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Modeling timber mill procurement influence effects on interstate sawlog exportation

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Abstract

Over the last three decades the exportation rate of raw sawlogs from Illinois to neighboring states for processing has nearly doubled. While the exportation of sawlogs has adverse impacts on the Illinois wood products manufacturing sector and local forest landowners, little research has been conducted to understand how the spatial arrangement of timber mills affects sawlog exportation. This research models, in a spatial environment, timber mill procurement influence within southern Illinois and the surrounding region in an attempt to understand how the location of mills is a partial explanation of the increase in sawlog exportation. Assuming equal market power, timber mills within the study area were found to be arranged in a manner that results in low competition for sawlogs within Illinois and high competition in neighboring states. Spatial models incorporating differential market power based on mill size characteristics suggest that Illinois experiences little procurement pressure from high production mills operating within the State but is under procurement pressure from high production timber mills operating in neighboring states.

Keywords: Timber procurement; Geographic information systems; Timber exportation; Forestry development

1. Introduction

Over the period from 1961 to 1996 the volume of sawlogs harvested from Illinois' forests has steadily increased from 131 mmbf in 1961 to 214 mmbf in 1996 (Blyth et al., 1987; Hackett and Sester, 1998). During the same period, however, the cumulative production rate of Illinois' sawmills has increased only slightly. Additionally, the Illinois sawmilling industry has experienced a marked loss in the number of sawmills in operation—from a high of 300 sawmills in 1961 to just 102 in 1996 (Blyth et al., 1987; Hackett and Sester, 1998). This reduction in total number of timber mills and an increase in the number and market production share of mid-sized to large mills mirrors trends elsewhere in the eastern hardwood sawmilling industry (Luppold, 1996b).

The disparity between increased sawtimber harvesting and stable statewide timber mill production rates suggests that an increasing number of Illinois' raw sawlogs are being processed outside the State. In

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1983 the statewide sawlog exportation rate was 15% (Blyth et al., 1987). By 1996 the statewide exportation rate had nearly doubled to 27% (Hackett and Sester, 1998). Sawlog importation into Illinois from neighboring states was miniscule in the same year (Hackett and Sester, 1998). The most dramatic increase in interstate exportation has occurred in the southernmost 16 counties of Illinois that comprise the Southern Forest Survey Unit. The export rate from the Southern Unit rose from 20% of the sawlogs harvested in the Unit in 1983 to 46% of the logs harvested in 1996. A similar, though not as dramatic, increase has occurred in the Claypan Forest Survey Unit located in the southern portion of central Illinois. See White et al. (2001) and White (2001) for further discussion of trade flows between southern Illinois and adjoining states.

The sawlogs harvested from the Claypan and Southern Forest Survey Units comprise nearly 2/3 of the State's total sawlog production. The exportation of unprocessed sawlogs from these regions adversely affects the State's economy and timberland owners. Increasing sawlog exportation translates in a reduction of income created from value-added processing, a decrease in economic exchanges among industries within the State, and a reduction in the present value of standing timber resulting from the increased transportation costs of sawlog exportation.

Little is understood about how the spatial arrangement of timber mills, and their associated timber procurement areas impact sawlog exportation from Illinois. The objective of this research is to model and map the spatial distribution of timber mill procurement influence across the landscape of southern Illinois and the surrounding region.

2. Timber procurement

Timber mills are generally classified into sizes based upon the production rate (or capacity) of the mill and/or the number of employees. The production rate of a timber mill, coupled with equipment characteristics and primary products manufactured may be used to generate some measure of mill quality (Sloan et al., 1995). These high quality/large mills may have the greatest influence over timber procurement and price structure (Luppold, 1995, 1996b; Sloan et al., 1995).

The area from which raw material is gathered to supply a mill is referred to as the mill's woodshed, territory, or procurement zone. As Stier et al. (1986) state, 'the size, shape and area of a mill's woodshed will depend on the mill's location relative to the forestland base, the availability and cost of (transportation)..., and the extent and competition from other wood users'.

The distance from which material is transported to the mill is the most often used indicator of procurement zone size. In a study of the pulpwood industry in Wisconsin, Stier et al. (1986) found 80% of the pulpwood supply was transported less than 201 km to the mill. This pulpwood transportation distance is consistent with the distance found by Lones and Hoffman (1990) in Maine.

Common distances for the transportation of hardwood sawlogs from stump to mill are not readily available in the literature. In Maine, Lones and Hoffman (1990) found the average hardwood sawlog transportation distance to be 66 km from stump to mill. The absolute maximum haul distance ranged from 64 to 402 km; however, 74% of the sawlogs procured were transported less than 80 km. In their study of the Jefferson National Forest timber market, Sloan et al. (1995) used a maximum hardwood sawlog hauling distance of 129 km. The range of transportation distances suggests that while great travel distances may be economically viable in some cases, they are the exception and not the rule.

3. Methods

3.1. Study area

The study area was delineated based upon the following objectives: (1) to include those Illinois counties located within the Claypan and Southern Forest Survey Units as identified in the Illinois Timber Product Output report (Hackett and Sester, 1998); (2) to include counties in neighboring states where Illinois sawlogs may be exported; and (3) to include counties in neighboring states that produce hardwood sawlogs and that have forest resources similar to those found in southern Illinois. Hackett and Sester (1998) did not identify sawlog exports to

Fig. 1. The 143 county study area within the southern Illinois region.

the state of Tennessee; therefore it was not included in this study.

In total, 143 counties in portions of Illinois, Indiana, Kentucky and Missouri were included in the study (Fig. 1). At its greatest width the study area measures 539 km from Dent County, Missouri east to Hardin County, Kentucky. It is 433 km from the bootheel of Missouri to the northernmost Illinois counties included in the study. The study area has a high percentage of land area dedicated to timberland and agriculture and the dominant forest-type throughout is oak-hickory. While each state does have areas of high and low resource base, there is no large-scale spatial pattern in the distribution of the timber resource. The only exception to this homogeneity occurs in several Missouri counties characterized by lower site potentials (White et al., 2001). However, the negative effects of these lower site potentials are most likely mitigated by the high percentage of land area in Missouri dedicated to timberland.

3.2. Mill location and production data

A spatial dataset of timber mills located in the entire eastern US was compiled by Pye and Prestemon (1999). The database of mill locations was created from state forestry organization records and geocoded using the reported mailing addresses. Variables within the dataset include latitude and longitude, mill name, a general description of production type, and the city and state in which the mill is located. The data were downloaded in an Environmental Systems Research Institute (1996) ArcInfo point coverage file via the Internet and converted to a shapefile. Those mills located within the study area were isolated and were used as the database of operating mills for the study.

Production figures for timber mills located within the study area were collected from a variety of state natural resource agency databases and publications (Indiana Department of Natural Resources, 2000; Illinois Department of Natural Resources, 1998; Kentucky Division of Forestry, 1997; Jones et al., 1996). A large number of missing production figures for mills located in Illinois necessitated that production figures be supplemented with data from a previous study of Illinois timber mill production completed by McCurdy and Phelps (1993). Production data (in mmbf) was entered into the database file of the timber mill location shapefile (described above) within ArcView. In each of the state databases, production was reported either as a range, e.g. 1–5 mmbf, or as being greater than some minimum rate, e.g. greater than 10 mmbf. In the case of the former, the midpoint of this range was used as the individual timber mill's production rate. For the latter, the minimum production rate was recorded. Several timber mills recorded their production in tons, cords, or other specialty units. Lacking a uniform conversion factor to mmbf, these production figures were not entered into the database and are treated as missing data points.

3.3. Modeling timber mill procurement influence

The area in which a timber mill has some degree of influence on sawlog prices, extent of harvesting, and the movement of sawlogs is identified for this study as the area of procurement influence. The area that falls under the procurement influence of a particular mill is determined by the distance from which timber is likely to be transported to that mill. Previous studies of timber mill procurement have found highly variable distances that timber may be transported from stump to mill (Lones and Hoffman, 1990; Stier et al., 1986). For this study it is suggested that hardwood sawlogs within the southern Illinois region may travel up to 161 km for processing. Thereby, for any tract of land within the study area, all timber mills located within 161 km may contribute to procurement influence on that tract. This distance is slightly greater than the 129 km sawlog hauling distance used by Sloan et al. (1995) and is within the range of maximum sawlog transportation distance found by Lones and Hoffman (1990).

Procurement influence is evaluated in this study by overlaying the mill location data layer with a rasterized map of the study area. The rasterized map divides the study area into individual tracts of land represented by pixels, or cells, at a resolution of slightly less than 2 km^2. Procurement influence exerted on a given cell is quantified by identifying the presence of mills within a specified search radius around the cell. The following equation yields a measure of the interaction between a given cell i and surrounding timber mills j:

$$P_i = \frac{\sum_{j=1}^{n_i} (x_j)}{A}$$

where:

P_i=procurement influence experienced by cell i;
X_j=the value associated with the presence of mill j;
n_i=the number of mills within search area A surrounding cell i;
A=area of search radius.

Those cells that have a greater occurrence of intersection with timber mills operating within the search radius have a greater procurement influence P_i. A graphic representation of the procurement influence model appears in Fig. 2. The search radius for each cell in the study area was set to 161 km, reflecting the accepted distance for the feasible transportation of hardwood sawlogs in the region. The model application results in a continuous surface map where each individual pixel is assigned a numeric value that is a function of the previous equation.

Two procurement influence scenarios were created: location-driven procurement influence and production-driven procurement influence. In the location-driven procurement influence scenario, each timber mill within the study area has equal ability to compete for available timber resources with other timber mills in operation regardless of production rate. Each timber mill that was found to be operating within the search radius of a cell was given a value of x_j=1. The resulting procurement influence P_i for each cell is a function of the summed number of mills located within the search area. This location-driven calculation of procurement influence models the competition between timber mills for timber resources within the study area.

In the production-driven scenario, the reported production rate for each timber mill 'j' was used as the value of x_j in the equation. The resulting procurement influence P_i for each cell is a function of the

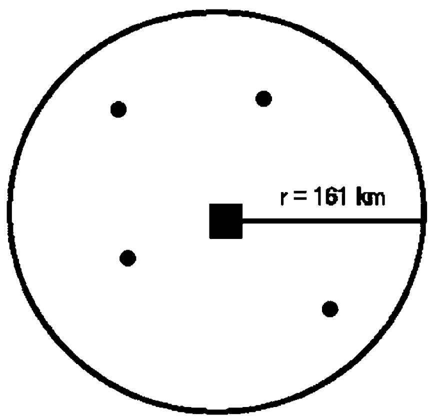

Fig. 2. Procurement influence methodology for a 2-km^2 pixel containing four mills within the 161 km search radius.

summed production rates of timber mills located within the search area. This scenario models timber procurement influence, recognizing that timber mills with high production rates have greater influence within their procurement region. This scenario models procurement influence based upon the market power of operating timber mills.

Of the 511 timber mills in the study area, 68 did not report a production rate or reported in a format that could not be transformed to mmbf. Since ArcView 3.2 does not recognize missing data points in the production-driven methodology, these mills were removed from the production-driven procurement calculations.

3.4. Testing for uniformity of procurement influence

Luppold (1996b) states that firms locate based upon fixed and variable costs and the quality and extent of the resource base. More specifically, classic location theory suggests that firms operating in a spatial environment where revenue is uniform will locate in an effort to maximize profits by minimizing costs (Kilkenny, 1998). The profit of a firm is a function of the quantity and price of outputs minus the costs of producing the output. Costs include the fixed-costs of production, cost of transportation to market, and the costs of the factor inputs of production: labor, capital and hardwood resources.

As stated previously, no large-scale spatial pattern exists in the extent of the forest resource base across the study area and there is no indication that fixed and capital costs vary by spatial location. Additionally, one can reasonably assume that the distance to market is similar given the strong secondary wood products industry in Illinois, Missouri and Indiana. The remaining variable costs to minimize are the costs of factor inputs labor and hardwood resources. Assuming that industry has little endogenous ability to reduce labor costs through spatial location, the price of delivered wood resources becomes the focus of a cost-minimizing firm. To reduce the costs of hardwood inputs a firm would, on a uniform plane of resource flows, choose to minimize competition and maximize the area of resource it serves. Given hardwood timber is a weight-losing product and resource flows are uniform, such a competition-minimizing strategy would result in a dispersed arrangement of mills with each mill attempting to maximize the distance to its nearest competitor.

Furthermore, a perfectly competitive market requires numerous dispersed sellers (forest owners) and numerous buyers (timber mills) to be arranged so that the transaction costs (transport cost) are similar throughout the study area (Löfgren, 1986; Kilkenny and Thisse, 1999). Since much of the sawlogs in the region are purchased free on board (fob) at the mill, such a requirement suggests the timber mills in a competitive market should be arranged so that any potential seller of sawlogs has several potential buyers for which the transaction cost (transport costs) are similar and not prohibitive.

In order to test the hypothesis that timber mill procurement is uniform within the study area, a two sample paired *t*-test was completed. This required the creation of four spatial databases: (1) a spatial database of location-driven procurement influence for the entire study area (PI); (2) a spatial database of the production-driven procurement influence for the entire study area (PIW); (3) a uniform representation of PI (PIU) where all cell values are equal to the mean of PI and (4) a uniform representation of PIW (PIWU) where all cell values are equal to the mean of PIW. The mean cell value of PI was calculated to be $\bar{X}$=0.004. The mean cell value of PIW was calculated to be 0.008. The databases of PI and PIU were exported from ArcView to S-Plus statistical software. A two-sample paired *t*-test was completed (alpha 0.05) testing whether PI differed significantly from PIU and if PIW differed significantly from PIWU.

Raster analysis of GIS data results in the creation of a great number of cell values. This occurs as a result of the great number of pixels within the spatial database. In this study, over 50 000 data points consisting of 2 km^2 pixels existed within the study area. While it is statistically viable to complete analysis using so many datapoints, the practical application of outcomes must be tempered with recognition that analysis of so many datapoints will likely result in statistically significant differences, largely due to the sample size. In recognition of this limitation, random samples of all procurement influence databases were generated using the S-PLUS software package (S-PLUS, 2001). All statistical tests relating to procurement

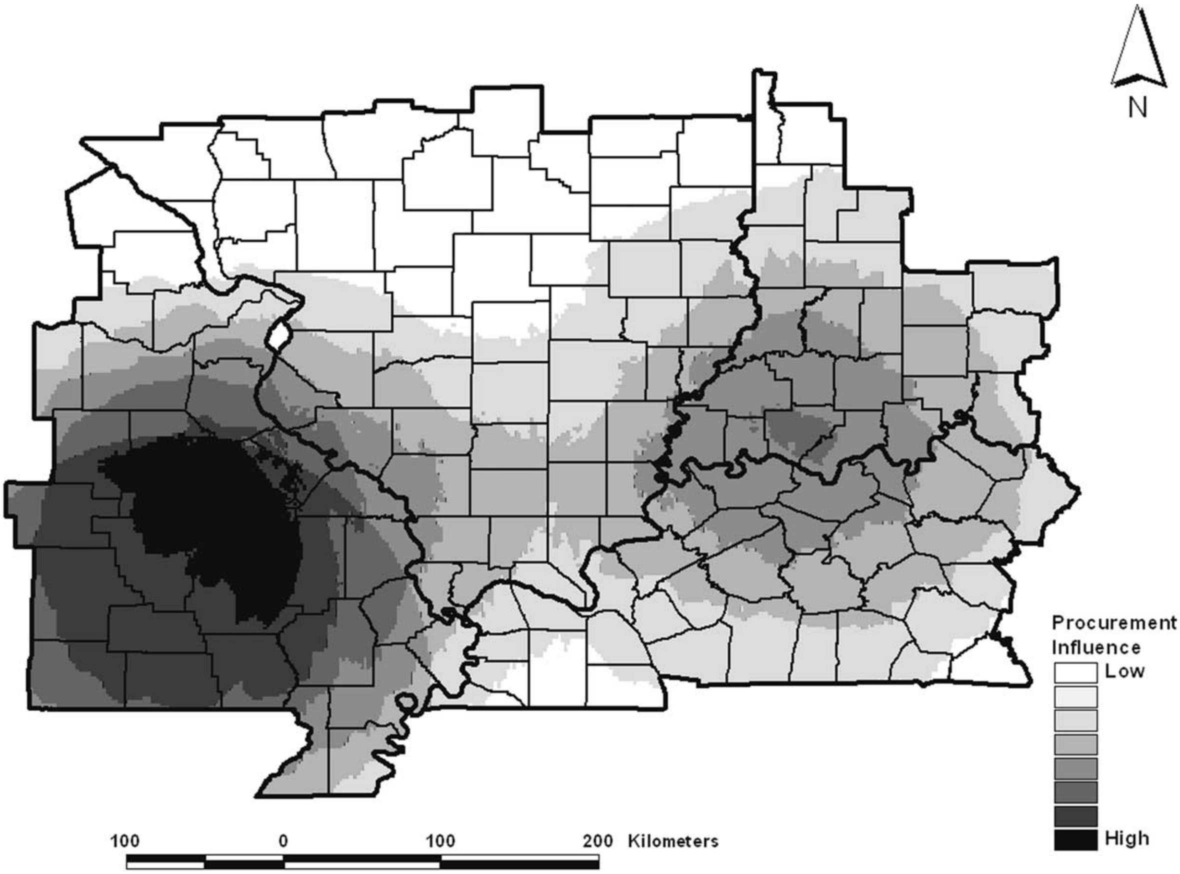

Fig. 3. Location-driven procurement influence of timber mills within the study area.

influence were calculated a second time utilizing 5000 randomly selected pixels.

4. Results and discussion

4.1. Location-driven procurement influence

The location-driven procurement influence results are depicted graphically in Fig. 3. Those cells with the greatest occurrence of timber mills within their search radius have the greatest procurement influence values—indicated by dark shading. Two concentrated areas of high procurement influence are immediately evident within Indiana and Missouri. Within these concentrated areas competition for sawlogs may be high. Shortages in sawlog supply from local resources may result in increased delivered sawlog prices accompanied by increases in the economically viable procurement distance. Sellers harvesting sawlogs from within areas of concentrated high procurement influence have the greatest number of potential mills available for processing.

Kilkenny (1998) states that concentration in industry location occurs as a result of '. . .economies onomies of scale, positive spatial spillovers, and imperfectly competitive market structures'. The degree to which any one or combination of these factors contributes to, or is in fact responsible for, the concentration of timber mills in portions of Missouri and Indiana is not empirically known. One may hypothesize, however, that agglomeration economies, increases in the availability of manufacturing inputs as a result of concentration, and/or regulatory or market activities may encourage this concentration.

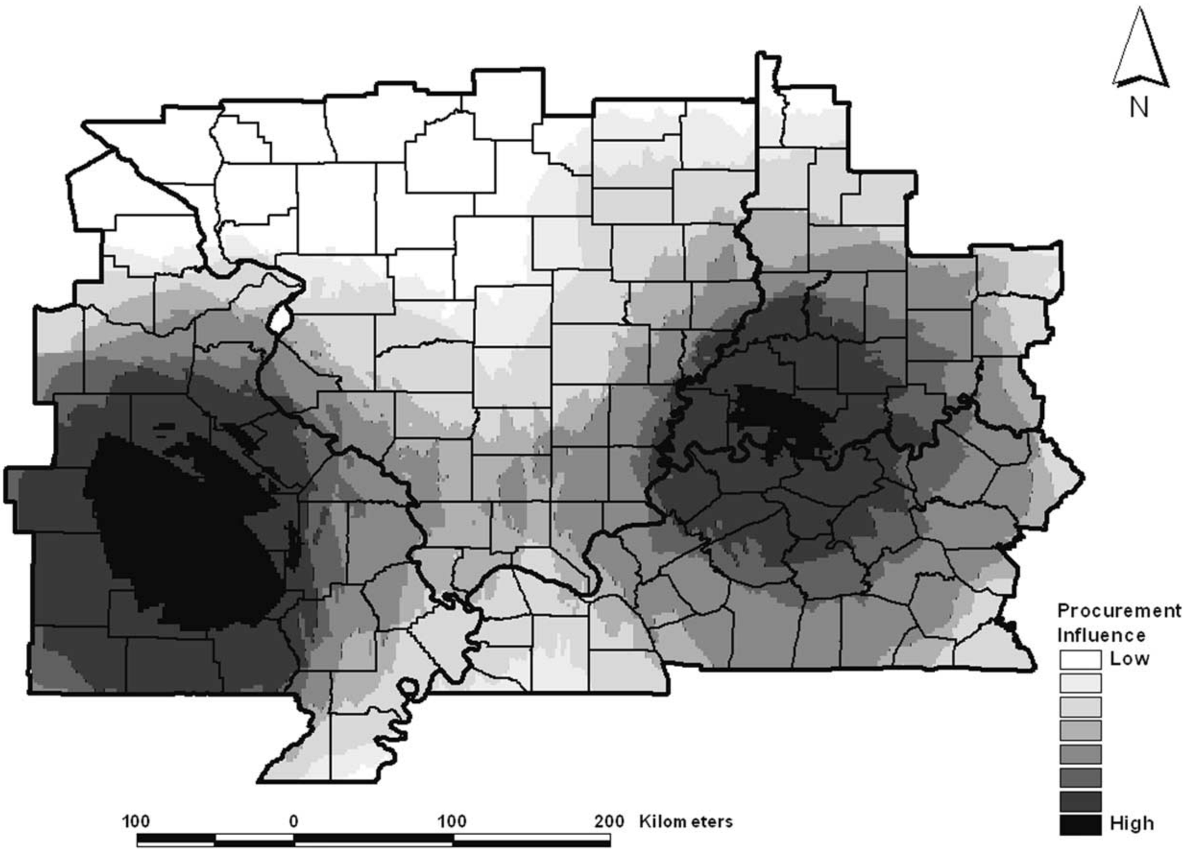

Fig. 4. The production-driven procurement influence of timber mills within the study area.

Much of the study area is under moderate to low procurement influence. These areas are located throughout much of Illinois and northern Missouri. Sawlogs harvested from regions of low procurement influence may have a limited number of potential timber mills available for processing. Due to decreased competition, timber mills located within this region may be able to offer lower delivered sawlog prices. If delivered sawlog prices in Illinois are indeed lower, potential sellers from these areas may have incentive to travel increased distances to sell sawlogs at a greater delivered price.

4.2. Production-driven procurement influence

Production-driven procurement influence was calculated by summing the timber mill production rates, rather than the simple occurrence, of mills within the search radius of a given pixel. Thus, high production timber mills have a greater degree of influence when included in the search area of any one pixel. Fig. 4 provides a graphic depiction of production-driven procurement influence within the study area. Increasingly dark shading again signifies values of high procurement influence while light colors represent low values. The areas of highest cumulative market power are located in southwestern Indiana and southeastern Missouri.

The greatest increases in procurement influence, when accounting for market power (comparing PI with PIW), occur in south-western Indiana. Moderate increases in procurement influence under the production-driven scenario occur within Illinois along its borders with Indiana and Missouri. This increase in procurement influence in Illinois originates from concentrated areas of influence in southwestern Indiana and southeastern Missouri.

4.3. Statistical analysis

The calculation of location-driven procurement influence (Fig. 3) was found to be statistically different from uniformity ($t=-9.80$, $P>t=0.00$). The calculation of production-driven procurement influence was also found to be statistically different from uniformity ($t=-37.12$, $P>t=0.00$). Sensitivity analysis using a random sample of the production-driven and location-driven procurement influence data pixels were generated and paired t-tests of the sample datasets were completed. Location-driven procurement influence throughout the study area was again found to be statistically different from uniformity in a sample of the data ($t=-2.91$, $P>t=0.00$). The sample of production-driven procurement influence data was also found to be statistically different from the uniform representation ($t=-11.52$, $P>t=0.00$).

Statistically significant results suggest that both the degree of mill competition and market power are not uniformly distributed spatially across the study area. This spatial divergence may provide insight into why Illinois sawlogs are being exported at such a high rate. The location-driven procurement influence model suggests that Illinois forest resources are under little pressure from competing in-State mills. Conversely, resources in Indiana and Missouri are under high procurement pressure from a large number of mills competing for resources within those states. Lack of timber mill competition within Illinois coupled with high competition in adjoining states could prime Illinois for high sawlog exportation as sawlog sellers travel out of state to take advantage of competition-induced higher delivered sawlog prices.

Additionally, areas of Illinois experience little procurement pressure resulting from high market power mills located within the State. The only areas of high procurement influence in Illinois under the market power scenario result from the spread of concentrated cumulative market power in Indiana and Missouri. The location of such high market influence in neighboring states may further promote the exportation of sawlogs to areas where high-production timber mills have greater influence.

5. Conclusions

Timber mills operating within the southern Illinois region were identified and isolated in a spatial database. The associated production rates of these timber mills were then collected. Timber mill procurement influence in the study area was quantified through location-driven and production-driven scenarios and then tested to determine if they differed significantly from uniformity.

Statistical tests of location-driven procurement influence and production driven procurement influence suggest that timber mills operating within the study area are arranged in a manner that does not promote a uniform distribution of competition or market influence. Sawlog exportation from Illinois may be promoted by the combination of low competition between mills and the lack of market power within the State and the existence of high competition and high market power in areas immediately across the border in neighboring states.

The spatial divergence in mill competition and market power across the study area identifies opportunity for expansion of the Illinois timber industry. The models of procurement influence suggest that large areas of low mill competition and low market power occur in the State. While an increase in either the number of mills or the market power of existing mills would have a positive effect on the timber mill industry in Illinois; achieving reductions in the current level of sawlog exportation requires increases in both areas.

The addition of a few high production mills to the Illinois timber mill industry may do little to decrease the current level of sawlog exportation. In the absence of mill competition (as has been shown in Illinois), the addition of high-production mills may depress delivered sawlog prices in the long-term. The potential for spatial monopsony as result of high-production timber mills is suggested by Luppold (1996a). Likewise an increase in the number of small and mid-size mills operating in Illinois may not be enough to overcome the strong cumulative market power found in neighboring states. Simply put, even with greater competition, Illinois mills may not have the ability to offer prices comparable with those found in neighboring states. Policy strategies that promote both the increase in number of mills and the creation of a select number of high production mills are needed to reduce sawlog exportation.

Future research should investigate the spatio-temporal arrangement of mills within the region to better understand how the spatial distribution of mills within the study area has changed over time. Additionally, research into the role that regulatory statutes and tax structures may have played in contributing to reduced mill competition within Illinois would be useful. Finally, policy alternatives that may increase the degree of timber mill competition and market power of Illinois mills should be identified.

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