Land Cover, Land Use, and Mill Characteristics as Predictors of Wood Procurement Range

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Abstract

Urbanization of forestland has the potential to reduce the timberland base indefinitely. Wood-using industry located in areas with declining timberlands may be forced to expand the range of procurement operations to meet production requirements. This article examines 11 different land use and land cover variables as predictors of woodshed area for sawmills in the northeastern United States. Based on woodshed maps provided by 175 sawmills in seven states, geospatial analysis and multiple regression are used to test the hypothesis that mills in areas with higher proportions of nontimber land have larger woodsheds. Results indicate that mill characteristics, not landscape variables, are the strongest predictors of woodshed area. Although some cover types, including farmland and open water, are associated with larger woodsheds, none of the measures of urbanization used in this study are significant predictors of woodshed area. If urbanization is leading to a reduced flow of sawlogs, the explanation for the lack of observed effects of urban cover on woodshed area may be tied to the flow of sawlogs from terminal harvests, prior relocation of sawmills out of urbanizing areas, or the implementation of alternative procurement and production strategies that help sawmills remain competitive as local wood supplies tighten.

The sawmill industry is characterized by relatively high transportation costs for raw materials, which results in a dependency on local sawlog suppliers (Murray and Prestemon 2003). For example, most sawmills in the northeastern United States purchase sawlogs and stumpage from landowners, loggers, and log brokers within 30 to 70 miles of the mill, depending on production requirements (Anderson and Germain 2007). The close relationship between sawmills and nearby sawlog suppliers makes these firms especially sensitive to local sawlog market conditions, which vary geographically because of variation in forest ownership, stand conditions, and product value (Luppold and Bumgardner 2006).

Several recent studies have documented a widespread perception that the sawlog resource is in decline in many areas of the Northeast. In a 2006 survey, the majority of more than 200 sawmill managers reported a decline in the total volume of logs available for purchase, a decline in the quality of logs available for purchase, and a decline in the average volume per log within their woodshed over the decade from 1994 to 2005 (Anderson and Germain 2007, Anderson et al. 2009). Egan et al. (2007) reported that ‘‘uncertainty about the future of the region's wood supply'' ranks as an important barrier to maintaining or expanding operations for most mills and loggers surveyed in Maine, New Hampshire, and Vermont. Based on the perceptions of professionals in the industry, it appears that a decline in the flow of sawlogs from forestlands has the potential to erode the profitability and long-term viability of the industry in this region.

Although analyses of stocking data from nonindustrial private forests in New York support the perceptions of sawmill managers and loggers (Germain et al. 2007, Munsell et al. 2008), these perceptions appear to be inconsistent with observed and predicted trends in sawlog stocks at regional and national scales (Luppold and Dempsey 1996, Sendak et al. 2003). The productivity and growth of US forestlands have improved over the past 50 years. Despite the loss of private timberlands to development and other nontimber land use, projections for the Northeast as a whole indicate that over the next 50 years the softwood timber harvest will stabilize at 0.5 billion cubic feet and that the hardwood timber harvest will grow to nearly 2 billion cubic feet (Haynes et al. 2007). These

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projections are predicted to coincide with increases in growing stock inventory, especially in hardwood stocks on nonindustrial private land (Haynes 2003). The difference between reported declines in log quality and availability and the projected increase in stocks illustrates the wood procurement situation confronting many sawmills in the Northeast. Land use and forest management patterns within individual woodsheds can negatively impact wood procurement, even as stocks increase at the regional scale.

In some areas, urbanization of forestland has been identified as a major problem for the forest industry because of its potential to negatively impact wood supply. Recent studies have shown that many regions of the country are experiencing net losses in timberland and forest cover because of conversion to nonforest uses, including development (Alig et al. 2004, Nowak et al. 2005, Stein et al. 2005). Research also indicates that these trends are likely to have negative long-term effects on both forest stocking and the flow of timber products from forestland in urbanizing areas (Wear et al. 1999, Munn et al. 2002, Alig et al. 2003, Nowak and Walton 2005). After an initial liquidation harvest, deforestation on the urban–rural interface for development purposes (i.e., urban sprawl) removes land from the base of working timberland that supplies the forest products industry with raw materials. Furthermore, by emphasizing nontimber and aesthetic values over timber management objectives, forest owners in rural residential communities along the urban–rural interface can reduce the supply of stumpage and logs to industry, even if land use change does not result in net loss of timberlands (Cubbage et al. 2003).

For sawmills operating in this environment, one potential response to declining local sawlog production is expanding the geographic range of procurement operations to purchase sawlogs from more distant sources. However, transporting logs from farther away from the mill can be expensive, with increasing costs cutting into profit margins. On-road transportation costs typically represent 15 to 40 percent of the costs associated with moving wood from the stump to the mill (Schuler 2005, Siry et al. 2006). All else being equal, these costs, measured against the value of manufactured products, determine the distance that a mill can range efficiently for wood (Bressler and King 1970). The efficiency of expanding woodshed area to meet production requirements depends on market conditions and on the cost structure of individual firms. If rising costs for raw materials are not accompanied by rising lumber prices, profits can turn into losses.

To assess the potential effects of urbanization on the range of wood procurement operations, this study uses geospatial analysis in GIS coupled with multiple regression to examine urban cover as a predictor of woodshed area. Urban cover is quantified using the delineation of urban areas made by the US Geological Survey in 2001 and impervious surface data from the 2001 National Land Cover Database (NLCD), with developed land defined as land where impervious surfaces account for 20 percent or more of the land cover based on multispectral remote sensing imagery. We also consider the relationships between woodshed area and other land use and land cover variables. The central hypothesis is that variables associated with nontimber land use, including urban development, are positively correlated with woodshed area. Previous studies have indicated that annual volume and mill type are correlated with procurement range (Anderson and Germain 2007), so variables describing mill characteristics are also included.

Methods

In an attempt to limit noise related to fluctuations in market conditions and cost structure over time, this study focuses on a snapshot of procurement operations in 2005. Paper maps of sawmill woodsheds were provided by mill managers as a part of a survey of sawmills located within 100 miles of the Northern Forest (Fig. 1). A comprehensive treatment of survey methods and nonresponse bias is included in Anderson and Germain (2007) and Anderson (2008). Each survey questionnaire included a detailed 6.0 by 6.5-inch, 1:4,500,000 scale map that was centered on the state of the responding mill. In the context of a series of open-ended questions focused on defining the geographic extent of procurement operations, respondents were instructed to ''outline your woodshed by drawing a line around your mill that shows the area where the closest 90 percent of your total log volume originates.'' Of the 379 sawmills surveyed, 180 provided woodshed maps and associated procurement data, which represents a 47 percent response rate for this portion of the survey. However, five of the respondents were removed from the sample because they reported significant portions of their wood supply originating in Canada. These mills are large softwood mills run by firms that have procurement operations and processing facilities on both sides of the US–Canada border and are not representative of most of the sawmills in the sample frame. Individual woodshed maps were digitized in ArcMap 9.2 at the same scale and projection as the analog map. ArcMap 9.2 was also used to calculate woodshed area and 11 different zonal variables for each woodshed.

The response variable in this analysis is total woodshed area in square miles in 2005, abbreviated WS_AREA. Fourteen predictor variables were chosen because they were hypothesized to influence the range of wood procurement operations and could be determined for all the woodsheds in the sample. Table 1 provides a complete list of all the variables, with descriptions and data sources. Predictor variables fall into three categories: sawmill characteristics, land cover/land use, and landownership. The four mill variables describe the attributes of the sampled mill and the density of sawmills within each mill's woodshed; the eight land cover/land use variables are based on remote sensing data, road network data, and US census data; and the two landownership variables quantify the percent of woodshed in state and federal ownership. Although some states have comprehensive landownership coverages available through state agencies, state and federal lands were the only ownership classifications that were standardized and available across the entire study region.

Using the NLCD cover type raster and the zonal statistics tool in ArcMap 9.2, we calculated the percent developed land (including the four NLCD-developed classes), percent farmland (including hay/pasture and crops), and percent open water as the proportion of 30 by 30-m cells within the woodshed that were classified in each cover/use category. Percent urban land was calculated using the same method but with a different data layer. Individual cells in the percent tree canopy and percent impervious surface NLCD rasters are coded with a value between 0 and 100. The value of impervious surface and tree canopy for each woodshed was calculated as the mean of all cells within the woodshed. Road density is presented as the linear density of major roads within the woodshed, which includes divided, multilane, and limited-access highways and paved secondary roads but excludes

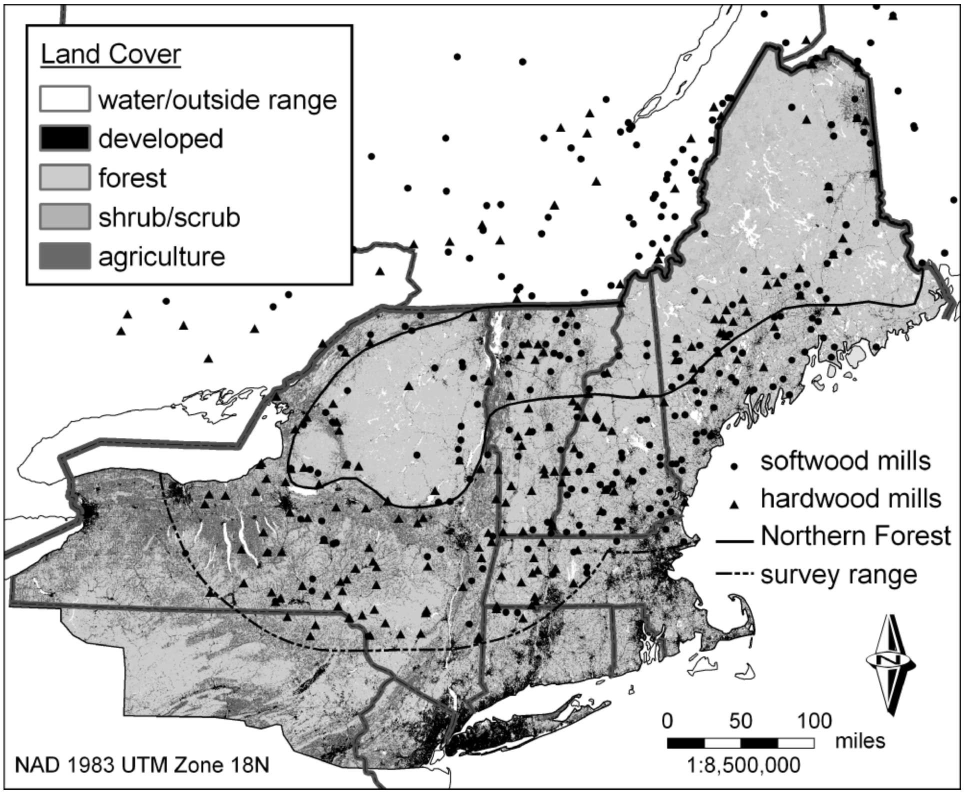

Figure 1.—Land cover across the study region (NLCD 2001). The extent of cover shown corresponds to the maximum boundary of all woodsheds included in the study.

municipal streets, tertiary state roads, and unpaved roads and tracts. Population density was calculated based on 2000 census data joined to census blocks and rasterized at 30 by 30-m resolution. Population density for each woodshed was calculated as the mean of all cells falling within the woodshed.

The relationships between the predictor variables and woodshed area are presented as estimated coefficients in ordinary least squares multiple regression models. Because the response variable and most of the predictor variables were significantly right skewed, log transformation was used on all variables to make data more closely approximate normal distributions, with the resulting distributions satisfying the assumptions of normality. Stepwise selection using 0.10 as the significance level for entry and the

Table 1.—Mill characteristics and woodshed variables used in this analysis.

Variable	Abbreviation	Data source	Data year
Response			
Woodshed area (mi^2)	WS_AREA	Sawmill survey	2005
Sawmill characteristics			
Annual volume (mmbf y^{-1})	MILLVOL	Sawmill survey	2005
Volume in hardwood (%)	MILLHWD	Sawmill survey	2005
Mill type[a]	MILLTYPE	Sawmill survey	2005
Mill density (mills mi^{-2})	MILLDEN	Sawmill survey	2005
Land cover and land use			
Tree canopy (%)	CANOPY	NLCD, percent canopy	2001
Impervious surface (%)	ISA	NLCD, percent impervious	2001
Developed (%)	DEVELOP	NLCD, land cover	2001
Farmland (%)	FARM	NLCD, land cover	2001
Open water (%)	WATER	NLCD, land cover	2001
Urban land (%)	URBAN	USGS, urban land	2001
Population density (people mi^{-2})	POPDEN	US Census Bureau	2000
Density of major roads (mi mi^{-2})	ROADS	USGS, major roads of the US	2001
Landownership			
Federal ownership (%)	FED	USGS, federal land	2001
State ownership (%)	STATE	Seven state agencies	1999–2005

[a] Categorical variable: softwood = 0, hardwood = 1.

Table 2.—Descriptive statistics for the variables used in this analysis ($n = 175$).

Variable	Units	Mean	Standard error	Median	Minimum	Maximum
WS_AREA	mi^2	4,225	408.9	2,439	85	31,880
MILLDEN	mills mi^{-2}	0.0064	0.00032	0.0054	0.0006	0.0260
MILLHWD	%	43.8	3.37	20.0	0.0	100.0
MILLVOL	mmbf y^{-1}	6.7	0.78	3.0	0.1	64.0
CANOPY	%	65.5	0.75	66.0	34.6	89.3
DEVELOP	%	6.4	0.33	5.7	0.5	32.3
FARM	%	12.0	0.74	8.5	0.0	46.4
ISA	%	1.5	0.11	1.1	0.1	12.5
POPDEN	people mi^{-2}	133	12.2	92.6	8.6	1,302.8
ROADS	mi mi^{-2}	0.33	0.008	0.35	0.04	0.60
URBAN	%	0.9	0.01	0.6	0.0	11.6
WATER	%	3.4	0.15	2.9	0.2	10.6
FED	%	3.7	0.58	0.4	0.0	41.9
STATE	%	8.3	0.62	6.2	0.2	74.0

significance level to stay was used to select the terms in a reduced model. Alternative models are compared using the coefficient of determination (R^2), adjusted R^2, the Akaike information criterion, and the Bayesian information criterion. Statistical Analysis System software version 9.1 (SAS Institute Inc. 2004) was used for all calculations and statistical tests.

In addition to the full model and the reduced model based on stepwise selection, a model with two parameters—mill annual volume and a dummy variable for mill type—is also included for discussion. The general form of this model is as follows:

$$\ln(A_m) = \beta_0 + \beta_1 \cdot T_m + \beta_2 \cdot \ln V_m + \beta_3 \cdot T_m \cdot \ln V_m$$

where A_m denotes the woodshed area of mill m in mi^2, T_m is a categorical dummy variable for mill type (softwood = 0, hardwood = 1), V_m is the mill's annual production volume in mmbf y^{-1}, $T_m \cdot \ln V_m$ is the interaction term, and β_0, β_1, β_2, and β_3 are parameters to be estimated. This model is useful for prediction purposes because annual volume and mill type are two of the variables that are widely reported in sawmill directories published by state agencies.

Results

Mean woodshed area for the sample is 4,225 mi^2 (simple radius = 36.7 mi), with a median area of 2,439 mi^2 (simple radius = 27.9 mi) (Table 2). For reference, these mean and median woodsheds correspond to 2.7 million acres and 1.6 million acres, respectively. Overall, these mills average 6.7 mmbf y^{-1} in log procurement, with 79 (45%) of the 175 mills in the sample classified as hardwood mills. The average mill density is 0.0064 sawmills mi^{-2}, including both respondent and nonrespondent mills. This means that, on average, sampled mills have 26 other mills located within the boundary of their woodshed. Land cover in these woodsheds averages 12.0 percent farmland, 6.4 percent developed, 0.9 percent urban, and 3.4 percent open water. Mean tree canopy cover is 65.5 percent, with mean impervious surface of 1.5 percent. State and federal land make up 8.3 and 3.7 percent of these woodsheds on average, with the maximum values in these categories observed for mills with significant portions of their woodsheds in the Adirondack Park region of New York and the White Mountain National Forest in New Hampshire and Maine. Population density in these woodsheds averages 133 people mi^{-2}, with a mean major road density of 0.33 mile of major roads per mi^2 of woodshed. For comparison, based on the 2000 census, the statewide population densities of states in the study region range from a low of 41 people mi^{-2} for Maine to a high of 810 people mi^{-2} for Massachusetts.

Parameter estimates for the complete regression model using 12 log-transformed variables are shown in Table 3. To avoid problems with multicollinarity due to the high

Table 3.—Parameter estimates for the full model using log-transformed variables with intercept followed by coefficients listed in order of significance based on the t statistic.

Parameter	Estimate	Standard error	Standard estimate[a]	t	P value
Intercept	−0.1292	2.8720	0	−0.05	0.9642
ln(MILLVOL)	0.3904	0.0431	0.4735	9.07	<0.0001
ln(MILLDEN)	−90.9121	19.0507	−0.2890	−4.77	<0.0001
ln(FARM)	0.4466	0.1030	0.3978	4.34	<0.0001
ln(WATER)	0.4253	0.1073	0.2302	3.96	0.0001
ln(ROADS)	−0.7754	0.3146	−0.2489	−2.46	0.0148
ln(FED)	0.1592	0.0668	0.1281	2.38	0.0183
ln(MILLHWD)	0.0807	0.0342	0.1227	2.36	0.0196
ln(CANOPY)	1.3272	0.6163	0.1604	2.15	0.0328
ln(STATE)	0.1893	0.1055	0.1244	1.79	0.0746
ln(POPDEN)	−0.1358	0.1339	−0.0934	−1.01	0.3122
ln(ISA)	0.1779	0.1941	0.1206	0.92	0.3609
ln(URBAN)	0.2622	0.2932	0.0895	0.89	0.3725

[a] The standardized regression coefficient, which is the result of regression analysis on variables standardized to have mean = 0 and standard deviation = 1.

Table 4.—Comparison of alternative models.

Model	No. of terms[a]	RMSE[b]	R^2	Adjusted R^2	AIC[c]	BIC[d]
Full model	13	0.8316	0.6273	0.5997	−52.03	−47.96
Reduced model[e]	9	0.8363	0.6138	0.5952	−53.78	−50.81
Directory only[f]	3	1.0058	0.4212	0.4145	5.012	7.116

[a] Number of terms in the model, including the intercept.
[b] RMSE = root mean square error.
[c] AIC = Akaike information criterion.
[d] BIC = Bayesian information criterion.
[e] Based on stepwise selection, URBAN, ISA, POPDEN, and STATE have been removed.
[f] Using only mill volume and mill type, two variables reported in sawmill directories.

Table 5.—Parameter estimates for the "directory only" model.

Parameter	Estimate	Standard error	Standard estimate[a]	t	P value
Intercept	6.9642	0.1088	0	64.02	<0.0001
ln(MILLVOL)	0.4978	0.0480	0.6037	10.37	<0.0001
MILLTYPE	0.5089	0.1533	0.1932	3.32	0.0011

[a] The standardized regression coefficient, which is the result of regression analysis on variables standardized to have mean = 0 and standard deviation = 1.

correlation between percent developed land and percent impervious surface ($r = 0.968$), only percent impervious surface is included in this model. Nine of the 12 coefficients are significantly different from zero. Mill volume, mill density, percent farmland, and percent open water show the highest level of significance ($P \leq 0.0001$ for all four). The coefficients for population density, percent impervious surface, and percent urban are not significantly different from zero. The full model accounts for around 60 percent of the variation observed in the data (Table 4).

Based on stepwise selection methods, percent state land, population density, impervious surface area, and percent urban land are not included in the reduced model (Table 4), which accounts for almost the same amount of variation as the full model (adjusted $R^2 = 0.595$). For comparison, the ''directory only'' model, which uses only mill volume and mill type as predictors, accounts for about 40 percent of the variation observed in the data (Table 4). Interaction between mill volume and mill type is not significant ($P = 0.9466$), so the interaction term was dropped. Estimated coefficients for this model are included in Table 5, and the model is plotted in Figure 2.

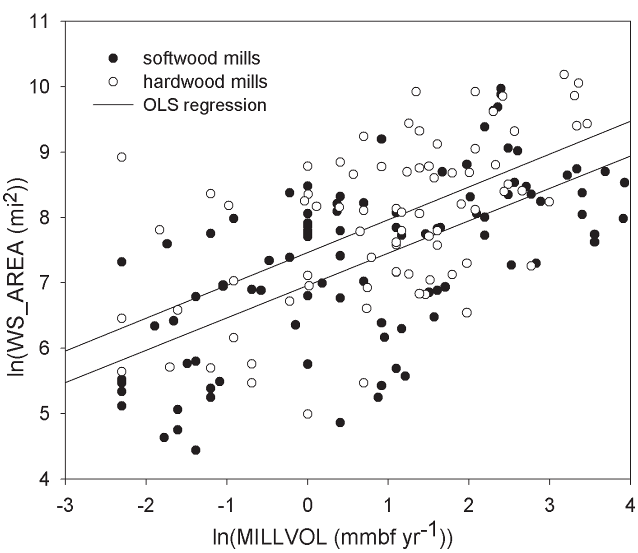

Figure 2.—Relationship between mill volume and woodshed area for hardwood mills (top line) and softwood mills (bottom line).

Discussion

We hypothesized that urbanization, as reflected by population density, road density, impervious surface area, and urban land, would be positively correlated with woodshed area. We expected that mills located in areas with higher population densities and higher proportions of urbanized land would have larger woodsheds because they would need to range farther for wood to compensate for a smaller timberland base. These results do not support this hypothesis. Among the variables considered in this analysis, the variables linked to urbanization are the poorest predictors of woodshed area. In contrast, sawmill characteristics and several other landscape variables, including farmland and open water, are significant predictors of woodshed area.

If urbanization negatively affects the flow of sawlogs to sawmills, there may be several reasons why sawmills in more heavily urbanized areas do not appear to have larger woodsheds than their counterparts in rural areas. In the short term, liquidation harvests related to land clearing may increase the log flow in places with high development pressure, even though the ultimate long-term effect will be fewer acres of forestland and less forestland open to harvesting. The lack of observed effects may also be related to technological advances in the industry. Productivity in the forest industry has improved 35 percent over the past 50 years, with more lumber and less waste produced from each unit of roundwood (Ince 1999, Haynes 2003). The adoption of technologies that improve yield and grade may have buffered local declines in sawlog quality and availability for mills in urbanizing areas.

Increasing timber stocks in the region may also buffer the effects of urbanization on sawmill procurement range in some areas. As reported in the introduction, the growing stock of both hardwoods and softwoods has increased over the past century. This trend is expected to continue for the first half of this century. Sendak et al. (2003) project that timber inventories across New York and New England will increase from 66.7 billion ft^3 in 2000 to 75.4 billion ft^3 by 2050 under a scenario of elevated harvest levels. Much of this net increase in volume is the result of the reforestation of former agricultural lands during the early to mid-20th century. The transformation of field to forestland has resulted in many stands of mature sawtimber and poles that are on the verge of economic viability. At the landscape level, this transformation is largely complete.

The observed results may also be related to changes in industry structure. In general, this industry has been moving toward increasing concentration, with fewer, larger firms producing higher output (Ince et al. 2007). The 1990s brought particularly intensive consolidation in the lumber industry (Spelter et al. 2007, Luppold and Bumgardner 2008). Despite the fact that sawlog markets appear to be workably competitive, it is possible that the study was executed at a time when the mills most affected by land use trends in urbanizing areas had already closed, while the remaining firms were reaping the benefits of consolidation, possibly in the form of higher demand for their products and less competition for sawlogs.

This possibility illustrates a broader point that the local effects of land use on wood procurement are occurring against a backdrop of global economic change that has impacted the industry in profound ways. In the hardwood sector, over the past 20 years, industrial uses, especially pallets, containers, and cross ties, have overtaken furniture as the dominant use of hardwood lumber produced in the Northeast (Luppold and Bumgardner 2008). Growth in demand for these products, which can be made from relatively low quality sawlogs, coupled with technologies to improve yield and grade, may have offset the effects of local declines in the flow of high-quality sawlogs on lumber production. However, the decline of markets for appearance-grade hardwood lumber used in furniture manufacturing, which has been negatively impacted by import competition, has coincided with increases in stumpage prices, especially for high-value species (Haynes 2003, Wagner and Sendak 2005). In addition, the demand for specific hardwood species used to produce appearance-grade lumber fluctuates with trends in consumer tastes and fashion, introducing additional volatility into lumber and stumpage prices (Luppold and Bumgardner 2007). In general, these trends have cut profit margins for hardwood sawmills in the Northeast.

Although softwood mills tend to be larger and are more generally focused on commodity grades of lumber, similar stressors are acting on mills in the softwood sector, where import competition has been intense (Ince et al. 2007). Although real stumpage price increases have been lower for softwood sawtimber than for hardwoods, the gap has narrowed between lumber prices and procurement costs, which include stumpage, management, transaction, and transportation costs. For both hardwood and softwood mills, all else being equal, as these costs rise, the range of procurement operations must contract if rising costs are not accompanied by rising lumber prices. These economic factors may have a relatively large effect on procurement range that obscures the effect of the land use variables examined in this study.

It may also be that there is an effect of urbanization on woodshed area, but this study was unable to detect the effect because of limitations related to its design. The region is fairly homogeneous with regard to land cover (Fig. 1). Although the Northeast has the highest amount of urbanized land of any region in the country and is seventh highest on the list of the fastest-urbanizing regions (Fulton et al. 2001, Nowak et al. 2005), forest cover is also very high. In addition, log exports to Canada complicate the procurement environment. Given the geography of urban centers in the study region, mills that are distant from urban areas tend to be closer to the Canadian border and experience higher competition for sawlogs from sawmills in Canada (Anderson et al. 2009).

This study was successful in quantifying the effects of other land use and land cover variables. Among these, percent farmland and percent open water seem to affect woodshed area in expected ways. Based on the positive coefficients for these variables, it does seem that mills in areas with more farmland and more open water have larger woodsheds, presumably because less of the land within their procurement range is forestland. But the weak magnitude and positive direction of the coefficient for percent forest canopy were opposite of the expected result (Table 3). Higher percent canopy appears linked to larger, not smaller, woodsheds.

One possible explanation lies in the relationship between forest cover and landownership. Both percent state land and percent federal land are positively correlated with tree canopy, and further analysis shows that mean percent tree canopy for these ownerships is higher than the average for the study area. State and federal lands in this region average 84 and 81 percent canopy cover, respectively, compared with the mean of 66 percent for all woodsheds and a mean of 71 percent within the boundary of the Northern Forest. Woodsheds with the highest mean canopy cover may also have high proportions of state and federal land, which is associated with high stocks but restricted flow, especially in New York, where 2.6 million acres of state-owned land within the Adirondack Park are off-limits to harvesting. Accordingly, the proportion of state and federal lands does appear to increase the size of woodsheds slightly, though the effect on the model is weak. In addition, reproduction harvests with young regeneration may have low canopy cover, reducing the average tree canopy value on forestlands that are under intensive management. This is especially relevant for northern Maine, which has a high proportion of land in industrial and investment-oriented ownership. These details muddle the interpretation of the relationship between forest cover and woodshed area.

A high density of transportation infrastructure is typically associated with smaller woodsheds because of improved timber access (Harouff et al. 2008). Although the effect is weak, the estimated coefficient for road density seems to support the conclusion that more roads leads to better access and smaller woodsheds, which aligns well with theoretical and empirical results from other studies (Bressler and King 1970, Harouff et al. 2008). However, in urbanizing areas, increasing road density, especially when it is connected to new housing developments on parcelized forestland, may also be associated with liquidation cuts and a reduced likelihood of sustained yield forest management (Vickery et al. 2009).

Mill annual volume and mill type (softwood or hardwood) account for around 40 percent of the variation in woodshed area in this sample. Larger mills and hardwood mills tend to have larger woodsheds (Fig. 2). In addition to these attributes, local sawmill density is a significant predictor of woodshed area. Mills in areas with higher densities of sawmills tend to have smaller woodsheds. This result may seem counterintuitive: would not high mill density result in higher competition for sawlogs, which would lead to larger woodsheds? Perhaps, but mill density is already well above the level where a few buyers in areas with low mill density could leverage their buying power to depress log prices (Murray 1995). The explanation is probably linked to the fact that sawmills tend to be clustered in areas with a favorable log supply (Luppold 1995, Bowe et al. 2004). It may also be that there are benefits to agglomeration in this industry (Ricci 1999). Up to a point, agglomeration may result in more favorable conditions for sawmills by facilitating robust markets for logging services, specialized labor, trucking, and forestry services. If agglomeration is an advantage, this result may support rural economic development strategies that encourage the clustering of new and established forest industry firms, at least with regard to wood procurement.

Conclusions

Based on this snapshot of procurement operations in 2005, it would be a mistake to conclude that urbanization is not having an effect on procurement. However, it appears that the range of procurement operations is more closely tied to mill characteristics than to land cover and land use variables related to urbanization, at least in the Northeast at this time. In addition, regional, national, and global trends in the forest industry determine lumber and stumpage prices, which are strong determinants of procurement range. As the industry moves forward in predicting wood supply trends and adapting wood procurement operations to land use changes, it is imperative that we identify appropriate measures of the impact that these changes have on wood flow and timber stocks. Further research should work to maintain the local log flow necessary to secure a long-term future for the primary forest products industry in the Northeast.

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