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Spatiotemporal Patterns of Urban Expansion in Major Cities of Jilin Province

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Abstract: This study investigates the spatiotemporal dynamics of urban expansion in major cities of Jilin Province using Landsat satellite imagery acquired in 2002, 2012, and 2022. To accurately extract urban land cover, the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) were employed, achieving an overall accuracy of 83% for urban boundary delineation. A 5 km grid-based analysis was further applied to quantify and map the spatial patterns of urban growth. Results indicate that the total urban land area in Jilin Province expanded from 1,100 km² in 2002 to 2,430 km² in 2022, with major cities (e.g., Changchun) experiencing the most substantial growth. Spatially, high urban coverage was concentrated in central urban agglomerations and gradually expanded outward, with the period 2012–2022 witnessing the most intense growth in core city regions. Topographic conditions, industrial development, regional policies, and transportation infrastructure were identified as the key drivers of these urban expansion patterns. This research provides critical insights into the dynamics of urbanization and land use change in Jilin Province, supporting evidence-based urban planning and land resource management.

Keywords: Jilin Province; Remote Sensing; Spatiotemporal Distribution; Urban Expansion; Major Cities.

1. Introduction

Urbanization represents a global socioeconomic trend, with profound impacts on land use systems and ecological environments. By the early 21st century, the global urbanization rate had reached 47%, while developed nations already had urbanization rates ranging from 70% to 90%. In contrast, developing countries are currently undergoing a phase of accelerated urbanization [1]. In China, the urbanization rate has surpassed 35%, exhibiting an irreversible trajectory of rapid growth [2].

Urban spatial expansion is one of the most conspicuous manifestations of the urbanization process, characterized by the outward sprawl of built-up areas [3]. It not only constitutes the primary form of urbanization and urban land use transformation but also reflects disparities in spatial layout and structural evolution across urban systems [4]. However, unregulated rapid urban expansion has given rise to a series of challenges, including inefficient urban land use planning, threats to food security due to the occupation of arable land, and degradation of native ecological systems [5–7].

As a major agricultural province in China, Jilin Province has attracted increasing attention regarding the ecological and agricultural impacts of urbanization. The booming development of emerging industries and ongoing government-led shantytown renewal projects have further accelerated the province's urbanization pace. Against the backdrop of industrial restructuring and upgrading, changes in arable land— a critical protected land resource—have become a focal concern. Therefore, a systematic analysis of the spatiotemporal characteristics of urban expansion in Jilin Province's major cities is essential for balancing urban development, agricultural protection, and ecological conservation.

2. Data and Methods

2.1. Extraction of Urban Land Cover in Major Cities of Jilin Province

Landsat satellite data were used as the primary remote sensing (data source) for this study: Landsat 7 ETM+ C2 L2 imagery for 2002, and Landsat 8–9 OLI/TIRS C2 L2 imagery for 2012 and 2022. All datasets were downloaded from the U.S. Geological Survey (USGS) Earth Explorer platform (https://earthexplorer.usgs.gov/).

To distinguish urban land from other land cover types (e.g., vegetation, water bodies), the NDVI and NDWI were calculated. Seasonal variations (spring, summer, autumn, winter) in the extreme values of NDVI and NDWI within urban sample zones were statistically analyzed (Fig. 1). Considering Jilin Province's unique surface cover characteristics—particularly the seasonal senescence of vegetation in autumn—autumn index extremes were selected as the criteria for urban extraction: NDVI ranging from 0 to 0.19 and NDWI < 0.

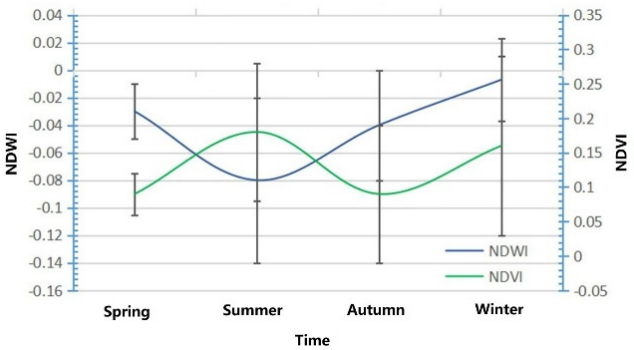


Fig 1. Seasonal Extreme Value Variations of Urban NDVI and NDWI

For accuracy validation, 200 ground truth sample points were randomly selected each year, imported into Google Earth, and cross-validated against historical high-resolution imagery. This verification process confirmed an overall accuracy of 83% for the urban extraction results. Finally, the extracted urban polygons were clipped to the administrative boundaries of Jilin Province's major cities to obtain the urban land area for each of the three study years.

2.2. Analysis of Urban Growth Rates in Major Cities of Jilin Province

To quantify spatial disparities in urban development, a 5 km grid system was overlaid on the extracted urban land cover maps for 2002, 2012, and 2022. The urban coverage ratio (i.e., the proportion of urban land within each grid cell) was calculated for each year. Difference analyses were then performed on the urban coverage ratio datasets to derive the spatial distribution of urban growth differences between 2002–2012 and 2012–2022.

3. Study Area

Jilin Province, abbreviated as "Ji," has Changchun as its provincial capital. Located in the central part of Northeast China, it borders Liaoning Province to the south, the Inner Mongolia Autonomous Region to the west, and Heilongjiang Province to the north. It also shares international borders with Russia and the Democratic People's Republic of Korea. Geographically, Jilin Province lies at the heart of Northeast Asia, covering a total area of 187,400 km² [8].

Administratively, Jilin Province comprises 8 prefecture-level cities and 1 autonomous prefecture, with a permanent population of 23.1731 million [8]. As one of China's 9 border provinces, it serves as a key gateway for northward opening under the "Belt and Road" Initiative and a critical hub for foreign trade and regional exchanges in Northeast China [9].

4. Results and Discussion

4.1. Temporal Trends in Urban Expansion

Urban land extraction results show that Jilin Province's total urban land area increased from 1,100 km² in 2002 to 1,290 km² in 2012, and further to 2,430 km² in 2022—representing a more than twofold increase over the 20-year period. Table 1 presents the urban coverage ratio (urban area as a percentage of administrative area) for each major city in Jilin Province. Due to the province's status as an agricultural powerhouse, arable land dominates most administrative units, resulting in relatively low overall urban coverage ratios. However, all cities exhibited an upward trend in urban area over the study period.

From 2002 to 2012, most cities experienced modest urban growth, with only Baicheng showing no significant increase. In contrast, the 2012–2022 period saw dramatic urban expansion across all cities. Over the entire 20-year study period, major cities such as Changchun (the provincial capital) and Siping recorded the most remarkable growth. While most cities grew in both stages, Baicheng's expansion was particularly pronounced in the later period (2012–2022).

Table 1. Urban Coverage Ratio of Major Cities in Jilin Province (%)

	Changchun	Jilin	Siping	Liaoyuan	Tonghua	Baishan	Baicheng	Yanbian	Songyuan
2002	1.5	0.5	1.2	0.9	0.5	0.3	0.3	0.3	0.4
2012	1.8	0.8	1.3	1.0	0.6	0.5	0.3	0.4	0.5
2022	3.3	1.4	2.6	1.6	0.8	1.1	0.7	0.6	0.8

4.2. Spatial Patterns of Urban Expansion

Fig. 2 illustrates the spatial distribution of urban coverage in Jilin Province based on the 5 km grid analysis. Regions with high urban coverage ratios were primarily concentrated in major cities (e.g., Changchun and Jilin) and their surrounding areas. Moderate urban coverage was also observed in eastern regions such as Yanbian, while western areas (e.g., Baicheng and Songyuan) had relatively low urban coverage.

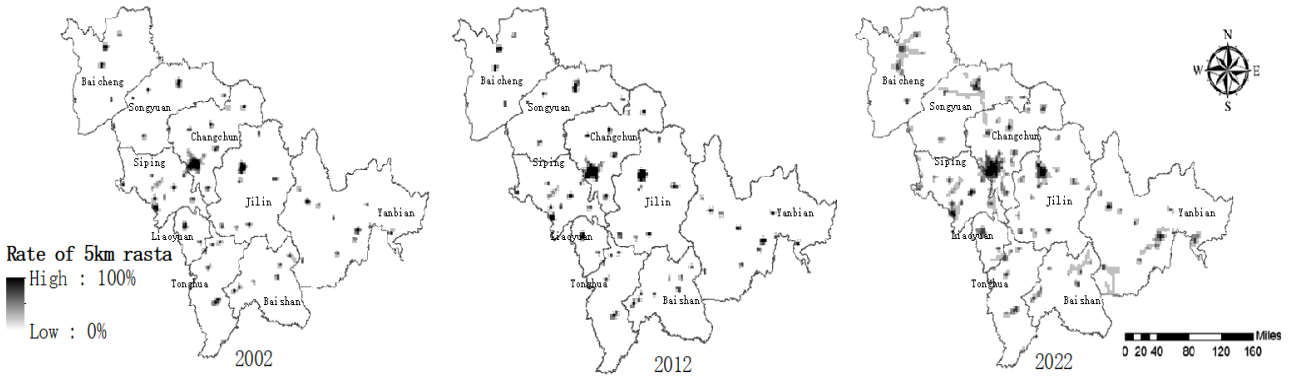


Fig 2. Spatial Distribution Characteristics of Urban Coverage in Major Cities of Jilin Province Based on 5km Grid Statistics

2002: High-coverage urban regions (dark-colored grid cells) were scattered and small in scale, with only limited concentrations in a few core areas (e.g., central Changchun).

2012: High-coverage areas in core cities (e.g., Changchun) expanded outward, and the urban coverage ratio of surrounding grid cells increased—leading to a more concentrated urban spatial pattern.

2022: High-coverage urban areas further expanded, with contiguous built-up zones (e.g., in Changchun) becoming increasingly prominent and extending to more distant surrounding regions. Meanwhile, urban coverage in Yanbian and other eastern regions became more widespread.

Overall, the spatial pattern of urban expansion in Jilin Province exhibited a clear trend of centralization and outward sprawl, with significant improvements in both the spatial extent and agglomeration degree of urban development.

4.3. Drivers of Urban Expansion

4.3.1. Topographic Constraints

Jilin Province's diverse topography—including mountains, plains, and hills—exerted a significant influence on urban construction and expansion. Cities located in plain areas (e.g., Changchun and Songyuan) faced fewer topographic barriers, facilitating large-scale urban sprawl. In contrast, cities in mountainous regions (e.g., Tonghua and Baishan) encountered greater constraints, limiting the scope and speed of urban expansion.

4.3.2. Industrial Agglomeration

As Jilin Province's capital and economic center, Changchun has a highly concentrated secondary and tertiary industry sector, attracting a large number of enterprises. In particular, the development of pillar industries such as automobile manufacturing, biomedicine, and high-tech industries has driven the demand for industrial and residential land, directly promoting urban spatial expansion [10].

4.3.3. Policy Guidance

Regional development policies—such as the Changchun-Jilin Integration Initiative—have played a key role in coordinating transportation infrastructure and industrial layout between Changchun and Jilin. This policy-driven integration has accelerated the convergence of urban spaces in the two core cities, forming a more cohesive urban agglomeration [11].

4.3.4. Transportation Infrastructure

The construction of transportation arteries—including highways, urban expressways, and rail lines—has strengthened connectivity within and between cities. This improved accessibility has promoted the development of land along transportation corridors, encouraging the expansion of built-up areas and enhancing the contiguity of urban zones [12].

4.4. Interdecadal Differences in Urban Growth (2002–2012 vs. 2012–2022)

Fig. 3 presents the changes in the 5 km grid-based urban coverage ratio for the two study decades.

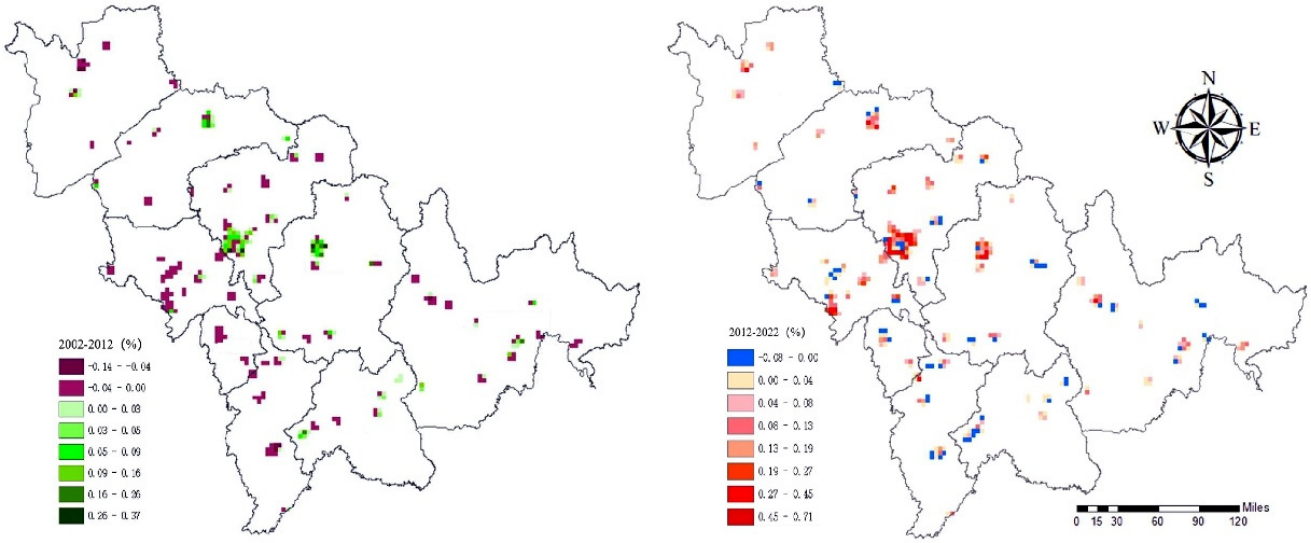


Fig 3. Changes in urban coverage ratio of 5km grid

2002–2012: Changchun and its surrounding areas were the core of urban growth, showing a clear agglomeration trend. Grid cells with positive growth (green) were densely distributed in this region—reflecting Changchun's role as the provincial capital in driving urban expansion through industrial development and population agglomeration. While cities such as Jilin, Siping, and Tonghua also experienced minor urban growth (evidenced by scattered green grid cells), their growth scope and intensity were far weaker than Changchun's, exhibiting a "scattered, small-scale" pattern. Grid cells with negative growth (purple) were widely distributed across multiple cities but remained small in scale—indicating only localized, minor declines in urban coverage without the formation of large-scale abandoned urban areas.

2012–2022: The growth momentum of Changchun and its surroundings intensified, with a large number of high-growth grid cells (red) concentrated in this region and forming contiguous zones. This indicates a further strengthening of the major city agglomeration effect, with a significant acceleration in the speed and scale of urban expansion. Additionally, cities such as Jilin and Yanbian saw the emergence of red and orange grid cells (representing moderate-to-high growth), with growth rates far exceeding those of the 2002–2012 period. This suggests that the radiating and driving role of core cities has been enhanced, promoting more extensive expansion from core areas to surrounding regions. Grid cells with negative growth (blue) were rare and extremely scattered, primarily located in the edge or non-core areas of some cities. Overall, the 2012–2022 period was dominated by robust urban growth, with both the concentration and intensity of growth far surpassing the previous decade.

Acknowledgments

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