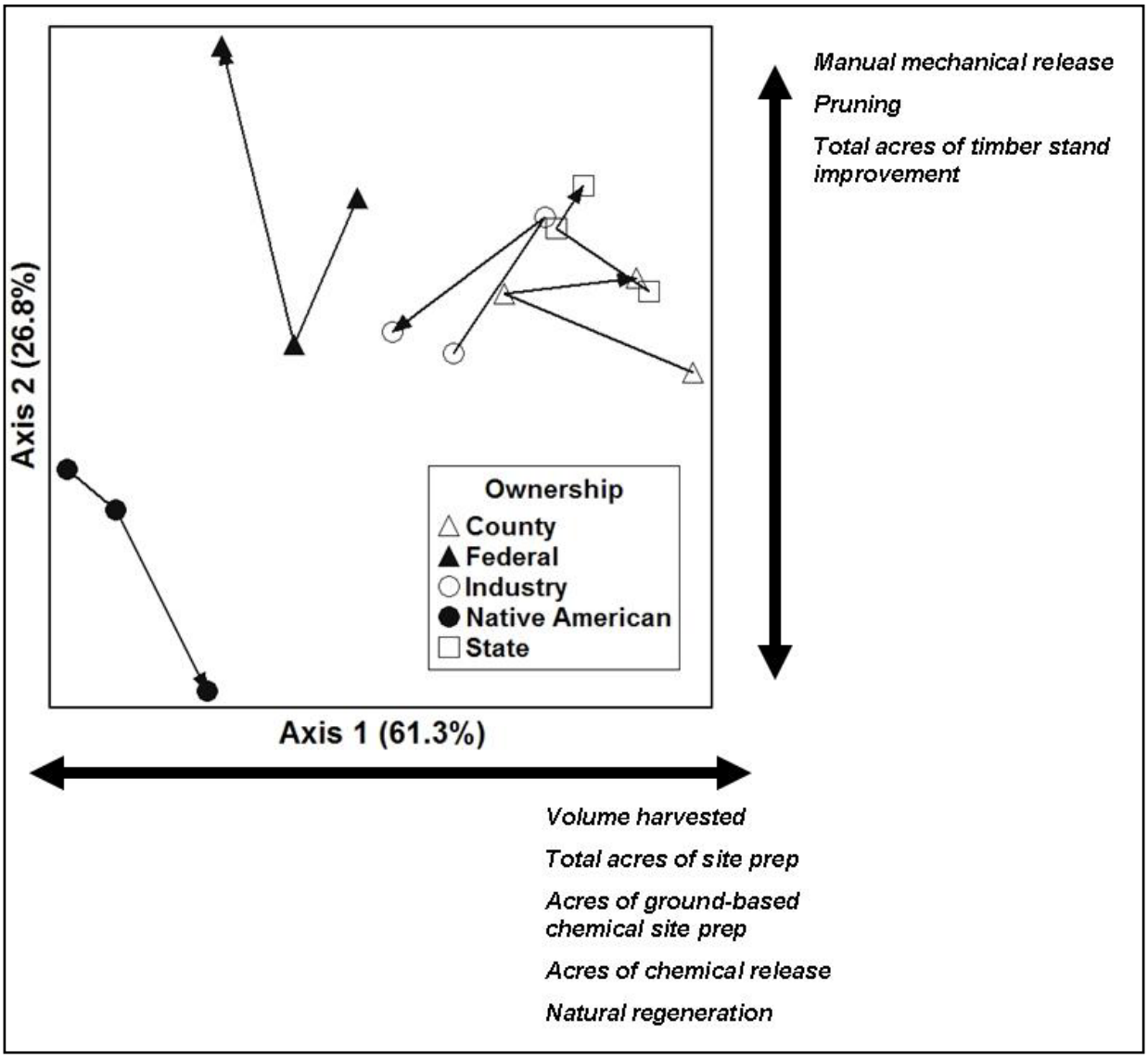

Figure 1. Nonmetric multidimensional scaling of silvicultural practices for 1991, 1996, and 2008 across ownerships within the state of Minnesota. Directional vectors by ownerships indicate the change in silvicultural practices over time in ordination space. Only variables significantly correlated (Bonferroni-corrected; $P < 0.05$) with each axis are listed.

APPENDIX A. Questionnaire used to assess 2008 silvicultural practices in Minnesota.

Survey of Silvicultural Practices

1. Annual Forest Management Operations in 2008

We would like to learn more about the silvicultural practices applied by your organization during the fiscal year 2008. If you wish to comment on any question or expand on your response, please feel free to use the space allotted on page 12 of this questionnaire. Your response will be kept confidential. All answers should be based on timberland only. See the last page of this questionnaire (page 13) or the document sent along with this survey for definitions of the silvicultural terms used in this questionnaire.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Respondent's Name**

*** 2. Organization Name**

*** 3. Please indicate the category that applies to your organization**

- ☐ National
- ☐ State
- ☐ County
- ☐ Private
- ☐ Forest Industry
- ☐ Native American
- ☐ Consulting Forester
- ☐ Other

Other (please specify)

*** 4. Area of timberland owned (acres)**

*** 5. Total acres harvested**

*** 6. Volume harvested (please report cords plus additional MBF or tons, where appropriate)**

Total (excluding fuelwood) cords	
Total (excluding fuelwood) MBF	
Total (excluding fuelwood) tons	
Fuelwood cords	
Fuelwood tons	

*** 7. Average clear-cut size of a block (acres)**

8. Average cut size of a block (acres)

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* **9. Information used to determine site productivity (e.g., soil atlas, biophysical, ECS, site index estimation)**

* **10. Do you use a silvicultural prescription form? If yes, please mail a copy of your form to Tony D'Amato, Department of Forest Resources, 1530 Cleveland Avenue North, Saint Paul, MN 55108-6112.**

- ◯ Yes
- ◯ No

Survey of Silvicultural Practices

2. Silvicultural Systems Used

Please base your response to the following questions on forest lands that were offered for sale during fiscal year 2008, regardless of whether it sold or not.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Total acres offered for sale**

*** 2. Total number of timber sales offered for sale**

*** 3. Total number of blocks offered for sale**

*** 4. Clear-cut, with or without residuals (acres)**

Block area >120 acres	
Block area 81 to 120 acres	
Block area 41 to 80 acres	
Block area 21 to 40 acres	
Block area 6 to 20 acres	
Block area 0 to 5 acres	

*** 5. Patch clear-cut (acres)**

*** 6. Strip clear-cut (acres)**

*** 7. Shelterwood (acres)**

*** 8. Seed tree (acres)**

*** 9. Group selection (acres)**

*** 10. Single tree selection (acres)**

*** 11. Thinning, commercial only (acres)**

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12. Other, please specify system type and the associated number of acres for each method

-
-
-

Survey of Silvicultural Practices

3. Regeneration Practices

This page is concerned with the regeneration practices used on forest land. Please base your response to the following questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

* 1. Planting

Total number of acres planted	
Percent of total acres planted with conifer species	
Percent of total acres planted with hardwood species	
Number of acres underplanted	
Percent of underplanted acres using conifer species	
Percent of underplanted acres using hardwood species	
Percent of planted seedlings that were containerized stock	
Percent of planted seedlings that were bare-root stock	

2. Direct Seeding

Number of acres direct seeded	
Percent of direct seeded acres using conifer species	
Percent of direct seeded acres using hardwood species	
Percent of direct seeded acres using ground-based methods	
Percent of direct seeded acres using aerial methods	

* 3. Number of acres planted with cuttings (e.g., hybrid poplar)

* 4. Number of acres established by natural regeneration from sprouts or suckers

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* **5. Number of acres established by natural regeneration from seed**

6. Other, please specify type of planting or regeneration and the associated number of acres for each method

-
-
-

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4. Site Preparation Methods

This page is concerned with the site preparation methods used on forest land. Please base your response to the following questions for the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Chemical-aerial (acres)**

*** 2. Chemical-ground (acres)**

*** 3. Prescribed burning (acres)**

*** 4. Mechanical (scarification, root raking, etc.) (acres)**

5. Other, please specify type of site preparation and the associated number of acres for each method.

-
-
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5. Timber Stand Improvements (TSI)

This page is concerned with timber stand improvement methods used on forest land. Please base your response to the following questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Chemical release-aerial (acres)**

*** 2. Chemical release-ground (acres)**

*** 3. Hack and squirt (acres)**

*** 4. Mechanical release (acres)**

*** 5. Pre-commercial thinning (acres)**

*** 6. Residual stem felling (acres)**

7. Other, please specify the TSI treatment and the associated number of acres for each method

-
-
-

Survey of Silvicultural Practices

6. Other Silvicultural Activities

This page is concerned with other silvicultural activities that occurred on forest land. Please base your response to the following questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Pruning (acres)**

*** 2. Underburning (acres)**

*** 3. Fertilization (acres)**

*** 4. Slash disposal (acres)**

Untreated, left on site (e.g., cut-to-length)	
Piled	
Windrowed	
Removed (whole tree skidded with topwood chipping)	
Backhauled onto site	

*** 5. Salvage logging (acres)**

6. Other, please specify silvicultural activity and the associated number of acres for each method

-	
-	
-	

*** 7. Percent or number of acres (please indicate units, percent or acres) harvested during fiscal year 2008 by season**

Winter (December-February)	
Spring (March-May)	
Summer (June-August)	
Fall (September-November)	

*** 8. On sales adjacent to streams, lakes, and open water wetlands, what percentage included harvesting within riparian management zones?**

Survey of Silvicultural Practices

7. Residuals After Cutting

Please base your answers to the following questions on clear-cut harvests within which residual trees were left to accomplish site-level guideline goals (e.g., wildlife habitat, aesthetics, protection around a seasonal pond). Please base your response to these questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Minimum number of residual trees or residual basal area (please indicate the appropriate measure) that would qualify a site as a clear-cut with residuals (if available, please mail a copy of your guidelines to Tony D'Amato, Department of Forest Resources, 1530 Cleveland Avenue North, Saint Paul, MN 55108-6112)**

*** 2. Please list the main criteria used for selecting residuals within clear-cuts for your (e.g., less merchantable species, windfirmness, topographic position)**

-
-
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*** 3. Acres that were clear-cut with residuals**

*** 4. Average density of residuals on sites that were clear-cut with residuals (please indicate trees per acre or basal area per acre)**

*** 5. Average proportion of the residual trees in clear-cuts that are (percent should add to 100):**

Alive (%)

Dead (%)

*** 6. Average % of the clear-cut acreage where the residuals are:**

Scattered throughout (%)

In clumps (%)

Survey of Silvicultural Practices

8. Biofuels (Woody biomass harvested for energy generation)

This page is concerned with silvicultural activities related to biofuels. Please base your response to the following questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Total acres of biofuel harvests**

*** 2. Percentage of biofuel harvest sites where biofuels were removed through a second entry into the stand (%)**

*** 3. Percentage of biofuel harvests where roundwood was sold as biofuel.**

4. In sites that roundwood were sold as biofuels what species were harvested:

-
-
-
-

*** 5. For two-stage biofuels harvests, what percentage or number involved first backhauling of slash (% or # of harvests)**

*** 6. Location of slash prior to collection (indicate percentage of sales):**

Windrows (%)

Piles at a landing (%)

Scattered (%)

Please indicate any other location (%)

*** 7. Average % or number of biofuel harvests in which (please indicate whether your response is a percent or the number of harvests):**

Sub-merchantable materials were harvested (% or # of harvests)

Hard snags were harvested (% or # of harvests)

Survey of Silvicultural Practices

9. Forest Health

This page is concerned with forest health. Please base your response to the following questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response, please check the NA column.

*** 1. Please check the appropriate preferred silvicultural treatment(s)/practice(s) being applied on your landbase to address each of the following insect and disease issues. For each insect or disease, please select a maximum of 4 treatments or practices**

	Thinning	Clear-cutting	Salvage harvests	Sanitation cuttings	Promotion of mixed species	Slash removal	Improved growing stock	Pathological rotation age	Pruning	NA
Blister rust	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Emerald ash borer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Gypsy moth	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Oak wilt	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bark beetles	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sirococcus/Diplodia	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hypoxylon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Spruce budworm	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Two-lined chestnut borer	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Ash decline	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Dwarf mistletoe	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Eastern larch beetle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
White pine weevil	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Root and butt rot	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

*** 2. If there are any insect or disease issues that are occuring on your landbase where you have prescribed treatments to address them, please indicate each issue and treatment**

-
-
-

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10. General Comments on Silvicultural Practices/Issues

Please answer the following questions dealing with problems or issues you have been experiencing related to silvicultural practices and objectives.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. Identify/describe the primary ways your silvicultural practices have changed over the past 5 years. What factors caused these changes**

*** 2. What site-level guidelines have most hindered your ability to achieve your silvicultural objectives? Please indicate how those guidelines hinder you.**

*** 3. What species are you currently having the most difficulty with regenerating? Please include the primary reasons for these regeneration issues.**

*** 4. Is there anything else, you would like us to know about your silvicultural practices or issues (e.g., availability of seedlings, operation logistics, planting quality, planning, exotic species, equipment issues)? Please write your comments here.**

Survey of Silvicultural Practices

11. Non-industrial Private Forest Owners

This page is concerned with the relationship between non-industrial private forest owners and forest land. Please base your response to the following questions on the 2008 fiscal year.

Questions marked by an asterisk require a response. If you are unable to provide a response to a question, please enter NA.

*** 1. If you have contact through your organization with non-industrial private landowners, please indicate how many acres of these ownerships you managed during the fiscal year 2008?**

*** 2. Please state to the best of your ability how these ownerships were managed in terms of**

Silvicultural systems used

Regeneration practices

Other silvicultural practices

Thank you! Please mail a copy of your silvicultural prescription form to:

Tony D'Amato
Department of Forest Resources
1530 Cleveland Avenue North
Saint Paul, MN 55108-6112

If you have any questions about this survey, please contact Tony D'Amato at:

Phone: 612-625-3733
Email: damato@umn.edu

Survey of Silvicultural Practices

12. Additional Comments

If you wish to comment on any question or expand on your response, please feel free to use this space to do so.

*** 1. Additional comments or responses to questions within the questionnaire (please indicate the question you are addressing).**

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Survey of Silvicultural Practices

13. Definitions

Below are definitions of terms used throughout the survey.

Biofuels: Any woody biomass used as a feedstock for bioenergy or the development of biofuels.

Clear-cutting (reproduction) method: A method of regenerating a forest stand in which new seedlings become established in fully exposed micro-environments after removal of most or all of the existing trees. The objective is to create an even-aged stand. Regeneration can originate naturally or artificially.

Direct seeding: Application of seed directly to the site.

Even-aged stand: A stand of trees having a narrow range of ages, e.g. not exceeding 20% of the rotation.

Group selection: A method of regenerating uneven-aged stands in which trees are removed, and new age classes are established, in small groups. The maximum width of groups is approximately twice the height of the mature trees, with small openings providing micro-environments suitable for more intolerant regeneration. In the Group Selection System, the management unit or stand in which regeneration, growth, and yield are regulated consists of a landscape containing an aggregation of groups.

Patch clear-cut: Utilizing the clear-cut method of regeneration in an area typically equal to or less than 3 acres.

Pre-commercial thinning: A thinning that does not yield trees of commercial value, usually designed to improve crop spacing.

Pruning: The cutting of lower limbs from standing trees.

Release (Release cutting, Release operation): A treatment designed to free young trees-usually not past the sapling stage (1.0-4.9" in the Lake States) from undesirable competing vegetation. Treatments include cleaning, liberation, and weeding.

Residual: A tree that remains on the landscape after a harvest takes place for reasons other than providing a source of regeneration (e.g., wildlife, aesthetics).

Reproduction method: A cutting method by which a new age class is created. Major methods are clear-cutting, seed-tree, shelterwood, selection, and coppice.

Salvage cutting: The removal of trees (dead or otherwise) to inhibit actual or anticipated spread of insects or disease.
Selection (reproduction) method: A method of regenerating a forest stand, as well as creating or maintaining an uneven-aged structure, by the periodic removal of trees. Trees are removed either individually or in small groups.

Seed-tree (reproduction) method: An even-aged regeneration method in which a new age class develops from seeds that germinate in fully-exposed micro-environments after removal of all the previous stand except a small number of trees left to provide seed. Seed trees are removed after regeneration is established.

Shelterwood (reproduction) method: A method of regenerating a forest stand in which part of the mature crop is left to provide shelter for regeneration. The harvest may consist of two or three cuttings. The objective is to create an even-aged stand. Regeneration can originate naturally or artificially, but is more usually natural from the residual trees.

Single tree selection: A method of creating new age classes in uneven-aged stands in which indivicual trees of all size classes are removed more-or-less uniformly throughout the stand to achieve desired stand structural characteristics.

Site index: An indirect measure of site quality for a given species, usually expressed as height of the dominant trees at an arbitrarily chosen base age (e.g. 25, 50, or 100 years).

Site preparation: A mechanical, chemical, fire, or hand treatment which modifies the site to provide favorable conditions for natural or artificial regeneration.

Sprout: A shoot originating from dormant or adventitious buds on the stem, branches, or stumps of trees.

Stand improvement: A term comprising all intermediate cuttings made to improve the composition, structure, condition, health, and growth of stands.

Strip clear-cut: Clear-cuts that run in a linear fashion typically forming edge microenvironments enhancing conditions for natural or artificial regeneration.

Sucker: A shoot or tree arising from adventitious buds on roots or rhizomes.

Thinning: An operation made to reduce stand density in immature groups of trees primarily to recover potential mortality and/or improve growth of residual trees.

Underburning: A prescribed fire lit to reduce undesired plant competition.

References:

Nyland, R. D. 1996. Silviculture: Concepts and applications. The McGraw-Hill Companies, New York, New York, USA.

Smith, D.M.; Bruce L.C.; Kelty, M.J.; & Ashton, P.M.S. 1997. The practice of silviculture: Applied forest ecology. Ninth edition. John Wiley & Sons, New York, New York, USA.

SAF Silviculture Working Group (D-2). 1993. Silviculture terminology. Working Group Newsletter, October, 1993.

APPENDIX B. Email sent with information regarding the 2008 silviculture survey

March 10, 2009

Dear <*Participant Name*>,

In 1991 and 1996, Minnesota conducted statewide surveys of silvicultural practices that have proven to be a valuable resource for policy makers, industry groups, and others. Since 1996, several important new factors have influenced silvicultural practices, including the development of bioenergy markets, reductions in markets for solid wood products following months of reduced housing starts, and implementation of site-level forest management guidelines. As such, we now need to update our information on silvicultural practices in Minnesota to gain a more contemporary understanding of how these and other factors are affecting forest management practices within the state. This effort is being funded by the Interagency Information Cooperative.

Tomorrow (March 11), I will send you an on-line questionnaire that is designed to help us better understand the silvicultural practices applied during the fiscal year 2008. In order for the results to truly reflect the status of forest management in the state, it is important that each forest landowner complete this questionnaire.

We are concerned about your privacy. The name on the survey will only be used to make sure that you do not receive reminders once you have returned your questionnaire. All individual responses will be kept confidential and we will not identify your response by your name or organization in any publications or presentations which we create.

The survey was designed to cover practices applied by various landowners in Minnesota. If your database does not contain the requested information, please give us your best estimate. Also, I have attached a glossary of silvicultural terms to this message for your reference while filling out this survey. This glossary is located on the last page of the questionnaire, as well. Finally, within the survey, we request copies of the silvicultural prescription and site-level guideline forms you use. These forms will be used to gain a better understanding of commonalities and opportunities in planning silvicultural practices across forest management organizations and landowners in Minnesota.

We greatly appreciate your participation in this survey. If you could please complete this survey by April 10, we would greatly appreciate it. If you have any questions, please do not hesitate to contact me at 612-625-3733.

Sincerely,

Tony D'Amato
Assistant Professor
Phone: (612) 625-3733
E-mail: damato@umn.edu

APPENDIX C: Survey results for nongovernmental organizations

Table A1. Reported harvesting activities on nongovernmental organization ownerships within Minnesota in 2008 (n=1).

Variable	
Ownership, harvesting, and regeneration	
Area of ownership (acres)	8700
Total volume harvested (cords)	0
Area with logging operation (acres)	30
Natural regeneration area (acres)	30
Artificial regeneration area (acres)	50
Acres by silvicultural systems and thinnings by ownership (%)	
Clearcutting >40 ac	0
Clearcutting 20-40 ac	0
Clearcutting 6-19 ac	10 (33)
Patch clearcutting	0
Strip clearcutting	0
Seed tree	0
Shelterwood	0
Singletree selection	0
Group selection	20 (67)
Thinning	0

Table A2. Reported acres of silvicultural practices on nongovernmental organization ownerships within Minnesota in 2008 (n=1).

Practices	
Regeneration	
Planting (total)	50
Underplanting	50
Direct seeding	0
Cuttings (e.g., hybrid poplar)	0
Natural regeneration, from sprouts	0
Natural regeneration, from seed	0
Total	50
Site preparation	
Chemical-aerial	0
Chemical-ground	10
Prescribed burning	0
Mechanical (scarification, etc.)	0
Total	10
Timber stand improvement	
Chemical release-aerial	0
Chemical release-ground	10
Hack and squirt release	0
Mechanical/manual release	20
Precommercial thinning	0
Residual stem felling	0
Pruning	0
Underburning	0
Total	30
Slash disposal	
Untreated, left on site	0
Piled or windrowed	0
Removed (whole tree skidding)	0
Backhauled onto site	0
Total	0
Salvage logging	0

APPENDIX D: Responses to open-ended questions (Question 10) within the 2008 survey of silvicultural practices

Question 1:

Identify/describe the primary ways your silvicultural practices have changed over the past 5 years. What factors caused these changes

1. Overall our practices have changed in the last five years to address new desired conditions and objectives from our 2004 Revised Forest Plan. All silvicultural practices incorporate the Minnesota Forest Resources Council's "Voluntary Site-level Forest Management Guidelines". The Plan changed us from a strong output (timber volume) objective to an outcome objective (desired vegetation conditions to meet a whole suite of current and future needs and interests in forest ecological, economic, and social values). More specifically, the factors that drove this change were increased public interest in managing forest composition, structure, and spatial patterns to better manage for timber (volume and product mix), wildlife habitat, biological diversity, scenic qualities, and fuels reduction. There is an increase in prescriptions that mimic natural disturbance that has historically occurred on the Superior NF. These disturbance based harvests address many of the ecologically based objectives of the Forest Plan. Below are some examples of recent prescription trends.
    a. The SNF has increased our ratio of partial overstory removal to clearcutting with reserves. In the earlier plan our clearcut with reserve was about 98% of all our timber harvest; the projection for decade 1 of plan implementation is 21%. Clearcut prescriptions over 20 acres include a minimum retention of a 5% legacy patch that is representative of the parent stand.
    b. We increased emphasis on managing for future sawtimber vs. mainly pulp. The main approach taken is more gap dynamics related prescriptions, which is conducive to longer rotation forestry. Thus the increase in sawtimber will continue.
    c. We also have increased the amount of diversity planting. This changed emphasis from natural regeneration where we got a lot of aspen regeneration to a restoration emphasis, most frequently to increase conifer component of stands. These plantings, (both conversions and diversity plantings) are more ecologically based than past planting efforts. In other words we try to fit the planted tree species to the site based on soil, topography, competitiveness, etc.
    d. We are placing a greater emphasis on managing stands in large patches, to the degree possible while dealing with a history of small patch cuts. This includes putting new harvest units up against recent (<30 yrs old) harvest units to create future large patches.

    e. Red and white pine thinning acres have also increased. These thinnings have utilized variable retention and group selection prescriptions to better mimic natural gap dynamics in pine ecosystems. (National)
2. Use of correct terminology. Standardized prescription format. Better communication with Research and other silviculturists. Better stand data. Stand lines have been redrawn. Stand exams are being conducted now. Better data for better diagnosis and prescriptions. Changes occurred due to change in personnel. (National)
3. Stopped summer/fall broadcast herbicide application for site preparation. Found that this was promoting establishment of cool season grasses that were competing with seedlings for moisture in the spring/early summer and resulting in high mortality of planted seedlings. (County)
4. Clearcut of ash with the current Emerald ash borer expectations. (County)
5. Increasing the amount of partial treatment acres in timber sale areas due to the natural diversity of the stands we are working in. (County)
6. The Ecological Classification System has allowed for a more standardized and streamlined process to track why a particular management scheme fits a certain part of the landscape. The hierarchical nested set-up allows us to see how management at a stand level affects the "big picture." It allows our staff a chance to see where future management options exist. ECS also helps with tree planting; we used to have many more "guesses" as to what species fits the site best. Additionally, we use soil information more. (County)
7. On the ground, application has changed very little over the past 5 years. Documentation of what is planned to occur on the ground has improved and will continue to change/improve as we implement [use/deploy] data recorders in the field. (County)
8. Better utilization of wood species has made silvicultural goals easier to accomplish. (County)
9. More residuals and legacy elements; use of formal prescription worksheet; use of ECS products in objective setting and prescription writing (State)
10. No changes (NGO)
11. All Silviculture treatments must meet or exceed set internal rate of return on investment before work can be done. Lower Stumpage Rates and Higher per acre contractor rates make some treatments no go. (Forest Industry)

Question 2:

What site-level guidelines have most hindered your ability to achieve your silvicultural objectives? Please indicate how those guidelines hinder you.

1. None. This is because most of our site level guidance serves to help us meet vegetation objectives; therefore they are not considered hindrances. Perhaps the key issues with some of our site level guidance are economic costs associated with practices that require a lot of paint and marking crews (more expensive). (National)

2. Threatened, endangered, and special concern (TES) species mitigations. They especially affect hardwoods in that selective cuts are restricted. Therefore multi-age management becomes difficult or impossible. (National)
3. Documented deviations help to address issues. (County)
4. Biomass harvesting. This stems from a lack of understanding of what a "true" biomass removal is. For example, if I have an oak shelterwood, where 3-5 trees/acre are left behind, why is it necessary to leave 1/5 of removed slash over the harvest area? I'm not performing a true "clearcut" where 100% of the stems are gone. Many folks feel the 1/5 slash guidelines only apply to "true" clearcuts and 100% biomass removal. We lack direction to inform loggers on specifics. (County)
5. Intermittent streams and vernal ponds. Can't throw a road killed animal without it landing in one or the other. (County)
6. None have had a significant impact on achieving objectives (County)
7. Individual interpretation of guidelines have at times caused challenges (State)
8. Scattered “leave” trees has hindered our Pre commercial Mechanical Aspen Thinning. Our program has declined 50% since “leave” trees have been implemented (Forest Industry)

Question 3:

What species are you currently having the most difficulty with regenerating? Please include the primary reasons for these regeneration issues.

1. Issues:
    a. White pine; due to blister rust and deer herbivory. We rarely cut cedar because of the difficulties in regeneration due to deer. In many stands we have challenges reestablishing conifers because of competition from aspen and shrubs in naturally regenerating stands.
    b. Paper birch; a light seeded species that has light seed and demanding site preparation requirements. Paper birch regeneration is a problem throughout its range. A very big problem with paper birch is when the access requires a frozen ground condition and the harvest operations are also under frozen conditions. The necessary scarification of the ground for the ideal seedbed for birch does not occur. This makes it very difficult to continue to maintain paper birch across the forest when you can't regenerate the type in place where scarification can't occur. (National)
2. Nothing that I'm aware of. (National)
3. Red, white and jack pine. Drought, grass competition, depredation by rabbits and deer. (County)
4. Oak & white pine due to competition with other species & deer browse (County)
5. *Pinus*- deer browse, Birch/Oak-seed catch, Balsam Fir-good seedbed (County)
6. Birch and Jack Pine. The problem with our birch is that it's 65+ years old. And, it's being harvested in frozen-winter time. That means there's 1.) poor stump sprout vigor, and 2.) no mineral soil exposure. We often have to plant cut-over hardwood areas.

Jack Pine problems stem from deer control. They eat those trees like candy. We have too many open-field plantings where it's easy for deer to access the trees. (County)

7. Conifer species have become increasingly more difficult to regenerate due to the high deer population in our operating area. Deer browse is a major concern when determining regeneration plans. (County)
8. Birch. Seasonal access issues hinder site treatments and winter treatments are marginal, yielding more clump birch vs. single stem. Single stem is preferred. (County)
9. Jack pine – Deer browse (County)
10. Cedar - deer and seed success (County)
11. Jack pine in the woodlands; white pine and others due to increased animal damage (State)
12. White pine and white cedar – deer (NGO)

Question 4:

Is there anything else, you would like us to know about your silvicultural practices or issues (e.g., availability of seedlings, operation logistics, planting quality, planning, exotic species, and equipment issues)? Please write your comments here.

1. We do not plant any exotic species. Our problems with exotic insects/disease are the same as for the rest of the state; gypsy moth, emerald ash borer (not yet but soon), etc. We have a well established reforestation program with the necessary infrastructure (FS nursery, coolers for planting stock, site prep equipment) and trained personnel that can handle a large and varied reforestation/restoration program. Harvest equipment issues can come up when you want to harvest minimal trees from a mature patch (such as a very dense red pine patch) but the spacing of trees may not help facilitate operations (most loggers have larger harvest equipment that will not be able to operate in these tight conditions). This can limit our opportunities for more forest management in such areas. (National)
2. In artificial methods we are attempting to move more toward direct seeding and less planting. Especially in white pine and Jack pine. (National)
3. We get most of our seedlings from PRT in Dryden, Canada. The containerized seedlings are ideal, they are reliable, and they perform better (observationally...I don't have statistical proof). We struggle with re-inventory and would like to have dollars to spend on those efforts. Also, many foresters lack VITAL ArcGIS skills that many of the young foresters have...there's a wide gap that needs to be closed. (County)
4. We will experiment with discs and fireplows, fire and springtooth drags. (County)
5. Lower Stumpage rates and delivered prices combined with high fuel and increasing Contractor rates have made some treatments difficult to justify to Investors. In the TIMO world a silviculture decision is no different than an investment decision or capitol expense in manufacturing industry. (Forest Industry)

APPENDIX E: Potential improvements for future surveys

The following are suggestions for improving future iterations of the "Survey of Silvicultural Practices" based on comments received from survey participants, as well as general observations by the authors of this report:

- Survey delivery: Many of the survey participants ran into issues using the SurveyMonkey software and preferred filling the survey out on a hard copy. In many cases, respondents filled out the hard copy and then input their responses to the survey website. In future surveys, all participants should be mailed a hard copy of the survey, along with detailed instructions regarding how to use the software.

- Survey timing: The survey was administered a few weeks after a similar survey of general forest management practices was distributed by Minnesota Forest Industries. As such, many of the respondents were "surveyed out" after completing these surveys, possibly limiting their enthusiasm for fully completing our rather lengthy survey. As such, future surveys should be coordinated with other agencies and organizations to minimize overlap in timing of survey administration.

- Survey length: Based on comments from several respondents, the survey was fairly long and took considerable time to complete. This is also reflected in the lower sample sizes for questions towards the end of the survey (e.g., Table 11), which some respondents failed to answer. Future surveys should be peer-reviewed by several land management agencies to ensure that the data we are requesting is readily available and can be input in a fairly time-efficient manner. In addition, we should be conservative about adding new questions to future surveys so as to keep them a reasonable length.

- Information on volume harvested per treatment type: It would be useful to include questions in future surveys that requested information regarding the volumes removed by a given treatment type (e.g., thinnings versus selection harvests). This would allow for better tracking of the general intensity of treatments over time.

- Nonindustrial Private Forest (NIPF) Landowners: As with past iterations of the survey, we were unable to document the status of practices occurring on NIPF lands. Although surveys were sent to consulting foresters to try to address this limitation, the length of the survey and lack of monetary incentive for survey completion precluded the participation of this group of individuals. Future survey efforts could possibly include monetary incentives for consulting foresters to complete surveys or should explore other options for filling in this information gap.