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ORIGINAL RESEARCH ARTICLE

Remote sensing analysis of land use/cover change

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ABSTRACT

Based on Landsat–7ETM + images of 2007 and 2012 and Landsat–8 images of 2018, this study took Fuyang City, Anhui Province (Yingzhou District, Yingdong District, Yingquan District) as the research object, and made a quantitative analysis of land use/cover change in Fuyang City from 2007 to 2018 with the Environment for Visualizing Images (ENVI) software. According to the data of land use types in three phases, the article analyzes the development trend of various land use types and the main reasons for the changes of land use, which provides a certain basis for the urban planning and environmental construction of Fuyang City. The results show that with the rapid economic development and continuous improvement of the urbanization level in Fuyang City during 11 years, the area of various land types in the study area has changed greatly. The area of construction land area changed by 448.27 km^2, with an increase of 543.57%; the area of arable land changed by 597.52 km^2, with a decrease of 34.74%; the area of bare land changed by 26.00 km^2, with a decrease of 80.68%. The changes were closely related to the rapid economic and social development in the study area. Under the influence of environmental protection policies and environmental awareness, the area of forest land changed by 85.00 km^2, with an increase of 97.58%; the water area changed by 84.35 km^2, with an increase of 201.39%.

Keywords: Land Use; Cover Change; Remote Sensing; Environment for Visualizing Images (ENVI)

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1. Introduction

Land use/cover change is a complex change caused by the interaction of natural and social systems at different time and spatial scales[1]. The breadth, depth and reasonable degree of land use/cover change are the concentrated reflection of land use/cover change, scale, level and characteristics of land production[2,3]. The rapid economic development and the rapid expansion of urban construction land in Fuyang City, the decreasing vegetation coverage, and water pollution are affecting land use/cover change, especially in the last 11 years. Returning farmland to forests, building a beautiful countryside plus restrictions on private housing construction and prohibition of arbitrary changes in land nature also have a deep impact on land use/cover change[4]. With remote sensing technology, relevant domestic research mainly concentrated in big cities, regions with rapid economic development and regions with fragile ecological environment such as western China[5–7], whereas the research of small cities with slow economic growth using remote sensing technology accounts for a relatively small proportion[8]. Yang[9] analyzed land use change in Fuyang City based on remote sensing technology (RS) and the geographic information system (GIS) in 2010. However, there is little research on recent land use change in Fuyang urban area. In this article, the Environment for Visualizing Images (ENVI) software calculated Landsat–7ETM + images of 2007 and 2012 and Landsat–8 image transfer matrixes and classification maps of 2018. Key data were analyzed by relevant modules and results were obtained to analyze the phenomenon and its causes. It has certain reference value for the decision-making of urbanization, environment and development planning in the study area[10,11].

2. Overview of the study area

The urban area of Fuyang City is located in the center of Fuyang City where Yinghe River and Quanhe River intersect, including Yingzhou District, Yingquan District and Yingdong District, with a total administrative area of 1957 km^2. The land type is mainly plain with open and flat terrain. Due to its geographical location, Fuyang has four distinct seasons, with appropriate rainfall and sunlight exposure. The city is very suitable for the development of agriculture, wheat, corn, soybeans, cotton, vegetables and other major crops. Fuyang is also one of the main cities exporting agricultural and sideline products in Anhui province. It borders Huainan City in the east, Zhoukou City and Zhumadian City in Henan province in the west, Lu'an City in the south across the Huaihe River, and Bozhou City in the north. As of the end of 2019, Fuyang has a permanent population of about 8.26 million, making it one of the most populous cities with a large labor source in Anhui Province, and has an urban population of 2.03 million. Fuyang has convenient transportation, with a railway network second only to Hefei in the province.

3. Research methods

3.1 Data acquisition and preprocessing

The latest vector boundary of Fuyang City was obtained from the National Natural Resources and Geospatial Basic Information Base (2017 I50. gdb vector diagram). Two phases of Landsat–7ETM + remote sensing images and one phase of Landsat–8 images were downloaded from the geospatial data cloud. The selected three phases of remote sensing images had a resolution of 30 m and the cloud amount was less than 5. The dates are August 1, 2007, September 15, 2012 and September 8, 2018.

Band fusion was performed on the downloaded image data. Stripe removal was carried out for Landsat–7ETM + images. ENVI's geometric correction module was started for geometric correction of remote sensing images in the study area. First, the Landsat–8 images of Fuyang City in 2018 were corrected according to the map to be taken as the reference images, and then other images of the two phases were used as the registration images. Twenty control points with obvious features in both the reference images and the registration images were selected to be corrected by using quadratic polynomial, and the pixel error after correction was within one pixel. Using the vector file of the urban area of Fuyang City, the vector images of the study area were cut out, and the remote sensing images of the study area were obtained after image masking.

3.2 Supervised classification and method selection

Based on the actual situation that the urban area of Fuyang City can reflect the development and change of land types and the actual interpretation ability of the three-phase images, the land use types of Fuyang City were divided into five categories: construction land, arable land, forest land, water area and bare land.

The confusion matrix in the ENVI software was used to select the supervised classification method with high classification accuracy. The main parameters included general classification accuracy and Kappa coefficient, and the formula was as follows.

Overall classification accuracy:

$$P_c = \sum_{k=1}^{m} P_{kk}/N \quad (1)$$

Kappa coefficient:

$$K = \frac{N\sum_{i=1}^{m} P_{ii} - \sum_{i=1}^{m}(P_{pi} - P_{li})}{N^2 - \sum_{i=1}^{m}(P_{pi} - P_{li})} \quad (2)$$

In the formula, P_c is the total classification accuracy; m is the number of classification categories; N is the total number of samples; P_{kk} is the discriminant sample number of class k. K is the Kappa coefficient; k is the total number of columns in a certain category; i is the total number of rows of a class.

Under the same training samples, six supervised classification methods including the maximum likelihood method, minimum distance method, parallelized hexahedron method, Mahalanobis distance method, support vector machine method and neural network method were used one by one to extract relevant parameters of land use/cover change. The accuracy of each classification method was counted and compared, as shown in **Table 1**. The maximum likelihood method was adopted because of its better classification effect.

Table 1. Comparison of classification accuracy

Classification method	2007		2012		2018	
	Total accuracy /%	Kappa coefficient	Total accuracy /%	Kappa coefficient	Total accuracy /%	Kappa coefficient
Maximum likelihood method	98.23	0.97	96.49	0.94	95.03	0.93
Minimum distance method	97.82	0.97	94.82	0.94	96.87	0.96
Parallelized hexahedron method	68.67	0.46	93.18	0.89	98.07	0.94
Mahalanobis distance method	93.35	0.92	96.74	0.95	97.13	0.96
Support vector machine method	96.59	0.94	98.59	0.98	54.13	0.44
Neural network method	89.65	0.83	94.85	0.91	92.08	0.88

3.3 Evaluation of classification accuracy

Based on the training samples determined by image classification of land use/cover change, the pixel level classification accuracy evaluation method was used to evaluate the accuracy of the land use/cover change classification map[12]. As can be seen from **Table 1** and **Table 2**, the overall classification accuracy of images is very high. Due to high resolution and common phenomena of different objects with the same spectra characteristics in Landsat–8 images, water classification accuracy is only 80.71%. In general, the classification effect is ideal. The overall classification accuracy of the three-phase images is above 95%, and the Kappa coefficient is above 0.93.

Table 2. Classification accuracy evaluation (unit: %)

Type	Producer accuracy			User accuracy		
	2007	2012	2018	2007	2012	2018
Construction land	98.31	99.52	96.64	65.13	75.24	98.25
Arable land	96.93	95.76	88.43	99.71	96.73	99.05
Forest land	94.97	87.60	99.63	95.75	83.79	72.69
Water area	99.71	91.94	80.71	90.10	100.00	53.63
Bare land	88.16	82.84	96.34	81.45	98.53	79.39

4. Results

4.1 Analysis of land type area change

Using the module of land use/cover change transfer matrix in the ENVI software, the three-phase land use/cover change transfer matrix in Fuyang City was obtained. Through analyzing the actual state of all kinds of land use changes in Fuyang City during the past 11 years from 2007 to 2018 reflected from the data in the table, the key data of land use type transfer matrix in the study area were obtained.

The classification of images in the three phases was statistically analyzed, and the table of change data was obtained, as shown in **Table 3** and **Table 4**. The total land area of the study area is 1,957.23 km^2.

Table 3. Transfer matrix in 2007–2012 (unit: km^2)

2017	2012					
	Construction land	**Arable land**	**Forest land**	**Water area**	**Bare land**	**Total**
Construction land	41.32	1.14	3.16	0.90	1.14	82.47
Arable land	115.02	1,444.57	11.66	23.85	24.77	1,719.88
Forest land	5.36	70.30	6.67	3.89	0.89	87.11
Water area	1.62	22.56	0.97	16.71	0.31	42.18
Bare land	3.03	20.26	1.37	0.45	0.49	25.59
Total	166.35	1,593.63	123.83	45.81	27.61	–

Table 4. Transfer matrix in 2012–2018 (unit: km^2)

2012	2018					
	Construction land	**Arable land**	**Forest land**	**Water area**	**Bare land**	**Total**
Construction land	134.59	22.56	4.06	4.95	0.19	166.35
Arable land	351.05	998.25	142.67	97.37	4.32	1,593.65
Forest land	30.75	77.13	10.31	5.39	0.26	123.84
Water area	4.92	11.68	11.30	17.87	0.04	45.81
Bare land	9.42	12.74	3.77	1.53	0.14	27.61
Total	530.73	1,122.36	172.11	127.12	4.94	–

From 2007 to 2012, the area of construction land in Fuyang City increased from 82.47 km^2 to 166.35 km^2, with an increase of 101.72%; the area of forestland increased from 87. 11 km^2 to 123.83 km^2, with an increase of 87.11%; the area of arable land decreased from 1,719.88 km^2 to 1,593.63 km^2, with a decrease of 7.34%; the water area increased from 42.18 km^2 to 45.81 km^2, with an increase of 8.62%; the area of bare land increased 2.02 km^2, with an increase of 7.89%.

From 2012 to 2018, the area of construction land increased by 364.38 km^2, and the area of arable land in the urban area of Fuyang City changed to 530.73 km^2, with a change of –29.57%; the area of forest land increased from 123.84 km^2 to 172.11 km^2, with a change of 38.97%; the water area increased by 81.31 km^2; the area of bare land decreased 22.67 km^2, with a change of –82.11%.

From 2007 to 2018, the area of construction land in the urban area of Fuyang City increased from 82.47 km^2 to 530.73 km^2, with an increase of 543.56%. The area of arable land decreased from 1,719.88 km^2 to 1,122.36 km^2, with a change of –34.74%; the water area changed by 84.94 km^2, with an increase of 201.39%; the area of forest land changed by 85.00 km^2, with an increase of 97.58%; the area of bare land changed by 20.65 km^2, with a change of –80.68%.

4.2 Dynamic change of land types

Using the dynamic degree formula of coverage type[12]:

$$L = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \tag{3}$$

In the formula, L is the dynamic attitude of a certain land use type in the research period; U_a and U_b are the amount of a certain land use type at the beginning and at the end of the study period respectively. T is the length of the study period. When T takes the unit of year, K is the annual change rate of a certain land use type in the study area. The dynamic degree of a certain land use type can be studied. According to the calculation, dynamic degrees of various land use types in the urban area of Fuyang City from 2007 to 2012, 2012 to 2018 and 2007 to 2018 are shown in **Table 5**.

Table 5. Dynamic changes of land use and cover in Fuyang City (unit: %)

Time span/year	**Construction land**	**Arable land**	**Forest land**	**Water area**	**Bare land**
2007–2012	20.34	–1.47	8.43	1.58	1.58
2012–2018	36.51	–4.93	6.50	29.56	–13.68
2007–2018	49.41	–3.16	8.87	18.31	–7.33

As can be seen from **Table 5**, from 2007 to 2012, the annual change rate of construction land was the highest (20.34%), followed by forest land (8.43%). From 2012 to 2018, the annual change rate of construction land was the highest (36.51%), followed by water area (29.56%). From 2007 to 2018, the annual change rate of construction land was the highest (49.41%), followed by water area (18.31%).

4.3 Dynamic degree of comprehensive land use

The quantitative reflection of the speed of comprehensive land use change in a certain research area is called dynamic degree of comprehensive land use, and its mathematical expression is[12]:

$$C = \left[\frac{\sum_{i=1}^{n} \Delta U_{i-j}}{2\sum_{i=1}^{n} U_i} \right] \times \frac{1}{T} \times 100\% \quad (4)$$

In the formula, ΔU_{i-j} is the absolute value of the area of i land use type converted to non-i land use type in a certain research period, and U_i is the area of i land use type in a certain research period. T is the length of the study period; when T is expressed in year, C is the annual change rate of land use type in the study area. The dynamic degree of comprehensive land use in the urban area of Fuyang City from 2007 to 2012, 2012 to 2018 and 2007 to 2018 is 1.29%, 4.20% and 2.87%.

5. Analysis of the change trend

(1) With the rapid economic development and accelerated urbanization process in Fuyang City, the area of land use types in Fuyang City has changed greatly during the period of 2007–2018. From 2007 to 2012, the area with stable land use types in Fuyang City was 1,704.50 km^2, accounting for 87.10%, and the area with land use type change in 5 years accounted for 12.90%; the average annual change area ratio of land use types was 2.58%; the dynamic degree of comprehensive land use was 1.29%. From 2012 to 2018, the area of stable land use types in the urban area of Fuyang City was 969.08 km^2, accounting for 49.52% of the total area, and the area with land use type change in 6 years accounted for 50.48%; the average annual change area ratio of land use types was 8.41%; the dynamic degree of comprehensive land use was 4.20%. From 2007 to 2018, the area with stable land use types was 720.63 km^2, accounting for 36.82% of the land area, and the area with land use type change in 11 years accounted for 63.18%; the average annual change area ratio of land use types was 5.74%; the dynamic degree of comprehensive land use was 2.7%. Thus, with the rapid development of Fuyang City, its urban land use change rate has a rapid growth.

(2) The area of construction land in Fuyang City increased by 101.72% from 2007 to 2012, with an annual growth rate of 20.34%. The area of construction land increased by 219.05% from 2012 to 2018, with an annual growth rate of 36.51%. With the rapid economic development of Fuyang City, the area of construction land in Fuyang City has been in a state of rapid development. In addition, by comparing the annual change rate between 2007–2012 and 2012–2018, it can be concluded that the growth of construction land area shows an accelerating trend.

(3) In 2007, 2012 and 2018, arable land was the dominant area, with an area ratio of 87.87% and 81.42% and 57.34%, respectively. Annual change rate of arable land during the 11 years saw a change rate of –3.16%, indicating that arable land is being continuously eroded. The main reason is that for the rapid development of the city, the arable land on the edge of the city has been nationalized and transformed into construction land. Secondly, many rural private houses occupying part of the arable land and the policy of returning farmland to forest caused a continuous decrease of the arable land area.

(4) From 2007 to 2018, the area of forest land in Fuyang City continued to increase, with an annual change rate of 8.87%. On the one hand, it is closely related to the establishment of the national advanced and civilized city. The government has increased the investment and construction of greening, which has greatly improved the rate of urban greening. On the other hand, the rapid increase of forest area is related to the implementation of the revised *Environmental Protection Law of the People's Republic of China* (2015).

(5) From 2007 to 2012, the water area increased to 127.11 km^2, increasing by 8.62%. With the rapid economic development, more attention has been paid to environmental protection policies.

The government has increased the control of water area, carried out a series of measures such as dredging of sediment and water plants treatment, which has increased the water area to some extent. From 2012 to 2018, the water area increased by 201.39%. Due to the reasons of visual interpretation and image resolution, it is difficult to accurately extract the information around the water area, resulting in the unreasonable phenomenon that the nearby farmland and forest land are transformed into water area.

(6) The area of bare land in Fuyang City increased first and then decreased, from 25.59 km^2 in 2007 to 27.61 km^2 in 2012, with an increase of 7.90%, and decreased to 4.94 km^2 in 2018, with a decrease of 80.68%. From 2007 to 2012, driven by economic interests, woods were cut down and part of forest land was converted into bare land. After 2012, with the improvement of economic development and urbanization level, part of bare land was converted into urban construction land and arable land.

6. Conclusion

This article studies the remote sensing analysis of land use/cover change in Fuyang City. In order to improve the classification accuracy of remote sensing images, six classification methods, including the maximum likelihood method, minimum distance method, parallelepiped method, Mahalanobis distance method, support vector machine method and neural network method, were selected to supervise the classification of the three-phase images in the study area and select the most suitable extraction method. At present, the research of artificial intelligence and machine learning algorithm is hot; a variety of classification methods combined with computer image processing technology are comprehensively applied to achieve the optimal accuracy of classification. Applying these new techniques and theories to remote sensing image processing will help to improve the classification effect.

Conflict of interest

The authors declare that they have no conflict of interest.

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