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Industrial Spatial Layout of the Changjitu Region

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Abstract: Against the background of economic globalization and Northeast China's revitalization, this study focuses on the Changjitu Region (covering 37 counties/cities centered on Changchun, Jilin City, and Yanbian Korean Autonomous Prefecture), a core node of the Tumen River cooperation and a gateway to Northeast Asia. Using POI data (85,451 in total) crawled from Baidu Maps, it applies GIS tools (e.g., ArcMap's Kernel Density Estimation, Mean Center) and Natural Breaks Classification to analyze industrial spatial patterns. Results show: 1) The three industries present a "southeast-northwest" distribution direction, centered on the Changchun-Jilin Urban Agglomeration. 2) The primary industry clusters in plains and water areas; the secondary industry (with auto industry accounting for 42% of regional industrial output) agglomerates in Changchun-Jilin and Yanbian; the tertiary industry concentrates in major cities. 3) Traditional heavy industry (58% of total) and insufficient regional coordination remain issues. This study provides a basis for optimizing the region's industrial spatial layout.

Keywords: Changjitu Region; Industrial Spatial Layout; GIS Spatial Analysis; Industrial Agglomeration.

1. Introduction

Against the backdrop of deepening economic globalization and regional integration, industrial spatial layout serves as the core support for regional economic development [1]. As the core of the Tumen River Cooperative Development Strategy, a key growth pole for the revitalization of the Northeast Old Industrial Base, and China's opening-up gateway to Northeast Asia, the Changjitu Region's optimization of industrial spatial layout directly affects resource allocation efficiency and regional competitiveness, bearing special strategic value [2, 3].

The Changjitu Region is in the overlapping period of the 14th Five-Year Plan and the comprehensive revitalization strategy of Northeast China, facing dual challenges in industrial development. On one hand, issues such as the high proportion of traditional heavy and chemical industries, intensified industrial homogeneous competition, and industrial hollowing-out in some areas remain unresolved, demanding spatial restructuring to drive transformation [3]. On the other hand, with the accelerated construction of the China-Mongolia-Russia Economic Corridor and the entry into force of the Regional Comprehensive Economic Partnership (RCEP) Agreement, the region's opening-up advantages have become prominent. How to guide industrial agglomeration relying on port and corridor economy has become a core proposition for releasing opening-up dividends [5, 6].

Based on this, this study takes the Changjitu Region as the research object and uses GIS spatial analysis to clarify the agglomeration characteristics and differential patterns of the current industrial space.

2. Study Area

Centered on Changchun, Jilin City, and Yanbian Korean Autonomous Prefecture, the Changjitu Region covers 37 counties (cities, districts). As the intersection of the Northeast Asian Economic Circle and China's Northeast Economic Plate, its industrial economy presents a pattern of "core leadership, circle radiation, and border-area characteristics" [7, 8].

With Changchun as the core of innovation-driven development, the region has formed an industrial cluster with the automobile industry as the pillar. FAW Group drives over 2,000 supporting enterprises in the upstream and downstream industrial chains; in 2024, the output value of the automobile industry accounted for 42% of the regional total industrial output value. Meanwhile, emerging industries such as biopharmaceuticals and advanced equipment manufacturing are developing rapidly—high-tech enterprises in Changchun New Area account for 35% of the province's total [9, 10].

Overall, the regional industry has formed a framework of "central industrial agglomeration, eastern border opening-up, and region-wide characteristic complementarity". However, issues such as the high proportion of traditional industries (the proportion of heavy industry reached 58% in 2024), insufficient regional industrial coordination, and low added value of border-area industries still exist, creating practical needs for the optimization of industrial spatial layout [11].

3. Data and Methods

Point of Interest (POI) represents the location and attributes of physical objects on a map. To identify the characteristics of the industrial spatial layout in the Changjitu Region, this study used web crawler software to collect industrial POI data of the region from Baidu Maps through keyword searches, in accordance with the industrial categories specified in the National Economic Industry Classification (GB/T4754-2017).

By industrial sector:

- For the primary industry, POIs were collected for four sub-sectors: agriculture, forestry, animal husbandry, and fishery.
- For the secondary industry, POIs covered mining, manufacturing, energy industry (electric power, heating power, gas, and water production and supply industries), and construction industry.

- For the tertiary industry, POIs included wholesale and retail industry, transportation, storage, and postal services, accommodation and catering industry, information technology services (information transmission, software, and information technology services), financial industry, real estate industry, leasing and business services, residential services (residential services, repair, and other services), health and social work, and culture, sports, and entertainment industry (culture, sports, and entertainment industries).

Due to the particularity of some industrial enterprises and the geographical constraints on industrial development sites, the total number of collectible POIs (i.e., the number of industrial enterprises) from public maps was 85,451. Specifically, the number of enterprise POIs collected for the primary, secondary, and tertiary industries was 838, 1,785, and 82,828, respectively.

This study used the spatial distribution density of POIs to express the spatial agglomeration characteristics of industries; the distribution direction, centroid, and radius distance from scattered points to the centroid of POIs were used to identify the development trend direction of industries, the distribution changes of industries or different sub-sectors, and the compactness of industrial development, respectively.

To obtain analytical results based on corresponding POIs:

1. The "Kernel Density Estimation" tool in ArcMap 10.5 was used to extract industrial agglomeration characteristics.
2. The "Directional Distribution" tool in the "Measuring Geographic Distributions" toolbox was used to calculate and map the standard deviational ellipse of industrial layout development directions.
3. The "Mean Center" tool was used to extract the centroid of industrial development distribution.
4. The "Standard Distance" tool was used to extract the centroid radius range of industrial distribution.

Given the dimensional differences in the number of enterprises across industries and the fact that industrial agglomeration of each industry is only evaluated based on its own development, the Natural Breaks Classification (Jenks Natural Breaks Optimization) was adopted to classify the density of industrial agglomeration. This method is based on the premise that there are turning points or breakpoints between any data groups; it uses clustering logic to classify data groups by similarity. Unlike clustering methods, it focuses more on the similarity of the range and quantity of elements in each category. The natural breakpoints or turning points calculated by this method have statistical significance. Based on kernel density, this study classified industrial agglomeration into three levels: highly concentrated distribution, moderately concentrated distribution, and dispersed distribution.

4. Results and Discussion

4.1. Spatial Distribution of Industries in the Changjitu Region

4.1.1. Spatial Distribution of the Primary Industry

Fig. 1 illustrates the current spatial distribution characteristics of the primary industry in the Changjitu Region and the layout of its four sub-sectors (agriculture, forestry, animal husbandry, and fishery).

Results show that the primary industry in the Changjitu Region has a development trend in the southeast-northwest direction. Among its sub-sectors, agriculture, forestry, and animal husbandry share the same development direction as the primary industry, while fishery shows the opposite direction (northeast-southwest).

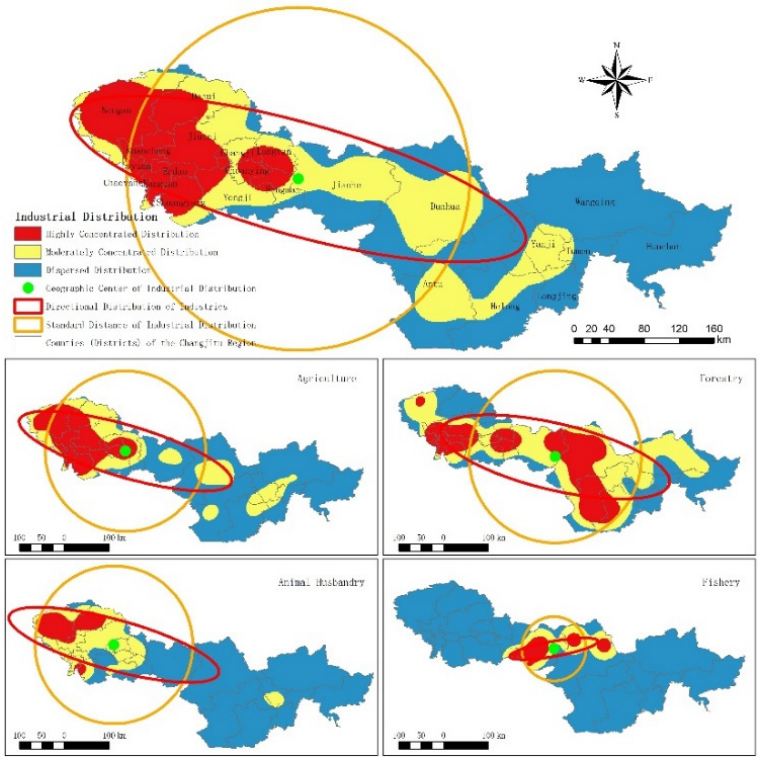


Fig 1. Spatial Distribution of Primary Industry Clusters

The spatial distribution center of primary industry enterprises in the Changjitu Region is located in central Jilin City (at the junction of Jilin Urban Area and Jiaohe City), leaning toward the central part of the Changjitu Region. Compared with the primary industry as a whole:

- The centers of agriculture and animal husbandry shift westward—agriculture's center falls in Jilin's urban area, and animal husbandry's center is at the junction of Changchun and

Jilin (closer to the western Changchun area than agriculture's center).

- The centers of forestry and fishery shift eastward, falling in the central part of the Changjitu Region.

Based on the standard distance of industrial distribution, the order of industrial concentration capacity from high to low among the primary industry sub-sectors is: fishery > animal husbandry > agriculture > forestry. The overall concentration capacity of the primary industry is lower than that of forestry.

In addition, the primary industry in the Changjitu Region takes the Changchun-Jilin Urban Agglomeration as the agglomeration core, forming two agglomeration centers (Changchun and Jilin). Changchun has a larger agglomeration scope than Jilin. Within the scope delineated by the development direction of the primary industry and the standard deviational ellipse (red line: Directional Distribution of Industries), most areas (including the Changchun-Jilin Urban Agglomeration and Dunhua City) have formed industrial agglomeration at or above the moderate level. In the eastern part of the region, the primary industry has formed a moderately concentrated industrial cluster economic belt along Antu-Heilong-Longjing-Yanji-Tumen.

Among the four sub-sectors of the primary industry:

- Agriculture shows similar agglomeration characteristics to the primary industry as a whole. Agricultural enterprises are mostly concentrated in the Changchun-Jilin Urban Agglomeration, and form a certain scale of agglomeration along the development direction in Jiaohe City, Dunhua City, Antu County, and the Heilong-Yanji-Wangqing area.

- Forestry has multiple highly concentrated areas along the direction indicated by its standard deviational ellipse, mainly in the western Yanbian Area (Dunhua-Antu-Heilong Area). Highly concentrated areas also appear in the southern and northwestern parts of Changchun's jurisdiction, Jilin's urban area, and both eastern and western sides of Jiaohe City.

- Animal husbandry forms large-scale agglomeration in the Changchun-Jilin Urban Agglomeration, with a small-scale agglomeration in the southern part of Yanji City. Its highly concentrated areas are distributed in Nong'an County, Dehui City, and the downtown area of Changchun.

- Fishery, as indicated by the standard distance circle, has a compact distribution scope of enterprises in the region and stronger concentration capacity than the other three sub-sectors. Its industrial agglomeration is mainly concentrated in the central part of the Changjitu Region, centered on Jiaohe City in Jilin Area and radiating to the northern part of Dunhua City.

4.1.2. Spatial Distribution of the Secondary Industry

The spatial distribution of the secondary industry in the Changjitu Region is shown in Fig. 2. The secondary industry has a significant development direction (southeast-northwest). According to the standard distance circle, most secondary industry enterprises in the Changjitu Region are concentrated in the western part of the region—the Changchun-Jilin Urban Agglomeration and its surrounding radiation areas. The geographic center of the secondary industry in the Changjitu Region falls in Fengman District of Jilin City.

Within the Changjitu Region, the secondary industry has formed four areas with moderately concentrated or higher industrial agglomeration, namely: the urban centers of Changchun and Jilin, central Dunhua City, and the junction of Yanji-Tumen-Heilong. Among these four agglomeration areas, the Changchun-Jilin Urban Agglomeration has two highly concentrated industrial areas with similar agglomeration scales.

As shown by the standard deviational ellipse, the four sub-sectors of the secondary industry share the same development direction as the secondary industry itself. Among them, the energy industry and construction industry have stronger cohesion and more prominent directional distribution than the other two sub-sectors.

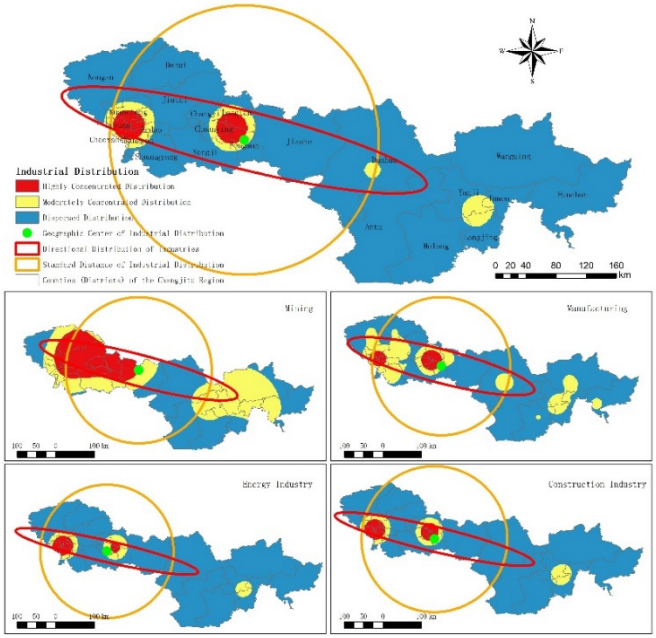


Fig 2. Spatial Distribution of Secondary Industry Clusters

From the perspective of spatial distribution (indicated by the standard distance circle), the four sub-sectors are relatively evenly distributed, with the energy industry showing relatively higher concentration. In terms of the geographic center of enterprise distribution:

- Manufacturing and construction industry have almost the same geographic center as the tertiary industry (note: corrected per context logic; original text may have a typo, referring to the secondary industry).

- The centroids of the energy industry and mining industry show obvious changes compared with the secondary industry as a whole—the energy industry's centroid shifts slightly toward Changchun, while the mining industry's centroid moves significantly eastward to the Changchun-Jilin Urban Agglomeration.

Regarding the agglomeration characteristics of the four secondary industry sub-sectors:

- The energy industry and construction industry show almost the same distribution characteristics as the secondary industry cluster, except for the lack of agglomeration in Dunhua City. However, the scale of highly concentrated energy industry in Jilin City is smaller than that in Changchun.

- The mining industry has two agglomeration zones in the Changjitu Region, located in the Changchun-Jilin Urban Agglomeration and the central-northeastern part of Yanbian Prefecture respectively. A highly concentrated industrial space is formed in the northern part of the Changchun-Jilin Urban Agglomeration.

- The manufacturing industry has six agglomeration areas. The two largest ones are located in the core areas of Changchun and Jilin—Changchun has a larger agglomeration scale, while Jilin has a significantly wider scope of highly concentrated areas. The Longjing - Yanji - Tumen - Wangqing area is the largest manufacturing agglomeration area in

Yanbian Prefecture; smaller agglomerations also appear in central Dunhua City, southwestern Hunchun City, and central Heilong City (the smallest among them).

4.1.3. Spatial Distribution of the Tertiary Industry

The tertiary industry in the Changjitu Region has the largest base of analyzable enterprises among the three industries, with relatively uniform spatial distribution of POIs. However, it still has an obvious development direction, consistent with the primary and secondary industries (southeast-northwest), as shown in Fig. 3. Tertiary industry enterprises in the Changjitu Region are still relatively concentrated in the Changchun-Jilin Urban Agglomeration, with their geographic center located in Jilin City and showing a development trend toward the central region.

Although the tertiary industry has an obvious development direction and strong industrial concentration capacity (similar to the primary and secondary industries), its density analysis shows that most areas present a dispersed distribution due to the uniform spatial distribution of industries. There are two highly concentrated industrial areas, located in Changchun and Jilin respectively, with small agglomeration scopes—consistent with the diverse and complex nature of tertiary industry economic activities. Agglomeration is mainly formed in the central areas of major cities, and the agglomeration degree is proportional to urban development.

The development trend direction and industrial concentration capacity of each tertiary industry sub-sector are consistent with the overall characteristics of the tertiary industry. Relatively, information technology services and real estate industry have slightly higher concentration degrees, with their distribution centers shifting toward Changchun. The agglomeration characteristics of each sub-sector are also similar to the overall agglomeration characteristics of the tertiary industry, and their agglomeration scales are proportional to urban development level.

All tertiary industry sub-sectors have formed highly concentrated industrial areas in the core area of Changchun. Jilin City has a slightly smaller scope of highly concentrated areas than Changchun. As the third largest city in the Changjitu Region in terms of economic development, Yanji City has formed industrial agglomerations of varying scales in wholesale and retail industry, accommodation and catering industry, financial industry, leasing and business services, residential services, health and social work, and culture, sports, and entertainment industry.

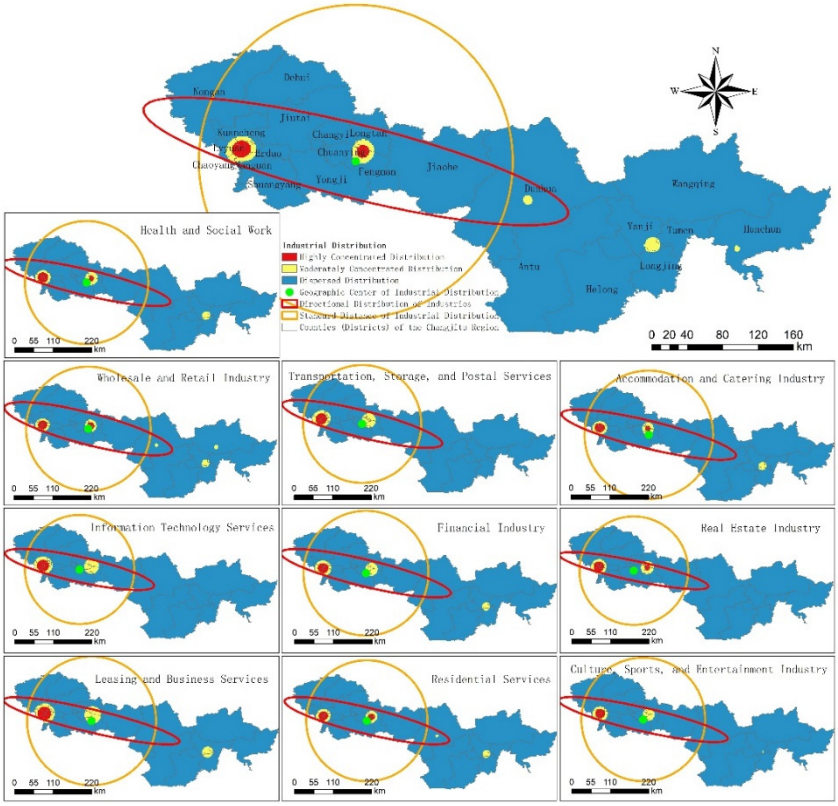


Fig 3. Spatial Distribution of Tertiary Industry Clusters

Dunhua City, close to the Changchun-Jilin Urban Agglomeration and affected by its radiation, has formed weak industrial agglomerations in wholesale and retail industry and residential services. As the most widespread economic activity, the wholesale and retail industry has also formed an industrial agglomeration area with a scale similar to that of Dunhua City in Wangqing County, in addition to the aforementioned four areas (Changchun, Jilin, Yanji, and Dunhua).

4.2. Layout Characteristics of the Three Industries in the Changjitu Region

In summary, the three industries in the Changjitu Region have an obvious directional layout, radiating eastward along the Changchun-Jilin Urban Agglomeration (southeast-northwest direction). Although Changchun, as the region with the highest output value of the tertiary industry, has an impact on the industrial distribution center, the geographic centers of the three industries and their sub-sectors still tend to shift toward downstream cities. This reflects Changchun's radiation capacity and also indicates that the Changjitu

Region is gradually moving toward balanced regional development.

Among the sub-sectors of the three industries, except for the fishery (whose distribution is significantly affected by geographical conditions), the other sub-sectors have consistent industrial concentration capacity and distribution direction with the overall characteristics of the three industries.

In terms of industrial agglomeration:

- The secondary and tertiary industries have similar overall agglomeration characteristics, with agglomeration degree proportional to urban development level. The difference lies in that the secondary industry has a similar agglomeration degree in Changchun and Jilin, while the tertiary industry's agglomeration degree in Changchun is significantly higher than that in Jilin.

- Most sub-sectors of the tertiary industry have agglomeration characteristics consistent with the overall tertiary industry, forming industrial agglomeration areas in or around Changchun, Jilin, and Yanji. Specifically: 1) The real estate industry only shows industrial agglomeration characteristics in Changchun and Jilin. 2) Residential services, consistent with the overall agglomeration characteristics of the tertiary industry, form a small-scale industrial agglomeration area in Dunhua City besides Changchun, Jilin, and Yanji. 3) The wholesale and retail industry even forms an industrial agglomeration area with a scale similar to that of Dunhua City in Wangqing County.

For the industrial agglomeration of sub-sectors under the secondary industry:

- Except that the mining industry forms a large highly concentrated zone in the northern part of the Changchun-Jilin Urban Agglomeration, manufacturing, energy industry, and construction industry all form two highly concentrated industrial patches centered on the central areas of Changchun and Jilin in the Changchun-Jilin Urban Agglomeration.

- Changchun has a slightly larger scale of highly concentrated areas than Jilin, while Jilin has a slightly larger scale of highly concentrated manufacturing areas than Changchun. In the moderately concentrated industrial space, the extension range of Changchun to the surrounding areas is wide and significantly larger than that of Jilin.

- The four sub-sectors in the center of Yanbian Prefecture all form moderately concentrated industrial spaces of different scales. Among them, the moderately concentrated manufacturing zones are relatively scattered, distributed in Dunhua City, Heilong City, Hunchun City, and along the Heilong-Yanji-Wangqing-Tumen area.

The development of the primary industry is obviously restricted by the geographical environment, which is well verified by the agglomeration of the primary industry and its four sub-sectors in the Changjitu Region:

- The agglomeration of agriculture and animal husbandry is obviously positively correlated with the flatness of the terrain. In particular, agriculture has formed industrial agglomeration at or above the moderate level in almost all plain areas of the region. Animal husbandry and agriculture have also formed large-scale highly concentrated industrial spaces in the Changchun-Jilin Urban Agglomeration (located in the Songnen Plain).

- Fishery agglomeration is distributed in the Songhua River and large water areas north of the Songhua River (Fengman District of Jilin City - Jiaohe City - northern Dunhua City).

- The distribution of forestry agglomeration at or above the moderate level is almost consistent with the distribution of forest land resources in the Changjitu Region—a large highly concentrated belt is formed in Dunhua-Antu-Heilong in the western part of Yanbian Prefecture, with additional highly concentrated forestry areas in the Changchun-Jilin Urban Agglomeration.

Affected by the agglomeration characteristics of various sub-sectors, the primary industry as a whole has two narrow moderately concentrated zones: one radiating from the Changchun-Jilin Urban Agglomeration to Dunhua City, and the other in the Antu-Heilong-Yanji-Tumen area. Within the former zone, highly concentrated industrial areas are formed in Changchun and central Jilin City, with the agglomeration scale in Changchun nearly five times that in Jilin City.

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