Study on the Change of Land Use and Landscape Pattern in Anhui Province

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Abstract Based on the statistical data concerning land use in Anhui Province from 1995 to 2005, this paper conduct comprehensive analysis on change of land use structure, change of land use degree, and landscape pattern change of land use in Anhui Province from 1995 to 2005 using statistical analysis and mathematical model. The results show that the land use structure has changed significantly; the rate of land use change is quick; the land use degree is not high; the spatial pattern of land use tends to be reasonable and gradually develops toward the equilibrium state.
Key words Land use, Landscape pattern, Anhui Province

Land is the most basic natural resource for human survival, the material base of human survival and development, and the basic premises of human activity, which plays an irreplaceable role in human social and economic activity. Although the rapid development of modern science and technology contributes greatly to the improvement of economic level and living standards, it never reduces dependence of human society on the land. In recent years, with the rapid development of industrialization and urbanization, a series of land issues arise in Anhui Province, such as decline of arable land, serious waste of land and imbalance of spatial structure, thus the conflicts between human and land have become increasingly prominent. Therefore, there is an urgent need to research regional land use change, so as to rationally tap and use land resources, protect and improve the regional ecological environment, and promote sustainable socio-economic development of regions in Anhui Province.

1 Overview of the study area and data source

1.1 Overview of the study area Anhui Province, located at 114°54′ – 119°37′ E, 29°41′ – 34°38′ N, in the hinterland of East China, is China's eastern inland province near the sea, across the Yangtze River, in middle and lower reaches of the Huaihe River. The topography in the province is high in the west and low in the east, high in the south and low in the north. There are many hills in Anhui's mountainous regions, and networks of rivers abound in many areas. In Anhui Province, the climate is mild; the sunshine is abundant; the monsoon is obvious; there are four distinct seasons. With the Huaihe River as the dividing line, the north of Anhui Province has the warm temperate semi-humid monsoon climate, and the south of Anhui Province has the subtropical humid monsoon climate.

1.2 Data source The data are from *Statistical Yearbook of Anhui Province* from 1996 to 2006, and survey of the status quo of land use conducted by Land Office of Anhui Province from 1995 to 2005. According to *Technical Stipulations of Survey on the Status Quo of Land Use* and *Daily Cadastral Management Approach* in China[1], from land use, operating characteristics, use patterns and coverage characteristics, *etc.*, the land use type in whole region is divided into farmland, garden patch, woodland, grassland, residential area and mining area, transportation land, water area and unused land[2].

2 Analysis of land use change

2.1 Change of land use structure

2.1.1 The extent of land use change. The extent of land use change is mainly reflected in overall change and relative variance of different types of land use. Through statistical analysis of the relevant data concerning all types of land use in the year 1995, 2000, and 2005, we can find that the land use structure of Anhui Province undergone significant changes. First, the woodland, garden patch, residential area and mining area and transportation land increased year by year, primarily because in this period, Anhui Province accelerated the process of urbanization, strengthened the building of transportation and other infrastructure, in the mean time paid attention to returning farmland to forest, and achieved remarkable results in ecological construction. Second, the area of farmland, pasture and unused land declined, and there was the most prominent decline in the area of farmland, especially after 2000, this trend accelerated noticeably, with the average annual net decrease of 51 346 hm^2. This also indicates that in the process of development and construction, the phenomenon of farmland occupation is very serious.

2.1.2 The rate of land use change. The rate of land use change can be used to compare the regional differences in various types of land use change, and at the same time, it plays a positive role in predicting the future trend of land use change[3]. The rate of land use change can be measured by the dynamic degree of land use. The dynamic degree of land use is divided

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into single dynamic degree of land use type and comprehensive dynamic degree of land use.

First, the single dynamic degree of land use type[3] is the change in amount of a certain land use type in a study area within a period, whose expression is as follows:

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

where K is the dynamic degree of a land use type within a study period; U_a, U_b are the amount of a kind of land use type at the beginning and end of study period, respectively; T is the length of study period of time; when the period of time of T is set as year, the value of K is the annual change rate of one land use type in this study area.

Second, the comprehensive dynamic degree of land use is the amount change of land use in a study area within a period, whose expression is as follows:

$$LC=\left[\frac{\sum_{i=1}^{n}\Delta LU_{i-j}}{2\sum_{i=1}^{n}LU_i}\right]\times\frac{1}{T}100\% \quad (2)$$

where LC is the dynamic degree of comprehensive land use; LU_i is the area of type i land use at starting time of monitoring; ΔLU_{i-j} is the absolute value of type i land use transformed into non-type i land use within the period of monitoring; T is the length of monitoring period; when the period of time of T is set as year, the value of LC is the average annual change rate of land use in this study area[3]. According to formula (1) and (2), I calculate the dynamic degree of land use in Anhui Province from 1995 to 2005, and the results are drawn up into Table 2.

Table 1 The extent of land use change in Anhui Province from 1995 to 2005

Land use type	1995		2000		2005		1995 –2000		2000 –2005		1995 –2005	
	Area $\times10^3$ hm^2	Proportion// %	Area $\times10^3$ hm^2	Proportion// %	Area $\times10^3$ hm^2	Proportion// %	Area $\times10^3$ hm^2	Proportion// %	Area $\times10^3$ hm^2	Proportion// %	Area $\times10^3$ hm^2	Proportion// %
Farmland	5 991.3	42.76	5 936.7	42.37	5 734.6	40.92	−54.6	−0.39	−202.1	−1.45	−256.7	−1.84
Woodland	3 378.8	24.11	3 406.8	24.31	3 599.5	25.69	28	0.2	192.7	1.38	220.7	1.58
Garden patch	341.4	2.436	342.2	2.44	342.1	2.44	0.8	0.004	−0.1	0	0.7	0.004
Grassland	43.4	0.31	34.3	0.24	20.1	0.14	−9.1	−0.07	−14.2	−0.1	−23.3	−0.17
Residential area and mining area	1 255.1	8.96	1 272.7	9.08	1 294.4	9.24	17.6	0.12	21.7	0.16	39.3	0.28
Transportation land	255.7	1.82	273.1	1.95	301.4	2.15	17.4	0.13	28.3	0.2	45.7	0.33
Water area	1 537.1	10.97	1 539.8	10.99	1 541.8	11.00	2.7	0.02	2	0.01	4.7	0.03
Unused land	1 209.9	8.63	1 206.9	8.61	1 178.7	8.41	−3	−0.02	−28.2	−0.2	−31.2	−0.22

Table 2 Dynamic degree of land use in Anhui Province from 1995 to 2005 %

Period	Farmland	Garden patch	Woodland	Grassland	Residential area and mining area	Transportation land	Water area	Unused land	Comprehensive dynamic degree
1995 –2000	−0.182	0.051	0.166	−4.213	0.280	1.368	0.035	−0.049	0.095
2000 –2005	−0.681	−0.008	1.131	−8.276	0.341	2.073	0.025	−0.468	0.349
1995 –2005	−0.429	0.022	0.653	−5.373	0.313	1.791	0.030	−0.258	0.222

As can be seen from Table 2, from 1995 to 2005, in terms of the rate of single land use change, the grassland decreased at the fastest rate, reaching −5.373%, and especially from 2000 – 2005, the rate reached −8.276%, followed by the farmland (−0.429 %) and unused land (−0.258), while the transportation land increased at the fastest rate, reaching 1.791%, followed by woodland (0.653%). From 1995 to 2005, the comprehensive dynamic degree of land use in Anhui Province was 0.222%, indicating that the overall land change was relatively moderate. However, after 2000, it reached 0.349%, indicating that there was a significant trend of fast rate.

2.2 The degree of land use change The degree of land use mainly reflects the breadth and depth of land use, which not only reflects the natural property of land in land use, but also reflects the integrated effect of human factor and environmental factor. The use of land use degree index and its rate of change can quantitatively describe the overall level and change trend of regional land use. According to the comprehensive analysis method of land use degree proposed by Mr. Liu Jiyuan, the land use degree is divided into four grades according to the natural equilibrium state of the natural complex of land under the influence of social factors, and assigned with grading index[4]. Furthermore, taking into account the actual situation of land use in the study area, I get the following table of grading and evaluation of land use degree (Table 3), so as to offer the quantitative expression of comprehensive index of land use degree.

Table 3 Grading and evaluation of land use degree

The state of land	Land use type	Grading index
Unused land	Unused land or the land difficult to use	1
Woodland, grassland, water area, and other agricultural land	Woodland /grassland/water area /other agricultural land	2
Agricultural land	Farmland, garden patch	3
Urban settlement land	Residential area and mining area, transportation land and water conservancy land	4

2.2.1 Comprehensive index of land use degree. This index can quantitatively reveal the comprehensive level of land use in the study area, and the expression is as follows:

$$L_j = 100 \times \sum_{i=1}^{n} (A_i \times C_i), L_j \in [100, 400] \quad (3)$$

where L_j is the comprehensive index of land use degree in the study area; A_i is the grading index of grade i land use degree within the study area; C_i is grading area percentage of grade i land use degree within the study area; n is the number of classification of land use degree.

The comprehensive quantitative indicator system of land use is an indicator with continuous variation from 100 to 400. The size of the comprehensive index can reflect the level of the land use degree[45]. Using the above formula, I calculate the comprehensive index of land use degree.

2.2.2 Variance and change rate of land use degree. The change in land use degree in a given region is the result of change in a variety of land use types. The land use degree and its variance and change rate can quantitatively reveal the overall level and change trend of land use within the region. The variance of land use degree and change rate of land use degree can be expressed as follows:

$$\Delta L_{b-a} = L_b - L_a = 100 \times [\sum_{i=1}^{n} (A_i \times C_{ib} - \sum_{i=1}^{n} (A_i \times C_{ia}] \quad (4)$$

$$R = \frac{[\sum_{i=1}^{n} (A_i \times C_{ib} - \sum_{i=1}^{n} (A_i \times C_{ia})]}{[\sum_{i=1}^{n} (A_i \times C_{ia})]} \quad (5)$$

where ΔL_{b-a} is variance of land use degree; R is the change rate of land use degree; L_b and L_a are the comprehensive index of regional land use degree at time b and a, respectively; A_i is grading index of grade i land use degree; C_{ib} and C_{ia} are the area percentage of grade i regional land use degree at time b and a; if $L_{b-a} > 0$ or $R > 0$, then the regional land use is in the period of development, and on the contrary, it is in the period of adjustment or recession.

According to formula (3), (4) and (5), I calculate the comprehensive index of land use degree in Anhui Province from 1995 to 2005, and variance and change rate of land use degree, which can be seen in the following Table 4.

Table 4 Land use degree in Anhui Province from 1995 to 2005

Time	Comprehensive index of land use degree	Variance of land use degree	Change rate of land use degree
1995	239.787	–	–
2000	239.914	0.127	0.053
2005	246.382	0.624	0.105

It can be seen that from 1995 to 2005, the variance and change rate of land use in Anhui Province are greater than 0 ($R > 0$), and the comprehensive degree index rises from 239.787 in 1995 to 246.382 in 2005, indicating that the land use degree is constantly enhanced in Anhui Province. But the comprehensive degree index is not high. In the same period, the comprehensive index of land use degree in China's central regions is about 250; the comprehensive index of land use degree in China's eastern regions is 275 – 325; the comprehensive index of land use degree in China's southeastern coastal regions is 325 – 400. Compared to the eastern and southeastern coastal areas of China, the land use degree in Anhui Province is low. Given that the index limit of land use degree is 400, the overall development intensity of land resources in Anhui Province has some room for rise.

3 Analysis of change in landscape pattern of land use

Land use/cover is composed of large and small patches, and the spatial distribution of patches is called pattern. The landscape ecologists present a number of different indicators in quantitative analysis of spatial landscape pattern, which lays solid foundation for study on spatial landscape pattern[5]. Now I select landscape diversity index (H), landscape dominance index (D), landscape evenness index (E), landscape fragmentation index (C), and landscape contagion index (CONTAG) to analyse the evolution of spatial pattern of land use.

3.1 Landscape diversity index (H) Landscape diversity index directly reflects the number of patch types in the study area and proportional change in all types. According to the rationale of information theory, in the case of unchanged landscape constituting elements, when the differences in proportion of all patches in landscape increase, the landscape diversity index declines, and vice versa. What the diversity index describes is the complexity and variability in land use type, and the calculation formula is as follows:

$$H = -\sum_{i=1}^{n} P_i \times \log_2 P_i \quad (6)$$

3.2 Landscape dominance index (D) Landscape dominance index is usually denoted by the difference between the maximum value and actual value of diversity index, thus showing the deviation between the landscape diversity and the biggest diversity, and the calculation formula is as follows:

$$D = H_{max} + \sum_{i=1}^{m} P_i \times \log_2 P_i \quad (7)$$

3.3 Landscape evenness index (E) Landscape evenness index is used to measure the degree of even distribution of different types of landscape, and the calculation formula is as follows:

$$E = (H/H_{max}) \times 100\% \quad (8)$$

3.4 Landscape fragmentation index (C) Landscape fragmentation index takes the number of patches per unit area as the indicator of fragmentation degree of landscape, and the greater the value, the higher the degree of fragmentation. The calculation formula is as follows:

$$C = \sum N_i / \sum A_i \quad (9)$$

3.5 Landscape contagion index (CONTAG) Landscape contagion index describes agglomeration degree or extension trend of different types of patch in landscape. Because the index contains the spatial information, so it is one of the most important indices describing the landscape pattern. In general, high value of contagion shows that a certain type of advantageous patch in landscape forms good connectivity; on the contrary, it indicates that the landscape is the dense pattern having a variety of elements, and the fragmentation degree of the

landscape is high. The calculation formula is as follows:

$$CONTAG = [1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}[(P_i \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}) \ln(P_i \frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}]}{2\ln m}] \times 100\% \quad (10)$$

In (6) – (10), P_i is the landscape proportion of patch i; m is the type of patch; $H_{max} = \log_2 m$; $\sum N_i$ is the total number of landscape patches; $\sum A_i$ is the total area of landscape; g_{ik} is the neighbouring number of patch type i and patch type k.

Using formula (6) – (10), I calculate the spatial pattern index of landscape in Anhui Province from 1995 to 2005 (Table 5).

Table 5 The spatial pattern index of landscape in Anhui Province from 1995 to 2005

Year	Diversity index (H)	Evenness index (E)	Dominance index (D)	Fragmentation index (C)	Contagion index (CONTAG)
1995	1.184 1	61.72	0.875 4	1.279 0	60.519 3
2000	1.348 9	64.53	0.732 9	1.325 5	49.743 0
2005	1.696 0	73.56	0.641 3	1.580 2	45.127 6

From Table 5, we can find that in the period 1995 – 2005, due to returning farmland to lakes, ecological migrants, implementation of strengthening forestry development and other policies, and the continuous development of roads and urban construction, the proportion of various land use types experienced great change, and the diversity index and evenness index of landscape showed an upward trend. The diversity index rose from 1.184 1 in 1995 to 1.696 0 in 2005; the evenness index rose from 61.72% in 1995 to 73.56% in 2005; the change in dominance was contrary to change in diversity, and the dominance index declined from 0.875 4 in 1995 to 0.641 3 in 2005; due to strengthening of human activities, the landscape fragmentation increased, and the fragmentation index increased from 1.279 0 in 1995 to 1.580 2 in 2005; in addition, the contagion of landscape declined, from 60.519 3% in 1995 to 45.127 6% in 1995, indicating that the aggregation degree tended to be decentralized from centralized.

4 Conclusions

First, through analysis of the change in land use structure in Anhui Province from 1995 to 2005, it indicates that the change in land use structure in Anhui Province is prominent, and the change in grassland, farmland, residential area and mining area, and construction land is prominent, and the ecological construction and municipal construction have a far-reaching impact on the change in land use structure.

Second, through analysis of the change in land use degree in Anhui Province from 1995 to 2005, it indicates that the land use degree in Anhui Province is not high, still in the period of development, but the extent and intensity of use are increased year by year.

Third, through analysis of landscape pattern change of land use in Anhui Province from 1995 to 2005, it indicates that the land use structure and the spatial distribution in Anhui Province are adjusted and optimized constantly, and the spatial pattern of land use tends to be reasonable and gradually develops toward the equilibrium state.

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excellent tourist attractions; focus on the construction of the tourism ring road in Sichuan Province, such as Jiuhuan Ring Road, Xihuan Ring Road, Hongse Ring Road, Sanguo Ring Road and Luoke Ring Road; accelerate the construction of Jiuzhai international tourist area, Wolong panda ecological park, and Shangri-la eco-tourism inner circle; strengthen the tourism marketing, pay attention to multi-level and high-level international publicity and promotion, further promote the tourism fame of the Tibetan areas, drive the rapid development of cultural tourism industry, and strive to construct the the Tibetan areas in Sichuan Province into the best destination of the world's natural heritage and eco-tourism. On the other hand, for abundant water energy resources and mineral resources in the Tibetan areas of Sichuan Province, we should establish new resources development model, make the dominant position of the autonomous region in resource development clear, establish and improve the benefit distribution pattern which gives consideration to government, business, and the masses, ensure the people's interests first, achieve interests sharing, and adhere to the road of sustainable development, placing equal stress on development and protection.

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