Land Use/Cover Changes in the rural-urban interaction of Xi’an Region, West China, using Lansat TM/ETM data

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Abstract
Landsat ETM/TM data and an artificial neural network (ANN) were applied to analyse the expanding of the city of Xi’an and land use/cover changing of its surrounding area between 2000 and 2003. Supervised classification and normalized difference barren index (NDBI) were used respectively to retrieve its urban boundary. Results showed that the urban area had increased by the rate of 12.3% per year, with area expansion from 253.37 km² in 2000 to 358.60 km² in 2003. Large areas of farmland in the north and southwest were converted into urban construction land. The land use/cover changes of Xi’an were mainly caused by: fast development of urban economic, population immigration from countryside, great development of infrastructure such as transportation, and huge demands of urban market. In addition, affected by the government policy of "returning farmland to woodland ", some farmland was converted to economic woodland, such as Chinese gooseberry garden and vineyard etc.

Key words: urban expansion, supervised classification, NDB, land use/cover change
Introduction

Urbanization process in Xi’an has been accelerated after the central government put up with Strategy of Grand Development of Western China about 4 years ago, which has caused the losing of farmland in urban periphery areas. What's more, urban expansion has also deeply affected urban periphery ecological environment. Understanding such interaction between urban cities and rural regions is important for sustainable development of those areas. The variation of urban boundary extracted from satellite can more efficiently and quickly reflect dynamic changes of urban expansion by comparing with traditional statistical data. Many experiments on land use/cover changes in cities or between the urban and rural areas had been carried out by researchers from all over the world since the first earth resource satellite was launched in 1970s in the United States. Land use/cover maps for the urban area of Boston were produced at level III of Anderson et al. (1972) scheme using large format camera shuttle photographs and national high altitude photographs. The accuracy of them was 65% and 70% respectively (Lo & Noble, 1990). The potential of SPOT XS images were tested for automatically outlining agricultural near-urban interfaces for an area around Yogyakarta, Central Java, and satisfying results were gotten which were comparable to those obtained from visual interpretation of 1:100 000 near-infrared aerial photographs (Gastellu-Etchegorry, 1990). Eight land covers were mapped at level of Anderson scheme on the urban fringe in England from Landsat MSS data (Curran & Pedley, 1990). 10 m resolution of the SPOT panchromatic band was used by registering it with the multi-spectral ones to obtain a classification of eight land covers at the urban-rural fringe of Toronto, Canada with an accuracy of 78% (Treitz et al., 1992). Three Landsat MSS images were also utilized to monitor the urban expansion of Montreal, Canada (Charbonneau et al., 1993). Five-category classification was obtained in the small urban area of Beaver Dam, Wisconsin (Harris & Entura, 1995). Detailed land cover maps were produced at the urban-rural periphery in southern Auckland using Spot XS data, and reflected the influence on land use at the urban fringe (Gao & Skillcorn, 1998). Using TM imagery residential areas were extracted with simple threshold of spectrum structure (Yang & Zhou, 2000). From TM imagery using normalized difference built-up index, the urban land-use map of Wuxi city was achieved (Zha, 2003). These researches have done available efforts on retrieving urban boundaries, but to obtain efficiently the urban boundary as to know more clearly the urban expansion and analyze its effect on land use/cover change need to be studied further.

The present paper analyzed urban expansion impacts on land use/cover changes in Xi’an from year of 2000 to 2003, with objectives of: (1) to retrieve the two phases of urban boundary of Xi’an in 2000 and 2003 using supervised classification and NDBI respectively followed by comparison of the results derived from these two different methods; (2) to map urban land
use/cover of Xi’an in 2000 and 2003, thus to find the factors caused land use/cover changes during the past 3 years; and (3) to propose some suggestions for the city’s development, while protecting limited farmland resources and ecological environment.

**Materials and methods**

**Study area**

Xi’an (107°41’-109°49’E, 33°39’-34°44’N), a city in West China, has an area of about 9,983 km², and located in the middle of the Guanzhong Plain (the alluvial plain of Weihe River). Elevation of the southeast of this area is high with Qinling Mountain surrounded while the northwest is relatively low (Fig. 1). It belongs to the continental climate region of temperate zone, annual average temperate is 13.0°C, and annual mean precipitation is 604.2 mm. In recent years, along with the increase of population, economic development, improvement of investment environment, Xi’an has witnessed a rapid urbanization, which in reverse has deeply affected ecological environment in the urban and rural regions.

![Fig. 1. Location of study area](image)
Data Acquisition

In this study, a Landsat 7 ETM+ image of 26 April 2000 and a Landsat 5 TM image of 29 May 2003 were required. The orbit data of the two images is 127/36, and their spatial resolution is 30 m. Digital Elevation Model (DEM) of study area with spatial resolution of 30 m in Xi’an region was also acquired. Besides, some statistical data of Xi’an was required here.

Fig. 2. The flow chart of analyzing driving force of urban expansion

Data processing

The basic idea of this research was to retrieve the urban boundary of different image phases using Landsat ETM/TM data, and then to map the land cover of the two years with artificial neural network (ANN), finally to analyse the impacts of urban expansion on land use/cover change (Fig. 2). Detailed illustration of data processing was as follows:

1) Imagery pre-processing
To retrieve urban boundary efficiently, the pre-processing included atmospheric correction, geometric correction, and orthographic correction. The purpose of atmospheric correction was to obtain accurate reflective characteristics of ground surface, followed by geometric correction which ground con-
control points were chosen referencing to a topographic map of 1:50 000. To efficiently reduce the topographic effect on solar radiation, DEM was employed to promote orthographic correction on remote sensing images.

(2) Retrieval of urban boundary
In this research, two methods were used to retrieve urban boundary, namely supervised classification and normalized difference barren index (NDBI). By comparing the results derived from these two methods, the more precise one was confirmed as the urban boundary.

(3) Mapping land cover of 2000 and 2003
Land use/cover both in 2000 and 2003 were mapped by using artificial neural network (ANN). Then the change of land use/cover during the three years can be acquired.

(4) Analyzing impacts of urban expansion on land use/cover change
Using the statistical data of Xi’an in recent years, effect of urban expansion on land use/cover change was analyzed.

**Retrieval of urban boundary in Xi’an**

**Supervised classification**

Supervised classification is the most common method in obtaining land use/cover information. In this research, after data pre-processing, training samples were selected according to spectrum features. Unlike conventional classification of land use/cover, in this paper, only two classifications of land cover were chosen, which were urban regions and non-urban regions. This could avoid the urban areas from extra classes. Then maximum likelihood classification was used to map the land use/cover of Xi’an. Figs. 3(b) and 4(b) are the results of the classification. It can be seen from the report provided by the software of PCI, that the overall accuracy of classification of 2000 and 2003 reached 98.96% and 96.80%, and the Kappa Coefficients of them were 0.99 and 0.97 respectively. From the classified images, it is clear to see that non-homogeneous urban area was influenced by green land and water body. In order to convert raster data into vector map, the classified result was filtered by a window of 5*5, and then carried out aggregation. That is to say, the non-urban part within the city was merged into urban area and the urban part outside the city was aggregated into non-urban part, then in turn, urban profiles were obtained. Based on this, urban boundaries of Xi’an in 2000 and 2003 were extracted by converting raster to vector. Figs. 3(c) and 4(c) are the results.
To ensure the authenticity of urban boundary, in this study, another method, normalized difference barren index (NDBI), was used to extract urban boundary of Xi’an based on the RS image of 2000. NDBI takes advantage of the unique spectral response of built-up areas and the other land covers. Built-up areas are effectively mapped through arithmetic manipulation of re-coded NDVI (normalized difference built-up index) (Zha et al., 2003). Like NDBI, NDWI (normalized difference water index) and NDSI (normalized difference snow index) were also developed to map water bodies and glaciers (Sidjak and Wheate, 1999; Hall et al., 1995; McFeeters, 1996; Gao, 1996).

From the spectrum feature of ground, band 4 (0.76-0.90 μm) of TM/ETM+ is the near infrared waveband which reflects vegetation information. Thus this band is very sensitive to detect vegetation, while reflectance of barren and
residential areas in this band is low. ETM/TM5 (1.55-1.75 \mu m), the short-wave infrared waveband, can reflect the information of moisture content in different land use types. For example, in band5 the reflectance of forest and farmland with high moisture content is low, but for residential and barren areas that have low moisture content, the reflectance is high. Researches indicated that on Landsat TM/ETM+ images, except urban and barren areas, the digital numbers of other landscape in band 4 are lower than that of band 5 (Yang, 2000, Zha, 2003). NDBI is the result of calculation of (band 5-band 4)/(band 5+band 4)(Fig. 5a). Because this index can reflect urban information, so it was named normalized difference built-up index (Zha, 2003). But considering that it reveals the barren feature of ground from essence, we define this index as normalized difference barren index (NDBI).

The value of NDBI in Xi’an ranges from -0.44 to 0.16. However, -0.1 was finally chosen as threshold value to do finalization processing for the NDBI map after enough training. The region where the NDBI varied between -0.44 and 0.1 was colour with blue, while the other region between -0.1 and 0.160142 was colour with green (Fig. 5b). Then mask processing was done to the binary image, thus urban area of Xi’an was extracted. By converting raster to vector, we get the urban boundary of Xi’an (Fig. 5c).

**Comparison of the two methods**

From Fig. 3(b) and Fig. 4(b), it can be easily found that although supervised classification had a high precision of in retrieving urban boundary, and its overall accuracy reached 98.96\%, by visual inspection small towns in the image still could not be retrieved. Big cities like Xi’an and Xianyang can be retrieved accurately, so to the research objectives in this paper, supervised classification is a perfect method. But if we want to retrieve all the towns from the image, the method should be further modified, especially in the aspect of choosing training samples, or a few towns need to be ignored.
So far as NDBI is concerned, it could retrieve almost all the information of towns. But comparing Fig. 3 and Fig. 5, we can find that, because of similar spectrum feature, the urban area contains some barren, even binarization processing cannot reduce the influence of barren, which magnified real urban areas. In this research, 80 checking points were selected from the results of urban boundary for precision analysis. Table 1 is the confusion matrix.

Table 1. Confusion matrix based on binary results

<table>
<thead>
<tr>
<th></th>
<th>Towns</th>
<th>Others</th>
<th>Total</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towns</td>
<td>6</td>
<td>3</td>
<td>9</td>
<td>66.67</td>
</tr>
<tr>
<td>Non-towns</td>
<td>14</td>
<td>57</td>
<td>71</td>
<td>82.28</td>
</tr>
<tr>
<td>Totals</td>
<td>20</td>
<td>60</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

From Table 1, the confusion matrix shows that the accuracy of urban areas and non-urban areas is 66.67% and 82.28% respectively, and average accuracy of them is 78.75%. By comparing the retrieved urban boundary and remote sensing images, we can find that some barren areas were contained in the boundary, thus area of the city was magnified.

In conclusion, both these two methods have advantages and disadvantages. But supervised classification is a perfect method in this research, as its precision is much higher than that of NDBI. Therefore, the urban boundaries extracted from supervised classification were reliable.

**Urban expansion and its features**

By analyzing the urban boundaries of Xi’an in 2000 and 2003 resulted from supervised classification, we can find that during the 3 years, Xi’an has witnessed a rapid urban expansion. From 2000 to 2003, the urban area has added 106.89 km², from 257.07 km² to 363.96 km². The average increase rate was 12.3% per year. The conspicuous expansion region mainly happened in the north of the city (Weiyang District) and the south (Yanta District and Chang-an District). However, there was little change in the east and west of the city. The causes of urban expansion in the north and the south Xi’an was the high and new technological industry zone and Xi’an economical and technological development zone which are newly located in these two regions, respectively. Because of large-scale construction of development zone, large scale constructions of infrastructures have made urban expansion to develop rapidly.
Land use/cover change of Xi’an from 2000 to 2003 and its causation

Principle of BP neural network

The algorithm which is widely used to adjust the weight of multiple layer perception, was proposed by Rummlerhart et al (1986), and that is the BP algorithm, which can be demonstrated as in Fig. 6: 3-layer neural network (including an input layer, a hidden layer and an output layer).

Fig. 6. The structure of neural network

Each node of x, y and z accordingly represents a nerve cell, a hidden node and an output node. There is not any relationship between the nodes in the same layer. Nodes between each layer formed a focalized connecting route, and the connecting intensity was denoted by w, namely weight value.

Mapping land use/cover of 2000 and 2003

The input of the neural network in this study are six bands of ETM+/TM images, so the node number in the input layer is 6, only one hidden layer was employed in the neural network. Since land use/cover is classified into six types, the output layer nodes are defined to 6. With these parameters, images of 2000 and 2003 were processed under BPNN method. The results of land use/cover maps are shown as Fig. 7. The area of each land cover in 2000 and 2003 can be seen in Table 2.
Table 2. Land use/cover change in Xi’an from 2000 to 2003

<table>
<thead>
<tr>
<th>Year</th>
<th>Land use/cover types</th>
<th>Urban built-up (km²)</th>
<th>Water body (km²)</th>
<th>Farmland (km²)</th>
<th>Orchard (km²)</th>
<th>Woodland (km²)</th>
<th>Uncultivated land (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td></td>
<td>202.64</td>
<td>8.01</td>
<td>41.71</td>
<td>28.97</td>
<td>0.50</td>
<td>82.13</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>256.45</td>
<td>9.68</td>
<td>7.93</td>
<td>39.77</td>
<td>1.51</td>
<td>48.62</td>
</tr>
</tbody>
</table>

Table 2 shows that affected by urban expansion, the land cover in Xi’an between 2000 and 2003 changed greatly. Urban infrastructure construction land added 53.91 km², woodland, orchard and water body increased 1.01 km², 10.80 km² and 1.67 km² respectively, while farmland and uncultivated land reduced 33.78 km² and 33.51 km².

Figure. 7. Land use/cover change of Xi’an from 2000 to 2003

Causes for land use/cover change

From analysis for land use/cover change in Xi’an during the past three years, it can be found that area of urban infrastructure construction and orchard land increased a lot, while farmland reduced rapidly. One direct reason for this change was the policy “returning farmland to woodland”, which converted a mass of farmland to economic woodland and other kinds of woodland. Besides this reason, there are still four important ones for this great change.

Firstly, Xi’an has been developing fast under the environment of rapid development of West China. GDPs of 2000 and 2003 were 326 billion (RMB) and 940 billion (RMB) respectively. For the sake of developing economy, Xi’an
established two large-scale development zones, namely Xi’an High Technology Industry Zone and Xi’an Economy & Technology Development Zone, which are located in the north and south of the city. Thus, the urban area increased rapidly. At the same time, a lot of farmland was converted to urban construction land.

Secondly, continuous increase of population and housing demands accelerated the real estate development on the outskirts of Xi’an city, which converted farmland to residential land.

What is more, traffic, water, power, natural gas and other various infrastructures are some other driving forces of urban development and expansion. Large-scale infrastructure construction has been developed in need of rapid urban development, which provided convenience for the development of real estate, industrial and economical development zones at the urban fringe. These constructions resulted in land use change.

In addition, great demands for increasing farming productivity due to urban expansion were also an important reason. Centralized urban markets need abundant farm production, which can bring considerable economic benefits, therefore to drive the adjustment of development of some special farm production and agricultural structures. This is the fundamental cause for internal conversion of different kinds of agriculture land use. In this study area, a lot of farmland was converted to orchard and other kinds of woodlands.

**Discussion and conclusion**

We can get the following conclusions by analyzing the effect of urban expansion on land use/cover changes that occurred in Xi’an between 2000 and 2003.

To retrieve urban boundary, supervised classification and normalized difference barren index (NDBI) were used. The spectrum of barren land is similar to that of urban area. NDBI became a primary noise in retrieving urban information. Therefore, how to reduce the effect of barren land needs further study. Once extracted Urban land-use in the region of the Taihu Lake was once extracted by NDBI and the result they got was satisfactory (Yang, 2000; Zha, 2003). While Xi’an locates in the northwest of China, where the climate is dry, the universality of NDBI should be further studied. In this paper, it is obvious that supervised classification is more accurate than NDBI for Xi’an in reducing effect of barren land. The average accuracy of supervised classification and NDBI is 98.96% and 78.75%. So we consider supervised classification as a perfect method in retrieving urban boundary. According to the urban boundary of 2000 and 2003 in Xi’an, urban area of Xi’an increased 105.23 km² during the 3 years and the increase rate was 12.3% per year.
Urban periphery of Xi’an is the region where land use/cover changed greatly. The primary feature of land cover change was that large numbers of farmland was occupied by urban construction. In addition, affected by the strategy of great development of western China and the policy of "Reclamation woodland from farmland", a lot of farmland was converted to economical woodland or other woodland.

Land use/cover change of Xi’an was driven by many factors, however human activity was the most important one. Rapid economic development and fast urbanization was the fundamental reasons for land cover change from 2000 to 2003. What is more, investment of social assets, development of urban economy, construction of infrastructure, such as transportation and internal adjustment of agricultural land use played important roles in the process of land change.

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