Spatiotemporal Evolution and Influencing Factors of Forestry Enterprises in Shaanxi Province: Postprint

Authors: Ni Honghong

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Abstract

Forestry is the primary battlefield for ecological civilization construction and an important foundational industry for economic and social development. As the concrete implementation point of the forestry industry economy, the analysis of spatiotemporal evolution patterns and influencing factors of forestry enterprises can assist decision-makers in rationally arranging forestry industry layouts and promoting the sound development of the forestry industry. Based on forestry enterprise data from Shaanxi Province for the period 2000–2020, this study employs geographic information system (GIS) spatial analysis methods including average nearest neighbor, standard deviational ellipse, and kernel density analysis to examine the spatiotemporal evolution characteristics of forestry enterprises in Shaanxi Province. The ordinary least squares (OLS) model and geographically weighted regression (GWR) model are utilized to investigate the spatial heterogeneity of factors influencing the distribution quantity of forestry enterprises across 107 counties and districts, revealing the influence mechanisms and spatial differentiation characteristics of different factors. The results indicate that: (1) The growth rate of forestry enterprise numbers in Shaanxi Province has gradually accelerated, with the spatial pattern exhibiting obvious agglomeration characteristics and continuously strengthening agglomeration intensity. (2) The spatial distribution of forestry enterprises in Shaanxi Province has shifted overall toward the east, but kernel density hotspot areas remain located in Xi'an City, forming a contiguous high-value region with Xianyang City. (3) Forestry enterprises in Shaanxi Province have distinct business scopes, primarily focusing on forestry-related "sales" and "services." With further optimization of the industrial structure, from primary processing to reprocessing and deep processing, the technological content of forestry enterprises has continuously increased, with related service items being expanded. (4) Regarding the influencing factors of forestry enterprise distribution quantity, external socioeconomic conditions such as total retail sales of consumer goods, gross regional

product, and permanent resident population have the strongest influence on forestry enterprise distribution quantity. However, industrial conditions including the proportion of primary industry added value and forest land area also exert positive effects. The negative correlation between average enterprise registered capital, garden plot area, and road density with forestry enterprise numbers reflects competitive pressure among similar enterprises, demonstrates the objective reality of large forestry enterprise areas, and aligns with the characteristic of a substantial primary industry proportion within the forestry sector. Significant spatial differentiation exists among the influencing factors of forestry enterprise distribution in Shaanxi Province. Governments and relevant departments must consider the characteristics of different regions when formulating industrial policies, adopt targeted measures, and promote the healthy and coordinated development of the forestry industry.

Full Text

Preamble

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Title

Spatiotemporal Pattern Evolution and Influencing Factors of Forestry Enterprises in Shaanxi Province

Authors

NI Honghong[1], MA Qiang[2], BU Yuankun[1], YANG Xiaoxuan[1], LI Weizhong[1]

[1]College of Forestry, Northwest A&F University, Yangling 712100, Shaanxi, China
[2]Resource and Environment College, Anhui Science and Technology University, Chuzhou 233100, Anhui, China

Abstract

Forestry is a pivotal domain in the construction of ecological civilization and constitutes a fundamental industry for economic and social advancement. Functioning as a specific cornerstone of the forestry industry economy, analyzing the spatial evolution and influencing factors is crucial for decision makers to judiciously organize the forestry industry layout and foster its development. Drawing on data spanning from 2000 to 2020 for forestry enterprises in Shaanxi Province, China, this study employs geographic information system (GIS) spatial analysis techniques, including average nearest neighbor, standard deviation ellipse, and kernel density analysis, to scrutinize the spatial and temporal evolution characteristics of these enterprises. In addition, ordinary least squares regression and geographically weighted regression models were used to explore

the spatial heterogeneity of factors influencing the distribution of forestry enterprises across 107 counties and districts. This study unveils the influence of various factors and spatial differentiation characteristics. The findings reveal the following: (1) The number of forestry enterprises in Shaanxi Province has steadily increased, demonstrating a discernible agglomeration pattern with strengthening degrees of concentration. (2) The overall spatial distribution of forestry enterprises in Shaanxi Province shifts eastward, yet the central nuclear density hotspot remains consistently situated in Xi'an City, forming a contiguous high-value area with Xianyang City. (3) Forestry enterprises in Shaanxi Province exhibit a distinct business scope, primarily revolving around sales and services related to forestry. As the industrial structure is optimized, there is an evident increase in the technical content of forestry enterprises, accompanied by the expansion of related service offerings from primary processing to reprocessing and deep processing. (4) Regarding the influencing factors of forestry enterprise distribution, socioeconomic factors such as total retail sales of consumer goods, gross regional product, and the number of permanent population exert the most substantial impact. However, industry-related factors, including the proportion of primary industry value added and forest area, also positively influence the distribution of forestry enterprises. Conversely, a negative correlation was observed between the registered capital average of enterprises, garden plot area, highway density, and the number of forestry enterprises, indicative of competitive pressures and the reality of expansive land area the forestry enterprises owned. These outcomes align with the characteristics of the forestry industry, which is predominantly driven by the primary sector. The factors influencing forestry enterprise distribution in Shaanxi Province exhibit notable spatial heterogeneity. Consequently, when formulating industrial policies, it is imperative for the government and relevant departments to consider regional nuances and adopt targeted strategies to facilitate the healthy and coordinated development of the forestry industry.

Keywords: Shaanxi Province; forestry enterprise; spatial analysis; temporal and spatial evolution; geographically weighted regression model

1. Introduction

Forestry occupies an extremely important position in national economic and social sustainable development strategies, delivering economic, social, ecological, and cultural values. Since the founding of the People's Republic of China, forestry output value has grown rapidly, increasing from 7.55$×10^{9}$ yuan to 2.39$×10^{12}$ yuan. Forestry also represents the largest green economy sector, playing a significant role in stimulating domestic demand, promoting green economic growth, and accumulating ecological assets. As the main component of forestry, forest ecosystems constitute the largest terrestrial carbon sink, providing strategic support for China's climate change mitigation efforts. Consequently, forestry construction is a fundamental issue concerning sustainable economic and social development, offering substantial economic benefits

alongside immense ecological and social functions.

Forestry enterprises, which primarily operate using forest resources, environments, and their products, generate positive impacts across economic, ecological, and social dimensions. These enterprises not only provide socially needed products and achieve healthy, sustainable development but also play crucial roles in promoting economic growth and ecological environmental construction. The development status of forestry enterprises directly relates to regional economic growth and ecological construction, making research on their spatial pattern evolution and influencing factor analysis particularly important.

Forestry industry, as the main body of forestry economic development, encompasses diverse types beyond direct forestry production and management, including forest cultivation, timber processing and wood product manufacturing, forest carbon sequestration, ecological tourism, forest health and wellness, forestry professional technical services, and other related activities. Current research on forestry enterprises primarily concentrates on forestry operation and management, social value, and industrial agglomeration. Regarding forestry operation and management, numerous scholars have investigated capital structure, performance, leverage ratios, and tax policies, proposing recommendations for optimizing development processes from a structural perspective. Concerning social value, researchers have examined carbon sequestration, ecological construction, and social responsibility, recognizing that forestry enterprises bear special social responsibilities in green sustainable development that distinguish them from general enterprises. Additionally, scholars have analyzed and discussed forestry industry agglomeration status and related factors. For instance, Munnich et al. applied Porter's "Diamond Model" and industrial cluster theory to analyze the competitive advantages of forestry industry clusters in northeastern Minnesota. Todd and Robert conducted spatial analysis of Mississippi's forestry enterprises based on labor, transportation infrastructure, and raw materials to identify potential clusters. Han Ying utilized panel data from 30 provinces to explore the spatiotemporal differentiation of China's forestry industry agglomeration and employed spatial econometric models to study its economic effects, proposing development strategies.

Currently, enterprise spatial pattern research represents a hot topic in economics, geography, and management, primarily focusing on technology-based enterprises, service enterprises, and innovative enterprises. Numerous scholars have employed spatial analysis techniques to investigate spatial evolution patterns, used regression models to explore influencing factors, and proposed resource optimization solutions. However, research on spatial patterns of agriculture and forestry enterprises—industries dominated by the primary sector with secondary and tertiary sectors as supplements—remains relatively scarce. Xiong Youyun et al. analyzed the macro and micro regional and industry-specific spatial layout characteristics of China's agricultural leading enterprises based on correlation analysis and ecological distribution pattern theory. Bai Rushan et al. employed modern geospatial methods such as nearest neighbor distance index

and kernel density estimation to investigate the spatial agglomeration patterns and influencing factors of agricultural leading enterprises in Fuyang City from a type-space two-dimensional perspective. Jiang Hui et al. examined the spatial distribution characteristics of China's agricultural industrialization leading enterprises and analyzed influencing factors through multiple linear regression.

These studies indicate that current enterprise layout research tends to utilize location theory to explore spatial patterns of secondary and tertiary industries like manufacturing and technology enterprises, while neglecting research on primary industry layouts such as agriculture and forestry. Among studies focusing on forestry enterprises, most emphasize operation and management as well as social value, with limited research on spatial layout evolution and influencing factors, primarily employing statistical methods to analyze industrial agglomeration from macro perspectives based on panel data.

1. Data and Methods

1.1 Study Area

Shaanxi Province serves as a crucial hub for the "Belt and Road" initiative and an important region for national development strategies including the new era Western Development and the ecological protection and high-quality development of the Yellow River basin. During the "13th Five-Year Plan" period, Shaanxi's forestry industry developed in an orderly and healthy manner, with total output value reaching 1.48$×10^{11}$ yuan. Relying on forest resource endowments, the province has developed green wealth-generating industries, forming an ecological economic system that promotes ecological construction through green industries and drives poverty alleviation through ecological development, with service industries such as ecological tourism, forest experiences, and forest health and wellness flourishing. However, Shaanxi's forestry industry also faces challenges including insufficiently close integration of the three industries, incomplete industrial chains, relatively small individual enterprise scale, and weak market competitiveness and risk resistance.

1.2 Data Sources and Screening

This study examines forestry-related enterprises in Shaanxi Province from 2000 to 2020. Enterprise sample data were primarily obtained from the national business inquiry platform "Qixinbao" through keyword screening of enterprise names and business scopes using terms "forestry industry," "forestry enterprise," and "forestry." The dataset includes enterprise name, registration status, legal representative, registration time, registered capital, address, enterprise type, telephone, email, and other information. The raw data were cleaned by removing enterprises with "revoked," "cancelled," or "delisted" status and those with unclear basic information. Since keyword crawling captures some unrelated enterprises with similar names, data were further cleaned through manual identification and semantic analysis of enterprise names and category labels to

determine main business activities and exclude irrelevant enterprises.

Influencing factor data sources include: 2000–2020 highway infrastructure data from the OpenStreetMap volunteer geographic information website (http://download.geofabrik.de/), processed through projection, segmentation, and calculation to obtain highway density; 2000–2020 permanent population, gross regional product, proportion of primary industry value added, and total retail sales of consumer goods compiled from the "China County Statistical Yearbook (County and City Volume)"; 2000–2020 average registered capital of enterprises calculated from forestry enterprise attribute data; and 2000–2020 forest land area and garden plot area obtained from the China Land Survey Results Sharing and Application Service Platform (https://gtdc.mnr.gov.cn/).

1.3 Methods

1.3.1 Average Nearest Neighbor Analysis Average nearest neighbor analysis calculates the average distance between enterprises to represent proximity levels, thereby characterizing the agglomeration degree of forestry enterprise data points. The nearest neighbor index (ANN) is calculated as follows:

$$ANN = \frac{\bar{D}_o}{\bar{D}_e}$$

where $\bar{D}_o$ represents the mean observed distance from each enterprise to its nearest neighbor, and $\bar{D}_e$ represents the expected mean distance for a random distribution. If ANN > 1, the distribution is dispersed; if ANN < 1, the distribution is clustered; if ANN $= 1$, the distribution represents a uniform pattern under ideal conditions.

1.3.2 Standard Deviation Ellipse Standard deviation ellipse and centroid effectively reflect the dispersion degree of forestry enterprise distribution. The ellipse size indicates the overall concentration level of spatial patterns, while the long axis reflects the dominant direction of distribution. The formulas are:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n}}$$

where x_i and y_i represent spatial location coordinates of each enterprise; $\bar{x}$ and $\bar{y}$ represent the arithmetic mean center of all enterprises; n represents the total number of enterprises; and SDE_x and SDE_y represent the longitude and latitude coordinates of the standard deviation ellipse centroid z.

1.3.3 Kernel Density Analysis Kernel density analysis calculates the density of features within their surrounding neighborhoods, intuitively reflecting the diffusion degree of forestry enterprises. The calculation formula is:

$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right)$$

where $f(x)$ represents the kernel density estimate; n represents the number of forestry enterprises; h represents the bandwidth; k represents the kernel function; and $x - x_i$ represents the Euclidean distance from estimation point x to sample point x_i. Higher values indicate greater enterprise agglomeration, while lower values indicate lower density.

1.3.4 Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) Models Multivariate linear regression analysis comprises two main types: global linear regression and local linear regression. The most traditional global linear regression method is the OLS model:

$$y = \beta_0 + \sum_{k=1}^{n} \beta_k x_k + \varepsilon$$

where y represents the observed dependent variable; β_0 represents the constant term estimate; x_k represents the value of the kth independent variable; β_k represents the coefficient estimate for the kth independent variable; n represents the number of independent variables; and ε represents the error term. The OLS model only provides global estimates for samples and variables without considering spatial correlation effects.

The GWR model extends the linear regression model and can effectively fit samples with spatial autocorrelation, reflecting their spatial characteristics:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{n} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

where y_i represents the n-dimensional dependent variable; x_{ik} represents the k-dimensional explanatory variable matrix; $\beta_k(u_i, v_i)$ represents the regression coefficient for factor k at regression point i; n represents the number of independent variables; (u_i, v_i) represents the longitude and latitude coordinates of the ith observation point; and ε_i represents the randomly distributed error term.

2. Results

2.1 Spatiotemporal Evolution Characteristics of Forestry Enterprise Distribution

2.1.1 Average Nearest Neighbor Analysis The nearest neighbor indices for Shaanxi Province forestry enterprises from 2000 to 2020 were all less than 1 and gradually decreased, indicating that the spatial distribution of forestry enterprises exhibits clustering characteristics with continuously strengthening agglomeration trends. In 2000, China's forestry enterprises were in the initial development stage. Due to Shaanxi Province's early implementation of mountain closure and grazing prohibition policies, combined with abundant forest resources, a large-scale forestry industry agglomeration center formed. Clustered distribution of forestry enterprises can effectively integrate human resources, capital, technology, and other factor conditions to build industrial clusters aligned with local characteristics, creating scale effects that promote industrial efficiency and regional economic development. After 2010, China's forestry industry entered a rapid development phase, with favorable factors including population agglomeration, technological advancement, natural resource development, supporting facility construction, and policy support driving increased spatial distribution density and agglomeration trends. In the Guanzhong region, particularly Xi'an and Xianyang cities, the economy is more developed, creating favorable conditions for forestry enterprise survival and development, resulting in more rapid density increases.

2.1.2 Standard Deviation Ellipse Analysis Standard deviation ellipses at different time points depict directional differences and centroid changes in forestry enterprise distribution. Regarding centroid trajectory, the pattern shows initial northeastward migration followed by southeastward movement, though the centroid remains in the southeastern part of Xianyang City with minimal interval variation, indicating relatively stable distribution and concentrated patterns. In terms of axis lengths, the ellipse's long axis expanded in the northeast-southwest direction while contracting in the northwest-southeast direction from 2000 to 2020. Regarding rotation angle, the azimuth decreased gradually, with faster growth in the northwest-southeast direction but spatial distribution still oriented along the northeast-southwest axis. Although the standard deviation ellipse centroid of forestry enterprises from 2000 to 2020 experienced slight migration, it consistently remained in this region, demonstrating concentrated distribution.

2.1.3 Kernel Density Analysis Kernel density analysis reveals that forestry enterprise distribution density at each time point demonstrates significant spatial agglomeration. From 2000 to 2020, the number of forestry enterprises continuously increased, with kernel density values rising from 0.036$×10^{-4}$ to 0.886$×10^{-4}$—an approximately 25-fold increase. Distribution patterns evolved from absolute concentration in 2000 to block-shaped agglomeration cen-

tered on Xi'an City, with gradually expanding scope. In 2000, forestry enterprises formed multiple dispersed block-shaped agglomeration areas in Xi'an, Hanzhong, Baoji, and Yan'an cities, corresponding to the Loess Plateau soil and water conservation zone, Guanzhong Plain ecological collaborative development zone, and Qinling-Daba water source conservation zone, creating a relatively balanced multi-center development pattern. By 2010, the number of hotspot areas in each city decreased significantly, with agglomeration centers becoming more prominent around urban districts. Hotspot areas concentrated primarily in the Guanzhong Plain ecological collaborative development zone, with resource-based forestry enterprises decreasing while agglomeration toward urban areas increased markedly. By 2020, small agglomeration centers had largely disappeared, with large agglomeration centers expanding slightly. Xi'an City serves as the highest-level agglomeration center, spreading northwestward and northeastward. New small agglomeration centers emerged in Ankang, Shangluo, and Yulin cities. The Xi'an-Xianyang junction area has become Shaanxi's forestry enterprise agglomeration center, with the advancement of Xi-Xian integration attracting more newly registered enterprises and forming a concentrated belt distribution along the Wei River. Yulin City added a new agglomeration area in the Mu Us Sandy Land ecological restoration zone. Overall, forestry enterprise development primarily depends on capital and markets, followed by forestry resource influences.

2.2 Business Scope Evolution and Influencing Factors

2.2.1 Business Scope Changes Word cloud analysis of business scopes reveals that forestry enterprises share commonalities while displaying distinct characteristics at different stages. The top 20 keywords remain consistent across time points, primarily comprising forestry-related basic product and service terms. These include operation attribute keywords such as "forest farm," "forestry bureau," and "limited company"; operation mode keywords including "sales," "service," "management," "wholesale," and "engineering"; and forestry-related keywords like "forestry," "agriculture," and "forest trees." Among these, "forestry," "sales," and "service" consistently rank as the top three keywords, indicating that forestry enterprises clearly focus on forestry-related product sales or derivative services. Subsequent keywords reflect different characteristics at each time point, evolving from "nursery" and "planting" to "biological control" and "equipment," then to "technology" and "technical consultation," demonstrating a development trajectory from primary processing to reprocessing and deep processing. While maintaining their industrial characteristics, forestry enterprises continuously increase their technical content and expand related service offerings.

From a temporal perspective, forestry enterprises in 2000 exhibited obvious state-owned characteristics, with "forestry bureau" and "forest farm" appearing more frequently than "limited company," indicating that state-owned traditional forestry enterprises dominated while private forestry enterprises were

relatively few. Between 2005 and 2010, the number of "limited company" keywords began exceeding "forestry bureau." With the rise of the market economy, the state issued the "Decision on Accelerating Forestry Development," encouraging non-public forestry development and attracting capital into the forestry industry, leading to increased private enterprises and the emergence of "investment" keywords. This period represented the fastest growth interval for Shaanxi's forestry industry, with rapid industrial scale expansion and booming product trade, causing "sales" and "service" keywords to surge and rank as the top two keywords. The forestry industry structure further optimized with enriched industry types including "flowers," "technology," "biological control," "landscaping," and "projects." From 2015 to 2020, forestry product sales and derivative services flourished, with increased derivative products such as "biological control," "ecology," and "equipment," gradually expanding business scopes and concentrating in policy-related and industrial upgrading domains. Keywords like "technical consultation," "projects," and "ecology" grew rapidly, though "agriculture" and "planting" remained among the top keywords, indicating that forestry enterprise development involved both quantitative expansion and incremental characteristic differentiation.

2.2.2 Influencing Factors on Forestry Enterprise Distribution Spatial agglomeration and distribution direction analyses indicate significant spatial heterogeneity in forestry enterprise distribution, warranting the use of GWR models for empirical analysis of influencing factors. Drawing on existing research and considering data availability, this study analyzes factors influencing forestry enterprise spatial distribution in Shaanxi Province, including transportation convenience, labor quantity, enterprise development status, economic development level, industrial structure, production conditions, and market scale.

The GWR model requires that the dependent variable (county-level forestry enterprise numbers) exhibits spatial autocorrelation. If spatial autocorrelation exists, OLS model estimates become biased, making GWR more appropriate. To measure factor influences on forestry enterprise distribution, all variables were normalized to minimize heteroscedasticity effects, and selected indicators underwent validity testing.

OLS regression results show a coefficient of determination (R^2) of 0.869, adjusted R^2 of 0.886, and Akaike information criterion (AICc) of 1178.622, indicating good global fit. Permanent population, gross regional product, proportion of primary industry value added, forest area, and total retail sales of consumer goods demonstrate positive effects on forestry enterprise distribution, while highway density, average registered capital of enterprises, and garden plot area show negative effects. The Koenker (BP) statistic of 0.036$×10^{-4}$ indicates that the model fails to account for spatial heterogeneity and other factors, suggesting that GWR models can better address spatial heterogeneity and heteroscedasticity issues to explore factor influences on spatial distribution.

GWR model results show R^2 of 0.900 and adjusted R^2 of 0.886. Statistical

analysis of regression coefficient medians, minimums, maximums, and averages reveals significant fluctuations, indicating substantial differences in influencing factors across counties. The larger adjusted R^2 demonstrates GWR model superiority in explaining variable impacts on forestry enterprise distribution.

Examining GWR regression coefficients reveals:

1) **Total retail sales of consumer goods** shows the most significant positive impact on forestry enterprise distribution. As forestry industry encompasses primary, secondary, and tertiary sectors, higher total retail sales indicate larger market size and commercial development, particularly benefiting tertiary sector forestry enterprises engaged in product sales and service provision, leading to greater enterprise numbers. Regression coefficients are positive across all counties, showing a northward increasing trend from southern Shaanxi, where forestry industry focuses on the primary sector with relatively small markets, to Yulin City in northern Shaanxi, which has a more developed economy and broader market.

2) **Gross regional product** demonstrates significant positive effects. As a representative indicator of regional economic strength, higher GRP ensures sustainable industrial development and provides favorable external environments for enterprise development, attracting enterprise establishment. Positive coefficients across all counties are highest in southern Shaanxi's Ankang and Hanzhong cities—single-core cities where urban districts have significantly higher GRP than other counties, leading to forestry enterprise agglomeration in urban centers.

3) **Permanent population** shows significant positive correlations. Shaanxi's forestry industry system, dominated by primary and secondary sectors with extensive operations, is primarily labor-intensive, creating substantial labor demand. High-value areas are mainly located in Hanzhong and Baoji cities—major forestry cities—though overall coefficient variation is small with similar influence intensity.

4) **Proportion of primary industry value added** exhibits significant positive correlations. Economic forests and fruit forestry occupy substantial proportions in Shaanxi's forestry industry structure. Regions with higher primary industry value added proportions demonstrate greater dependence on forestry industry, such as Hanzhong City—the forest industry center of Shaanxi—where more forestry enterprises are located. Regression coefficients transition from southwest to northeast, consistent with Shaanxi's forest resource distribution.

5) **Forest area** significantly and positively influences forestry enterprise distribution. As a crucial indicator of forestry resource abundance, forest area is essential for primary and secondary forestry industries. Regions with larger forest areas host more forestry enterprises. Coefficient variations show stronger impacts in Hanzhong and Baoji cities with abundant

forest resources, and weaker impacts in Yulin City with relatively scarce forest resources.

6) **Garden plot area** demonstrates significant negative correlations. Shaanxi's garden plots constitute approximately 1/10 of forest area, mainly distributed in Weinan, Yulin, Yan'an, and Xianyang cities, focusing on fruit orchards. The fruit forestry industry features large land occupation and relative dispersion, dominated by small and individual enterprises, resulting in negative but small absolute value coefficients. Southern Shaanxi has smaller garden areas but higher absolute coefficient values.

7) **Highway density** shows unexpected negative correlations. Higher highway density may indicate greater urbanization and less abundant forestry resources, which is unfavorable for primary industry layout and development. Additionally, Shaanxi's unique topography results in low road density in northern and southern Shaanxi plateau and mountainous areas, yet these regions host numerous forestry enterprises, creating a negative correlation between highway density and forestry enterprise distribution.

8) **Average registered capital of enterprises** exhibits negative effects in most regions. Most forestry enterprises are resource-dependent, while local forest land and resources are limited. Higher average registered capital indicates larger average enterprise scale and more intense market competition, which discourages new enterprise establishment. Coefficients show a decreasing trend from south to north, indicating gradually reduced pressure on forestry enterprise distribution. Positive coefficients in Yulin City reflect its unique forestry industry structure, where besides economic fruit forestry, forest health and wellness, under-forest economy, ecological tourism, and forestry engineering are also well-developed with strong government guidance and support, maintaining high registered capital values alongside increasing enterprise numbers.

3. Discussion

Previous research has thoroughly examined enterprise spatial patterns and driving factors, but explorations of primary industry enterprise pattern evolution, particularly for forestry, remain scarce with relatively weak research foundations. This study integrates methods from other industry research, employing GIS spatial analysis techniques to quantitatively investigate the spatiotemporal evolution characteristics of Shaanxi's forestry enterprises. Considering forestry industry particularities, GWR models were used to analyze factor influences and intensities from perspectives including transportation convenience, labor quantity, enterprise development status, economic development level, industrial structure, production conditions, and market scale.

Shaanxi's forestry enterprise spatial patterns indicate that as industries dominated by primary and secondary sectors, forestry enterprises migrate relatively

slowly through continuous processes. Business scope keyword analysis reveals obvious industrial structure adjustments, with significantly increased numbers of forestry service enterprises in the tertiary sector. The measurement results of influencing factors demonstrate that total retail sales of consumer goods, permanent population, gross regional product, proportion of primary industry value added, and forest area show significant positive correlations with forestry enterprise distribution, particularly total retail sales of consumer goods with the strongest influence. These findings align with Shaanxi's forestry industry characteristics of being dominated by primary and secondary sectors, resource-dependent, and labor-intensive. Negative correlations for average registered capital of enterprises, highway density, and garden plot area reflect competitive pressures and the need to balance enterprise numbers with market capacity, economic development levels, and resource advantages.

Therefore, we recommend that government departments optimize forestry resource allocation in three aspects: (1) **Refine the primary industry**: Leverage forestry and human resources to develop characteristic economic forest industries focusing on apples, walnuts, and kiwifruit, promoting product extraction and deep processing. (2) **Strengthen the secondary industry**: Utilize market resource allocation and industrial cluster spillover effects to promote forestry industry agglomeration in advantageous areas, strengthen industrial cluster development, achieve industrial chain integration between primary and secondary sectors, and balance resource and market advantages. (3) **Expand the tertiary industry**: Fully exploit tourism, health and wellness, and cultural values in Shaanxi's forestry industry, cultivate new business forms and industries, leverage capital advantages, and create distinctive service brands.

4. Conclusions

Shaanxi Province possesses diverse and abundant forestry resources. The spatiotemporal pattern evolution and influencing factor analysis of its forestry enterprises yields representative conclusions: (1) **Temporal changes**: From 2000 to 2020, the growth rate of forestry enterprises in Shaanxi accelerated continuously, with development momentum strengthening. The nearest neighbor index showed a decreasing trend, with spatial distribution types consistently clustered and agglomeration degrees continuously strengthening. (2) **Spatial distribution**: The standard deviation ellipse of forestry enterprises generally follows a southwest-northeast direction, with distribution centroids stably located in eastern Xianyang City. Kernel density hotspot areas consistently center on Xi'an's urban district without significant changes, while secondary hotspot areas gradually expanded westward along the Lianyungang-Horgos Expressway to the Yangling Demonstration Zone. (3) **Business scope**: Forestry enterprises exhibit distinct but gradually expanding business scopes, primarily focusing on forestry-related product sales and derivative services. Industrial structure optimization is evident, with increasing technical content from primary to deep processing. (4) **Influencing factors**: Total retail sales of consumer goods,

gross regional product, permanent population, proportion of primary industry value added, and forest area demonstrate significant positive correlations with forestry enterprise distribution, with total retail sales of consumer goods showing the strongest influence. Garden plot area, highway density, and average registered capital show negative correlations, indicating that forestry enterprise distribution requires balancing competitive pressures among similar enterprises with regional market capacity, economic development levels, and resource advantages.

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Note: Figure translations are in progress. See original paper for figures.