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ARTICLE

Assessing the influence of forest ownership type and location on roundwood utilization at the stump and top in a region with small-diameter markets

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Abstract: Research conducted in a variety of hardwood regions across the United States has indicated that utilization of small-diameter roundwood is hindered by a lack of markets. Efficient removal of such material could enable silvicultural practices to improve stand conditions and economic return for landowners. However, evidence from other studies has suggested that markets alone may not be enough to encourage small-diameter utilization, and that management decisions are important as well. This study sought to compare roundwood utilization at the stump and top for different ownership categories and locations in north-central Wisconsin, a region with active pulpwood and other low-grade markets and different types of forest ownerships. Thirty-six recently harvested sites were visited in 2007 and 2008 across three ownership types (managed county-owned forests, private land timber sales involving a professional forester, and private land timber sales without involvement of a professional forester) and two locations (county groupings) with different markets. Results of a linear mixed model indicated that ownership type was a significant predictor variable for the utilization measures studied (stump diameter, top diameter, and stump height). Location effects were significant for stump diameter and stump height. Sales on unmanaged private forests exhibited the largest stump and top diameters and highest stump heights, regardless of location. Overall, this study suggests that both management practices and markets influence harvest site small-diameter utilization.

Résumé : Les travaux de recherche effectués dans diverses régions, un peu partout aux États-Unis où il y a des forêts feuillues, ont montré que l'utilisation du bois rond de faible diamètre est freinée par l'absence de marchés. Si la récolte de ce matériel était efficiente, les pratiques sylvicoles permettraient d'améliorer les peuplements et les retombées économiques pour les propriétaires. Cependant, selon d'autres études il appert que la présence de marchés seule pourrait ne pas suffire à encourager l'utilisation des bois de faible diamètre et que les décisions d'aménagement seraient également importantes. Cette étude a cherché à comparer l'utilisation du bois rond à la souche et au fin bout pour différentes catégories de propriétés et différents endroits dans le centre nord du Wisconsin, une région où existent des marchés pour le bois à pâte et le bois de qualité inférieure, ainsi que différents types de propriétés forestières. Trente-six sites récemment récoltés et représentant trois types de propriétés (forêts aménagées appartenant au comté, ventes de bois provenant de terrains privés auxquels est associé un forestier professionnel et ventes de bois provenant de terrains privés auxquels n'est pas associé un forestier professionnel) et deux endroits (groupements de comtés) avec différents marchés ont été visités en 2007 et 2008. Les résultats d'un modèle linéaire mixte indiquent que le type de propriété est une variable prédictive significative pour les mesures d'utilisation étudiées (diamètre à la souche, diamètre au fin bout et hauteur de la souche). L'endroit avait des effets significatifs dans le cas du diamètre à la souche et de la hauteur de la souche. Le bois provenant des forêts privées non aménagées avait le plus gros diamètre à la souche et au fin bout ainsi que la hauteur de souche la plus élevée peu importe l'endroit. Dans l'ensemble, cette étude indique que les pratiques d'aménagement et les marchés influencent l'utilisation des bois de faible diamètre des sites de coupe. [Traduit par la Rédaction]

Introduction

The earliest decisions affecting log value in the wood supply chain occur in the forest, including what practices are followed when cutting. Similarly, decisions concerning which trees are cut can affect future forest conditions and the potential future economic return. This is especially true when considering utilization of small-diameter or other low-grade roundwood. In many cases finding economical uses is difficult, leading to efforts to develop new production and marketing systems to utilize this material (Reynolds and Gatchell 1979; Bumgardner et al. 2001). Often, the assumption behind these efforts is that by developing new markets, utilization can be improved.

Research conducted in a variety of primarily hardwood regions across the eastern United States has indicated that utilization of small-diameter roundwood is hindered by a lack of markets, even though efficient removal could lead to a greater variety of silvicultural practices to improve stand conditions (Huyler and Turner 1993) and economic return for landowners (McCay and Wisdom 1984). More recent studies have contrasted low-grade and small-diameter market opportunities across eastern US states and analyzed the associated implications for forest management (Munsell et al. 2008), and assessed the economic feasibility of harvesting small-diameter material for hardwood crop tree management (Becker et al. 2011). A lack of markets for low-grade hardwood material has been associated with primarily sawlog-based and diameter-limit cutting (Fajvan et al. 1998), and with unwanted roundwood being left as logging residue after harvests (Grushecky et al. 2006). Munsell et al. (2008) suggest that context factors (e.g.,

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location, markets, or forest type) can influence management outcomes on nonindustrial private forestlands in the eastern US.

However, evidence from other studies has suggested that markets alone may not be enough to encourage small-diameter utilization and that management decisions are important as well. For example, even with the addition of new regional markets for lower value or lower grade hardwood roundwood, diameter-limit-based cutting still appeared to be the principal method of determining tree removal (Luppold and Alderman 2007). Landowners, in the absence of professional guidance, often fail to fully appreciate the complexity of hardwood forest management and the implications for long-term economic return (Smith 2010). Preliminary research has indicated that utilization of small-diameter timber is suggestive of professional management in the upper Midwest, even in areas without readily accessible pulp markets (Bowe and Bumgardner 2006).

Despite the potential importance of management to small-diameter utilization, comparative studies of harvest-related utilization by ownership categories or management practices appear to be limited, especially for northern hardwoods and smaller private ownerships. A study by Moss and Heitzman (2010) found that harvests in West Virginia involving professional foresters were more likely to have smaller diameter trees removed, and that the residual stands were more likely to be in a fully stocked condition with dominant and codominant trees. A study conducted in Mississippi compared several activities associated with management intensity across three ownership groups including timber investment management organizations (TIMO), large industrial landowners, and small industrial landowners, and found that smaller owners were less likely to invest in site preparation, planting, and midrotation treatments (Rogers and Munn 2003). Another study similarly found that management intensity in Mississippi was greater on lands of industrial and TIMO ownership than on nonindustrial private and public (state) ownerships (Arano and Munn 2006). Forest type, size of ownership, and management objectives were noted as influencing the differences in management intensity.

Problem statement, objective, and study setting

The preceding review of the literature suggests that market and management influences both can be expected to play a role in efficient utilization of small-diameter or other low-grade roundwood material. While other studies have identified the need for these drivers, or described feasibility studies to develop new production systems and markets for such material, little empirical data exists to assess the role these influences are playing together in a case setting where both are present to varying degrees. Such information can be used when assessing the potential impacts of new markets or production systems; for example, is market development "enough" or will the potential to better utilize small-diameter material be diminished in the absence of sound forest management?

This study sought to compare utilization practices for different ownership categories (managed county-owned forests, private land timber sales involving a professional forester, and private land timber sales without involvement of a professional forester) and locations (counties) in a region (north-central Wisconsin) with viable markets for small-diameter material generally, but with local differences in such markets. The potential influences of harvesting method (mechanized or chainsaw) are considered as well. Mechanical harvesting systems are becoming increasingly common in eastern hardwood forests (LeDoux 2010) and in Wisconsin specifically (Rickenbach and Steele 2005).

The study was conducted in four counties in north-central Wisconsin to help control for the influence of forest type and access to pulp markets. Approximately 69% of the roundwood removed annually in Wisconsin is utilized as pulpwood, which includes the roundwood received by particleboard, oriented strand board (OSB), and other engineered board plants (Reading and Whipple 2007). Northern Wisconsin exhibits greater relative pulpwood roundwood production (cords per acre) than any other location in the north-central region of the United States (Piva 2006). The region also is realizing increased demand from biomass markets. Many traditional forest products companies have used biomass for decades for process heat and steam. In recent years, wood pelletizing and electrical energy generation firms, as well as facilities in need of thermal and process heat, have added to wood utilization demands in Wisconsin (T. Mace, Wisconsin Department of Natural Resources, personal communication, 2010). Initially, much of the use for biomass was in the form of residues (e.g., sawmill byproducts), and specific roundwood removals for industrial fuelwood remained at low volumes in the state through the mid2000s (Reading and Whipple 2007). However, more recently (since data collection for the study), residual volumes have declined in conjunction with lower demand for lumber and thus more emphasis likely is being placed on roundwood.

Wisconsin is similar to most other states in having a state-sponsored tax program in place (the Managed Forest Law program, MFL) to encourage forest management on private lands through property tax incentives. Such programs have been shown to have relatively high awareness levels among landowners (Jacobson et al. 2009). Studies also have suggested that compliance with the mandatory practices of the program is generally high on enrolled properties (Shockley and Martin 2000). Properties enrolled in this program represent private property with a required professional management plan in place and, consequently, with forester involvement in both development of the plan and approval of any harvesting. There are approximately 3.1 million acres (1.3 million ha) of forestland enrolled in the MFL, which represents approximately 19% of Wisconsin's 16 million acres (6.5 million ha) of total forestland (K. Mather, Wisconsin Department of Natural Resources, personal communication, 2010). This enrolled total also represents approximately 28% of the eligible (privately owned) forestland in the state (based on ownership breakdowns provided by Finan (2000)). In addition, 29 of Wisconsin's 72 counties have actively managed publically owned county forests (where timber sales often are bid out), making the state a good place for comparing management on different types of forest ownerships.

Utilization measures at the stump and top

The primary interest in the current study was on the impacts of the aforementioned factors (management and location) on small-diameter utilization. Measures readily available in the field from recent harvest sites were sought to enable data collection across a wide area within given cost constraints. Stump diameter is an important measure of the size of trees removed and was a dependent variable in this study. Another consideration is potential differences in the top diameters of harvested roundwood. Although some work has shown that opportunities might exist to improve sawlog small-end diameter utilization in mechanized bucking operations (Boston and Murphy 2003), less is known regarding the impacts of forest management on top diameter utilization. Perhaps more important to top utilization are markets. In locations without economical proximity to low-grade markets, hardwood logging residue in the form of tops is commonly left in the woods (Grushecky et al. 2006), although there is some evidence that managed forests exhibit better use of hardwood tops even when pulp markets are not proximate (Bowe and Bumgardner 2006). Top diameter also was a dependent variable in this study.

Another utilization factor that plays an important role in potential value loss of logs is stump height (Boston and Dysart 2000), which also was a dependent variable in the study. While perhaps not directly related to small-diameter utilization, it likely is an indirect measure in that larger stumps might be expected to have

Fig. 1. Four-county study area (bold outline) in Wisconsin, forest cover, forest ownerships, and mill locations (in and near Wisconsin) at the time of the study.

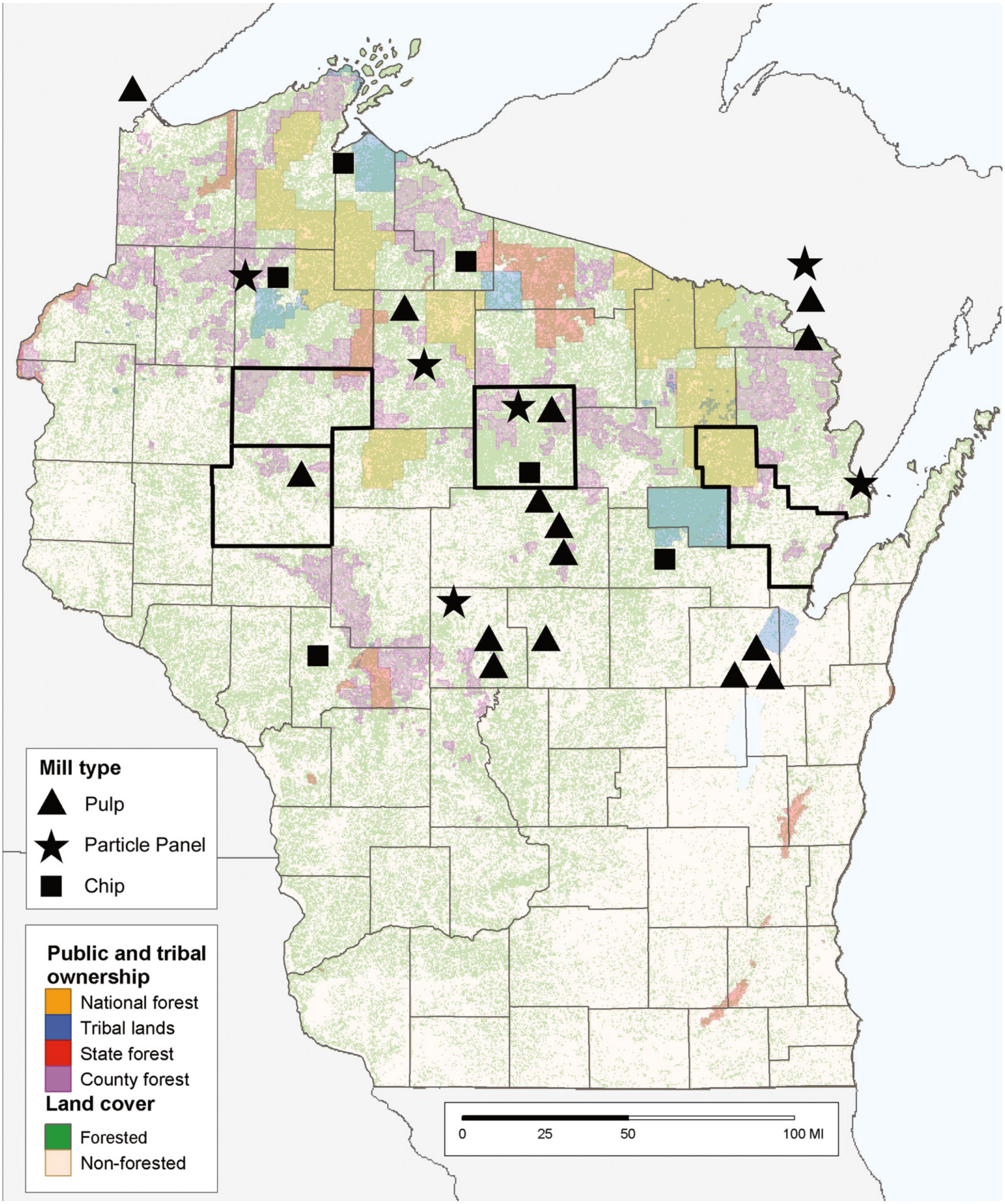


Table 1. Pulpwood production characteristics (as roundwood) by county.

County and study location	Pulpwood production (standard cords)[a]	Acres of timberland[b]	Production (standard cords) per 1000 acres
Lincoln (Eastern)	176886	398576	443
Oconto (Eastern)	57071	227000	251
Rusk (Western)	68965	409548	168
Chippewa (Western)	33151	224250	148

[a]Source: Piva (2006). Data is for the year 2004 and includes all primary products made from reconstituted wood fiber, including pulp, particleboard, and engineered products.

[b]Source: USDA Forest Service (2012). Data were retrieved for the year 2004 to correspond with the production data from Piva (2006). Timberland acres for Oconto County are net after removing federal lands, which accounted for 36.3% of the Oconto County total; there were no federal timberlands reported in the other counties.

Table 2. Forest characteristics by study location.

Location	Quadratic mean diameter (in.)	Number of growing stock trees per acre	Growing stock volume per acre (cubic feet)
Western counties	9.3	125.4	1157.4
Eastern counties	9.0	162.7	1361.1

Note: Source: USDA Forest Service (2012); data were retrieved for the year 2008 to correspond with the data collection period for the study. 1 in. = 2.54 cm; 1 ft. = 0.3048 m.

higher stump heights given swell at the tree base. Furthermore, little previous research has been published concerning the potential impacts of management on stump heights, although there are several studies that have shown that mechanized-cut harvests tend to have lower stump heights than manual chainsaw-cut harvests (Boston and Dysart 2000; Han and Renzie 2005; Hall and Han 2006).

Methods and descriptive data

Four counties (Chippewa, Lincoln, Oconto, and Rusk) were selected as the study area (Fig. 1), based on several criteria including data availability and the presence of a mix of ownership and harvesting types, and were judged to be typical of forest, harvesting, and market conditions in north-central Wisconsin. While all four counties were generally proximate to potential pulpwood and (or) other low-grade markets based on mill locations in the State[1] (Fig. 1), the eastern-most counties (Lincoln and Oconto) realized higher relative pulpwood roundwood production than the western-most counties (Chippewa and Rusk), suggesting they were generally closer to such markets (Table 1). As will be discussed later, the four counties were combined into these two groupings to facilitate analysis; furthermore, primary interest was in general location effects rather than those of specific counties. In addition, when comparing general forest characteristics between the two locations, the eastern counties exhibited more growing stock trees and greater volume per acre (Table 2). Species composition also differed in some ways between the two locations (discussed in the next section). Overall, market (and forest) characteristics were different between these two county groupings even though average tree size was similar.

Cutting notices on file with each respective county for private ownerships, as well as records of timber sales for county-owned forests, were obtained to identify harvests that had been completed in 2007 and 2008. A total of 36 sales were sampled — in each of the four counties, three sales each were randomly (i.e., systematically) selected for each of the three ownership types: (1) county forest sales, (2) forester-involved (FI) private sales (mostly MLF-enrolled ownerships, although two of the harvests in this category involved a forester without being in the program), and (3) forester not involved in private sale (NFI). In cases where field access was denied by the landowner, the next cutting notice was used.

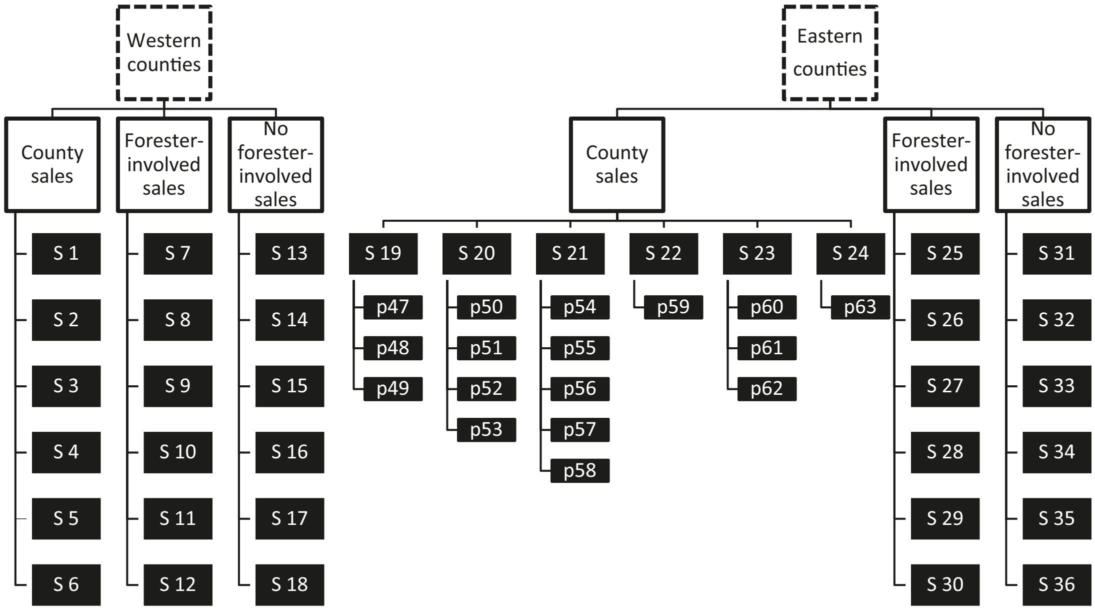
An attempt was made to include both mechanized and chainsaw harvests in each county and ownership type, given the increasing importance of mechanized operations. However, harvesting method proved difficult to control for, e.g., there was a lack of information (a priori) on how the wood was harvested on some sales (especially private sales), and it was not uncommon for sales to be a combination of mechanized and chainsaw cutting. In one county-owned forest, it was not possible to find a chainsaw sale. Therefore, the potential impacts of harvesting method will be discussed qualitatively in the analysis. The sample included 14 mechanized harvests, 14 chainsaw cuts, and 8 that were a combination of mechanized- and chainsaw-cut harvests. On the combination harvests, chainsaw felling generally was limited to only the larger diameter trees. The mechanized cuts included both cut-to-length and tree length skidding operations.

Utilization data were gathered on 1/5-acre (0.08 ha) fixed plots. Plot location was determined based upon a 10 × 10 chain grid pattern starting at the southeast corner of the sale. A plot center was established for every 10 acres (4.0 ha) at the site for sales of 50 acres (20.2 ha) or less. For sales greater than 50 acres (20.2 ha), five plots were established to represent the entire area. The largest sales was approximately 90 acres (36.4 ha), and only four were larger than 50 acres (20.2 ha). Data concerning stump diameter (and the species of the tree harvested), stump height, and top diameter (the point at which utilization of the stem stopped) were collected. On chainsaw-cut plots, data were collected based on trees found within the plot, i.e., tops were matched with stumps. On mechanized harvests, stumps and tops were counted separately within the plot, chiefly because the number of stumps tended to be higher on mechanized plots and often it was not possible to match stumps to tops. Plots to measure residual basal area were variable and made with a basal area stick (10 factor). Also, at the plot center, observational field notes of harvesting activities and stand characteristics were made on 1-acre (0.4 ha) plots (laid out by pacing but not tape-measured like the 1/5-acre plots). The type of forest management treatment observed for the overall sale also was recorded.

Data were collected during nonwinter months to avoid snow cover influencing detection and measurement of stumps and pulpwood left in the woods. Most of the sample sales were harvested in nonwinter months (69%); however, a proportionally high number of the FI sales (58% compared with 17% each for county and NFI sales) were harvested in the winter (potential implications are discussed in the Results). Generally, each sale involved a different logging contractor (i.e., the loggers were not the same across sales), although in some regions the likelihood of the same contractor being involved in more than one sale increased. However, even if the same logging firm was involved in more than one of the sample sales, the specific crews were likely to differ.

[1]While individual mills will vary according to diameter and quality specifications and the quantities of roundwood required, Fig. 1 is intended to show that the region, in general, is proximate to multiple users of small-diameter material. Pulp mills, particleboard/engineered wood mills, and stationary chip mills (which can provide chips for both pulp mills and biomass users) are indicated.

Fig. 2. Hierarchical structure of the study design with crossed fixed effects designated by white boxes (broken lines for location and solid lines for ownership type) and random nested effects designated by black boxes ("S" for sale and "p" for plot). The representation of the plot-level random effect is shown for only one branch to simplify the figure.



Data analysis

The dependent variables were stump diameter, top diameter, and stump height.[2] The data were analyzed as a hierarchical design (Fig. 2), with sales (a random effect) being nested within location (a fixed effect with two levels) and ownership type (a fixed effect with three levels). There were six sales nested under each cross-classification (although in the case of tops, some plots contained no tops for NFI sales in the western counties; the combining of counties into two groups helped alleviate this problem for analysis). Accounting for sales as a nested factor helped account for the fact that the sales were often different in several respects, e.g., terms of species composition, size (acreage), age, and whether harvested mechanically or by chainsaw.

In addition, since most sales had multiple plots, plots also were nested within sale as a random effect[3] (Fig. 2). Since plots were fixed radius (e.g., there was an unequal number of stump and top measurements in each cell), and since the number of plots per sale differed depending on the size of the sale, the design was unbalanced. Therefore, all post-hoc comparisons were based on adjusted (least squares) means. Analysis was conducted using the proc MIXED function (using restricted maximum likelihood or REML as the estimation method, type III fixed effects tests, and incorporating the COVTEST option) within the Analyst program in SAS version 9.2 (SAS Institute, Inc., Cary, North Carolina). For each dependent variable, the model used is shown in eq. [1].

$$[1]\qquad y_{ijklm} = \mu + \alpha_i + \gamma_j + (\alpha\gamma)_{ij} + c_{k(ij)} + d_{l(k)} + e_{ijklm}$$

where y_{ijklm} is the observation (e.g., stump diameter), μ is the overall mean, α_i is the fixed ownership type effect, γ_j is the fixed location effect, $(\alpha\gamma)_{ij}$ is the fixed ownership type by location effect, $c_{k(ij)}$ is the random effect of sale nested within ownership type and location, $d_{l(k)}$ is the random effect of plot nested within sale, and e_{ijklm} is the random error.

Analysis of residuals indicated that the distributions were generally normal or close to normal for each of the dependent variables (skewness of 1.1 or less for each variable; kurtosis of 3.2 for stump height, 2.7 for stump diameter, and 0.7 for top diameter). Visual inspection of plots of the residuals versus predicted values indicated no clear patterns to suggest that heterogeneity of variance was a major problem.

Descriptive data

Data were collected at 85 plots covering approximately 949 acres (384.0 ha). Stumps less than 5 in. (12.7 cm) in diameter were excluded from analysis because the associated trees generally were felled for safety or timber stand improvement purposes and not utilization, resulting in a total of 1423 usable stumps. The sample breakdown by ownership category was 42.2% county, 32.3% FI, and 25.4% NFI (Table 3). In addition, 829 tops were measured with the sample breakdown being 42.9% county, 33.2% FI, and 23.9% NFI. County forest sale data points were more numerous relative to the other ownerships types (larger sample size) given their relatively large acreages and the fact that each ownership type was sampled equally in terms of number of sales and plot intensity, which was a function of using cutting notices and

[2]The dependent variables were assessed to determine normality, an assumption when using a linear mixed model. For each of the dependent variables, skewness values were between 1.0 and 2.0. For kurtosis, stump diameter was less than 2.0, while kurtosis for stump height was 4.7 and top diameter was 5.3. A contributing factor to the moderately high kurtosis values (Curran et al. 1996; Kline 2011) for stump height and top diameter was the presence of some extreme outliers, defined as exceeding 3 times the interquartile range plus the upper quartile (Ott 1993). There were 10 such observations for stump height and six for top diameter (there also were two for stump diameter, but these did not cause skewness or kurtosis to exceed 2.0 for this variable). An inspection of these outliers indicated they were valid data points and, in the case of top diameter, all occurred on a single sale. In an attempt to make the distributions closer to normal, but limit the removal of data, only the most severe of these outliers were removed (top diameter of 11 in., or two observations; stump height of 30–32 in., or four observations; 1 in. = 2.54 cm). This lowered kurtosis to 2.7 for stump height and 3.2 for top diameter. Results for the fixed effects and LS means were very similar using the trimmed and untrimmed dependent variables; the results reported in Tables 5–7 are based on the trimmed distributions.

[3]Given the use of plots in data collection, there was a possibility that the data for each plot would be correlated spatially and thus pseudoreplicated (Hurlbert 1984; Lazic 2010). Other than including plots as a random nested effect, another approach is use of the mean as a single datum for each plot. The analysis also was run in this fashion for each dependent variable (keeping sale as a nested random effect), and the results were very similar to those reported in Tables 5–7 for the fixed effects and LS means.

Table 3. Background characteristics by ownership type.

Characteristic	County sales	FI sales	NFI sales
Stumps sampled	601	460	362
Tops sampled	356	275	198
Sale size (mean acres)[a]	39.5 (25.6)[b]	23.0 (19.3)	16.6 (7.6)
Number of stumps per plot (mean)	15.4 (7.6)	18.4 (13.4)	17.2 (15.2)
Residual basal area[c] (mean square ft.^{2}/acre)[d]	91.4 (29.9)	105.7 (41.3)	62.4 (15.2)
Harvest method (% of stumps by mechanized)	74.0	83.3	61.6
Species percentages of stumps			
Maple[e]	46.2	34.6	30.9
Birch[f]	18.3	5.2	11.1
Aspen (*Populus tremuloides* Michx.)	6.7	16.7	21.0
Oak[g]	6.3	10.7	8.3
Basswood (*Tilia americana* L.)	11.3	5.8	1.9
Red pine (*Pinus resinosa* Ait.)	0.0	20.4	5.0
All other misc. softwoods	4.3	1.3	18.2

Note: FI, forester involved; NFI, forester not involved.
[a]1 acre = 0.405 ha.
[b]Numbers in parentheses are standard deviations.
[c]Excluding clearcuts; the 95% confidence interval was within 20% of the estimate for each group.
[d]1 ft^2/acre = 0.230 m^2/ha.
[e]Includes hard and soft maples (*Acer* spp.).
[f]Includes white and yellow birches (*Betula* spp.).
[g]Includes red and white oaks (*Quercus* spp.).

county records as the basis for sampling. The stump sample was larger than the top sample because tops sometimes were removed or moved around, i.e., moved outside the plot in the case of mechanized harvests or impossible to match to chainsaw-cut stumps.

The overall age for residual stands on the nonclearcuts generally was variable (four sales were clearcuts and two additional sales were partial clearcuts, which were distributed somewhat evenly across the ownership types and locations); across the individual plots that had an even age, the average was 68.1 years (s = 17.3).

Maple species (*Acer* spp.) accounted for 38.6% of the overall stump sample (*Acer rubrum* L. (red maple) accounted for 21.0%), aspen (*Populus tremuloides* Michx.) accounted for 13.6%, birches (*Betula* spp.) for 12.2% (*Betula papyrifera* Marsh. (white birch) accounted for 11.2%), and basswood (*Tilia americana* L.) for 7.2%. Oaks (*Quercus* spp.) also were somewhat common, accounting for 8.2% of the stumps (red oaks, 6.5%). In total, 26 species were represented and most were hardwoods (14.8% of the total was softwoods, mostly *Pinus resinosa* Ait. (red pine) in plantations).

For stumps, 73.9% of the overall sample was mechanized- or processor-cut. NFI sales were the only ownership type to be predominately chainsaw-only cuts (66.7%), and NFI sales had the lowest proportion of mechanized-cut trees overall (Table 3). For tops, 79.7% of the overall sample was processor-cut, slightly more than for the stump sample. For tops, the most common "stopper" (the factor that dictated the top of the utilized stem) was diameter, accounting for 70.7% of stops. Otherwise, some feature was present that affected the top diameter; forks accounted for another 24.4% and crookedness accounted for 2.9%. The remainder was related to splits, limbs, sweep, rot, and breaks.

Some overall trends are notable from Table 3 concerning differences in the ownership types. Private sales tended to be smaller than county forest sales; this was especially true for NFI sales. NFI sales also tended to have much lower residual basal area than the other ownerships, even though the stumps cut per plot was similar across all ownerships. By field observation, over half of the NFI sales sampled could be categorized as diameter-limit cuts, whereas selective (e.g., crop tree release or species selection) and thinning methods were much more common on county and FI ownerships (over three-quarters of the harvests, respectively, and no diameter-limit harvests were observed). NFI sales also were more likely to be chainsaw cut, which is consistent with overall trends for Wisconsin reported by Rickenbach and Steele (2005) that mechanized logging firms sourced a higher proportion of their stumpage from state and county forests, whereas non-mechanized firms relied more heavily on nonindustrial private forests.

Regarding differences by location, summary statistics (Table 4) indicate that the stumps cut per plot were higher in the eastern counties relative to the western counties, possibly suggestive of the relative proximity of pulp and related markets in the eastern location (Fig. 1 and Table 1) and consistent with the higher number of growing stock trees and volume in the eastern counties (Table 2). Although the two location samples were quite similar in terms of maple, birch, and aspen composition (Table 4), there were some notable differences in terms of other species. Oak was much more common in the western counties, comprising nearly one-fifth of the stumps sampled. Softwoods, including red pine, were more common in the eastern counties, accounting for about one-fifth of the sampled stumps there. Overall, the composition of the stump samples was generally consistent with forest inventory data for the two study locations, i.e., maple was the most common genus in the growing stock inventory of both locations, with oak being more common in the western counties and softwoods more common in the eastern counties (Table 4).

Results

Stump diameter results

Results for the stump diameter analysis are shown in Table 5. Both ownership and location were statistically significant and the interaction of ownership*location was not significant. Across both locations, NFI ownerships exhibited the largest stump diameters (adjusted mean = 13.9 in. or 35.3 cm), whereas stump diameters for county and FI ownerships were smaller (by about 3 in. or 7.6 cm) and not statistically different from each other. Across ownerships, stump diameter was significantly higher in the western counties than in the eastern counties (by about 4 in. or 10.2 cm). The random effects of sale nested within ownership and location (covariance parameter estimate = 4.10; z = 2.80, p= 0.002) and plot nested within sale (covariance parameter estimate = 1.01; z = 2.50, p = 0.006) also were significant, suggesting that there was significant variability among sales, and among plots within sale.

Table 4. Background characteristics by location.

Characteristic	Western counties	Eastern counties
Stumps sampled	547	876
Tops sampled	259	570
Sale size (mean acres)[a]	29.9 (25.5)[b]	22.8 (14.8)
Number of stumps per plot (mean)	11.9 (5.7)	22.5 (14.0)
Residual basal area[c] (mean ft.²/acre)[d]	91.7 (28.7)	85.2 (40.9)
Harvest method (% of stumps by mechanized)	69.3	76.7
Species percentages of stumps		
Maple[e]	40.2 [30.4][f]	37.6 [25.1]
Birch[g]	10.4 [na]	13.4 [na]
Aspen (*Populus tremuloides* Michx.)	11.0 [14.6]	15.2 [14.7]
Oak[h]	18.3 [11.5]	1.9 [3.5]
Basswood (*Tilia americana* L.)	11.0 [7.4]	4.8 [2.4]
Red pine (Pinus *resinosa* Ait.)	3.3 [6.4]	10.7 [9.7]
All other misc. softwoods	1.0 [7.0]	10.8 [26.2]

[a]1 acre = 0.405 ha.
[b]Numbers in parentheses are standard deviations.
[c]Excluding clearcuts; the 95% confidence interval was within 20% of the estimate for each group.
[d]1 ft.²/acre = 0.230 m²/ha.
[e]Includes hard and soft maples (*Acer* spp.).
[f]Numbers in brackets are the number of growing stock trees (percent, in 2008) using the Forest Inventory and Analysis (FIA) database (USDA Forest Service 2012). Data is omitted for birch because it is grouped in multiple categories and therefore not available (na); the red pine data includes white pine (species are grouped in the database), and the aspen data likewise includes cottonwood.
[g]Includes white and yellow birches (*Betula* spp.).
[h]Includes red and white oaks (*Quercus* spp.).

Table 5. Fixed-effects model results for stump diameter.

Variable	*F*	df	*P*
Ownership	6.31	2, 26	0.006
Location	25.95	1, 26.2	<0.001
Ownership*Location	1.42	2, 26	0.260
	NFI	County	FI
LS means (in.)[a] for Ownership[b]	13.9a (0.7)[c]	11.1b (0.6)	10.9b (0.7)
	Western	Eastern	
LS means (in.) for Location	13.9a (0.5)	10.0b (0.5)	

Note: FI, forester involved; NFI, forester not involved; LS, least squares.
[a]1 in. = 2.54. cm.
[b]LS means with different letters are significantly different (α = 0.10, with Tukey–Kramer adjustment for the multiple Ownership tests).
[c]Numbers in parentheses are standard errors.

Stump height results

Results for the stump height analysis are shown in Table 6. Again, both ownership and location were statistically significant, whereas the ownership*location interaction was not significant. Stump heights for NFI sales (adjusted mean = 7.9 in. or 20.1 cm) were significantly higher than stump heights for county sales (adjusted mean = 5.4 in. or 13.7 cm) across locations, whereas average stump heights for FI sales fell between NFI and county sales. Given that several of the FI harvests were carried out in the winter months as noted previously, it is possible this affected (i.e., made higher) stump heights for the FI sales. Stump height in the western counties was much higher than in the eastern counties (by about 4.5 in. or 11.4 cm) across ownership types. The random effects of sale nested within ownership and county (covariance parameter estimate = 4.18; z = 2.61, p = 0.005) and plot nested within sale (covariance parameter estimate = 0.77; z = 2.37, p = 0.009) also were significant, suggesting that there was significant variability among sales and plots within sale.

Table 6. Fixed-effects model results for stump height.

Variable	*F*	df	*P*
Ownership	3.53	2, 21	0.048
Location	36.18	1, 21.2	<0.001
Ownership*Location	0.61	2, 21	0.553
	NFI	FI	County
LS mean (in.)[a] for Ownership[b]	7.9a (0.7)[c]	6.4ab (0.7)	5.4b (0.6)
	Western	Eastern	
LS mean (in.) for Location	8.8a (0.5)	4.3b (0.5)	

Note: FI, forester involved; NFI, forester not involved; LS, least squares.
[a]1 in. = 2.54. cm.
[b]LS means with different letters are significantly different (α = 0.10, with Tukey–Kramer adjustment for the multiple Ownership tests).
[c]Numbers in parentheses are standard errors.

Given the similar results for the stump diameter and stump height models, it is not surprising that stump diameter and stump height were significantly correlated (Pearson's r = 0.295, p < 0.001). This suggests that smaller stump diameters were associated with lower stump heights, although the magnitude of the association was not particularly strong. Overall, both of these measures (stump diameter and height) tended to be higher on NFI sales (unmanaged) and in the western counties (farther from pulp markets).

Top diameter results

Results for the top diameter analysis are shown in Table 7. Ownership was found to be statistically significant, but location was not. The interaction also was not significant. Across locations, NFI sales again were different from both county and FI sales, exhibiting a significantly larger top diameter than both of the other groups by about an inch or 2.5 cm (adjusted mean = 5.3 in. or 13.5 cm). The random effects of sale nested within ownership and county (covariance parameter estimate = 0.87; z = 3.08, p = 0.001) and plot nested within sale (covariance parameter estimate = 0.069; z = 2.03, p = 0.021) also were significant, suggesting that there was significant variability among sales and among plots within sale.

Summary and discussion

It was anticipated that ownership type (via forest management) and location (via markets) would influence the utilization factors investigated in this study. These propositions were generally supported. Only in the case of top diameter for location was a statistically insignificant result obtained. Overall, there was a clear trend of NFI (unmanaged) sales being different from managed forests (county and FI) for each of the utilization measures investigated in this study; namely, NFI sales exhibited the largest stumps, highest stump heights, and largest top diameters across the different market locations. In short, forest management matters, even when markets for small-diameter and low-grade roundwood are present. It may not be enough to develop new markets, in the absence of sound management, to fully realize the potential silvicultural or economic benefits of better utilization of small-diameter material. At the same time, location mattered as well for stump utilization, regardless of management activity, suggesting that markets also can improve small-diameter utilization. Overall, utilization seemingly is enhanced when both markets and management are present.

The point of discussion then becomes to discern the possible drivers of these findings. As noted previously, the NFI sales in the sample were smaller and more likely to have been chainsaw cut

Table 7. Fixed-effects model results for top diameter.

Variable	*F*	df	*P*
Ownership	3.91	2, 24.3	0.034
Location	1.66	1, 24.5	0.210
Ownership*Location	0.48	2, 24.3	0.623
	NFI	County	FI
LS mean (in.)[a] for Ownership[b]	5.3a (0.4)[c]	4.2b (0.3)	4.1b (0.3)
	Western	Eastern	
LS mean (in.) for Location	4.8a (0.3)	4.3a (0.2)	

Note: LS, least squares.
[a]1 in. = 2.54 cm.
[b]LS means with different letters are significantly different (α = 0.10, with Tukey–Kramer adjustment for the multiple Ownership tests).
[c]Numbers in parentheses are standard errors.

relative to the other ownership types. These points likely are related and suggest that many NFI sales simply lack the scale necessary to realize some of the potential benefits of mechanized harvesting.[4] But lack of management likely played a role as well. For example, there was evidence that unmanaged (NFI) sales were more likely to have been diameter-limit cut (perhaps why stump diameters were larger on NFI lands) and have substantially lower residual basal area, even though the number of stumps cut per plot was similar on each ownership type (such a pattern might suggest repeated diameter-limit cutting). On managed lands, more thought likely is given to preharvest planning and silviculture to remove and utilize some smaller diameter material (Bowe and Bumgardner 2006) to improve or sustain future forest conditions. In addition, the relatively larger top diameters found on the NFI sales suggests a focus on sawlog harvests with less attention being paid to finding markets for smaller diameter material (although it is possible that the larger stump diameters also may have contributed to larger top diameters). The small size of many NFI sales might limit opportunities for professional management;[5] however, for these sales the average size (16.6 acres or 6.7 ha) exceeded the minimum size (10 acres or 4.0 ha) for qualification for Wisconsin's MFL program (Shockley and Martin 2000), suggesting that opportunities exist for improved management (and improved utilization) on these lands.

The importance of markets to small-diameter utilization was highlighted by the significant impact of location to the stump utilization measures (diameter and height) in the study. The western counties had substantially higher stump diameter and stump height measurements, on average, likely a reflection in part of the relatively large proportion of oak harvested there. Perhaps cutting of smaller diameter material is more limited in areas where oak (and sawlogs generally) make up a sizeable portion of the harvest. In sawlog-dominated harvesting regions, operational efficiency is enhanced when larger trees are harvested (Luppold and Alderman 2007). The number of stumps cut per plot was higher, and stump diameter was smaller, in the eastern counties where relative pulpwood roundwood production was higher. Mechanized harvesting also was slightly more common in the eastern counties. Top diameter was not different between the eastern and western counties. This suggests that, once harvested, trees across the entire region were utilized for small-diameter markets, whether related to the markets depicted in Fig. 1 or to strengthening markets for biomass. It seems utilization opportunities for smaller diameter material were driving merchandising of tops to an average of 4.3 in. (s = 1.1) or 10.9 cm across both locations. Overall, it seems location influenced the type of trees that were cut; but once they were cut, utilization of the harvested material was similar across north-central Wisconsin.

Lastly, the dynamics involved with any given harvest cannot be discounted, as the random effect of sale (and even plots within sale) also had significant influence on all of the utilization measures studied. Such dynamics include a myriad of factors including (but not limited to) species composition, age structure, past management or harvest activity, harvesting method, and site-specific factors. This illustrates, in part, the complexities involved with forest management and utilization (Munsell et al. 2008; Smith 2010), with many such factors being beyond the scope and control of this study and thus representing a limitation. In addition, market conditions are dynamic, and it is likely that more roundwood markets for biomass currently exist than did at the time of the study. However, results from the study indicated that ownership type and location did influence roundwood utilization; active forest management can improve small-diameter use, as can the presence of markets.

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[4]Although beyond the scope of this paper, a growing body of research is dedicated to the topic of parcelization and harvesting. For example, see Allred et al. (2011) for a recent review and analysis.
[5]For example, Kittredge et al. (1996) found that as woodlot size decreases, loggers require increasing timber value to economically enter the stand. Other authors (e.g., McCay and Wisdom 1984) also have noted that timber utilization can be constrained on small forest ownerships.

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