Analysis of Land Use Change in Jining City

Nanjia Lu¹, Xingyuan Xiao¹*

¹College of Geomatics, Shandong University of Science and Technology, Qingdao, Shandong, 266590, China
²Corresponding author’s e-mail: xiaoxy_111@163.com

Abstract. Based on the LANDSAT remote sensing image data of 2000, 2005, 2010 and 2015, this paper applies RS, GIS, mathematical statistics and other methods, mainly about land use transfer matrix, single land use dynamic and comprehensive land use dynamic to analyse land use change in Jining City during the period from 2000 to 2015. The results show that: (1) The transfer intensity of grass is gradually increasing. Dry land and house-site in the countryside are transferred largely into town house. The transfer between dry land and house-site in the countryside is obvious. The imported area of waters is always larger than the exported area in three periods. Retention rate of dry land has remained relatively high. In addition, the unutilized land retention rate varies greatly. (2) The single dynamic of paddy field, town house and unutilized land are large, indicating changes of these types are intensive; the lower dynamic of dry land and waters indicates the stability of these types is good. The comprehensive land use dynamics first decreased and then increased, indicating that the intensity of land use change in Jining City first decreased and then increased, and the overall land use change is large.

1. Introduction

Research on land use change has now become a classic topic worldwide, since the International Geosphere Biosphere Programme (IGBP) and International Human Dimension Programme on Global Environmental Change (IHDP) jointly published the Land Use/Cover Change Scientific Research Program in 1995, Many scholars have carried out research on the main content of land use change forms and types, process analysis and driving factors analysis. In traditional research, Skole believes that the completion of relevant research requires three levels of work: measuring spatio-temporal features, acquiring dynamic processes, predicting trends, and their effects [1]. With the development of satellite and computer technology, the extensive application of RS, GIS technology and its supporting software and model analysis has become an important tool for land use change. For example, Kienast summarizes the classic GIS spatial statistical methods and spatial overlay analysis [2], Iverson used GIS technology to analyze the land use change in Illinois [3], and Tang summarized various LUCC models [4]. In recent years, computer artificial intelligence and deep learning have made image processing and change analysis more efficient and faster.

China currently has a large population and uneven distribution of resources. It faces land problems such as irrational land use and tension between people and land. With the introduction of land policies such as “basic farmland protection” and “red line of cultivated land”, scholars and governments at all levels pay more attention to land use issues, and research on land use change has gradually become a new means of supervising and guiding the rational and legal development of industrial and agricultural construction, efficient use of land and serving the social economy. In recent years, Chinese land use change research work mainly includes: Li Xiubin, Li Mao and others study the impact of land use
change on food security [5-6]; Shi Peijun, Li Jing and others study the impact of land use change on the ecological environment [7-8]; Liu Jiyuan and others study the national land use change Time and space patterns and new features [9-10]. Jining City is a typical area with rich mineral resources and developed water system, at the same time of rapid socio-economic development, various urbanization problems and ecological environment issues are becoming more and more prominent; studying the issue of land use change will better guide regional coordinated development and sustainable development, optimize land use structure, correctly handle conflicts between people and land, and build a harmonious society.

2. Study area

Jining City is located in the hinterland of southwest Shandong Province. The geological structure belongs to the depression area of southwestern Shandong. Its terrain is dominated by plain and depressions, the terrain is high in the east and low in the west, and the landform is more complicated. There are lots of mountains in the eastern region. The four endpoints are located at 35°57′N, 34°26′S, 117°36′E, 15°52′W. It is 167km long from north to south and 158km long from east to west. Rich in mineral resources, there are more than 70 kinds of minerals that have been discovered and proven reserves. The plain area of the city is mainly composed of agricultural land and construction land. Forest land and grassland are concentrated in the mountainous hills in the east, and the southeast is the Nansi Lake, the largest lake in Shandong Province. Jining City has jurisdiction over 11 districts and counties (cities) including Rencheng District, Yanzhou District, Weishan County, Yutai County, Jinxian County, Jiaxiang County, Wenshang County, Sishui County, Liangshan County, Qufu City and Zoucheng City.

3. data and methods

3.1. data sources and image processing

Jining City has a large span from north to south. In order to dynamically monitor land use/cover change, LANDSAT remote sensing images (track numbers 122/35, 122/36) were selected for 2000, 2005, 2010 and 2015. The main remote sensing data is shown in Table 1.

| Date       | 2000.09.14 | 2005.04.16 | 2010.08.30 | 2015.10.02 |
|------------|------------|------------|------------|------------|
| resolution | 30m        | 30m        | 30m        | 30m        |
| data sources| Landsat5   | Landsat5   | Landsat7   | Landsat8   |

According to the actual situation of the study area and the quality of remote sensing images, the preprocessing of remote sensing images mainly includes image radiation correction, geometric correction, band combination, image mosaic-cutting and so on.

According to the Classification of Land Use Status jointly issued by the General Administration of Quality Supervision, Inspection and Quarantine and the State Administration of Standardization on September 3, 2007, a land use classification system was formulated. According to the actual situation of the study area, the land use types are divided into dry land, paddy fields, wood land, grass, town house, house-site in the countryside, waters and unutilized, and the land use types determined in accordance with Jining City remote sensing interpretation marks. This paper uses automatic interpretation and visual interpretation to extract land use information. Finally, the land use classification maps of Jining City in 2000, 2005, 2010 and 2015 are shown in Figures 1, 2, 3 and 4.
3.2. Study methods

3.2.1. Land use transfer matrix.

Transfer matrix:

The transfer matrix mainly reflects the land use structure in the initial and final stages of the study and the transfer of land use types at each time period. It is mainly used to understand the flow loss of the land use type at the beginning of the study and the source of the land use type at the end of the study.

Equation [11]:

\[
A = \begin{bmatrix}
    A_{11} & \cdots & A_{1j} \\
    \vdots & \ddots & \vdots \\
    A_{i1} & \cdots & A_{ij}
\end{bmatrix}
\]

Where, the row indicates the type of land use in the t period; the column indicates the type of land use in the t+1 period; i and j are the land types; and \( A_{ij} \) is the area in which the land use type i in the t
period is converted to the land use type j in the t+1 period. When i=j, A_{ij} is the area where the type i has not been transferred.

Retention rate:
First introduce the concept of the percentage of transfer, and the percentage of transfer refers to the proportion of land use type i in t period to the land use type j in t+1 period. The equation is:

\[ B_{ij} = \frac{A_{ij}}{\sum_{j=1}^{n} A_{ij}} \times 100\% \]

Where, B_{ij} represents the percentage of transfer; A_{ij} is the area of land use type i converted to t-time land use type j during period t; \( \sum_{j=1}^{n} A_{ij} \) is the area of type i at the beginning of the study (t period).

The retention rate refers to the proportion of the area where a land type has not been transferred to the area of the type at the beginning of the study period. It can reflect the stability of each land type in different periods. The equation is closely related to B_{ij}. The value of B_{ij} obtained when i=j is the retention rate.

3.2.2. Land use dynamics
The land use dynamic degree model is divided into a single land use dynamic degree model and a comprehensive land use dynamic degree model [12]. The dynamic degree index can comprehensively consider the transfer of land use types during the study period, reflect the intensity of regional land use change, and facilitate the identification of hotspots of land use change on different spatial scales.

Single land use dynamic:
The single land use dynamic degree expresses the quantity change of a certain land use type within a certain time range of a study area.
Equation [13]:

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

Where, K represents the dynamic of a land use type during the study period (also known as the rate of change of land use type); U_a and U_b are the number of land use types at the beginning of the study and at the end of the study period; T is the length of the study period. When the time period of T is set to year, the value of K is the annual rate of change of a certain land use type in the study area.

Comprehensive land use dynamics:
The comprehensive land use dynamic degree reflects the overall situation of the dynamic change of each land use type, focusing on the process of change rather than the result. Its significance is to reflect the intensity of regional land use change and to find out the hot spot of land use change. The greater the value, the more dramatic the change in land use dynamics.
Equation [13]:

\[ LC = \frac{1}{2} \times \frac{\sum_{i=1}^{n} \Delta U_{i-j}}{\sum_{i=1}^{n} LU_i} \times \frac{1}{T} \times 100\% \]

Where, LU_i is the area of land use of type i at the starting time; \( \Delta U_{i-j} \) is the absolute value of the area of land use of type i converted to non-i land type in time T. When T is set to year, LC is the annual rate of change in comprehensive land use in the study area.

4. Results and analysis

4.1. Analysis of land use transfer matrix analysis

4.1.1. Analysis of grass
In the period of 2000-2005, the imported area of the grass was 8276.89hm^2, and the exported area was 10388.07hm^2. The main imported type was dry land, and the main exported type was wood land; the grass retention rate was 84.76%, and the overall area changed little. In the period of 2005-2010, the imported area of the grass was 2575.86hm^2, and the exported area was 7738.13hm^2. The main
imported and exported types were dry land, indicating that the transfer between grass and dry land was obvious. The grass retention rate was 88.83%, and the area change was becoming steady. In the period of 2010-2015, the imported and exported area of grass increased by 10144.85hm$^2$ and 46389.95hm$^2$ respectively, and the exported area greatly increased far beyond the imported area, indicating that the grass transfer intensity was enhanced.

4.1.2. Analysis of town house
From 2000 to 2005, the town house imported area was 16194.96hm$^2$. From 2005 to 2010, the town house imported area was 14624.78 hm$^2$. From 2010 to 2015, the town house imported area was 38915.39hm$^2$, and the town house area increased greatly. The main imported types were all dry land or house-site in the countryside during the three periods. It can be seen that with the acceleration of the economy and urbanization, the dry land and house-site in the countryside has been transferred into town house, and the town house area has been increasing.

4.1.3. Analysis of dry land
From 2000 to 2005, the imported area of dry land was 82,622.06 hm$^2$, and the exported area was 37,462.06 hm$^2$. The main imported types were paddy field and house-site in the countryside and the exported type was not obvious. From 2005 to 2010, the imported area of dry land was 24,320.43 hm$^2$, and the exported area was 40429.16hm$^2$. The main imported types and the exported types were all house-site in the countryside. From 2010 to 2015, the imported area of dry land was 94,391.95hm$^2$, and the exported area was 111,489.23hm$^2$, the main imported types were grass and house-site in the countryside, the main exported type is house-site in the countryside and town house. The exported area of dryland continued to increase during the three periods, the imported area changed greatly, and the transfer between dry land and house-site in the countryside was obvious, which was closely related to the adjustment of agricultural policies, the rapid development of population and economy and the crowding of cultivated land. The dryland retention rates were 94.58%, 94.51%, and 84.53%, respectively, which showed a general downward trend.

4.1.4. Analysis of wood land
From 2000 to 2005, the imported area of wood land was 9663.61hm$^2$, and the exported area was 4540.34hm$^2$. From 2005 to 2010, the imported area of wood land was 2890.15hm$^2$, and the exported area was 1495.18hm$^2$. From 2010 to 2015, the imported area of wood land was 10581.31hm$^2$, and the exported area was 14358.59hm$^2$. The main imported and exported types were all grass or dry land during the three periods, the imported and exported area were all first increased, then decreased, then increased. Overall, the area has increased slightly, indicating that the ecological environment is gradually improving.

4.1.5. Analysis of house-site in the countryside
From 2000 to 2005, the imported area of house-site in the countryside was 14082.63hm$^2$, and the exported area was 30007.85hm$^2$. From 2005 to 2010, the imported area of house-site in the countryside was13738.44hm$^2$, and the exported area was 12008.68hm$^2$. From 2010 to 2015, the imported area of house-site in the countryside was 69923.78hm$^2$, and the exported area was 38725.5hm$^2$. The main imported and exported types were all dry land or town house during the three periods, the imported and exported area were all first increased, then decreased, then increased. Overall, the area has increased slightly, the transfer between house-site in the countryside and dry land was obvious.

4.1.6. Analysis of paddy field
From 2000 to 2005, the imported paddy field was 4597.17hm$^2$, and the exported area was 52902.06hm$^2$. From 2005 to 2010, the imported area of paddy field was7233.16hm$^2$, and the exported area was 4178.43hm$^2$. From 2010 to 2015, the imported area of paddy field was 3459.79hm$^2$, and the
exported area was 6633.64 hm². The main imported and exported types were all dry land or waters during the three periods, the retention rate and the total area were both increased first and then decreased.

4.1.7. Analysis of waters
From 2000 to 2005, the imported area of waters was 14362.82 hm², and the exported area was 9805.75 hm². From 2005 to 2010, the imported area of waters was 11084.64 hm², and the exported area was 9939.05 hm². From 2010 to 2015, the imported area of waters was 21583.02 hm², and the exported area was 17744.19 hm². The main imported and exported types were all dry land or paddy field during the three periods, and the imported area is always larger than the exported area, waters area has increased steadily. The retention rates were 92.21%, 92.38%, and 86.52%, respectively.

4.1.8. Analysis of unutilized land
From 2000 to 2005, the imported area of unutilized land was 929.49 hm², and the exported area was 2654.02 hm². The main imported types were grass and dry land and the exported types were grass and waters. From 2005 to 2010, the imported area of unutilized land was 1302.34 hm², and the exported area was 614.68 hm². The main imported type was dry land and the exported types were paddy field and dry land. From 2010 to 2015, the imported area of unutilized land was 2580.24 hm², and the exported area was 3368.1 hm². The main imported types were dry land and grass and the exported types were dry land and waters. The retention rates were 43.71%, 79.44%, and 8.42%, respectively, increased first and then decreased indicating that the development of mineral resources has brought about changes in land use. Later, under the influence of relevant policies and environmental awareness, abandoned land is well utilized.

Table 2. 2000-2005 Land use transfer matrix (hm²).

|          | grass   | town house | dry land | wood land | house-site in the countryside | paddy field | waters | unutilized land | total    |
|----------|---------|------------|----------|-----------|-------------------------------|-------------|--------|----------------|----------|
| grass    | 57786.17| 58.38      | 2656.04  | 5055.93   | 244.89                        | 302.94      | 1738.63 | 331.26         | 68174.24 |
| town house| 64.14   | 17409.75   | 1932.66  | 76.12     | 699.3                         | 165.38      | 31.88   | 20379.23       |          |
| dry land | 3552.56 | 7635.63    | 654005.72| 3404.33   | 12113.56                      | 1553.97     | 8925.95 | 276.06         | 691467.78|
| wood land| 1191.98 | 50.42      | 2874.53  | 19005.35  | 88.04                         | 266         | 69.37   | 23545.69       |          |
| house-site in the countryside | 473.53  | 7768.34    | 20692.67 | 543.02    | 86839.87                      | 35.38       | 372.44  | 122.47         | 116847.72|
| paddy field | 972.74  | 419.41     | 48160.55 | 206.78    | 754.35                        | 4745.01     | 2348.59 | 39.64          | 57647.07 |
| waters   | 712.09  | 227.96     | 5974.28  | 211.87    | 123.64                        | 2497.1      | 116112.65| 58.81          | 125918.4 |
| unutilized land | 1309.85 | 34.82      | 331.33   | 165.56    | 58.85                         | 207.78      | 545.83  | 2060.65        | 4714.67  |
| total    | 66063.06| 33604.71   | 736627.78| 28668.96  | 100922.5                      | 9342.18     | 130475.47| 2990.14        | 1108694.8|
### Table 3. 2005-2010 Land use transfer matrix (hm²).

|           | grass  | town house | dry land | wood land | house-site in the countryside | paddy field | waters | unutilized land | total       |
|-----------|--------|------------|----------|-----------|--------------------------------|--------------|--------|-----------------|-------------|
| grass     | 58684.95 | 296.53     | 5434.09  | 103.85    | 78.49                          | 892.7        | 472.75 | 99.72           | 66063.08    |
| town house| 98.7    | 31878.22   | 1136.86  | 100.65    | 215.5                          | 168.33       | 6.45   | 33604.71        |
| dry land  | 1940.25 | 11630.91   | 696198.61| 2483.67   | 13099.29                      | 1411.44      | 9399.7 | 463.9           | 736627.77   |
| wood land | 70.89   | 302.04     | 827.69   | 81.92     | 70.74                          | 141.9        | 28668.95|
| house-site in the countryside | 71.41 | 2114.9     | 9299.86  | 159.95    | 88913.81                      | 62.43        | 280.3  | 109922.49       |
| paddy field| 35.37  | 119.56     | 2946.16  | 12.08     | 5163.75                       | 509.2        | 556.06 | 9342.18         |
| waters    | 241.32  | 160.80     | 4553.62  | 64.13     | 4756.2                        | 120536.34    | 156.38 | 130475.39       |
| unutilized land | 117.92 | 0.04       | 122.15   | 15.43     | 207.03                        | 112.46       | 2375.46| 2990.14         |
| total     | 61260.81| 46503.01   | 720519.04| 30063.92  | 102652.25                     | 12396.91     | 3677.8 | 1108694.71      |

### Table 4. 2010-2015 Land use transfer matrix (hm²).

|           | grass  | town house | dry land | wood land | house-site in the countryside | paddy field | waters | unutilized land | total       |
|-----------|--------|------------|----------|-----------|--------------------------------|--------------|--------|-----------------|-------------|
| grass     | 14870.85 | 471.18     | 33479    | 7076.73   | 691.59                         | 290.48       | 1373.39| 1007.58         | 61260.8     |
| town house| 36.51   | 33231.88   | 6165.07  | 4.73      | 6011.35                        | 163.33       | 740.33 | 149.81          | 46503.01    |
| dry land  | 6984.65 | 25965.86   | 609029.79| 3133.9    | 58244.7                        | 1547.67      | 1458.84| 1063.61         | 720519.02   |
| wood land | 2281.22 | 1102.4     | 9202.2   | 15705.33  | 1211.52                        | 286.86       | 274.39 | 30063.92        |
| house-site in the countryside | 360.37 | 10697.62   | 26603.12 | 87.53     | 63926.75                       | 66.83        | 867.93 | 42.1            | 102652.25   |
| paddy field| 53.9   | 3150.35    | 333.09   | 5763.26   | 3084.95                        | 11.35        | 12396.9|
| waters    | 113.82  | 389.71     | 14465.29 | 227.81    | 1186.24                        | 1329.92      | 113876.79| 31.4            | 131620.98   |
| unutilized land | 368.28 | 234.72     | 1726.92  | 50.61     | 245.29                         | 61.56        | 680.72 | 309.7           | 3677.8      |
| total     | 25015.7 | 72147.27   | 703821.74| 26286.64  | 133850.53                      | 9223.05      | 135459.81| 2889.94         | 1108694.68  |

### Table 5. Imported and exported area (hm²).

|          | 2000-2005 | 2005-2010 | 2010-2015 |
|----------|-----------|-----------|-----------|
| imported | exported  | imported  | exported  |
|          |           |           |           |
Table 6. Retention rate (%).

|          | grass | town house | dry land | wood land | house-site in the countryside | paddy field | waters | unutilized land |
|----------|-------|------------|----------|-----------|-------------------------------|-------------|--------|-----------------|
| 2000-2005 | 84.76 | 85.43      | 94.58    | 80.72     | 74.32                         | 8.23        | 92.21  | 43.71            |
| 2005-2010 | 88.83 | 94.86      | 94.51    | 94.78     | 88.10                         | 55.27       | 92.38  | 79.44            |
| 2010-2015 | 24.27 | 71.46      | 84.53    | 52.24     | 62.28                         | 46.49       | 86.52  | 8.42             |

4.2. Analysis of land use dynamic

4.2.1. Single land use dynamic

According to the equation, the single land use dynamic in Jining City is calculated. From Table 7, it can be seen that the order of dynamic K in 2000-2005 is: paddy field, town house, unutilized land, wood land, house-site in the countryside, dry land, waters and grass. The order of dynamic K in 2005-2010 is: town house, paddy field, unutilized land, grass, wood land, dry land, house-site in the countryside and waters. The order of dynamic K in 2010-2015 is: grass, town house, house-site in the countryside, paddy field, unutilized land, wood land, waters and dry land.

Looking at the three time periods, the dynamic degree of paddy field, town house and unutilized land is the largest, indicating changes of these types are the most intensive. With the change of farming methods, large areas of paddy field are transferred into other land types such as dry land. With the rapid development of the economy, the urbanization process has accelerated, and a large number of other land types have been transferred into town house. The original unutilized land has been exploited and utilized, and some of the land that has been exploited has been turned into abandoned land. The dynamics of dry land and waters are the lowest, indicating that the stability of these sites is good, which is consistent with the high retention rate of the land.

Table 7. Single land use dynamic (%).

|               | grass | town house | dry land | wood land | house-site in the countryside | paddy field | waters | unutilized land |
|---------------|-------|------------|----------|-----------|-------------------------------|-------------|--------|-----------------|
| 2000-2005     | 0.62  | 12.98      | 1.31     | 4.35      | 2.73                          | 16.76       | 0.72   | 7.32            |
| 2005-2010     | 1.45  | 7.68       | 0.44     | 0.97      | 0.34                          | 6.54        | 0.18   | 4.60            |
| 2010-2015     | 11.83 | 11.03      | 0.46     | 2.51      | 6.08                          | 5.12        | 0.58   | 4.28            |
4.2.2. Comprehensive land use dynamics

According to the equation, the comprehensive land use dynamic of Jining City is calculated. It is seen from Table 8 that the comprehensive land use dynamics first decreases and then increases, indicating that the intensity of land use change in Jining City first decreases and then increases, and the overall land use change is larger.

Table 8. Comprehensive land use dynamic

| time          | 2000-2005 | 2005-2010 | 2010-2015 |
|--------------|-----------|-----------|-----------|
| comprehensive land use dynamic LC | 1.36      | 0.70      | 2.27      |

5. Conclusion

Based on the LANDSAT remote sensing image data of 2000, 2005, 2010 and 2015, this paper applies RS, GIS, mathematical statistics and other methods, mainly about land use transfer matrix, single land use dynamic and comprehensive land use dynamic to analyse land use change in Jining City during the period from 2000 to 2015. The results show that:

(1) In all kinds of land use changes, the transfer intensity of grass is gradually increasing. With the acceleration of the economy and urbanization, dry land and house-site in the countryside are transferred largely into town house, and the town house area has been increasing. The transfer between dry land and house-site in the countryside is obvious. The area of wood land is gradually increasing. The change of transfer area of paddy field fluctuated greatly. The imported area of waters is always larger than the exported area in three periods and waters area has increased steadily. The unutilized land area is generally reduced.

In various time periods, transfer of various land use types have been complex, and the retention rate is also different. The retention rate of various land use types decreased significantly during 2010-2015, but the dry land as the largest land use type in Jining City, its retention rate has remained relatively high. In addition, the waters retention rate is higher, the paddy field retention rate is lower, and the unutilized land retention rate varies greatly.

(2) Combining the single land use dynamic during three time periods, the dynamic of paddy field, town house and unutilized land are the largest, indicating changes of these types are the most intensive; the lower dynamic degree of dry land and waters indicates the stability of these types is good.

The comprehensive land use dynamics first decreased and then increased, indicating that the intensity of land use change in Jining City first decreased and then increased, and the overall land use change is larger.

References

[1] Skole DL, Chomentowski W, Salas WA. et al. (1994) Physical and human dimensions of deforestation in Amazonia. BioScience, 44:314-322.
[2] Kienast F. (1993) Analysis of historic landscape patterns with a geographical information system-a methodological outline. Landscape ecology, 8:103-118.
[3] Iverson L, Prasad A. (1998) Estimating regional plant biodiversity with GIS modelling. Diversity and Distributions, 4:49-61.
[4] Tang H, Wu W, Yang P, et al. (2009) Recent progresses of land use and land cover change (LUCC) models. Acta Geographica Sinica –Chineses Edition, 64: 456-468.
[5] Li X (1999). Change of arable land area in China during the past 20 years and its policy implications. Journal of Natural Resources, 14: 329-333
[6] Li, M, Zhang H. (2003). Provinicial difference in cultivated land and grain productivity in China. Resources Science, 25: 49-56.
[7] Shi P, Pan Y, CHEN J, et al. (1999) Land use/cover change and environmental security in Shenzhen region. Journal of Natural Resources, 14: 293-299
[8] Li J, Ren Z. (2007). Research on the Value of Soil and Water Conservation in Loess Plateau in Northern Shaanxi Province. Scientia Agricultura Sinica, 40:2796-2803.

[9] Liu J, Kuang W, Zhang Z, et al. (2014) Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s. Journal of Geographical Sciences, 24: 195-210.

[10] Liu J, Ning J, Kuang W, et al. (2018) Spatiotemporal patterns and characteristics of land-use change in China during 2010–2015. Journal of Geographical Sciences, 28: 547-562.

[11] Zeng H, Gao L, Xia J. (2003) Dynamic analysis of urban landscape using a modified conversion matrix method: A case study in Nanchang City. Acta Ecologica Sinica, 23: 2201-2209.

[12] Zhu H, Li X. (2003) Discussion on the index method of regional land use change. Acta Geographica Sinica –Chines Edition, 58: 643-650.

[13] Wang X. (1999) Study on the methods of land use dynamic change research. Progress in geography, 18: 81-87.