

# SPATIAL ANALYSIS OF FORESTS PRODUCTS MANUFACTURER CLUSTERS IN LOUISIANA

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## ABSTRACT

The forest products (FP) industry is the most important segment of the agricultural sector in the state of Louisiana with regard to farm gate value and added value. According to Michael Porter, the FP industry has cluster characteristics concentrating in geographic areas due to competitive advantages. This analysis explores the spatial distribution of Primary and Secondary FP manufacturers in Louisiana in order to identify spatial clusters and model industry frequencies as a function of socio-economic variables. Forest Products industry, socio-economic, and geographic data were obtained from the Louisiana Forest Products Development Center and the U.S. Census Bureau. Results suggest that Primary FP companies show a higher spatial dependency compared to Secondary FP manufacturers as well as evidence of clustering of Secondary FP manufacturers. Regression analysis shows that total population is the variable most significantly correlated to clustering of Secondary FP manufacturers.

*Keywords:* Forest products industry, clusters, spatial analysis, Louisiana.

## INTRODUCTION

The theory of clusters developed by Michael Porter is premised on the notion that companies tend to spatially concentrate in places where they experience unusual competitive success. A cluster is a critical mass of companies in a particular field in a particular location (Schmitz 1995, Porter 1998b). Clusters are generally geographically concentrated and are comprised of a group of companies encompassing related industries in an industry supply chain (Porter 1998a,b, 2000). They may include input suppliers, ancillary service providers, or providers of specialized infrastructure. Clusters can extend horizon-

tally or vertically to take advantage of production and commercialization efficiencies. An example discussed by Porter (1998a) is the California Wine Cluster. This includes 680 commercial wineries and several thousand independent wine grape growers, along with input and service suppliers as well as local educational institutions that support the industry.

The study and identification of clusters can contribute to a better understanding of contemporary patterns, processes of industrial transformation, industry competitiveness, and regional development (Hallencrutz and Lundquist 2003; Peneder 1995). According to Hallencrutz and Lundquist (2003), the current shift in industrial and regional policies towards adopting cluster-based economic development strategies

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highlights the importance of clustering in current business models.

The forest products industry in the United States is considered to have cluster characteristics. Porter (2003) ranks the forest products industry among the top 25 largest clusters in the country based on the number of people employed and spatial concentrations. Various factors seem to affect industry concentration in certain regions. For example, transportation costs and associated proximity to resources and markets are important factors contributing to the concentration in the forest products industry as they represent a major component of the delivered cost of raw materials and products. Sawmills benefit from economies of scale, and the spatial aggregation of Primary and Secondary manufacturers can result in gains in efficiencies and cost reductions (Murray 1995). Hence, there seems to be a spatial tendency for Primary and Secondary manufacturers to conglomerate in clusters. Braden et al. (1998) and Porter (1998a) provide empirical evidence of clustering in the forest products industry in the Pacific Northwest and North Carolina, respectively.

The forest sector is by far the most important segment of the agricultural sector in the state of Louisiana. According to the Louisiana State University Agricultural Center (2004), the forest sector, including solid wood and pulp/paper, contributed more than \$3.37 billion dollars to the state economy in 2003. This is comprised of gross farm income of \$956,351,993 and value-added of \$2,744,730,221. This exceeds all other agricultural crop commodities combined. According to the Louisiana Forestry Association (2004) and Louisiana Economic Development (2003), the forest products sector accounted for 11.8% of total manufacturing jobs in Louisiana in 2002. The industry (including harvesting and transportation) is the second largest manufacturing employer in the state, employing nearly 28,000 people in 2003 (Louisiana Forestry Association 2004).

In this paper we describe a spatial analysis applied to the Primary and Secondary forest products (FP) manufacturing sectors in Louisiana. Forest Products can be broadly character-

ized as Primary or Secondary products (Braden et al. 1998; Vlosky and Chance 2001). This classification is not always clear, but most industry observers agree on general definitions of the groups:

- Primary products are those that are produced directly from raw timber input. Examples include pulp, chips, lumber, veneer, plywood, and their by-products.
- Secondary manufacturers use primary products as input for remanufacturing. Examples of Secondary products include various types of paper, paperboard, panels, engineered composites, or dimension stock. Secondary products can also include final consumer products such as furniture.

Spatial analysis is the process of extracting or creating new information about a set of geographic features. Spatial data consist of measurements taken at specific (known) locations or within a specified area. Locations may be point or aerial-referenced (Kaluzny et al. 1997). Spatial data analysis extends and modifies standard statistical techniques so that data point locations and their arrangement are given greater importance in the analysis of results (Downer 2004). Spatial data may come from archival sources (digitized maps, census material, and aerial photos), field observations, experimental simulation, or remote sensing (satellite imagery). Because of the availability of information in diverse formats, spatial analysis often requires the use of Geographic Information System (GIS) combined with statistical tools. For example, Blackman et al. (2003) analyzed digitized aerial photographs built into a GIS database and developed a regression model to study forest land cover changes in Mexico as a function of some socio-economic variables. GIS and other statistical tools can be helpful in forest management (Hardwick 1999).

#### THE STUDY

This study was conducted in the fall of 2004. The objective was to explore the distribution and possible clustering of Louisiana Primary and

Secondary FP manufacturers. Spatial point patterns and spatial correlations of companies were calculated as functions of state-level socio-economic variables.

The data were obtained from the Louisiana Forest Products Development Center (LFPDC) (2004) and the U.S. Census Bureau (2004a, b). The LFPDC maintains lists of primary and secondary manufacturers for the state of Louisiana. The original LFPDC database includes 157 Primary FP manufacturers and 525 Secondary FP manufacturers. The zip codes for these companies were matched against the 5-digit zip code tabulation areas available from the U.S. Census Bureau for Louisiana. Only those companies for which their 5-digit code coincided with the cartographic maps were used in this study, representing 78 Primary manufacturers and 176 Secondary manufacturers.

Using the final lists, frequencies aggregated by zip code were calculated. Ideally, latitude-longitude (Lat-Long) coordinates for company locations would be used, but because many addresses contained in the database reference post office boxes and not street addresses, zip codes were used as a proxy. The next step was to geo-reference the centroids (Lat-Long coordinates of the zip codes) using map projection U.S. NADCOM 1983, zone 15, for the state of Louisiana.

Next, socio-economic data from the 2000 U.S. Census (U.S. Census Bureau 2004a) were merged with the zip code map projections, and regression analysis was conducted to identify zip code locations as a function of socio-economic variables using a correlated errors model. Finally, geo-spatial industry clusters for primary and secondary FP manufacturers were identified.

Figures 1a and 1b are scatter plots indicating company locations for primary and secondary manufacturers, respectively. Again, these correspond to the centroids of the respective zip codes. The locations generally depict the shape of the state of Louisiana. Casual inspection seems to indicate clustering in the northwest and southeast areas of the state, particularly for secondary manufacturers, while primary manufac-

turers are dispersed throughout the state's forest resource areas.

#### SPATIAL ANALYSIS

##### *Spatial independency: model variograms*

The classical variogram is a measure of the continuity of spatial data expressed as an average squared difference between measured quantities at different locations (Bailey and Gatrell 1995). Typically a variogram estimate is created for a specific distance interval defined by the number of lags in the model. Three main values are used to interpret variograms: sill, range, and nugget effect (Cressie 1993; Downer 2004). Sill is the level at which the variogram levels off and is indicative of the sample variance. The range is the distance at which spatial dependency disappears (distance at which the variogram reaches the sill). The nugget effect indicates variability at a lower scale than the one measured and/or sampling errors.

Model variograms were produced for both primary and secondary manufacturers. This process identified one outlier in the primary industry data. The revised dataset resulted in a better fit to the model variogram by reducing the objective value from 0.6608 to 0.0378. The objective value is a goodness-of-fit measurement used to accurateness of a model variogram to represent the data. Variograms with the best fit are shown in Figs. 2a and 2b for Primary and Secondary manufacturers, respectively.

The variogram indicates that beyond 0.26 degrees, the frequency of primary manufacturers becomes independent (Fig. 2a). The nugget effect was "0". For Secondary manufacturers, the relationship is not as strong as for primary manufacturers (Fig. 2b). Note that the objective value is also much larger (3.2766) than for the Primary manufacturers (0.0378).

The range values indicating spatial independency suggest that for distances above 0.2636436 Lat-Long degrees, the frequency of Primary FP manufacturers is not spatially dependent. For Secondary manufacturers, this holds for distances above 0.0003034706 Lat-Long de-

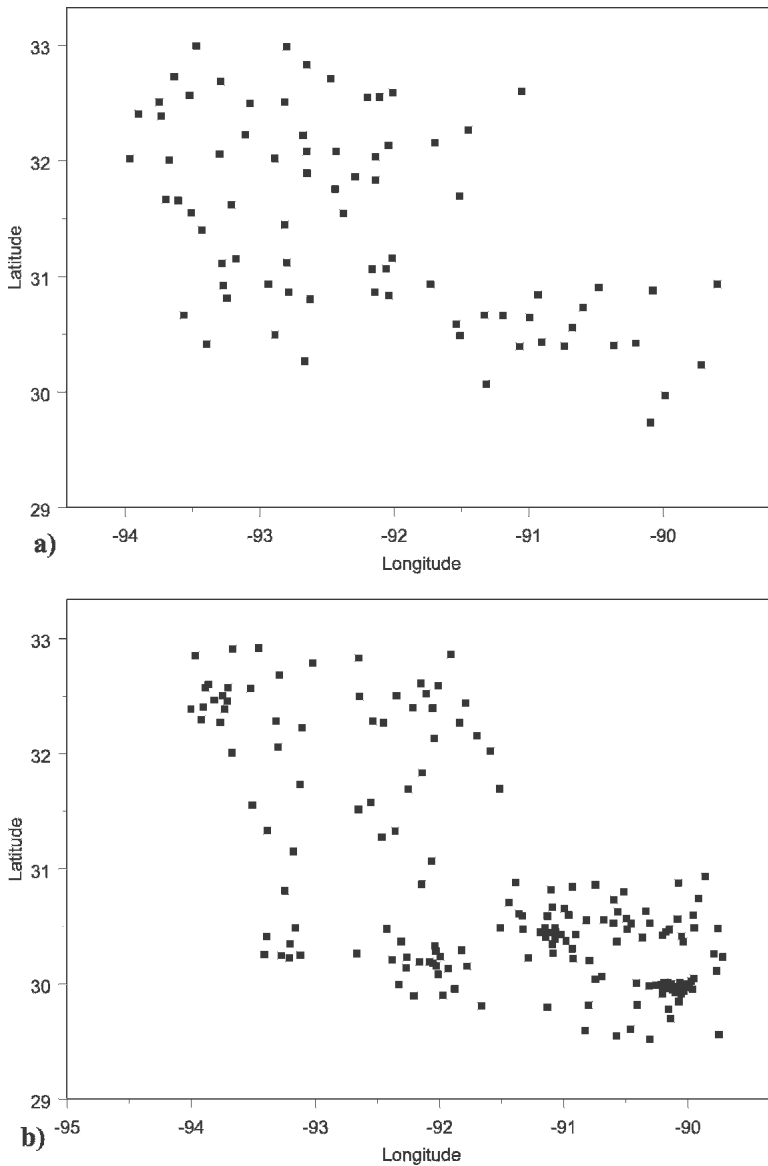


FIG. 1. Lat-long locations of zip code centroids with frequencies of Primary (a) and Secondary (b) FP manufacturers in the State of Louisiana.

grees. The higher spatial dependency for Primary manufacturers may be due to the fact that these companies are typically located close to a resource base (forest) and also that the number of companies is often restricted due to limited availability of raw materials. Other factors such as transportation costs may also have an effect on these spatial arrangements. Andersson (2002)

stresses that the spatial allocation of forests is a complex issue involving economic, social, technical, and temporal factors.

#### *Modeling company frequencies as a function of spatial and socio-economic variables*

Both datasets were merged and joined to socio-economic data obtained from the Census

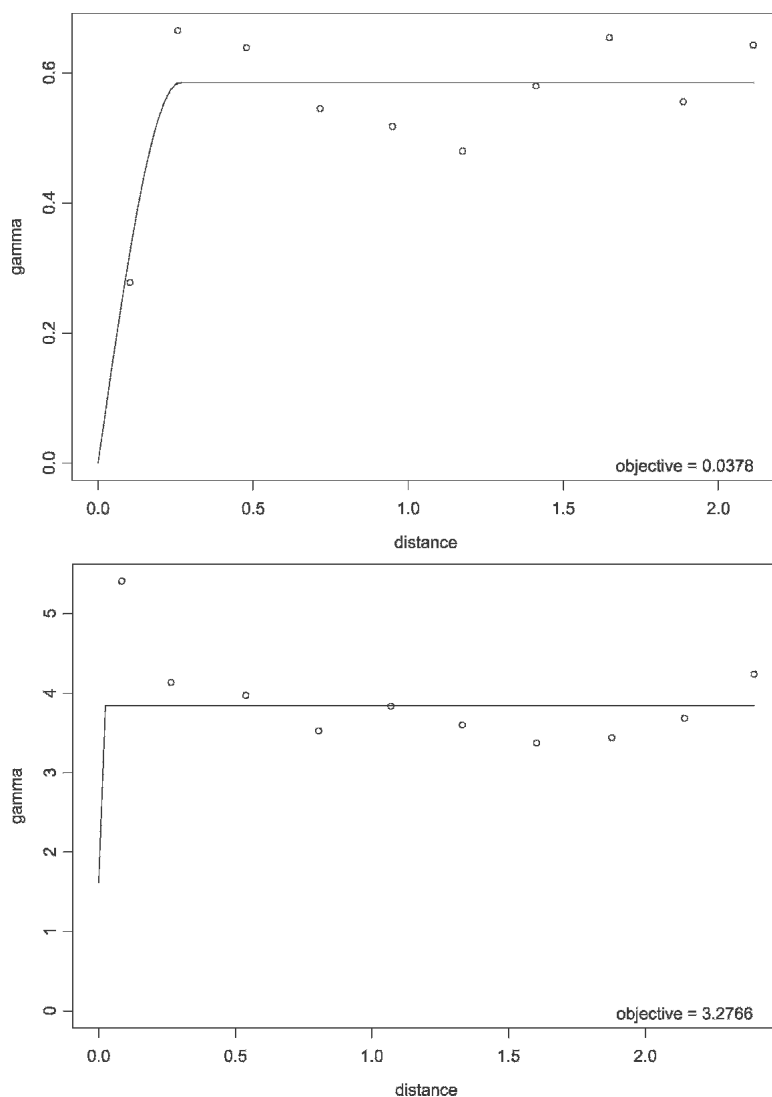


FIG. 2. Model variograms for Primary(a) and Secondary (b)FP manufacturers in Louisiana (Nlag = 10). Primary FP manufacturers spherical function, range: 0.2636436, sill: 0.5849148, nugget: 0.0. Secondary FP manufacturers spherical model function, range: 0.0003034706, sill: 2.2277050110, nugget: 1.6180414937.

2000 database (zip-code level). Several multiple linear regressions were modeled. The first model included the frequency of primary manufacturers as a function of their Lat-Long coordinates. The same model was created using secondary manufacturers as the dependent variable. Finally a model was developed where secondary manufacturer frequency was the dependent variable as a function of Lat-Long coordinates and primary frequencies. None of the independent variables

considered in the model were significant at  $\alpha = 0.05$ , suggesting no Lat-Long dependency between primary and secondary sectors.

Additional correlated errors models were also fitted to help predict the locational frequency of Primary and Secondary FP manufacturers. Table 1 shows a model with the best fit (lowest -2 Res Log Likelihood) where the frequency of Secondary companies is a function of the frequency of Primary companies (FP1), Lat-Long coordinates

TABLE 1. *F-value results for a correlated errors procedure modeling frequency of Secondary FP manufacturers per zip code as a function of frequency of Primary, FP, Longitude, Latitude, Latitude\*Longitude interaction and total population.*

Effect	Numerator DF	Denominator DF	F Value	Pr > F
Primary FP (FP1)	1	39	1.06	0.3093
Longitude (Long)	1	39	0.49	0.4875
Latitude (Lat)	1	39	0.51	0.4775
Lat Long interaction (Lat*Long)	1	39	0.51	0.4815
Total population (POP)	1	39	18.75	0.0001*

-2 Res Log Likelihood goodness of fit = 206.5.

\* Denotes statistical significance at  $\alpha = 0.05$ .

(Lat and Long), Lat and Long interaction (Lat\*Long), and total population (POP). Total population was selected as a proxy to estimate any relation between the frequency of Secondary FP manufacturers and consumers' markets. Variables Lat, Long, and Lat\*Long were used to predict Secondary FP manufacturers frequency as a function of location. Other variables such as land area, median income, and urban population were tested to explore any significant effect on Secondary FP frequency but were dropped because they did not offer any additional information to the model. Values used in all models correspond to each zip code as reported in the U.S. Census Bureau (2004b) 5-digit zip code tabulation areas. The parameter values used in the regression models correspond to those of the variogram for the secondary FP manufacturers.

With the correlated errors model, total population (POP) was the only variable found to be significant at the  $\alpha = 0.05$  significance level. This suggests that the number of Secondary FP manufacturers per zip code is correlated to the total population per zip code block. This finding indicates that Secondary companies tend to locate near highly populated consumer markets. Other variables such as land area or spatial coordinates were not found to be significant in this analysis.

### Cluster patterns

To identify any clustering patterns for Primary and Secondary FP manufacturers, various inter-point distance methods were used including measures of intensity, the empirical distribution for the origin to nearest neighbor point dis-

tances (Ghat). Finally, the deviation of the empirical pattern of Primary and Secondary companies was tested against Complete Spatial Randomness (CSR) using a Lhat analysis.

A binning method with a 0.1 smoothing parameter was used for both datasets to check for intensity. It is important to note that when analyzing for intensity, the data are now seen as a point pattern where the actual frequencies are dropped and now receive a value of 1. It is a binary data analysis with the information pertaining to the number of companies per zip code being lost, but the incidence of a company per zip code is maintained.

In Fig. 3a a lighter color indicates a higher incidence of Primary FP manufacturers. Note that there are several clusters of primary companies throughout the state. Primary FP manufacturers are forest resource-dependent and are located primarily close to the forest and raw materials (logs) (Porter 2003). In the northwestern part of the state, the predominant forest type is loblolly/shortleaf, in the southwest longleaf/slash pine, and in the southeastern gum/oak and cypress as reported by Frey (1991). The dominant species in these areas may be a factor affecting this spatial pattern.

Regarding the intensity of Secondary FP manufacturers (Fig. 3b), the frequency is less dispersed. The largest incidence is located in the southeast part of the state, suggesting that the two largest incidences of secondary manufacturers are located close to the largest urban areas in the state, New Orleans and Baton Rouge. Recall that in the regression model, the variable population was the only factor significant at  $\alpha = 0.05$  level. Although the regression model fits a value

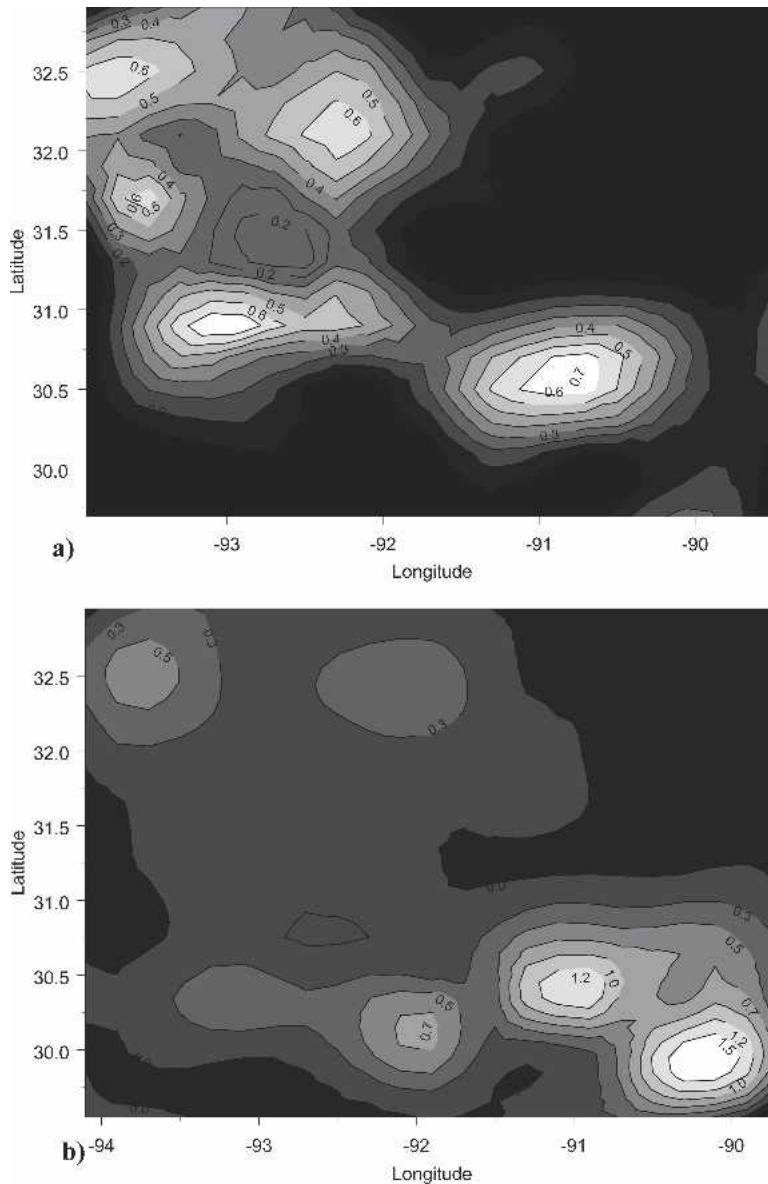


FIG. 3. Primary (a) and Secondary (b) FP manufacturers analyses for intensity (Binning). Default number of bins used and 0.1 smoothing parameter.

for the frequency of companies and not binary data (as it is the case for intensity modeling), this still further helps to explain the higher presence of secondary companies in this part of the state. Compared to the Primary FP industry, Secondary manufacturers are typically situated near final consumers for their products in more populated areas. This pattern of agglomeration near

urban areas is in part motivated by easier access to consumer information and potential benefits derived from scale economies as a cluster grows larger. Secondary FP manufacturers can source input materials from other areas (regions or even countries) and are not spatially tied to the source of input materials. These clusters constitute core nuclei that embody fundamental commonalities

that can lead to successful forest sector economic development.

The empirical Ghat (identifying nearest neighbor) for Primary FP manufacturers (Fig. 4a) suggests that there is some level of clustering

in the data as shown by a large number of short distance neighbor points compared to a fewer number of long distance neighbors at above 0.3. Figure 4b shows the same Ghat analysis applied to the original Secondary manufacturers dataset.

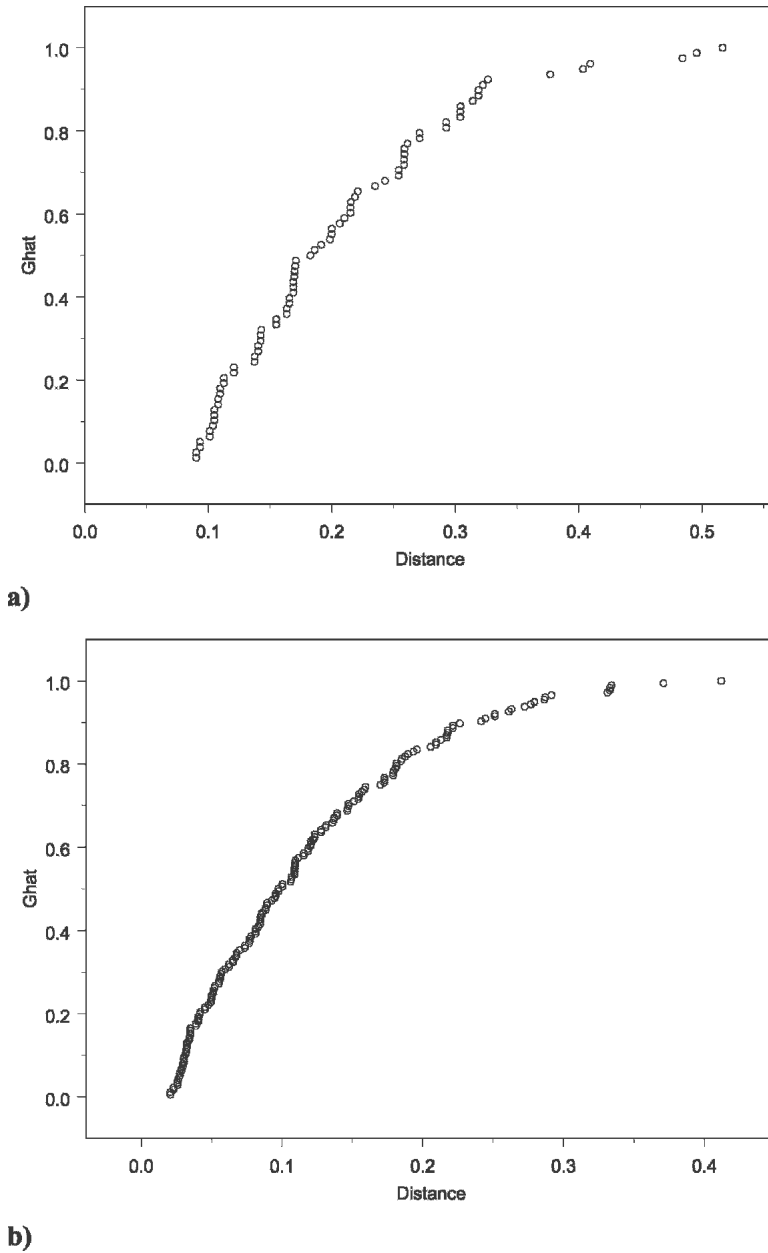


FIG. 4. Results of Ghat analyses for the occurrence of Primary (a) and Secondary (b) FP manufacturers in the State of Louisiana.

This analysis provides a stronger evidence of spatial point clustering. Finally, Figs. 5a and 5b show a model for the deviation of the empirical spatial location of Primary and Secondary FP manufacturers from complete spatial randomness. Note that these charts suggest that Secondary companies show a higher level of deviation from CSR as denoted by the wider deviation from a straight line.

Braden et al. (1998) suggest that FP industry clusters develop in order to take advantage of competitive opportunities created by these types of business structures. Some of the elements that encourage companies to be a part of a cluster include proximity to markets, access to plentiful supply of raw materials and potential customers, and skilled labor. Our results reinforce some of those findings. Primary FP manufacturers are

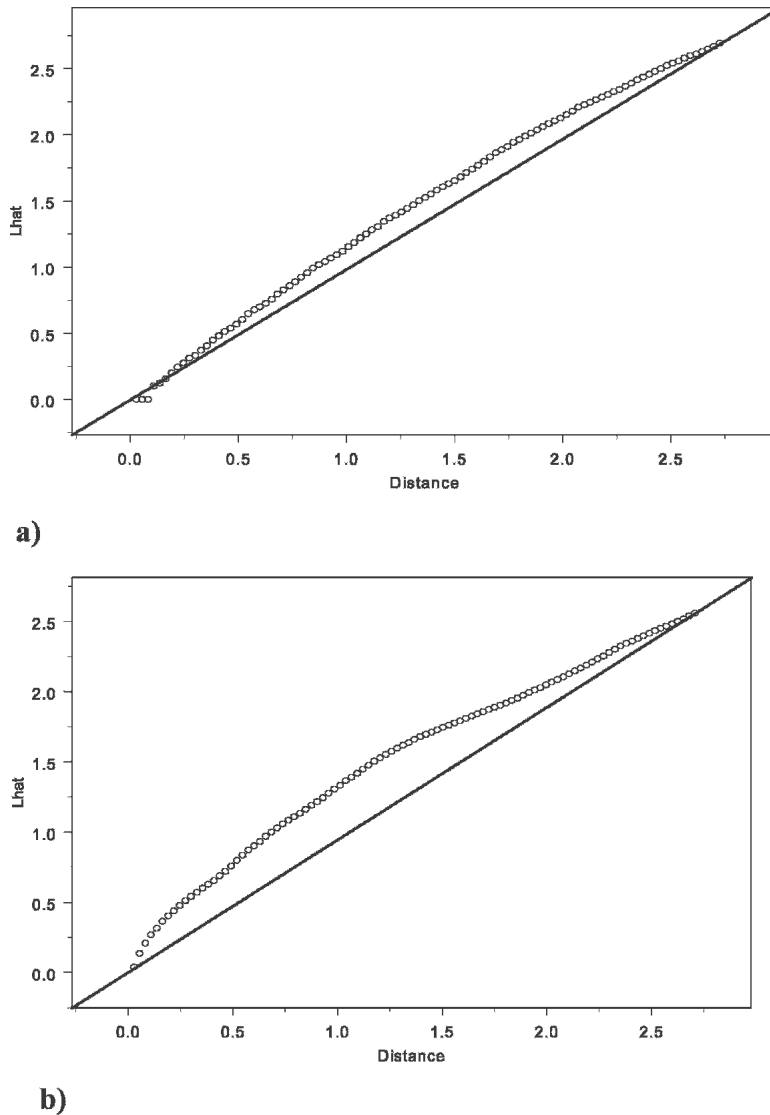


FIG. 5. Lhat analysis, deviation of empirical spatial location from Complete Spatial Randomness (CSR) for the occurrence of Primary (a) and Secondary (b) FP manufacturers in the State of Louisiana.

found in Louisiana near raw material supplies, while Secondary FP manufacturers are concentrated near major populated areas.

While the proposed model for spatial analysis can be effective at assessing the spatial concentration of companies, it is limited in its capacity to determine linkages between Primary and Secondary FP companies only and not other participants in the supply chain. Testing of our model suggests that there is no statistically significant association between these two sectors. We must stress that this finding is based only on geographic industry concentrations and does not assess clustering in the context of business relations that may exist between Louisiana Primary and Secondary manufacturers. Nevertheless, we have presented a technique that can be used to analyze the spatial distribution of manufacturers and assess evidence of geographic industry clustering using GIS and statistical tools.

#### CONCLUSIONS

The spatial analysis of the occurrence of Primary and Secondary FP manufacturers in Louisiana suggests that the frequency of Primary FP manufacturers shows higher spatial dependency compared to Secondary FP manufacturers as denoted by higher range values when modeling a spatial variogram. In addition, population is the variable that significantly affects the frequency of Secondary FP manufacturers per zip code area as calculated in a correlated errors regression. No other socio-economic variables seem to directly affect the frequency of Primary FP manufacturers.

Primary FP manufacturers are scattered throughout the state but are close to forest resources, while there is evidence suggesting the existence of two clusters of Secondary FP industries in the southeastern region of the state corresponding to the most populated areas in Louisiana. Further analyses show a higher level of deviation from complete spatial randomness for the Secondary FP manufacturers suggesting a pattern aggregated in clusters.

These clusters constitute core nuclei that embody fundamental commonalities that can lead

to successful forest sector economic development. Although not all companies fit neatly into a cluster with common characteristics, they may have a "reach" or peripheral interface that can allow them to link to mutual support, develop scale economies through participation, and have access to market information. Cluster-based economic development can support regional-based economic development, industrial recruitment strategies, and corporate site location decision-making.

Future research will build on this analysis to identify geo-spatial locations of supply chain members in the wood producing sector, model more complex business relations, and ultimately identify additional socio-economic factors that contribute to or hinder supply chain success.

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