

# Measurement of cultivated land change and analysis of its spatial characteristics in Luoyang City

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## ABSTRACT

Cultivated land is a crucial foundation for agricultural production and an important pillar for the development of human society. To better coordinate the relationship between economic development and cultivated land protection in the context of urbanization, and to pursue a path of mutual promotion between economic growth and cultivated land conservation, this study takes Luoyang City as the research area. Using data related to cultivated land resources and socio-economic statistics, it analyzes the impact of the new urbanization process on the quantity and spatial distribution of cultivated land resources in Luoyang City from 2005 to 2020. The results show that: (1) The single dynamic degree of cultivated land use was -0.25% in Luoyang City from 2005 to 2020, indicating a declining trend in cultivated land quantity with a relatively slow rate of change. Only during 2005–2010 did cultivated land show an increasing trend, and the dynamic degree of cultivated land area was the highest during this period, representing the fastest change in cultivated land area. (2) Changes in cultivated land resources varied across counties and districts in Luoyang City. The relative change rate of cultivated land in all counties and districts from 2005 to 2020 was greater than 1, indicating that the rate of cultivated land change in each region was faster than that of Luoyang City as a whole. (3) The spatiotemporal change in cultivated land area in Luoyang City exhibited a continuous decreasing trend. From 2005 to 2015, the ANN value was close to 0, indicating that the spatial distribution of cultivated land in Luoyang City was closer to a clustered distribution. From 2015 to 2020, the ANN value was closer to 1, indicating that the spatial distribution of cultivated land during this period was more random compared to the previous three years. This study provides a scientific basis for coordinating the dynamic balance between urban construction and cultivated land protection, and for ensuring regional food security.

## KEYWORDS

Cultivated land use change; Spatial evolution; Average Nearest Neighbor index; Luoyang City.

## 1. INTRODUCTION

Cultivated land is a fundamental resource for human survival and development, serving as a core carrier for ensuring food security and maintaining ecological balance. Its quantitative stability and spatial layout rationality are critical to regional food security and high-quality economic development [1]. Currently, with the rapid advancement of urbanization and industrialization in China, human activities such as urban expansion, industrial restructuring, and infrastructure construction have significantly occupied cultivated land resources, leading to increasingly prominent issues of reduced total cultivated land area and declining quality. These changes constrain regional agricultural development and threaten food security [2,3]. Therefore, analyzing the spatiotemporal changes of cultivated land and studying its spatial evolution characteristics are of great importance for implementing cultivated land protection policies and optimizing land resource allocation. Luoyang

City, located in western Henan Province and situated in the middle and lower reaches of the Yellow River Basin, features complex and diverse topography. It serves not only as a key nodal city in the Central Plains Economic Zone but also as an important agricultural production base in Henan Province, bearing the mission of ensuring food supply [4]. In recent years, with the accelerating urbanization process in Luoyang City, the demand for urban and rural construction land has continuously increased, intensifying the contradiction between cultivated land protection and economic development. Consequently, the quantity and spatial distribution of cultivated land have undergone changes [5]. Conducting research on the measurement of cultivated land changes and their spatial characteristics in Luoyang City is of great theoretical and practical significance for clarifying the patterns of cultivated land change, ensuring regional food security, and promoting sustainable agricultural development.

Domestic research on the dynamic changes of cultivated land resources primarily focuses on change monitoring, spatial heterogeneity, and driving mechanisms, employing remote sensing technology in conjunction with various statistical datasets to comprehensively analyze the spatiotemporal evolution of cultivated land. For instance, Zhao Xiaoli utilized remote sensing monitoring to examine the spatiotemporal characteristics of cultivated land change over the past three decades, revealing that the national cultivated land area experienced a turning point around 2000, increasing before that year and decreasing thereafter until 2010 [6]. Tai Lingxiao, using the cultivated land use dynamic degree and principal component analysis to study Yan'an City from 2010 to 2019, found that the cultivated land area exhibited a declining trend under the influence of factors such as population dynamics and industrial structure [7]. In contrast, international scholars have predominantly concentrated on the environmental impacts of land use change. For example, W. Halicki investigated the effects of changes in cultivated land use on soil degradation in 20th-century Siberia [8]. L. N. Sholikah, after identifying the conversion of agricultural land in the mountainous region of Kulon Progo Regency from 2005 to 2020, analyzed its impact on regional food security. [9].

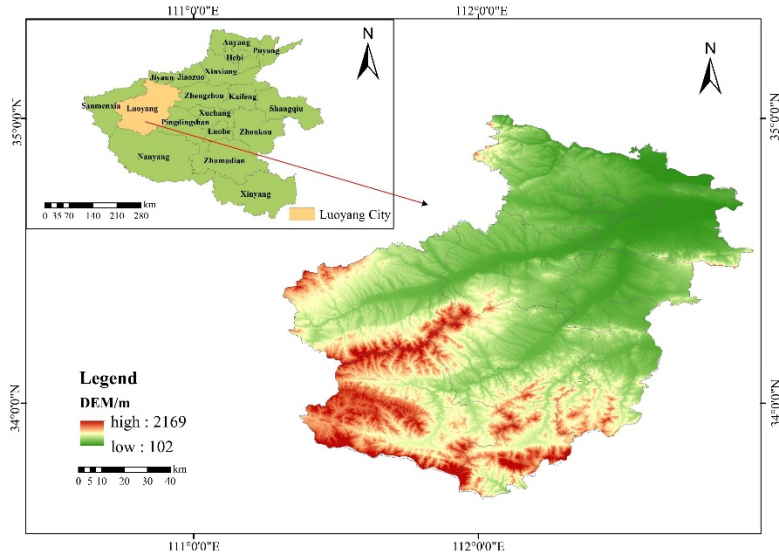
This paper takes Luoyang City as the research object to explore and analyze the impact of the development context of new urbanization on the evolution pattern of its cultivated land use. This study aims to enrich the current research on the evolution of cultivated land patterns in this region and provide a theoretical basis for formulating effective cultivated land protection measures and further promoting sustainable economic and social development within the region.

## **2. STUDY AREA OVERVIEW AND DATA SOURCES**

### **2.1. Study area overview**

#### **(1) Physical geography overview**

Luoyang City is a prefecture-level city in Henan Province and a deputy central city of the Central Plains Urban Agglomeration. Located in western Henan Province, it borders Jiaozuo to the north, Pingdingshan and Nanyang to the south, Sanmenxia to the west, and Zhengzhou to the east. It is situated between latitudes 34°39' N and 35°25' N and longitudes 111°16' E and 112°47' E, stretching approximately 178 kilometers from east to west and 167 kilometers from north to south. The terrain of Luoyang City is high in the west and low in the east, with complex topography and geomorphology. The annual average temperature ranges from 12.2°C to 24.6°C, average annual humidity is between 60% and 70%, annual sunshine duration is 2200–2300 hours, and annual precipitation is 528–800 millimeters. The climate is a warm temperate continental monsoon climate. Major rivers in the region include the Yellow River, Yi River, Ru River, and Luo River.



**Figure 1.** Location map of Luoyang City.

## (2) Overview of economic development

By the end of 2021, the permanent resident population of Luoyang had reached 7.069 million, an increase of 0.17% compared to the previous year. Among them, the urban permanent resident population increased from 4.585 million last year to 4.657 million, an increase of 1.57%. The urbanization rate increased by 0.91% compared to last year, reaching 65.88%. As of the end of 2021, the gross domestic product (GDP) of Luoyang had reached 544.71 billion yuan, an increase of 4.8% compared to the previous year. Among them, the GDP of the primary industry was 26.10 billion yuan; the GDP of the secondary industry was 237.87 billion yuan; and the GDP of the tertiary industry was 280.74 billion yuan. The proportion of the three industrial structures was 4.8:43.7:51.5. The per capita GDP was 77,110 yuan, an increase of 4.4%.

## 2.2. Data sources

The data used in this study consist of spatial data on cultivated land use and socio-economic development data for Luoyang City. The spatial distribution data of cultivated land were obtained from the Resource and Environment Science Data Center of the Chinese Academy of Sciences (<https://www.resdc.cn/>). Population data were derived from the Luoyang Statistical Yearbooks for 2005, 2010, 2015, and 2020.

## 3. RESEARCH METHODS

### 3.1. Single land use dynamic degree

The single land use dynamic degree expresses the quantitative change of a specific land use type within a defined study area over a certain period, commonly represented by  $K$  [10]. This paper uses the single dynamic degree to study the quantitative change characteristics of cultivated land resources in Luoyang City. The specific calculation formula is as follows:

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

Where:  $U_a$  and  $U_b$  represent the area of the land use type at the beginning and end of the study period, respectively, and  $T$  represents the time interval between the two periods.

### 3.2. Relative change rate

The relative change rate is used to reveal regional differences in changes for a specific land use type. There are differences in nature, society, policy, population, economic development, and other aspects across different counties and districts in Luoyang City during various periods. To study the relationship between changes in cultivated land within the internal regions of Luoyang City and the city as a whole, this paper employs the relative change rate [11]. The formula is:

$$R = \frac{|K_b - K_a| \times C_a}{K_a \times |C_b - C_a|} \times 100\% \quad (2)$$

Where: R is the relative change rate;  $K_a$  represents the cultivated land area of a specific region in Luoyang City at the beginning of the period;  $K_b$  represents the area at the end of the period;  $C_a$  represents the total cultivated land area of Luoyang City at the beginning of the period;  $C_b$  represents the total area at the end of the period. When the R value of a region is greater than 1, it indicates that the change in cultivated land use in that region is greater than that of the entire region [7].

### 3.3. Average nearest neighbor index

The principle of the ANN is to measure the average distance between each patch centroid point and its nearest neighboring patch centroid point, and then compare this value with the expected average distance to determine whether the spatial distribution of patches is clustered, random, or uniform [12]. To study the spatial agglomeration characteristics of cultivated land in Luoyang City, the Average Nearest Neighbor index method can be employed.

If the ANN is 0, it indicates a completely clustered distribution trend; if the index is 1, it indicates a random distribution trend; if the index is greater than 1, it indicates a uniform distribution trend; if the index is less than 1, it indicates a clustered distribution trend [13]. The specific calculation formula for the ANN value is as follows:

$$ANN = \frac{\bar{D}_0}{\bar{D}_e} \quad (3)$$

$$\bar{D}_0 = \frac{\sum_{i=1}^n d_i}{n} \quad (4)$$

$$\bar{D}_e = \frac{1}{2\sqrt{n/A}} \quad (5)$$

Where: ANN is the Average Nearest Neighbor index;  $\bar{D}_0$  is the observed mean distance (m);  $\bar{D}_e$  is the expected mean distance (m); d is the distance (m); n is the total number of cultivated land patches; A is the area of the minimum enclosing polygon of all features.

## 4. RESULTS ANALYSIS

### 4.1. Analysis of quantitative changes in cultivated land resources

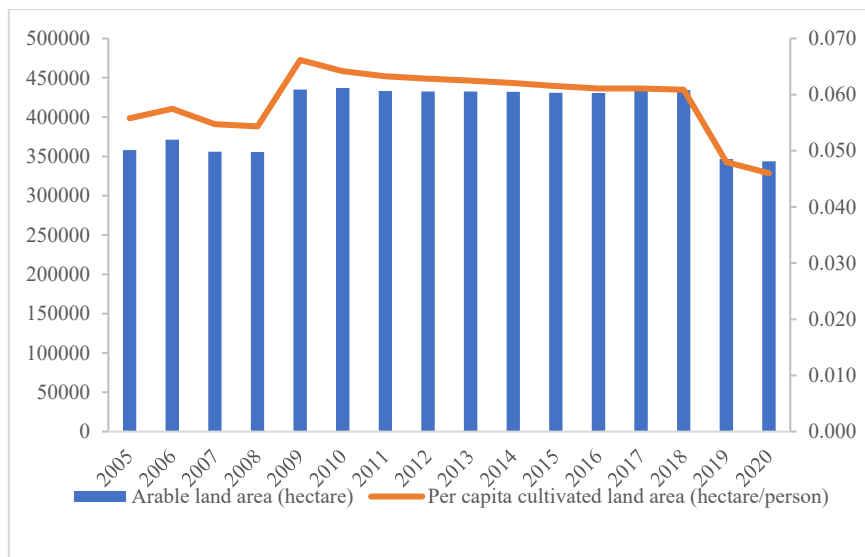
As shown in Table 1, only the cultivated land use dynamic degree from 2005 to 2010 was positive, at 3.68%, with a growth rate of cultivated land area of 22.08%. This indicates that cultivated land area increased during this stage, likely due to the relatively low level of urbanization and slow development speed in Luoyang City during this period, coupled with a strong awareness of cultivated land protection, leading to an increase in cultivated land area. Additionally, the dynamic degree of cultivated land area was highest from 2005 to 2010, at 3.68%, indicating that this period had the fastest rate of cultivated land change. Overall, the cultivated land use dynamic degree in Luoyang City from 2005 to 2020 was -0.25%, suggesting a relatively slow rate of change overall, and the

negative value during this period indicates a declining trend in the quantity of cultivated land in Luoyang City.

**Table 1.** Cultivated land use dynamic degree in Luoyang City (2005–2020).

Time period	Cultivated land use dynamic degree (%)
2005-2010	3.68
2010-2015	-0.23
2015-2020	-3.37
2005-2020	-0.25

As illustrated in Figure 2, the per capita cultivated land area in Luoyang City decreased from 0.056 hm<sup>2</sup>/person in 2005 to 0.046 hm<sup>2</sup>/person in 2020, a reduction of 17.86%. This is primarily attributable to two factors: on the one hand, the rapid population growth in Luoyang City during this period; on the other hand, in the context of new urbanization, Luoyang City engaged in various urban construction activities to enhance its urbanization level, expanding urban population size and leading to disorderly expansion of urban land, which resulted in the encroachment of large areas of cultivated land and a reduction in its area. Overall, the current situation of cultivated land in Luoyang City is not optimistic.



**Figure 2.** Trends in cultivated land resources and per capita cultivated land in Luoyang City (2005–2020).

#### 4.2. Analysis of regional differences in cultivated land resources

As shown in Table 2, there were significant differences in the average annual change rate and relative change rate of cultivated land across different regions of Luoyang City from 2005 to 2020, indicating clear spatial differences in the changes of cultivated land area.

As shown in Table 2, the relative change rates of cultivated land in all counties and districts within Luoyang City were greater than 1, indicating that the rate of cultivated land change in each region was faster than that of the city as a whole. The most notable change was in Jianxi District, with an average annual change rate of cultivated land of 26.67%, making it the region with the fastest increase in cultivated land within Luoyang City. This is attributed to Jianxi District's earlier focus on industrial development for its own growth, establishing a series of industrial parks that occupied a large amount of cultivated land, accelerating the non-agriculturalization of cultivated land in the area and gradually leading to a scarcity of cultivated land resources. In recent years, to achieve balanced industrial development, move away from an industry-dominated economic structure, and realize urban transformation, Jianxi District has not only vigorously tapped into its local cultural potential and fully

activated local tourism resources, promoting the development of the tourism industry, but has also implemented corresponding cultivated land protection measures, resulting in an increase in cultivated land area.

From 2005 to 2020, cultivated land decreased in seven study regions: Laocheng, Xigong, Chanhe, Yanshi, Mengjin, Xin'an, and Yichuan. Among these, Yichuan County had the smallest relative change rate of cultivated land at 2.97%, representing the slowest rate of cultivated land decrease in Luoyang City. This is because Yichuan County has a relatively low level of economic development and urbanization, with slower growth rates of urban and rural populations, leading to less encroachment on cultivated land resources.

**Table 2.** Average annual change rate and relative change rate of cultivated land in counties and districts of Luoyang City.

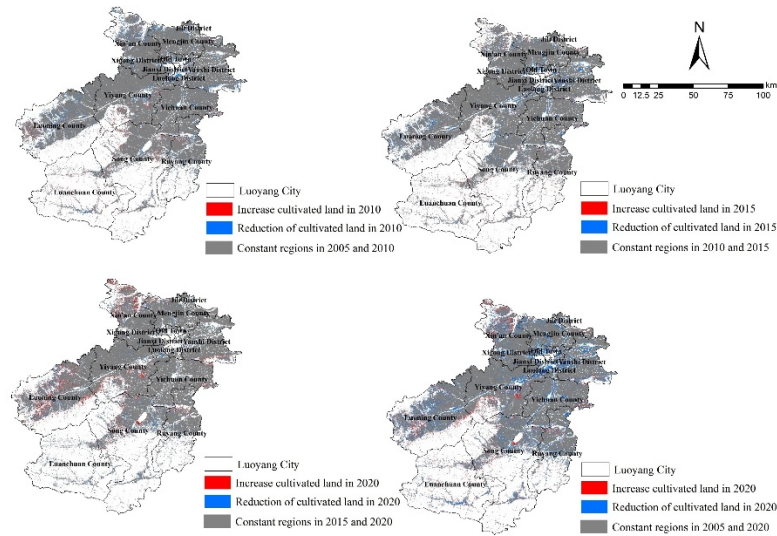
Region	Cultivated land area of 2005 ( $\times 10^3$ hm <sup>2</sup> )	Cultivated land area of 2020 ( $\times 10^3$ hm <sup>2</sup> )	Average annual change rate (%)	Relative change rate (%)
Laocheng	1.71	0.9	-3.16	11.86
Xigong	1.49	0.7	-3.53	13.27
Chanhe	0.52	0.3	-2.82	10.59
Jianxi	0.16	0.8	26.67	100.14
Luolong	7.70	14.3	5.71	21.46
Yanshi	50.02	24.3	-3.43	12.87
Mengjin	38.81	28.4	-1.79	6.76
Xinan	32.11	28.2	-0.81	3.05
Luanchuan	9.10	9.5	0.29	1.10
Songyang	31.27	40.2	1.90	7.15
Ruyang	24.41	32.7	2.26	8.50
Yiyang	59.23	66.5	0.82	3.07
Yichuan	58.54	51.6	-0.79	2.97
Luoning	41.81	45.4	0.58	2.17
Luoyang	358	343.80	-0.26	—

### 4.3. Analysis of spatial characteristics of cultivated land resources

#### (1) Analysis of spatial evolution of cultivated land resources

As shown in Figure 3, the area where cultivated land remained unchanged from 2005 to 2020 was extensive, which is significant for protecting cultivated land resources and promoting sustainable agricultural development. From 2005 to 2010, the areas of cultivated land decrease were mainly concentrated in Xin'an County, Luolong District, and central Luoning County, while the areas of increase were mainly concentrated in northeastern Song County, western Luoning County, and eastern and southern Yiyang County. From 2010 to 2015, areas of cultivated land decrease were concentrated in Song County, Yichuan County, Yiyang County, and Yanshi District; areas of increase were mainly concentrated in central Luoning County and around the existing cultivated land in Luanchuan County. From 2015 to 2020, areas of cultivated land increase were mainly concentrated in Luoning County, Yiyang County, northern Xin'an County, southern Yanshi District, and northern and central Song County; areas of decrease were mainly concentrated in Mengjin District, around the existing cultivated land in Luanchuan County, northeastern Song County, and northwestern Yanshi District. The areas of both increase and decrease were quite evident from 2005 to 2020. Areas of increase were mostly concentrated in northern Xin'an County, western Luoning County, and eastern and southern Yiyang County; areas of decrease were mainly concentrated in Luolong District, Mengjin District, central Yichuan County, central Luoning County, and eastern Yanshi District. All

regions in Luoyang City should formulate appropriate policies based on their actual development situations to promote positive interaction between economic development and farmland protection.

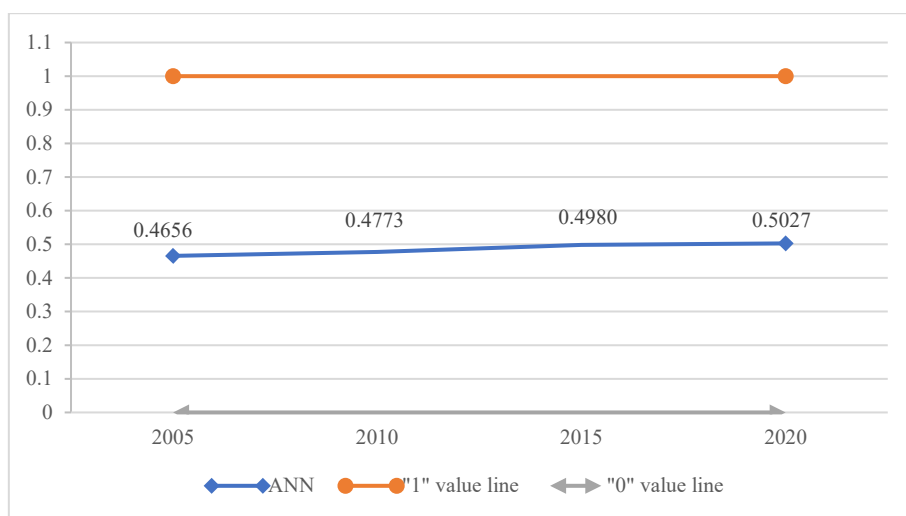


**Figure 3.** Spatial evolution of cultivated land resources in Luoyang City (2005–2020).

(2) Analysis of spatial agglomeration of cultivated land resources

Investigating the spatial agglomeration characteristics of cultivated land enables a clear understanding of its spatial evolution patterns and agglomeration intensity across different temporal scales, which holds significant theoretical and practical importance for grasping its evolutionary dynamics over time. In this study, the Average Nearest Neighbor (ANN) index was employed to analyze the spatial agglomeration characteristics of cultivated land use in Luoyang City. Using the Average Nearest Neighbor tool in ArcGIS10.8 software, the ANN values for the distribution of cultivated land in Luoyang City from 2005 to 2020 were obtained, as shown in Figure 4.

As shown in Figure 4, the ANN values for cultivated land distribution in Luoyang City for each stage from 2005 to 2020 were 0.4656, 0.4773, 0.4980, and 0.5027, respectively, all less than 1. From 2005 to 2015, the ANN value was closer to 0, indicating that the spatial distribution of cultivated land in Luoyang City during this period was closer to a clustered distribution. However, from 2015 to 2020, the ANN value was 0.5027, closer to 1, indicating that the spatial distribution of cultivated land in Luoyang City during this period was more random compared to the previous three years.



**Figure 4.** Trend of cultivated land ANN values (2005–2020).

## 5. CONCLUSION

Based on data related to cultivated land resources in Luoyang City and its counties/districts from 2005 to 2020, this paper analyzes the changes in the quantity, regional distribution, and spatial pattern of these resources. The results show that: (1) The single dynamic degree of cultivated land use in Luoyang City from 2005 to 2020 was -0.25%, indicating a declining trend in cultivated land quantity with a relatively slow rate of change. Only from 2005 to 2010 was the cultivated land use dynamic degree positive, at 3.68%, indicating an increase in cultivated land area during this phase. The dynamic degree was highest from 2005 to 2010, indicating this was the period with the fastest change in cultivated land area. (2) Changes in cultivated land resources across counties and districts in Luoyang City from 2005 to 2020 exhibited regional differences. The relative change rate of cultivated land in all counties and districts was greater than 1, indicating that the rate of change in each region was faster than that of Luoyang City as a whole, with Jianxi District experiencing the fastest increase. (3) The spatiotemporal change in cultivated land area in Luoyang City showed a continuous decreasing trend. From 2005 to 2015, the ANN value was closer to 0, indicating a spatial distribution closer to clustering; from 2015 to 2020, the ANN value was closer to 1, indicating a more random spatial distribution compared to the previous three years. This study provides important theoretical value for the optimization of cultivated land resources and the sustainable development of agriculture in Luoyang City.

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