ISSN 1946-7664. MCFNS 2022
Vol. 14, Issue 2, pp. 1–8
Mathematical and Computational Forestry & Natural-Resource Sciences

AVAILABLE ONLINE AT HTTP://MCFNS.COM

Submitted: May 18, 2022
Accepted: Aug. 19, 2022
Published: Oct. 30, 2022
Last Correction: Oct. 25, 2022

SPATIAL DEPENDENCIES WITHIN MISSISSIPPI'S PRIMARY FOREST PRODUCTS MANUFACTURERS

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Abstract. We determined whether wood-using mills' locations spatially depended upon timber product harvest levels and the number of complementary species group mills within and between counties in Mississippi. County mill count for either the pine or hardwood timber industry was the dependent variable. County timber product harvest levels (thousand green tons) for pine sawtimber, pine pulpwood, and pine poles along with count of hardwood mills were predictors for the pine model; hardwood sawtimber and pulpwood harvests along with the number of pine-type mills served likewise for the hardwood model. Poisson regression models were constructed and, as necessary, augmented to Spatial Lag of X models where spatial dependency within 100 miles of a county's centroid was identified.

Direct effects of pine product harvesting were absent. Pine mills were not located based on own-county timber resources. Some evidence for hardwood mills supporting pine mill count was found (t = 1.65, p = 0.0987). Own-county pine pulpwood harvests positively influenced pine mill counts in neighboring counties (t = 3.21, p = 0.0013); pine sawtimber to a lesser degree (t = 1.77, p = 0.0766); while pine pole harvests produced the opposite effect (t = -1.96, p = 0.0505). Competition for pine sawtimber and pulpwood increased as procurement radii increased. Greater hardwood pulpwood harvesting (t = 4.44, p <0.0001) and pine mill count (t = 2.70, p = 0.0085) indicated a significant own-county hardwood mill presence. This finding is germane to log trucking output, wood utilization efficiency, standing timber prices, and consequently forestland value.

Keywords: harvesting; mills; pulpwood; sawtimber.

1 Introduction

Transportation theory limits the movement of bulk commodities like timber, which is heavy and bulky. All else equal, standing timber prices will be higher for tracts closer to the manufacturer because trucking costs, which are the greatest service charge for timber conversion (McConnell 2020), are lowered. Mills thus locate where they can maximize the affordability of the available wood supply that is appropriate for their production process. Hunter (1982) concluded pine product prices were higher where competition within 100 miles was more intense. Mill size also plays a role in a facility's procurement zone, or wood supply shed. Wiedenbeck and Sabula (2008) found sawmill procurement zones were positively related to mill capacity. Mill consolidation in the forest products industry has been an evolving process for decades that has resulted in fewer, yet larger, mills. Where competition among these large facilities is reduced by a major participant(s) leaving the region, survivors can exert considerable market power. They can tighten the radius of their procurement zones, set quotas, enter into supply agreements, and invest in technological upgrades to improve efficiencies, among others.

Pine timber products are generally more uniform, while tree form in hardwoods is more variable. Greater uniformity lowers conversion costs in the woods, which provides flexibility to the trucking component (McConnell 2020). Pine stands are commonly artificially regenerated and managed intensively to produce this uniformity. Economies of size are normally required for the pine industry's supply chain to generate the needed returns on investments. Large pulpmills can sur-

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pass procuring three million tons pine timber annually (Bentley and Cooper 2015), while pine sawmills commonly purchase one million tons of roundwood or more. Larger timber tract size directly benefits the logger (to a point) by enabling fixed costs to be spread over more acres (Cubbage et al. 1989). Greater acreages of timber product uniformity increase productivity and consequently lower both milling and harvesting costs (Parajuli et al. 2019). Depending on levels of mill size and competition as previously noted, mills can be motivated to reach farther for this preferred wood, and ultimately provide a higher value for the standing pine timber. This higher value encourages reinvestment and management of future stands (Bullard et al. 1981).

Hardwoods are less commonly artificially regenerated for producing future timber income due to prohibitive establishment costs (Self and Cunningham 2020). Hardwoods thus tend to naturally regenerate on tracts of various sizes, site qualities, and topographies. Their natural proliferation includes invading passively managed former pine sites and retired farmlands (Bullard et al. 1981). Despite this, hardwoods are less responsive to silvicultural prescriptions than pines. This carries long-term implications regarding species mix, stand volumes, and logging equipment access (Walter 1998). Hardwood sawtimber species pricing is not cointegrated (Luppold and Prestemon 2003), and tree quality is generally lower in the US South (Luppold 1997). Hardwood sawtimber is often sold as "mixed" with little species segregation beyond separating preferred oak species in regions where secondary manufacturers will purchase ungraded appearance lumber. Where appearance-grade hardwood markets are robust, skill and care must be exercised in the felling and bucking processes (Walter 1998). These factors along with the fragmentation present in the hardwood marketplace led to hardwood sawmill output averaging around 3 million board feet per year, whereas pine sawmills average 60 million board feet per year (Luppold 1996; Sasatani and Zhang 2015). Hardwood pulpwood fibers are often mixed with pine in the production process, but this is not always the case. The size of pulpmills, hundreds of thousands of tons, can push procurement limits for pulpwood beyond that needed for sawtimber, where large hardwood sawmills require approximately 50,000 to 150,000 tons of roundwood.

The objective of this work was to construct Poisson regression models where logged mill counts by county, either pine or hardwood species groups, were explained as functions of county timber product harvest levels and the mill count of the complementary species group. Spatial dependency was examined for these variable and where identified, spatial lags of those predictors were included. This provided the means to determine how county-level timber product harvest levels and mill counts for other species influence the number of pine or hardwood forest products mills both within a county and among nearby counties.

2 Methods

Primary processing mill locations in Mississippi were obtained from the Forest Products Locator Primary Forest Products Network website (Southern Regional Extension Forestry 2021). The number of mills residing in each of Mississippi's 82 counties was tallied for two broad species groups, pine and hardwood. Timber harvest data by county by product were obtained from Mississippi State University Extension's *Harvest of Forest Products* report (Auel 2020). The *Harvest of Forest Products* report is developed from timber severance tax data provided by the Mississippi Department of Revenue. The tax paid is converted to product harvested using timber severance tax rates. The rate is \$0.12 per ton for both pine sawtimber and pine pulpwood, and it is \$0.08 per ton for both hardwood sawtimber and hardwood pulpwood. Pine poles are taxed \$3.60 per cunit, which was converted to \$1.20 per ton using a conversion factor of 60 pounds per cubic foot (Miles and Smith 2009). All timber product harvest levels were analyzed on a per thousand green ton basis.

2.1 Pine Mills and Timber Products A Spatial Lag of X (SLX) Poisson Regression model utilized logged pine mill counts per county as the dependent variable. Timber product harvest levels (thousand green tons) for pine sawtimber, pine poles, and pine pulpwood were predictors along with a spatial weight matrix of Mississippi's 82 counties. The matrix was calculated using county centroids and filtered to include only county relationships where $w_{ij} < \frac{1}{100\,miles^2}$. The matrix was normalized by its maximum eigenvalue (Elhorst and Vega 2015). The presence of spatial lag effects was first examined using the Lagrange Multiplier by determining whether

$$H_0 : wPST = wPPW = wPPOLE = wHMILL = 0$$

$$H_1 : At\,least\,one \neq 0$$

The variables *wPST*, *wPPW*, *wPPOLE,* and *wHMILL* were spatial lag terms for pine sawtimber, pulpwood, poles, and hardwood mills that captured local spillovers to counties within 100 miles of County i. If the null hypothesis of no spatial lag effects failed to be rejected, the study model was defined by Equation 1. Rejecting the null hypothesis of no spatial lag effects would expand Equation 1 to Equation 2

$ln\,P = \alpha_0 + \alpha_1 PST + \alpha_2 PPW + \alpha_3 PPOLE + \alpha_4 HMILL$, [1]

$ln\,P = \alpha_0 + \alpha_1 PST + \alpha_2 PPW + \alpha_3 PPOLE + \alpha_4 HMILL + \alpha_5 wPST + \alpha_6 wPPW + \alpha_7 wPPOLE + \alpha_8 wHMILL$, [2]

$\%\,P = (e^{\alpha_i} - 1) * 100\%$, [3]

where $ln\ P$ was the logged number of pine mills in a county, PST was pine sawtimber, PPW was pine pulpwood, $PPOLE$ was pine poles, and $HMILL$ was the number of hardwood mills. The variables $wPST$, $wPPOLE$, $wPPW$, and $wHMILL$ were spatial lag terms for each timber product and hardwood mills that captured local spillovers to neighboring counties within 100 miles of County i. Parameter α_0 was the intercept term; Parameters α_1 to α_4 were interpreted as the mean percent change in the number of mills residing in a county due to own-county effects of a one thousand ton change in harvest level and number of hardwood mills residing there, i.e., a direct effect. Parameters α_5 to α_8 represented the average total spillovers to neighboring counties. Thought of another way, α_5 to α_8 described how pine harvest levels and hardwood mill presence within one county indirectly impacted the number of pine mills residing within 100 miles of County i. Equation 3 provided the conversion from a continuous rate of change to an average one.

2.2 Hardwood Mills and Timber Products The hardwood SLX Poisson Regression model utilized logged hardwood mill counts per county as the dependent variable. County timber product harvest levels (thousand green tons) for hardwood sawtimber and hardwood pulpwood were independent variables along with the spatial weight matrix described above for the pine model. The presence of spatial lag effects was examined initially using the Lagrange Multiplier by determining whether

$$H_0 : wHST = wHPW = wPMILL = 0$$

$$H_1 : At\,least\,one \neq 0$$

The variables $wHST$, $wHPW$, and $wPMILL$ were spatial lag terms for hardwood sawtimber, hardwood pulpwood, and number of pine mills that captured local spillovers to neighboring counties within 100 miles of County i. If the null hypothesis of no spatial lag effects failed to be rejected, the study model was defined by Equation 4. Rejecting the null hypothesis of no spatial lag effects would expand Equation 4 to Equation 5

$ln\,H = \beta_0 + \beta_1 HST + \beta_2 HPW + \beta_3 PMILL$, [4]

$ln\,H = \beta_0 + \beta_1 HST + \beta_2 HPW + \beta_3 PMILL + \beta_4 wHST + \beta_5 wHPW + \beta_6 wPMILL$, [5]

$\%\,H = \left(e^{\beta_i} - 1\right) * 100\%$, [6]

where $ln\ H$ was the logged number of hardwood mills in a county, HST was hardwood sawtimber, HPW was hardwood pulpwood, and $PMILL$ was the number of pine mills residing in County i. The variables $wHST$, $wHPW$, and $wPMILL$ were spatial lag terms for each timber product that captured local spillovers to neighboring counties within 100 miles of County i. Parameter β_0 was the intercept term; Parameters β_1 to β_3 describe the mean percent change in the number of mills residing in a county due to own-county harvesting of hardwood timber products and the number of pine mills residing there, i.e., a direct effect. Parameters β_4 to β_6 represent the average total spillovers to neighboring counties, i.e., they describe how own-county hardwood harvest levels and pine-based manufacturing in counties indirectly impact the number of hardwood mills residing within 100 miles of County i. Equation 6 converted the model's coefficients from continuous to average rates of change.

3 Results

A frequency Table highlighting total mill counts by county is provided in Table 1. While timber harvesting occurred in all 82 counties, over one-third (n = 31 of N= 82) possess no primary forest products mill. At least one primary facility resided in 51 counties, and 19 counties had at least three mills present. The geographic distribution of pine timber harvest levels and mill counts is shown in Figure 1, and Figure 2 depicts the same for hardwoods.

3.1 Pine Mills and Timber Products The hypothesis of no spatial lag effects was rejected ($\chi^2 = 24.07$, p <0.0001). Thus, the full model was developed. Table 2 provides the full model's results from Equation 2 and the interpretations for the model's coefficients. Harvests of pine products did not influence own-county logged mill counts (each p $\geq$ 0.1935). Since own-county pine product harvesting did not directly affect mill location, it can be concluded that pine product mills possess larger procurement zones. The number of hardwood mills within a county did exert a moderate direct effect on logged pine mill count (p = 0.0987). For every hardwood mill in a county, pine mill count increased by 21%.

Spatial lag effects were varied. The spatial lag was highly significant for pine pulpwood (p = 0.0013), less so for pine poles (p = 0.0505), and more restrained for pine sawtimber (p = 0.0766). The spatial lag effect for pine poles was negative, while the other two products' coefficients were positive. The interpretation of the spatial lag estimate is that of an indirect effect, where a positive increase in own-county harvest levels led to higher mill counts in neighboring counties of $(e^{\alpha_i} - 1) * 100\%$ (or a decline if the respective α coefficient was negative). For example, pine pulpwood harvests within a county did not affect the logged mill counts therein, but high pine pulpwood harvest levels did positively influ-

Table 1: Frequency Table of mill counts by county in Mississippi in 2019. The number of counties in the state totals N = 82.

Mills	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0	31	37.80	31	37.80
1	19	23.17	50	60.98
2	13	15.85	63	76.83
3	7	8.54	70	85.37
4	7	8.54	77	93.90
5	4	4.88	81	98.78
6	1	1.22	82	100.00

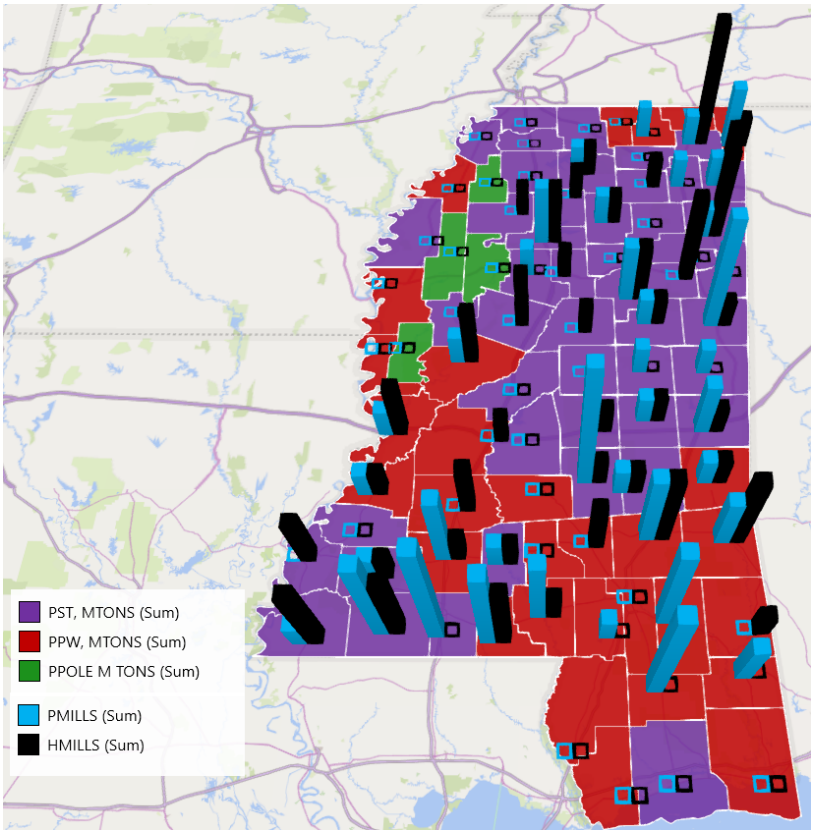


Figure 1: Pine timber processing mills (PMILLS) residing in Mississippi counties. Greater column heights by county represent larger numbers of mills (hardwood timber processing mills = HMILLS). County shading is based on the dominant timber product harvested in the county (thousand tons, MTONS), whether pine sawtimber (PST), pulpwood (PPW), or poles (PPOLE).

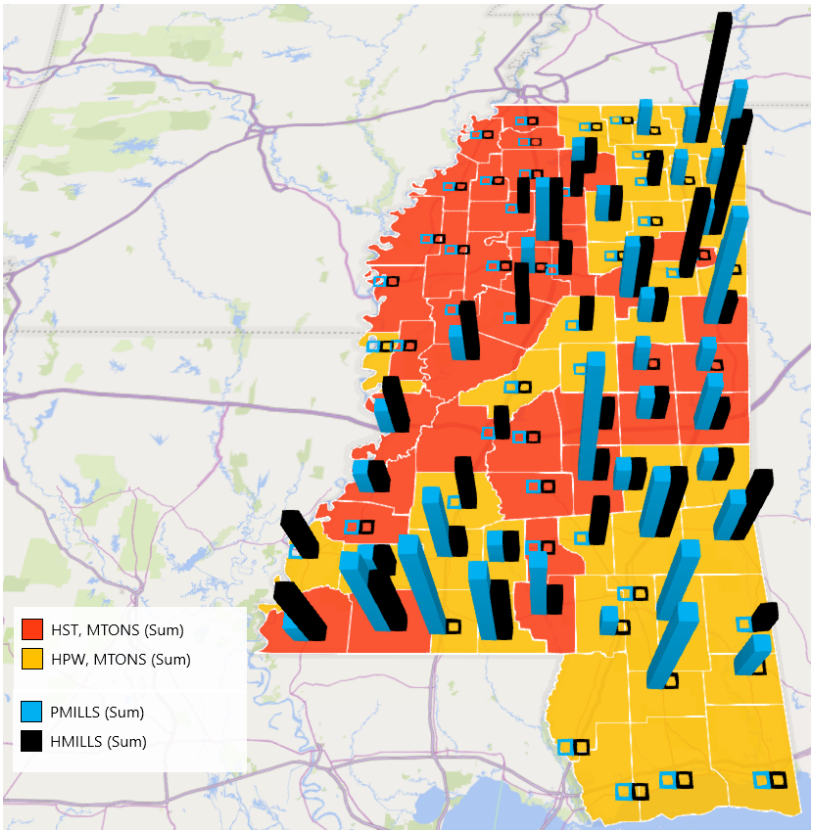


Figure 2: Hardwood timber processing mills residing in Mississippi counties (HMILLS). Greater column heights by county represent larger numbers of mills (pine timber processing mills = PMILLS). County shading is based on the dominant timber product produced in the county (thousand tons, MTONS), whether hardwood sawtimber (HST) or hardwood pulpwood (HPW).

Table 2: Poisson regression model results for logged pine mill counts as a function of pine timber product harvest levels, the presence of hardwood processing mills, and spatially lagged pine timber product harvest levels. Impacts of own-county pine timber product harvest levels and hardwood mills were direct effects on logged county mill counts in Mississippi. Spatially lagged pine timber harvest levels defined indirect effects of pine mill counts within a county.

Parameter	**Estimate**	**Standard Error**	**t Value**	**p Value**	***Direct Effect***	***Indirect Effect***
Intercept	-2.5498	0.4989	-5.11	<.0001		
PST	0.0005	0.0010	0.51	0.6103		
PPW	0.0016	0.0017	0.95	0.3424		
PPOLE	-0.0675	0.0519	-1.30	0.1935		
HMILL	0.1922	0.1164	1.65	0.0987	*21.19%*	
wPST	0.0053	0.0030	1.77	0.0766		*0.53%*
wPPW	0.0116	0.0036	3.21	0.0013		*1.17%*
wPPOLE	-0.2961	0.1514	-1.96	0.0505		*-25.63%*
wHMILL	-0.2152	0.4370	-0.49	0.6225		

Table 3: Poisson regression model results for logged hardwood mill counts as a function of hardwood timber product harvest levels and the presence of pine processing mill.

Parameter	Estimate	Standard Error	t Value	p Value	*Average Effect*
Intercept	0.1664	0.1504	1.11	0.2720	
HST	-0.0021	0.0030	-0.69	0.4919	
HPW	0.0209	0.0047	4.44	<0.0001	*2.11%*
PMILL	0.1954	0.0724	2.70	0.0085	*21.58%*

ence the logged number of mills in neighboring counties by 1.17%. Figure 1 shows a large contiguous area of southeast Mississippi where pulpwood production predominated. The spatial lag effect of pine sawtimber indirectly contributed 0.53% to logged number of mills in neighboring counties. Figure 1 shows this effect occurred in the state's southwest corner and more broadly across central Mississippi. High pine pole harvest levels had an average -25.7% impact on the logged number of mills in neighboring counties, which occurred in the northwest portion of the state.

3.2 Hardwood Mills and Timber Products The hypothesis of no spatial lag effects for hardwood mills was not rejected ($\chi^2 = 4.40,\ p < 0.2214$). Thus, the reduced model (Equation 4) was developed. Table 3 provides the reduced model's results and interpretations of the model's coefficients. Only hardwood pulpwood harvests significantly affected the presence of hardwood mills ($p < 0.0001$). This meant counties where hardwood pulpwood harvesting was high, the logged number of hardwood mills was also high, with the opposite occurring if hardwood pulpwood harvests were low (refer to Figure 2). Own-county hardwood pulpwood harvesting influenced mill counts by an average of 2.11%. Counties containing pine mills significantly impacted the number of hardwood facilities residing there ($p = 0.0085$). Each additional pine-type mill increased the count of hardwood facilities by an average 1.216 times (21.6%).

4 Discussion

The SLX model provided a means of assessing the spatial distribution of timber resources and the location of processing facilities. Much of northwest Mississippi was once dominated by bottomland hardwood forest lands, but this region has been extensively cleared for agricultural crop production. Thus, there are fewer processing facilities in that part of the state (see Figures 1 and 2). The southern counties along the Gulf Coast are low lying, environmentally sensitive areas. This area relies more so on natural resources based tourism than timber production.

The absence of any own-county direct effects due to pine timber product harvesting can be explained by pine processing facilities requiring large supplies of wood. For example, pine sawmills in the state typically take in more than one million tons annually, while pulp mills may take two to three times that amount (Gray et al. 2018). The presence of indirect effects across counties illustrated these volumes must be procured over large areas that encompass multiple counties. Loblolly-shortleaf pine forest comprises 47% of the state's forest inventory. Pulpwood production is greatest in the southern portion of the state with much of the production in that region in younger, artificially regenerated plantations (Oswalt 2019). This may be an indication of high pulpwood demand driving shorter rotations of pine timberland in south Mississippi. Or natural disasters may be impacting the landscape, resulting in younger forests. Pine, particularly loblolly pine, has been noted as an important species in reforesting storm-damaged locations near the Gulf Coast (Sharma et al. 2021). Given the risks of having large volumes of wood blown down by tropical storm systems, further analyses of causation regarding these issues could be equally interesting.

County hardwood mill count was significantly dependent upon the number of pine processing mills in the county along with the county's production of hardwood pulpwood. Natural forests comprise 68.5% of Mississippi's 19.2 million acres, or 13.1 million acres (USDA Forest Service Forest Inventory and Analysis 2022). Species mixtures are common in these forests at the stand level, primarily on uplands where successional transitions are occurring between pine and hardwoods (Willis et al. 2019). However, pine timber product harvests accounted for 86% of Mississippi's 2019 harvest of forest products (Auel 2020). Logging costs for hardwoods exceed pine and smaller diameter trees generally cost more to log than larger trees (Cubbage et al. 1989). The Mississippi timber price trends backed these generalizations; the 1992 to 2018 trends for timber conversion (harvest plus haul) followed the order of hardwood pulpwood >pine pulpwood >hardwood sawtimber >pine sawtimber (McConnell et al. 2021). The more limited management generally practiced on natural

stands also carries harvesting cost implications regarding inventory and access (Walter 1998).

Where hardwood pulpwood harvest volumes were high, conversion costs would need to be lower in order to produce acceptable returns to hardwood pulpwood stumpage for the landowner. This is because hardwood pulpwood is a less versatile timber product. Variations across species, such as structure, density, heating value, etc., limit its current use to primarily pulp production when delivered in mixed species loads. Lower demands for writing and newsprint papers have factored significantly into pulpmill conversions and/or closures (Bentley and Cooper 2015). As a result, hardwood pulpwood harvests have fallen 56% from 2003 to 2019 (Mississippi State University Extension 2022). A recent emerging market for hardwood pulpwood is wood pellets. This is a growing segment of the Mississippi forest sector, with its proximity to deep water ports in not only Mississippi but also Louisiana and Alabama. This industry could help bolster competition for hardwood pulpwood's and increase its marketability along greater distances. While spatial lags were not revealed hardwood mills and timber products model, further research in this area could expand on testing whether spatial lags hold for mills classified according to species by product types, such as pellet, paper, structural panels, lumber, etc.

A harvest operation's cut-and-load rate for longwood can be considered somewhat fixed for the type of harvest performed on a tract, such as cost per ton for thinning a natural stand or performing a final harvest, if the degree of multiproduct sorting were set aside (Kimbrough and Bullard 1992). The variable component is transportation, which is also the greatest individual cost of roundwood conversion (McConnell 2020). Given Cubbage et al. (1989) and McConnell et al. (2021) above, transportation costs for hardwood pulpwood would therefore need to be minimized. Hourly truck costs, payload, and average speed are essentially market driven variations, whether due to supply and demand or regulations; these factors are dynamic. Distance to mill, as a tract characteristic, is relatively static over time. Minimizing procurement distance helps lessen transportation costs despite swings due to market characteristics. Lower hauling costs from natural, mixed stands, facilitate moving hardwood pulpwood to market, which brings a more complete harvest of the site. This improves stumpage prices, and consequently enhances timberland's position as an attractive financial asset.

5 Conclusions

This study described the locations of primary forest products mills in Mississippi's counties as they relate to timber harvest levels and complementary species group processing facilities, both directly within the county and indirectly via local spillovers to neighboring counties. No direct effects of pine product harvesting were noted regarding pine-based facilities. Pine sawtimber and pulpwood were transported to greater numbers of mills beyond their home counties' borders, because local competition did not pressure these materials. Hardwood pulpwood harvests directly and positively affected own-county mill count. County hardwood sawtimber harvests did not influence the locations of hardwood-type mills. Pine mills residing in a county further attracted hardwood facilities. These conclusions carry implications linked to trucking costs, utilization efficiencies, timber prices, and consequently timberland valuation.

References

Auel, J.B. 2021. Harvest of forest products. Publication MTN-35C, Mississippi State University Extension, Mississippi State, MS. 7 p.

Bentley, J.W. and J.A. Cooper. 2015. Southern pulpwood production, 2012. e-Resour. Bull. SRS-206. U.S.D.A. Forest Service, Southern Research Station Asheville, NC. 39 p.

Bullard, S.H., G.H. Weaver, and W.W.S. van Hees. 1981. Stand-age analysis on Mississippi's private, nonindustrial forests. Bulletin 896, Mississippi Agricultural and Forestry Experiment Station, Mississippi State, MS. 11 p.

Cubbage, F.W., W.D. Greene, and J.P. Lyon. 1989. Tree size and species, stand volume, and tract size: Effects on southern harvesting costs. South J Appl For 13(3):145–152.

Elhorst, J.P. and S.H. Vega. 2017. The SLX Model: extensions and the sensitivity of spatial spillovers to W. Papeles de Economía Española 152:34–50.

Gray, J.A., J.W. Bentley, J.A. Cooper, and D.J. Wall. 2018. Southern pulpwood production, 2013. e-Resour. Bull. SRS-218. U.S.D.A. Forest Service, Southern Research Station, Asheville, NC. 15 p.

Hunter, T.P. 1982. Regional price variation of southern pine sawtimber and pulpwood. Forest Prod J 32(9):23–26.

Kimbrough, D. and S.H. Bullard. 1992. A break-even study on in-woods merchandising opportunities for hardwoods in the Alabama-Mississippi-Tennessee region. Pages 85–94 *in* Proceedings Southern Forest Economic Workshop, April 29–May 1, Mobile, AL.

Luppold, W. 1996. Structural changes in the central Appalachian hardwood sawmilling industry Wood Fiber Sci 28(3):346–355.

Luppold, W.G. 1997. Regional examination of red oak lumber price trends. North J Appl For 14(4):173–177.

Luppold, W.G. and J.P. Prestemon. 2003. Tests for long-run relationships in hardwood lumber prices. Forest Sci 49(6):918–927.

McConnell, T.E. 2020. Unit costs and trends within Louisiana's logging contract rate. Forest Prod J 70(1):50–59.

McConnell, T.E., B. da Silva, C. Sun, S. Tanger. 2021. Forest to mill price trends and relationships for Mississippi, USA timber products. Forest Prod J 71(2):177–187.

Miles, P.D. and W.B. Smith. 2009. Specific gravity and other properties of wood and bark for 156 tree species found in North America. Res. Note NRS-38. U.S.D.A. Forest Service, Northern Research Station, Newtown Square, PA. 35 p.

Mississippi State University Extension. 2022. Harvest history—Summary of harvest values from 1940 to present. `http://extension.msstate.edu/node/28346`. Last accessed May 17, 2022.

Oswalt, Sonja N. 2019. Mississippi's forests, 2017. Resour. Bull. SRS-226. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 68 p.

Parajuli, R., S. Tanger, R. Abt, and F. Cubbage. 2019. Subregional timber supply projections with chip-n-saw stumpage: Implications for southern stumpage markets. Forest Sci 65(6): 665–669.

SAS Institute. 2020. Version 9.4. Cary, North Carolina.

Sasatani, D. and D. Zhang. 2015. The pattern of softwood sawmill closures in the US South: A survival analysis approach. Forest Sci 61(4):635–643.

Self, A.B. and K. Cunningham 2020. Upland hardwoods: Natural regeneration Publication 3476, Mississippi State University Extension, Mississippi State, MS. 8 p.

Sharma A., S.K. Ojha, L.D. Dimov, J.G. Vogel, and J. Nowak. 2021. Long-term effects of catastrophic wind on southern US coastal forests: Lessons from a major hurricane. PLoS ONE 16(1): e0243362. https://doi.org/10.1371/journal.pone.0243362

Southern Regional Extension Forestry. 2021. Forest products locator. `https://primary.forestproductslocator.org/`. Last accessed November 29, 2021.

USDA Forest Service Forest Inventory and Analysis. 2022. EVALIDator. `https://apps.fs.usda.gov/Evalidator/evalidator.jsp`. Last accessed May 18, 2022.

Walter, M.J. 1998. Documentation of productivity and efficiency relationships for a group of southern logging contractors. PhD dissertation. Virginia Tech. 131 pp.

Wiedenbeck, J. and A. Sabula. 2008. Ohio roundwood utilization by the timber industry in 2006. Res. Bull. NRS-32. U.S.D.A., Forest Service, Northern Research Station, Newtown Square, PA. 18 p.

Willis, J.L., J.S. Gordon, S. Tanger, M.A. Blazier, A.B. self, and A. Brodbeck. 2019. Managing mixed stands: Reassessing a forgotten stand type in the southeastern United States. Forests 10:751.