Analysis of Spatial and Temporal Variation of Land Use in Xiong’an New Area Based on Remote Sensing Data

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Abstract. Aim to better plan the spatial layout of land use in Xiong’an New Area well, it is very important to research the land use in Xiong’an New Area. In view of Landsat5 TM data in 2009, Landsat8 OLI data in 2013 and 2017 in Xiong’an New Area, this research conducted necessary data processing and quantitatively studied the changes of land use in time and space in the past eight years in Xiong’an New Area by land utilization dynamic attitude model, transfer matrix and land use degree model. In addition, land use data in 2009 and 2017 were compared to determine specific changes in land use classifications. The consequences indicate that: From 2009 to 2017, the region of residential land in Xiong’an New Area increased significantly, the region of unused land extremely declined, and the region of cultivated land and woodland decreased slowly. From 2009 to 2017, the dynamic level of integrated annual change rate was 5.54%. Between 2009a-2013a and 2013a-2017a, the dynamic attitude towards comprehensive land use in Xiong’an New Area was 4.84 % and 8.73 %. The progress of the Xiong’an New Area in the latter four years had been faster than the previous four years.

1. Introduction
Xiong’an New Area, which is a prominent and regional place, located in Baoding City, Hebei Province, containing Xiong County, Rongcheng County, Anxin County and other parts. The construction of Xiong’an New Area can effectively alleviate the non-capital functionalities of Beijing and provide a new model for the development of highly developed regions. Therefore, it has a major sense for the coordinated progress of Beijing-Tianjin-Hebei region. Land Use and Land Cover Change (LUCC) is the content of IGBP and IHDP with the purpose of studying the mutual effect among mankind events and the environment. With the progress of science and technology, the dynamic analysis method, mathematical statistics and models of RS and GIS have become considerable tools for spatial-temporal distribution of land use variation. The method of combining geographic information technology with RS technology to research land use has become matured. In foreign countries, B.L. Teurner [1], Mas et al. [2], Yuan et al. [3], and An et al. [4] have conducted land coverage classification and variation analysis by using RS technology. In China, Liu Ying et al. [5], Ma Hongbin et al. [6], Gu Lin et al. [7], He Liheng et al. [8], Li Baihong et al. [9], Wang Shiyi [10], and Wang Dongxiang [11] have studied land use change and degree by using the dynamic analysis method combining RS and GIS. Mathematical statistics and models are applied commonly to the study of land use variation mainly including principal component analysis, multiple regression analysis, typical correlation analysis, fractal feature research method, gray
correlation method and Markov process prediction method. In foreign countries, MaximShoshany [12], Boerne et al. [13-15], Castella [16], Bakke et al. [17], Almeida [18] and Kuninori et al. [19] have conducted in-depth studies on land use variation employing different mathematical statistical and models. In a word, the study on land use variation is in the ascendant. A large number of scientific research institutions, organizations of higher learning and social organizations have entered into the study, which is conducive to promote the research progress of land use variation. In the paper, the integrated use of a dynamic analysis method of RS, GIS, the method of mathematical statistics model of Xiong’an New Area, and the land use present situation and the developing trend in recent years, the dynamic analysis, the present situation and the specific changes of land use were obtained.

2. Overview of Research Area and Data Sources
The Xiong’an New Area covers Xiong County, Anxin County, Rongcheng County and other regions. The total region of the three counties is about 1576.6km². Xiong’an New Area has a great significance for regional planning due to its special geographical location. Therefore, the government has decided to set up Xiong’an New Area with high standards and requirements, which will have a great significance in Chinese history. Xiong’an New Area is situated in the Daqing River, in the middle of the Jizhong Plain with flat terrain. Xiong’an New Area is in the mid-latitude region and has a continental climate. The weather has four distinct seasons. The scope of the research region as shown in figure 1.

![Figure 1. Scope of the studying area.](image)

In this research, Landsat8 RS pictures were selected to study land use variation and its drivers. The data of vector administrative division comes from 1:100,000 basic vector map nationwide. The economic statistics, road data, policy planning data and population data needed for driving force analysis are from the latest statistical yearbook of the Xiong’an New Area.

3. Research Methods

3.1. Land Use Dynamic Model
The dynamic degree of single land use refers to the variation of the quantity of land use types expressed in a determined period of time in the research region. The calculation equation is as follows:

\[ K = \frac{U_2 - U_1}{U_1} \times \frac{1}{t_2 - t_1} \times 100\% \] (1)

Type: \( K \) is a dynamic degree of single land use; \( t_2 - t_1 \) is the time interval; \( U_1 \) is the initial region of a certain type of land use; \( U_2 \) is the area during the research cycle of the land use type, and \( U_2 - U_1 \) is the change of this type of land region during the research cycle.
The dynamic degree calculation equation of comprehensive land use is as follows:

$$LC = \frac{\sum_{i=1}^{n} \Delta LA(i, j) \times 1}{\sum_{i=1}^{n} LA(i, t_i) \times t_2 - t_1} \times 100\%$$

(2)

Type: $LC$ represents the comprehensive land use dynamic attitude over time; $\Delta LA(i, j)$ delegates the absolute terms of class $i$ land over time $t_2 - t_1$; $LA(i, t_i)$ is the region of class $i$ type of land use in the region during the initial cycle $t_i$, and $t_2 - t_1$ is the time interval.

### 3.2. Land Use Change Model

**Table 1. Land use type classification index.**

| type                | unused land | forest, grass and water land | agricultural land | settlement land |
|---------------------|-------------|-------------------------------|-------------------|-----------------|
| land use type index | waste, unused land | water area | field, meadow | urban land |

3. The dynamic degree of comprehensive land use can be expressed as:

$$L_j = 100 \times \sum_{i=0}^{n} (Ai \times Ci)$$

(3)

Type: $L_j$ represents the dynamic degree of comprehensive land use in the research region; $n$ represents the number of land use index grades; $Ai$ represents the grade $i$ land use degree grading index in the research region, and $Ci$ represents the area percentage of land use index grade $i$ in the research region [20].

The land use index change model is showed as:

$$\Delta L_{2-1} = L_2 - L_1 = 100 \times \left( \sum_{i=0}^{n} (Ai \times C_{i_2}) - \sum_{i=0}^{n} (Ai \times C_{i_1}) \right)$$

(4)

The expression is:

$$R = \frac{\sum_{i=0}^{n} (Ai \times C_{i_2}) - \sum_{i=0}^{n} (Ai \times C_{i_1})}{\sum_{i=0}^{n} (Ai \times C_{i_1})}$$

(5)

In equation (4), $L_1$ and $L_2$ respectively represent the dynamic degree of comprehensive land use in a region of period 1 and period 2; $Ai$ is the index of land use degree $i$; $Ci_1$, $Ci_2$ represent the area percentage of land use degree $i$ in a region of time 1 and time 2 [21].

### 4. Research on Land Use Change and Drivers

#### 4.1. Land Use Classification

Based on specific land types in Xiong’an New Area, the land use sorts were grouped as residential land, woodland, grassland, cultivated land, water area and unused land. The raster data were further improved by the projected transformation of the coordinate system, atmospheric correction, linear gray stretch and band fusion. The maximum likelihood monitoring classification was used to classify the RS pictures of Xiong’an New Area in 2009, 2013 and 2017. The accuracy of the classified results was evaluated, and the evaluation accuracy was 80% all above, which met the requirements of this study. The classification results are shown in figure 2.
(a) Land use map of Xiong’an New Area in 2009

(b) Land use map of Xiong’an New Area in 2013
4.2. Analysis of Temporal and Spatial Change of Land Use

This research studied the specific situation of land use structure, variation speed and change degree of Xiong’an New Area through statistical area and its proportion, dynamic degree of single land use, dynamic degree of comprehensive land use, transition matrix and land use degree model. After calculation, the area and proportion of land use types in Xiong’an New Area (table 2), the dynamic degree of comprehensive land use in Xiong’an New Area (table 3) and the transition matrix of land use types in Xiong’an New Area (table 4) were obtained.

Table 2. Land use type area and its percentage.

| year type      | 2009        | 2013        | 2017        |
|----------------|-------------|-------------|-------------|
|                | area (ha)   | ratio (%)   | area (ha)   | ratio (%)   | area (ha)   | ratio (%)   |
| residential land| 18848.3     | 12.1        | 23192.0     | 14.9        | 49926.4     | 32.1        |
| unused land    | 23511.4     | 15.1        | 21549.3     | 13.8        | 10094.1     | 6.5         |
| woodland       | 15471.5     | 9.9         | 11024.1     | 7.1         | 10391.7     | 6.7         |
| water area     | 4100.2      | 2.6         | 12105.4     | 7.8         | 7442.1      | 4.8         |
| cultivated land| 65811.1     | 42.3        | 68483.4     | 44.1        | 58132.8     | 37.5        |
| grassland      | 27496.1     | 17.7        | 18884.4     | 12.1        | 19251.5     | 12.4        |
| total          | 155238.6    | 100.0       | 155238.6    | 100.0       | 155238.6    | 100.0       |
Table 3. Dynamic degree of comprehensive land use.

| Year       | 2009-2013 | 2013-2017 | 2009-2017 |
|------------|-----------|-----------|-----------|
| Type       | Area (ha) | Dynamic Degree (%) | Area (ha) | Dynamic Degree (%) | Area (ha) | Dynamic Degree (%) |
| residential land | 4343.7  | 5.8       | 26734.4 | 28.8       | 31078.1  | 20.6       |
| unused land  | -1962.1  | -2.1      | -11455.2 | -13.3      | -13417.3 | -7.1       |
| woodland     | -4444.7  | -7.2      | -632.4  | -1.4       | -5079.8  | -4.1       |
| water area   | 8005.2   | 48.8      | -4663.3 | -9.6       | 3341.9   | 10.2       |
| cultivated land | 2672.3  | 1.0       | -10350.6 | -3.8       | -7678.3  | -1.5       |
| grassland    | -8611.8  | 7.8       | 367.1   | 4.9        | 8244.7   | -3.8       |

Table 4. Land use type change transition matrix.

| Land use change | 2009          |
|-----------------|---------------|
|                 | residential land | water area | woodland | grassland | unused land | cultivated land |
| residential land | 203472.0       | 2246.0     | 36832.0  | 35419.0   | 121189.0    | 122777.0       |
| water area      | 1824.0         | 35777.0    | 9905.0   | 12063.0   | 3153.0      | 18428.0        |
| woodland       | 724.0          | 201.0      | 15876.0  | 7687.0    | 10219.0     | 40053.0        |
| grassland      | 1095.0         | 2225.0     | 15415.0  | 32017.0   | 17758.0     | 75037.0        |
| unused land    | 92.0           | 2.0        | 1187.0   | 14533.0   | 28523.0     | 62126.0        |
| cultivated land | 2641.0         | 2426.0     | 28925.0  | 109014.0  | 98366.0     | 510390.0       |

Through table 2, table 3 and table 4, the primary features of land use change in time and space in 2009a-2017a were obtained. In 2013a-2017a, the dynamic attitude of comprehensive land use was 8.73%, with a relatively high degree. It could be found according to the dynamic changes of land use that the area of cultivated land declined, which has become the land for residential land. However, the overall area of cultivated land remains stable and relatively safe. The area of water area remains basically unchanged, the area of woodland and grassland declined, and the area of unused land significantly decreased. The unused land has been well utilized, among which 121,189.00 hectares have been transformed into residential land.

The land use degree change model was applied to calculate the comprehensive land use degree index of Xiong’an New Area in 2009, 2013 and 2017. In 2009, 2013 and 2017, the comprehensive indexes of land use degree were 281.09, 279.35 and 314.34. According to value range of the comprehensive indexes of land use degree, the development degree has reached the medium level. In 2009a-2013a and in 2013a-2017a, the change rates of land use degree were -0.062 and 0.120. This indicated that the research area was in a weak period of development and decline in 2009a-2013a, while the study region was in a period of development in 2013a-2017a, and the development speed was relatively fast.

4.3. Single Land Use Type Distribution

A single land use distribution analysis was conducted with the 2017 land use classification map (figure 3) to obtain the detailed land use classifications in Xiong’an New Area.
Figure 3. Distribution of single land use types.

In figure 3, Xiong’an New Area currently (2017) the land use type of cultivated land accounted for most of the cultivated land, residential land and cultivated land distribution in the three counties is relatively uniform, residential land mainly concentrated, land of residential in Anxin County is relatively small, compared to other two counties, Anxin County urbanization level is not high; The amount of unused land in Rongcheng County and Xiong County is relatively large. Compared with the situation of unused land in 2009, the unused land has been fully utilized to a large extent, resulting in a serious
decline of the unused land. The distribution of the water area is closely related to the distribution of natural factors. The water area is mainly concentrated in Baiyangdian in Anxin County, and the construction of a better ecological environment cannot be separated from Baiyangdian's great role.

4.4. Single Land Use Type Change Distribution
By studying the land use classification results of the Xiong’an New Area in 2009 and 2017, this paper studied the various land use changes from 2009 to 2017. The specific transform of sure type from 2009 to 2017 can be obtained through the establishment of the model (figure 4), the changes included the increases and the decreases. The results of the study can clearly indicate the specific location and scope of a sure type change so as to accurately and clearly study the specific changes of land use in Xiong’an New Area in time and space.
Figure 4. Distribution of single land use analysis changes.

5. Conclusion
This paper comprehensively used the dynamic analysis method of RS and GIS as well as mathematical statistics and models to conduct dynamic analysis on the land use status quo and variation trend in recent years in order to research the specific land use variations in time and space in Xiong’an New Area. From this study, we found the specific quantity change of land use in Xiong’an New Area, the speed of change in different time and the current variation. The conclusions drawn from the comprehensive analysis are summarized as follows:

(1) From 2009 to 2017, the residential land added rapidly, and its proportion of the area increased gradually. The percentage of woodland and grassland declined slowly. The percentage of unused land fell rapidly with the biggest change. The results obtained through the change model can be seen that from 2009 to 2013, the residential land increased significantly and the unused land area decreased rapidly.

(2) The dynamic degrees of land use were 4.84% and 8.73% respectively, showing that the land use of Xiong’an New Area was in the stage of slow change on the whole. However, the dynamic attitude of land use clearly showed that the variation from 2013 to 2017 was faster than that from 2009 to 2013.

(3) The comprehensive index of land use in the Xiong’an New Area in 2017 was 314.34, which was a medium level. From 2013 to 2017, the change rate of land use was 0.120, indicating that the land use was in the development stage from 2013 to 2017 and the development speed was relatively fast.

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