Analysis of land use change in Xi’an based on GIS and RS

XueBei1*, Gao Shujing1, Zhang Xiuqin1

1Shaanxi, Xi’an, Engineering University of PAP, College of Information Engineering, 710054, CHINA

xhlin214@whu.edu.cn
*Xuebei123@126.com

Abstract: Along with fast economic growth, population increase and accelerated urbanization, the land use pattern of Xi’an is experiencing tectonic changes. Studying the land use change volume and spatial distribution in different regions in Xi’an will provide a basis for future studies on the urban spatial arrangement, land use management optimization and sustainable land use development. Based on GIS and RS technologies, this study explored the land use changes in Xi’an, analyzed the type, quantity, spatial arrangement and density of land use change, and introduced quantitative parameters including the dynamic level of land use, the transfer matrix, etc., for analysis. The results revealed that: 1) the major land use types in Xi’an were farmland, forest and built-up land; 2) in these 15 years, the area of grassland and built-up land increased, while the area of farmland decreased; 3) the dynamic level of comprehensive land use change increased, indicating intensive land use changes in Xi’an.

1. Introduction
Scientific advancement accelerated population aggregation in cities and regional economic growth, leading to rapid urbanization and inevitable land use changes [1]. China’s Western Development Initiative accelerated urbanization, followed by a considerable decrease in farmland and forest to support urban development; the intensive changes in land use pattern and spatial arrangement caused by urbanization in turn left an impact on the development of the city and its spatial arrangement [2]. Xi’an is now in a fast development stage and is experiencing a spate of problems including short supply of land, pollution, shortage of ecological land as well as the heat island effect caused by industrial development [3]. Using RS, GIS technologies and ArcGIS and statistical analysis, this study explored the spatio-temporal changes of land use in different regions in Xi’an, analyzed the quantity and spatial arrangement of land use change in Xi’an in the past 15 years, in hopes of providing a basis for rational land use arrangement, protection of environment and sustainable land use development in the future.

2. Study area and methods

2.1. Introduction to the study area
Xi’an is the largest city of fast economic growth in northwestern China. Located in Guanzhong Basin and adjacent to Qinling Mountain, the study area is featured by complex land form and rich resources, and it is a key ecological protection area. The city covers an area of 1097.7 km2, with 11 districts and 2 counties. This study analyzed the land use changes of 6 districts in Xi’an city and other 7 areas in Xi’an (Figure 1).
2.2. Data source and data processing

The data used in this study were Landsat remote sensing images, with a spatial resolution of 30 m. The images were obtained in June 2000, May 2005, June 2010 and May 2015, with good qualities. The ENVI5.5 software was used to conduct geometric correction, image alignment, radiometric calibration, atmospheric correction of the images, the Ecognition software was used to interpret the images and obtain land use data of different time periods (Figure 2). The major land use types included farmland, forest, grassland, water bodies, built-up land and unused land. Later, through random sampling, we selected verification sites in land use maps in four time periods to verify the interpretation accuracy of images, obtained the Kappa coefficient and the classification results. The accuracy was above 85% and the classification performance was good, and thus the land use data met the requirements of the paper.
2.3. Study methods

Study on land use change is wide covering and has many methods, the major parameters involved include quantity change, spatial distribution change, change of land use degree [4]. This study analyzed the general change patterns of land use in Xi’an from 2000 to 2015, and made quantitative analysis of regional difference of land use change in Xi’an based on indicators including dynamic land use change degree and transfer matrix, and obtained the dynamic spatio-temporal changes in land use pattern in 8 regions in Xi’an.

2.3.1. Land use change speed

Dynamic land use change degree describes the land use change rate of a region, and it plays a crucial role in forecast of future land use change [5]. There were two types of studies: study of change in a single-type land use and study of comprehensive land use change.

The single-type land use change reflects the impact of human activities on one certain land use type, as Eq. (1) shows [6, 7]:

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

where \( K \) is dynamic change of one single land use type of a given region; \( U_a \) and \( U_b \) is the quantitative change of a give land use type at the start and end of the study; \( T \) is the step size of the study phase.

The comprehensive land use change reflects the overall land use change in a given area, as Eq. (2) shows [6-10]:

\[ S = \frac{1}{t} \times \sum_{i=1}^{n} \left( \frac{\Delta S_{i-1}}{S_i} \right) \times 100\% \quad (2) \]

where \( S \) is the dynamic change of comprehensive land use change, \( t \) is the specific time period of change, \( \Delta S_{i-1} \) is the area of land type \( i \) converted into other land use types; \( S_i \) is the area of land use type \( i \).

2.3.2. Direction of land use transfer

The land use transfer matrix is used to conduct quantitative analysis of the volume and spatial arrangement of land use transfer [11]. The study used vectors pretreated by ArcGIS and established the transfer matrix, the mathematical model of which is as follows [12, 13]:

\[
P = P_{ij} = \begin{bmatrix}
p_{11} & \cdots & p_{1n} \\
\vdots & \ddots & \vdots \\
p_{n1} & \cdots & p_{nn}
\end{bmatrix}
\quad (3)
\]
3. Results and analysis

3.1. Overall features of land use change in Xi’an

Through interpretation and analysis of remote sensing images of Xi’an obtained in four time periods, we obtained the land use distribution data, and used Excel and GIS to make statistical analysis, the result of which is shown in Table 1.

| Time  | Type     | Farmland | Forest    | Grassland | Water bodies | Built-up land | Unused land |
|-------|----------|----------|-----------|-----------|--------------|---------------|-------------|
| 2000  | Area     | 4234.42  | 4832.54   | 242.56    | 66.08        | 645.01        | 77.10       |
|       | Proportion | 41.93%   | 47.86%    | 2.40%     | 0.65%        | 6.39%         | 0.76%       |
| 2005  | Area     | 4105.34  | 4845.58   | 247.62    | 57.10        | 762.33        | 79.73       |
|       | Proportion | 40.66%   | 47.99%    | 2.45%     | 0.57%        | 7.55%         | 0.79%       |
| 2010  | Area     | 3988.11  | 4857.92   | 254.87    | 55.20        | 863.02        | 78.59       |
|       | Proportion | 39.50%   | 48.11%    | 2.52%     | 0.55%        | 8.55%         | 0.78%       |
| 2015  | Area     | 3836.06  | 4845.59   | 306.59    | 74.48        | 947.45        | 87.54       |
|       | Proportion | 37.99%   | 47.99%    | 3.04%     | 0.74%        | 9.38%         | 0.87%       |

From 2000 to 2015, the areas for farmland, forest and built-up land took up a large proportion in Xi’an. Forest was the most widely distributed land type, while grassland, water bodies and unused land took a much smaller proportion. The data show that in the 15-year period, the “grain-for-green” policy and the coverage of Qingshui Mountain increased the area of forest in Xi’an from 4832.54 km² to 4845.59 km², accounting for 47.99% of the total area. The population boom increased the area of built-up land from 645.01 km² to 947.45 km², showing the most marked changes. Eco-reservation initiatives increased the grassland from 242.56 km² to 306.59 km²; the increase of area of other land use types led to a decrease in the area of farmland from 4234.42 km² to 3836.06 km², taking up only 37.99% of the total area. The area of water bodies and unused land increased to 74.48 km² and 87.54 km², respectively. Due to national policies and eco-protection initiatives, the area of farmland decreased quickly in Xi’an, while that of built-up land and grassland rose considerably, but showing difference among regions. The type and quantity of land use change also differ in different time periods (Table 2).

| Time  | Land use type | Yanling District | Lintong District | Gaoling District | Changle District | Lantian District | Chang’an District | Huyi District | Zhouhi County | Total |
|-------|---------------|------------------|------------------|------------------|------------------|------------------|------------------|--------------|--------------|-------|
| 2000-2005 | Farmland       | -3.97            | -9.13            | -10.61           | -46.03           | -9.03            | -30.85           | -12.36       | -7.10        | -129.08 |
|         | Forest         | 0.07             | 0.18             | 3.24             | 2.87             | 2.17             | 1.24             | 3.28         | 13.04        |
|         | Grassland      | 2.00             | 0.89             | 1.64             | -0.03            | -0.03            | 0.33             | 0.23         | 5.06         |
|         | Water bodies   | -0.82            | -2.35            | -1.65            | -4.06            | -0.45            | 0.31             | 0.04         | 8.98         |
|         | Built-up land  | 4.73             | 8.97             | 10.91            | 45.16            | 5.97             | 29.12            | 9.46         | 117.32       |
|         | Unused land    | 0.32             | 0.47             | 0.06             | 0.21             | 0.01             | 1.00             | 0.56         | 2.63         |
| 2005-2010 | Farmland       | -2.86            | -5.61            | -8.03            | -78.94           | -4.10            | -12.59           | -2.54        | -117.23      |
From 2000 to 2005, farmland and built-up land showed the most marked changes, where the changes in Chengliu District and Changan District were most tangible; the farmland reduced by 46.03 km² and 30.85 km², respectively, and the built-up land increased by 45.16 km² and 29.12 km², respectively. With the implementation of the “Grain-for-Green” strategy, the forest area in Xi’an increased by 13.04 km², with Zhouzhi County marking an increase of 3.28 km². The area of water bodies in Xi’an decreased, while that of grassland increased by 5.06 km².

From 2005 to 2010, accelerated urbanization caused a rapid shrink of farmland in Xi’an by 117.23 km², with the area of land converted to built-up land increased by 100.68 km², and the forest land increased by 12.34 km². The built-up land has been expanding in different regions; in Chengliu District, the farmland decreased by 78.94 km², and built-up land increased by 69.22 km²; in Chang’an District, the farmland decreased by 12.59 km², and 12.40 km² of land was converted to built-up land; the increase of built-up land in Gaoling District was mainly from the decrease of 8.03 km² of farmland; In Huyi District, farmland and water bodies shrank, while built-up land and grassland rose by 2.32 km² and 1.81 km², respectively. In Yanliang District, the major land use transfer was marked by conversion from farmland to built-up land; In Tonglin District, farmland was converted into forest and built-up land. In Lantian District, the farmland and grassland reduced by 4.10 km² and 0.06 km², respectively, leading to an increase in forest and built-up land by 3.10 km² and 1.06 km², respectively.

From 2010 to 2015, Xi’an witnessed considerable change in the area of farmland, and the total decrease of farmland reached 152.05 km², the built-up land and grassland increased by 84.43 km² and 51.72 km², respectively, and the forest reduced by 12.33 km². Among all the regions studied, Chengliu District, Chang’an District and Lantian District marked the largest changes: built-up land in Chengliu District increased to 45.07 km², and by 36.57 km² in Chang’an District. Zhouzhi District and Lantian District marked the largest change in forest, i.e. -30.84 km² and 15.95 km²; the grassland also showed considerable change, having increased by 28.24 km² and 25.62 km², respectively. In Chengliu District and Zhouzhi District, the water bodies increased by 6.15 km² and 5.49 km², showing more tangible changes than in other regions.

### 3.2 Dynamic land use change analysis of Xi’an

From 2000 to 2005, the largest single-type change occurred in water bodies and built-up land, where
Yanliang District and Gaoling District showed the largest decrease of water bodies. The dynamic land use change rates of built-up land in Chang’an District and Gaoling District were 0.33 and 0.29; from 2005 to 2010, all areas in Xi’an except Zhouzhi County showed a decrease in farmland, with Chengliu District showing the largest decrease, with a dynamic change rate of -0.17; Chengliu District showed considerable change in forest and built-up land; Huyi District and Gaoling District had a grassland change rate of 0.59 and 0.34, respectively, marking the largest change among all regions. From 2010 to 2015, the grassland, water bodies and built-up land in different regions showed changes, where the following marked the largest changes: the grassland change rate in Zhouzhi County reached 0.56, the water bodies change rate in Chengliu District reached 0.84, and the built-up land change rate in Chang’an District was 0.27.

The software was used to calculate the comprehensive dynamic land use change rate of Xi’an, the result of which showed sharp changes in land use types in the studied regions. In 2000 – 2005, there was large difference in comprehensive land use change in different regions in Xi’an: Gaoling District and Yanling District had a comprehensive land use change rate of 0.51% and 2.02%, respectively; Zhouzhi County showed slow land use change, indicating the small impact of human activities on land use change; in 2005 – 2010, Chengliu District, Gaoling District and Huyi District marked the largest land use change, with a comprehensive land use change rate of 0.39%, 0.26%, and 0.23%, respectively. In 2010 – 2015, the comprehensive dynamic land use change rate in Xi’an showed considerable change, indicating intensive land use change, where Zhouzhi County had the largest rate of 1.18%, while that for Chang’an District, Lantian County and Yanliang District was 0.78%, 0.77% and 0.46%, respectively; Chengliu District had a dynamic comprehensive land use change rate of 0.34%.

3.3. Spatial analysis of land use change in Xi’an
ArcGIS was used to process the data to obtain the land use transfer matrix, with five years as the unit. The analysis result showed that forest and built-up land showed the largest increase, while farmland and grassland decreased constantly. A land use transfer matrix was built to analyze the land use change data from 2000 to 2005 in Xi’an. The result showed that built-up land, forest and grassland showed considerable increases in Xi’an, while the area for farmland and water bodies decreased markedly. The conversion from farmland to built-up land reached 117.26 km², 14.55 km² farmland was converted to forest, and the area of water bodies converted to forest and grassland reached 14.74 km² and 5.83 km².

From 2005 to 2010, the farmland reduced by 117.23 km², showing the biggest change. Most farmland was converted to built-up land, reaching 100.28 km²; 11.81 km² farmland was converted to forest, 4.92 km² to grassland, and 3.05 km² to water bodies. The area of grassland converted to farmland and forest was 0.67 km² and 0.25 km², respectively; the area of water bodies converted to farmland and grassland was 2.05 km² and 4.46 km², respectively; the changes in water bodies and unused land were smaller than other land use types, with a minor decrease caused by conversion into other areas (1.9 km² and 1.14 km², respectively). From 2010 to 2015, the largest mutual conversion occurred among farmland, forest and grassland. 60.33 km² of forest was converted into grassland, and 25.38 km² of grassland was converted into forest; 24.16 km² of farmland was converted into forest, and 11.48 km² into grassland. The increase in water bodies was mainly converted from farmland and forest, the conversion area was 17.77 km² and 1.52 km², respectively. The area of unused land converted to forest and grassland was 1.00 km² and 5.29 km², respectively.

The land use transfer matrix in the three time periods. As the figure shows, the grassland and built-up land in Xi’an has been expanding, while the area of farmland decreased considerably. Chengliu District marked the largest conversion among land use types, which is consistent with the analysis of land use change.

4. Conclusions
With remote sensing images obtained from RS, this study used RS and GIS to interpret land use change data of Xi’an in different time periods, and through Excel analysis, the following conclusions
were reached:

First, in 2000 – 2005, the major land use types in Xi’an were farmland, forest and built-up land; while grassland, water bodies and unused land took a smaller proportion; forest accounted for the largest area;

Second, in the context of rapid economic growth and implementation of national policies, the general land use pattern in Xi’an was: the area of farmland decreased, while that of built-up land and grassland increased rapidly.

Third, in 2000 – 2005, Chengliu District and Chang’an District showed the largest land use change, and the largest single-type land use change occurred in built-up land and water bodies; in 2005 – 2010, farmland in Xi’an decreased by 117.23 km², and the area of water bodies showed little change.

To realize effective development and utilization of land resources, and solve conflicts between economic growth and land use, we should coordinate development of land in Xi’an according to the local characteristics and strengthen land use planning and management.

References
[1] Tao Wenfang, Zhang Renhui, et al. spatio-temporal land cover change in Xi’an and driving factors [J]. Agricultural Research in the Arid Areas, 2010, 28(02):231-236.
[2] Li Yuan, Lin Feng, Yan Zexing. Urban evolution analysis based on Landsat remote sensing images – a case study of Xiamen [J]. Urbanism and Architecture. 2019, 16(25):138-142.
[3] Li Fengxia, Shi Hui, et al. Dynamic evolution of land use pattern in Xi’an and driving factors [J]. Bulletin of Surveying and Mapping, 2015(12):41-45+56.
[4] Guo Honglei, Zhou Qigang, Jiao Huan, et al. Characteristics of land use change in Three Gorges Reservoir area [J]. Research of Soil and Water Conservation, 2016, 23(2):313-317.
[5] Wang Xiulan, Bao Yuhai. Research methods for land use dynamic change [J]. Progress in Geography, 1999, 18(1):81-87.
[6] Song Kaishan, Liu Dianwei, Wang Zongming, et al. Land use change in Three River Plain since 1954 and driving factors [J]. Acta Geographica Sinica, 2008, 63(1):93-104.
[7] Ren Zhiyuan. Land use change in suburbs and regional eco-security dynamics [M]. Science Publishing House, 2006
[8] Liu Jiuyuan, Buhe Aosier. Spatio-temporal characteristics of land use change in China – based on satellite remote sensing data [J]. Quaternary Sciences, 2000, 20(3):229-239.
[9] Liu Jiuyuan, Liu Mingliang, Zhuang Dafang, et al. spatial pattern of recent land use change in China [J]. Scientia Sinica, 2002,32(12):1031-1040.
[10] Liu Jiuyuan, Kuang Wenhui, Zhang Zengxiang, et al. Basic characteristics and spatial pattern of land use change in China since the 1980s [J]. Journal of Geographical Sciences, 2014,69(1):3-14.
[11] Ren Feipeng, Jiang Yuan, Xiong Xing, et al. Spatio-temporal changes in land use change in Dongjiang Basin in the last 20 years [J]. Resources Science, 2011, 33(1):143-152.
[12] Bai Genchuan, Xia Jianguo, Wang Chuangquan, et al. Analysis of land use conversion in Dongpo District in Meishan City based on the land type spatial conversion model [J]. Resources Scieince, 2009,31(10): 1793-1799.
[13] Lin Xiaohu, Yao Wanqiang, Qiu Chunxia. Land use change driven by the Grain to Green strategy in the valleys of Losses Hill area – a case study of Zhifang River Basin in Ansai County, Shaanxi Province [J]. Journal of Mountain Science, 2015(6): 759-769.