

## Postprint: Evolution and Driving Mechanisms of Production-Living-Ecological Spatial Patterns in Shaanxi Province

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### Abstract

As an important province in China serving as a crucial link between east and west, the rational planning of land use in Shaanxi Province is of great significance for promoting regional high-quality development. From the perspective of land function, this study employs models such as the land use transfer matrix to investigate the quantitative and distribution characteristics and change trends of the ‘production-living-ecological’ space in Shaanxi Province from 2000 to 2020, and ultimately analyzes the underlying causes of distribution changes at different scales. The results indicate that: (1) The comprehensive land use dynamic degree of the ‘production-living-ecological’ space fluctuated at 0.2%, with two rate increases during the period. The first increase was caused by the expansion of living space, and the second was related to the growth of ecological space. Among the single dynamic degrees, living space exhibited the largest value, mostly positive; production space ranked second, mostly negative; ecological space was mostly positive, stabilizing at 0.1%. (2) From 2000 to 2020, production space experienced the most significant change, with a total area reduction of 2,913 km<sup>2</sup>, while other types increased, with ecological space showing greater growth. In the secondary classification, production-ecological space decreased by 4,036 km<sup>2</sup>, representing the largest change; all other types increased except for potential ecological space, with green ecological space expanding by 2,025 km<sup>2</sup>, the largest increase. (3) The distribution of ‘production-living-ecological’ space is correlated with topography and landforms. Overall, ecological space dominates, being primarily distributed in the southern part of the province; production space is mainly located in the central part of the province; living space is mostly distributed in the Xi’an metropolitan area, with the smallest area but expanding outward year by year. (4) In factor detection, population factors play a dominant role in the evolution of ‘production-living-ecological’ space in Shaanxi Province; after interaction detection, the results of multi-factor interactions are stronger than the simple explanations of single factors.

## Full Text

### Preamble

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#### Research on the Evolution and Driving Mechanisms of “Production-Living-Ecology” Spatial Patterns in Shaanxi Province

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### Abstract

Shaanxi Province serves as a critical link between eastern and western China, making rational land-use planning essential for promoting high-quality regional development. From a land function perspective, this study employs models such as the land-use transfer matrix to investigate the quantitative and distributional characteristics and changing trends of “production-living-ecology” spaces in Shaanxi Province from 2000 to 2020, and analyzes the underlying causes of these changes at different scales. The results indicate: (1) The integrated land-use dynamic degree of “production-living-ecology” spaces fluctuated around 0.2%, with two periods of accelerated growth—first driven by living space expansion, and later associated with ecological space growth. Among single dynamic degrees, living spaces showed the highest values, mostly positive; production spaces ranked second, mostly negative; and ecological spaces remained mostly positive and stable at 0.1%. (2) From 2000 to 2020, production spaces experienced the most significant change, with a total area reduction of 2,913 km<sup>2</sup>, while other types increased, with ecological spaces showing greater growth. At the secondary classification level, production-ecology spaces decreased by 4,036 km<sup>2</sup>, representing the largest change, while all other types except potential ecological spaces increased, with green ecological spaces expanding by 2,025 km<sup>2</sup>. (3) The spatial distribution of “production-living-ecology” spaces correlates with topography, dominated overall by ecological spaces primarily located in southern Shaanxi, production spaces concentrated in the central region, and living spaces—though smallest in area—clustered around the Xi'an metropolitan area and expanding outward annually. (4) Factor detection reveals that population factors play a dominant role in the evolution of Shaanxi's “production-living-ecology” spaces, while interaction detection demonstrates that multi-factor interactions produce stronger explanatory power than single factors alone.

**Keywords:** production-living-ecology spaces; land use/cover change; spatio-temporal evolution; driving mechanism; Shaanxi Province

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## 1. Introduction

Since China's active participation in global supply chains, urbanization and industrialization have advanced rapidly, with the national urbanization rate reaching 63.89% by 2020. More than half of the population now resides in cities, accompanied by problems such as encroachment on farmland and excessively rapid land urbanization. Development requires continuous resource acquisition, and land serves as both the carrier and essence of resources. The scarcity and non-renewability of resources have intensified conflicts among land functions, making spatial dysfunction a primary obstacle to high-quality regional development. Revealing land-use patterns that coordinate land functions and promote long-term development has become a key research frontier.

Currently, "production-living-ecology" spaces have received extensive attention as a national priority and frontier in land research. First, regarding spatial classification, Chen et al. established a functional classification system emphasizing ecological functions to promote sustainable use, while Li et al. identified "production-living-ecology" spaces in Tangqi Town through biophysical measurement and value transformation. Although a unified standard has not yet been formed, a basic framework has been established. Second, research has examined influencing factors, coupling relationships, and pattern optimization of various spaces. The 18th National Congress of the Communist Party proposed the goal of "promoting intensive and efficient production spaces, livable and moderate living spaces, and beautiful ecological spaces," providing direction for optimizing land resources. The 14th Five-Year Plan (2021-2025) further emphasizes "optimizing the ecological security barrier system and gradually forming three spatial patterns: urbanization areas, major agricultural product production areas, and ecological function zones," with multiple policy documents repeatedly mentioning "production-living-ecology" spaces.

Existing research has primarily focused on eastern coastal regions, with fewer studies on western areas and limited analysis of influencing factors. As new strategies such as the Western Development and the ecological protection and high-quality development of the Yellow River Basin are implemented, Shaanxi has become an important economic growth engine in western China. However, severe soil erosion in northern Shaanxi, frequent high-temperature weather in central Shaanxi, and rising ecological sensitivity in southern Shaanxi have created contradictions between development aspirations and resource limitations, necessitating urgent research on spatial layout. While some scholars have studied land use in Shaanxi, systematic discussions on the evolution characteristics and influencing factors of "production-living-ecology" spaces at different scales remain lacking. Therefore, this study investigates the spatio-temporal evolution

and driving mechanisms of “production-living-ecology” spaces in Shaanxi from a top-down perspective, aiming to enrich land-use research in western China and provide strategies for scientific land resource management.

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## 2. Study Area and Methods

### 2.1 Study Area Overview

Shaanxi Province, located deep in China’s interior, radiates and drives development across northwestern provinces. Its terrain is high in the north and south and low in the central region, comprising three main areas: the Northern Shaanxi Plateau (Yulin and Yan’ an), the Guanzhong Plain (Xi’ an, Xianyang, Weinan, Tongchuan, and Baoji), and the Southern Shaanxi Mountains (Hanzhong, Shangluo, and Ankang), covering a total area of  $2.06 \times 10^5$  km<sup>2</sup>. The province features diverse climate conditions across humid, semi-humid, semi-arid, and arid zones, with varied landforms including plateaus, plains, and mountains. By 2020, the permanent population reached  $3.96 \times 10^7$ , with a GDP of  $2.6 \times 10^{12}$  yuan and a three-industry structure ratio of 0.09:0.43:0.48, making it the largest economy in northwestern China.

[Figure 1: see original paper] Scope of study area

### 2.2 Data Sources

Land-use data at 30m resolution for Shaanxi Province from 2000-2020 were obtained from the Resource and Environmental Science and Data Center. Natural environment data, including meteorological data, were sourced from the China Meteorological Data Network. Normalized Difference Vegetation Index (NDVI) was calculated from Landsat imagery using ENVI software. Socioeconomic data, including population, GDP, industrial output, fiscal revenue, total retail sales of consumer goods, fixed asset investment, and urban residents’ disposable income, were collected from the *Shaanxi Regional Statistical Yearbook*, *Shaanxi Statistical Yearbook*, and statistical bulletins of national economic and social development for each district and county.

### 2.3 “Production-Living-Ecology” Spatial Classification System

Based on China’s land-use remote sensing monitoring data classification system, we reclassified subcategories according to spatial meanings and proposed a “production-living-ecology” spatial classification system (Table 1). Considering the mixed functions of certain land types (e.g., farmland and urban land), we identified production-living and production-ecology spaces based on dominant and auxiliary functions, classifying them according to their primary functions. This system includes all land categories and can be applied to different regions, though Shaanxi does not contain all spatial types (permanent glaciers, beaches, oceans, etc.).

Production-living-ecology spatial classification system

## 2.4 Analytical Methods

### 2.4.1 Integrated Land-Use Dynamic Degree

This model measures the overall degree of land-use change during a specific period:

$$LC = \sum_{i=1}^n \frac{LA_i}{T} \times 100\%$$

where  $LC$  is the integrated land-use dynamic degree,  $n$  is the number of land-use types,  $LA_i$  is the area of land type  $i$  at the initial period, and  $T$  is the study period length.

### 2.4.2 Single Land-Use Dynamic Degree

This model examines changes in specific land-use types:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\%$$

where  $K$  is the dynamic degree of a specific land-use type, and  $U_a$  and  $U_b$  are the areas at the beginning and end of the period, respectively.

### 2.4.3 Land-Use Transfer Matrix

This matrix reflects both static areas and dynamic flows between land-use types:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix}$$

where  $S$  represents area,  $i$  and  $j$  are land-use types before and after conversion, and  $n$  is the number of types.

### 2.4.4 Geographical Detector

This statistical method, developed by Wang and Xu, explores spatial differentiation and driving forces through factor detection, ecological detection, interaction detection, and risk detection. After discretizing natural environment, urban scale, and economic development factors, we applied factor detection and interaction detection. Factor detection measures the explanatory power of independent variables on spatial differentiation, while interaction detection analyzes the combined effects of different factors.

### 3. Results

#### 3.1 Dynamic Degree Analysis

##### 3.1.1 Integrated Land-Use Dynamic Degree

The integrated dynamic degree of “production-living-ecology” spaces fluctuated around 0.2%, with two acceleration periods: first increasing to 0.3% then decreasing to 0.1% before returning to 0.2%. Combined with single dynamic degree analysis, the first acceleration was driven by living space expansion during rapid urbanization and population growth, while the second was associated with ecological space growth following implementation of the “Two Mountains Theory” and rising societal demands for ecological quality.

##### 3.1.2 Single Land-Use Dynamic Degree

During the study period, living spaces showed the highest dynamic degrees (mostly positive), followed by production spaces (mostly negative), while ecological spaces showed the lowest but consistently positive values around 0.1%. From 2000-2010, living spaces expanded fastest while ecological spaces grew slightly and production spaces shrank. During 2010-2015, living space growth accelerated to 0.8%, ecological spaces grew at the same rate, and production spaces continued to decline. From 2015-2020, living space growth slowed to 0.2%, production spaces expanded slowly, and ecological spaces decreased at the same rate.

Rate of production-living-ecology spaces change in Shaanxi Province

##### 3.1.3 Primary Classification Transfer Matrix Analysis

From 2000-2020, production spaces changed most significantly, decreasing by 2,913 km<sup>2</sup>, while other spaces increased, with ecological spaces showing greater growth. At the secondary classification level, production-ecology spaces decreased by 4,036 km<sup>2</sup> (the largest change), while all other types except potential ecological spaces increased, with green ecological spaces expanding by 2,025 km<sup>2</sup>.

Transfer matrix of production-living-ecology spaces in Shaanxi Province from 2000 to 2020

##### 3.1.4 Secondary Classification Transfer Matrix Analysis

From 2000-2010, production-ecology spaces changed most dramatically (-961.0 km<sup>2</sup>), primarily converting to green ecological and rural living spaces. From 2010-2015, the pattern was similar, but blue ecological spaces shifted from increase to decrease. From 2015-2020, production-ecology spaces again showed the greatest change (-982.2 km<sup>2</sup>), converting mainly to green ecological spaces, while green ecological spaces increased most significantly (824.6 km<sup>2</sup>). The reduction of green ecological spaces was primarily related to industrial and living space expansion, while their increase reflected strengthened environmental protection consciousness through programs like the Grain for Green Project.

### 3.2 Spatial Distribution Characteristics

Shaanxi's "production-living-ecology" spatial pattern is dominated by ecological spaces, primarily located in the southern province (south of Baoji and Xi'an, and throughout southern Shaanxi), with smaller clusters in central and northwestern areas. Production spaces are widely distributed, mainly in central Shaanxi (northern Weinan, Xianyang, northern Xi'an, eastern Baoji) and partially in southern Yulin, northern Yan'an, and central Hanzhong. Living spaces, though smallest in area, are concentrated in the Xi'an metropolitan area, expanding outward annually as rapid land urbanization drives continuous growth.

At the secondary classification level, living-production spaces expanded prominently along water systems and at blue ecological space boundaries, while rural living spaces were evenly embedded as small patches within production-ecology spaces. Industrial production spaces were located near large living space patches, reflecting close production-life connections. Green ecological spaces were primarily distributed in southern Shaanxi, with some in potential ecological spaces of western Yulin.

### 3.3 Driving Force Analysis

Based on existing research and considering regional natural conditions, we examined driving mechanisms for Shaanxi Province as a whole and for its three subregions (Northern Shaanxi, Guanzhong, and Southern Shaanxi). We selected 11 factors as independent variables ( $X_1$ : average annual temperature,  $X_2$ : average annual precipitation,  $X_3$ : total population,  $X_4$ : population density,  $X_5$ : fiscal revenue,  $X_6$ : total retail sales of consumer goods,  $X_7$ : primary industry added value,  $X_8$ : secondary industry added value,  $X_9$ : tertiary industry added value,  $X_{10}$ : total fixed asset investment,  $X_{11}$ : NDVI), with spatial types as dependent variables ( $Y$ ) to explore driving forces at three time points (2000, 2010, 2020).

Transfer matrix of the secondary production-living-ecology spaces in Shaanxi Province from 2000 to 2020

Production-living-ecology spaces driving force indicators

#### 3.3.1 Factor Detection

All factors passed significance tests ( $p < 0.01$ ), confirming model reliability. At the provincial scale, population density showed the strongest explanatory power (around 0.4), followed by natural condition factors ( $X_1$ ,  $X_2$ ) and population-related factors ( $X_3$ ,  $X_4$ ), reflecting the fundamental role of natural conditions and population. Economic factors, particularly industrial added values ( $X_8$ ,  $X_9$ ), also showed high explanatory power, demonstrating the important influence of industrial structure.

At the subregional scale, Northern Shaanxi was strongly influenced by natural environment and population factors; Guanzhong showed strong correlations with natural environment and urban scale factors; and Southern Shaanxi was

primarily affected by urban scale factors and fixed asset investment ( $X_{10}$ ). Overall, while dominant factors varied by region, all were significantly influenced by urban scale factors, representing local consumption capacity, labor reserves, and development potential.

[Figure 2: see original paper] Results of factor detector

### 3.3.2 Interaction Detection

Interaction detection reveals that combined factors show significantly enhanced explanatory power compared to single factors, with most relationships showing non-linear enhancement. At the provincial scale, interactions between natural environment and population factors were particularly prominent in 2010, while by 2020, most factor combinations showed enhancement effects, especially those involving population density.

At the subregional scale, factor combinations showed highest explanatory power in Northern Shaanxi (mostly  $>0.5$ ), with strong enhancement effects from natural environment-population and natural environment-economic factor combinations. Guanzhong showed weaker enhancement, likely due to its more complex and longer development history. Southern Shaanxi showed clear effects from urban scale and economic development factor combinations, particularly population factors and fixed asset investment, reflecting the region's ecological orientation and tourism-driven development model.

[Figure 3: see original paper] Results of interaction detector

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## 4. Discussion

Although driving factor combinations differ across Shaanxi's regions, all correlate with population factors, consistent with existing research. However, this study introduces a new scale by examining influencing factors by subregion, considering local differences.

The continuous shrinkage of production spaces contrasts with population growth trends, demanding higher development efficiency in living spaces and greater productivity in production spaces. Shaanxi should strengthen regional cooperation to create complementary development patterns. Northern Shaanxi must enhance mine restoration and adhere to rational, moderate development. The Xi'an metropolitan area's living space expansion reflects successful talent attraction policies, radiating to surrounding areas and fostering tertiary and strategic emerging industries. Southern Shaanxi should implement graded governance and fine management, prioritizing environmental protection in industrial activities and promoting the Grain for Green policy in unsuitable cultivation areas.

The expansion of ecological spaces demonstrates enhanced environmental awareness, primarily through increases in green and potential ecological spaces. However, potential ecological spaces require long-term cultivation to convert to

higher ecological value spaces. Notably, blue ecological spaces continue to decline, requiring strengthened protection and management of water bodies including the Yellow River, Wei River, Hongjiannao Lake, and Yinghu Lake, with specialized regulations and enhanced implementation of policies like the river chief system.

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## 5. Conclusion

This study reveals that: (1) Shaanxi's "production-living-ecology" spatial distribution is influenced by socioeconomic activities at approximately 0.2% dynamic degree. Living spaces showed the highest but gradually decreasing single dynamic degree, production spaces were mostly negative with slight increases, and ecological spaces remained positive at 0.1%. (2) From 2000-2020, production spaces decreased most significantly (-2,913 km<sup>2</sup>), while other spaces expanded, with ecological spaces showing greater growth. At the secondary classification level, production-ecology spaces decreased most (-4,036 km<sup>2</sup>), while green ecological spaces increased most (+2,025 km<sup>2</sup>). (3) Spatial distribution shows clear regional characteristics: ecological spaces dominate in southern Shaanxi, production spaces are concentrated in central and northern areas, and living spaces cluster in central regions. (4) Population factors consistently dominate in both factor and interaction detection, with population density showing the strongest single-factor influence. However, single-factor driving forces are limited, and multi-factor interactions predominantly show non-linear enhancement effects, with socioeconomic factors demonstrating stronger explanatory power in northern and southern Shaanxi.

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## References

- [1] Statistics Bureau of Shaanxi Province, National Bureau of Statistics Survey Office in Shaanxi Province. Shaanxi statistical yearbook: 2021[J]. Beijing: China Statistics Press, 2021.
- [2] Li Tao, Liao Heping, Yang Wei, et al. Urbanization quality over time and space as well as coupling coordination of land, population and industrialization in Chongqing[J]. Economic Geography, 2015, 35(5): 65-71.
- [3] Yin Hongling, Xu Teng. The mismatch between population urbanization and land urbanization in China[J]. Urban Planning Forum, 2013(2): 10-15.
- [4] Huang Zhengxue, Qin Chenglin, Li Zhengtu, et al. Regional development during the 14th Five-Year Plan period[J]. Regional Economic Review, 2019(6): 1-12, 165.
- [5] Fan Shuping, Cheng Congkun, Liu Youzhao, et al. Review and prospect on land use/cover research in China[J]. Areal Research and Development, 2017,

36(2): 94-101.

[6] Zhou Yan, Huang Xianjin, Xu Guoliang, et al. The coupling and driving forces between urban land expansion and population growth in Yangtze River Delta[J]. *Geographical Research*, 2016, 35(2): 313-324.

[7] Chen Jing, Shi Peijun. Discussion on functional land use classification system[J]. *Journal of Beijing Normal University (Natural Science Edition)*, 2005, 41(5): 536-540.

[8] Li Guangdong, Fang Chuanglin. Quantitative function identification and analysis of urban ecological production living spaces[J]. *Acta Geographica Sinica*, 2016, 71(1): 49-65.

[9] Li Ming, et al. Temporal and spatial pattern of “production-living-ecology” spaces in Henan Province[J]. *Chinese Journal of Agricultural Resources and Regional Planning*, 2018, 39(9): 13-20.

[10] Huang An, Xu Yueqin, Lu Longhui, et al. Research progress of the identification and optimization of production living ecological spaces[J]. *Progress in Geography*, 2020, 39(3): 503-518.

[11] Zhang Juntao, Zhai Jingtong. Study on the coupling coordination degree of production living ecological space in the coastal central cities of China[J]. *Modern Urban Research*, 2020(7): 2-8.

[12] Dai Wenyuan, Jiang Fangqi, Huang Wanli, et al. Study on transition of land use function and ecosystem service value based on the conception of production, living and ecological space: A case study of the Fuzhou New Area[J]. *Journal of Natural Resources*, 2018, 33(12): 2098-2109.

[13] Chen Long, Zhou Shenglu, Zhou Bingbing, et al. Characteristics and driving forces of regional land use transition based on the leading function classification: A case study of Jiangsu Province[J]. *Economic Geography*, 2015, 35(2): 155-162.

[14] Gong Yanan, Han Shucheng, Shi Xiaobiao, et al. Temporal and spatial evolution and associated eco-environmental effects of production living spaces in Guangdong Province[J]. *Research of Soil and Water Conservation*, 2020, 27(3): 203-209.

[15] Dou Ruiyin, Zhang Shengling, Liu Xuemin. Spatial and temporal diversity patterns and influencing factors in production-life system ecosystem coupled coordination in resource-based cities in China[J]. *Journal of Beijing Normal University (Natural Science Edition)*, 2021, 57(3): 363-371.

[16] Yang Qingke, Duan Xuejun, Wang Lei, et al. Land use transformation based on ecological production living spaces and associated eco-environment effects: A case study in the Yangtze River Delta[J]. *Scientia Geographica Sinica*, 2018, 38(1): 97-106.

[17] Cheng Bo, Zhao Aning, Zhang Xinshe. Study on Xi'an City geology and sustainable development[J]. *Northwestern Geology*, 2021, 54(4): 259-265.

- [18] Yang Xiaojun, Fang Chuanshan, Hou Yezi. Optimization of ecological recreation land in Xi' an City based on ecological footprint[J]. Geographical Research, 2018, 37(2): 281-291.
- [19] Wang Cheng, Tang Ning. Spatio-temporal characteristics and evolution of rural production-living-ecological space function coupling coordination in Chongqing Municipality[J]. Geographical Research, 2018, 37(6): 1100-1114.
- [20] He Xiaohui. Analysis on land use structure of ecological production living space in Shaanxi Province[J]. Remote Sensing Information, 2021, 36(6): 120-124.
- [21] Ma Qi, Wang Zirou, Zhao Yonghong. Evolution of spatial-temporal pattern and functional measurement of production-living-ecological space in Xi' an, China[J]. Mountain Research, 2021, 39(5): 722-733.
- [22] Wang Siyu, Lin Gaorui. Identification and pattern analysis of ecological production living space in Shangluo downtown area[C]//Urban Planning Society of China. Space Governance for High-quality Development: 2020 Proceedings of China Urban Planning Annual Conference (20th Overall Plan). Beijing: China Architecture & Building Press, 2021: 527-538.
- [23] Han Mei, Kong Xianglun, Li Yunlong, et al. Environmental effects and its spatial heterogeneity of ecological production living land use transformation in the Yellow River Delta[J]. Scientia Geographica Sinica, 2021, 41(6): 1009-1018.
- [24] Wang Jinfeng, Xu Chengdong. Geodetector: Principle and prospective[J]. Acta Geographica Sinica, 2017, 72(1): 116-134.
- [25] Song Yongyong, Xue Dongqian, Xia Siyou, et al. Change characteristics and formation mechanism of the territorial spatial pattern in the Yellow River Basin from 1980 to 2018, China[J]. Geographical Research, 2021, 40(5): 1445-1463.
- [26] Li Xiaohua, Feng Jianmin, Wen Qi. On characteristics of land use and landscape pattern change and its driving forces in Shaanxi Province[J]. Scientific and Technological Management of Land and Resources, 2021, 38(1): 107-117.
- [27] Wang Zhulian, Wang Ping, Zhi Linjiao. Evolution and driving forces of ecological productive living space pattern in Dianchi Lake area during 2000-2020[J]. Bulletin of Soil and Water Conservation, 2021, 41(6): 265-273, 281.

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