Analysis of land-use change and its mechanism based on graphical information and statistical model

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Abstract

Investigation of land-use change is important to economic development and analysis related to climate change. Using the spatial analysis tool in GIS, the land use change information was generated and analyzed quantitatively. Results indicate that: (i) The arable land gradually increased; the grassland and forestland decreased firstly but then increased gradually; there was little change on water surface and residential area; and unused area increased annually. (ii) Square index and fractal dimension of forestland, grassland and unused land increases when the area increases, however, nearly circular index decrease, area caused by the change of shape index and fractal dimension change is much less. (iii) We constructed a linear fitting of the graphic information of land use, this model fitted well the relationship between 1991~2000 land use change and its graphical information.

Keywords: graphic information, land-use change, landscape index

1 Introduction

Land use change is formed in the joint effects of natural factors and social economic factors. It is also one of the main reasons causing other global change issues [1-4]. Patch of land use is the product of interactions between human and natural activities, the strength and direction of change its shape features with human interaction and change, and this is the basis of function and the dynamic change of land use research. Starting from the geographical spatial information analysis, changes in plaque and its pattern of land value, geometric features are estimated using changes land use patch spatial pattern parameters; we found that there was great differences between different kind of graphical features. Obviously, these differences are a reflection of the inherent characteristics of land use, land use change driving factors, which have certain correlation to drive a graphic feature change. Studies on land use change driving mechanism require not only to determine the driving factor, but also to analyze the relationship between the driving factors and the driving factors of land use change.

For long, scientists have developed numerous LUCC models from different point of view [5-10], human factor data used by these models are mainly obtained from the historical statistics or field survey, but this causes a series of problems. First, the lack of data consistency of the human factors; Second, only care about the attribute data area in statistical data, which leads to changes in spatial location difficult to determine and the area of inaccurate measurement, etc. Third, the various statistics data of human interference. In addition, many cultural factors have significant effects on LUCC, and the quantification of these factors is difficult, there are no rules on how to determine the quantitative index to replace them.

Changes between land use patterns and land use have correlation. The land use difference can cause change in the characteristics of land use pattern in different directions. Then, through the establishment of functional relationship model of between graphic feature change and land use change, which can replace the land use change driving human and natural factors in the model, so as to reduce man-made interference model. The objective of this study is to develop a driving model based on the characteristics of land use pattern, which is a new endeavor to supplement the description and analysis of land use/cover temporal-spatial evolvement process.

2 Study area

The Changling County is located between 123°07' – 124°45' E and between 43° 59' – 44° 45' N, which is at the western of the arched area from the Shuangchengbao to the Fulongquan at the Songliao Plain. It borders to the east with Nong'an County; to the south near the border of the Gongzhuling and the Shuangliao County; to the west, it is adjacent to Inner Mongolia Horqin Left Middle Banner; to the north, it is contiguous to the Tongyu, Qianan and Qian Gorlos Mongolian autonomous County. The County is flat and slightly tilted from the southeast to the northwest, there is no mountains and very few

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rivers. The elevation is 144~266 m and it obtains a semi-arid and sub-humid temperate continental monsoon climate. Rainfall is rare and unstable. The precipitation is mostly concentrated in the growing season, e.g. the annual rainfall throughout the county is 470.60 mm, the average annual temperature is 4.9°C, with good heat conditions, the annual average accumulative temperature of more than 10°C reaches 2932.8°C and the duration is about 160 days. The Changling County presents transitional natural landscape from the forest steppe to the dry steppe, which has created the advantageous condition for its animal husbandry's development and has already become the main of the county's industrial structure. With the development of economy and population, the water and soil erosion, grassland degradation, desertification and other environmental problems have become a global sensitive ecological fragile zone.

3 Methodology

3.1 EXTRACTION OF DYNAMIC CHANGES OF LAND-USE

The remote sensing image data was digitized as input by ARCGIS to build graphics and the attribute database; and carried on the spatial analysis in order to gain more land use change information in the period. We then extracted change information in order to understand the various types of spatial change. The technical flow chart (see Figure 1).

Three scenes of Landsat-Thematic Mapper (TM) image in September 1991, September 1995 and September 2000 were selected in this study. In addition, the topographic map of the study area with a scale of 1: 100,000 is also collected. This map presents land use map, soil type map and so on for different periods of time series analysis. This study not only realized TM images standard false color synthesis, enhance, and geometric correction with ERDAS, but also matched the RS images and topographic maps to ensure high precision superposition analysis of the images[11-13]. This study combined with the way of land use in Changling County, for reasonably using data and the realization of the research target, the land use types will be divided into six levels, namely the cultivated land, wood land, grassland, water area, residential areas and unused land [14-18]. The study area of the thesis, including the land uses in 1991, 1995 and 2000 are shown in Figure 2.

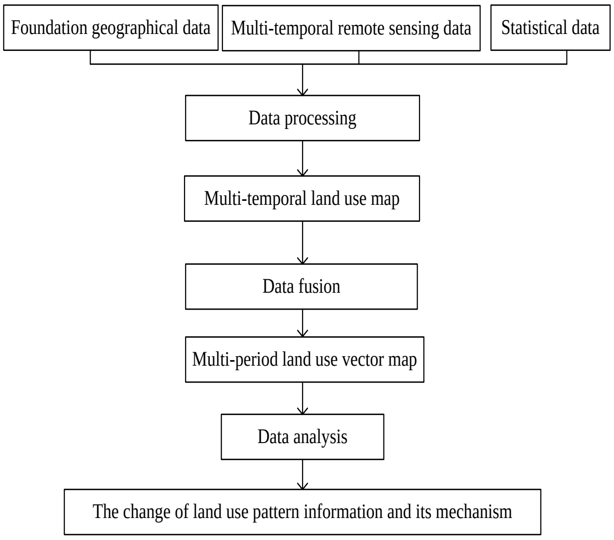
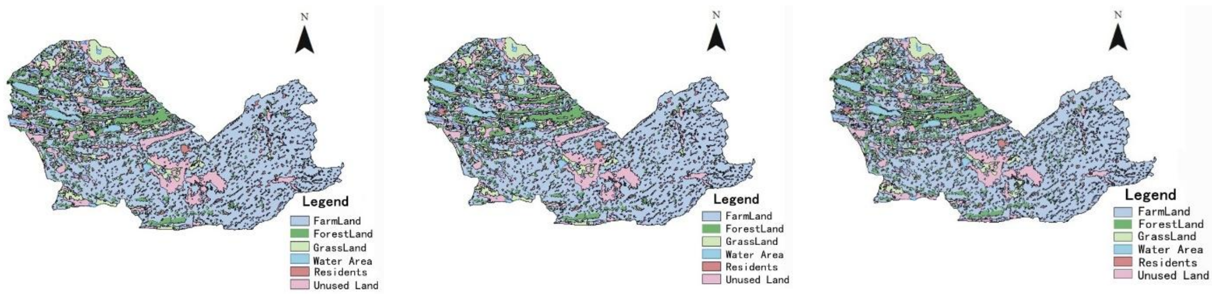


FIGURE 1 The flow chart

From the polygon attribute Table and Three-arc-sect attributes list based on the three periods land use vector data, we obtained graphical information about the patch of land use. Through the query function of ARCGIS and statistical analysis function of SPSS, we could quantitatively describe the graphical information of the land use, and could also conduct the interactive mechanism research between the changes of the land use and the changes of graphic features.



a) 1991 b) 1995 c) 2000

FIGURE 2 The extracted land use patterns of Study area in 1991, 1995 and 2000

3.2 INDICES OF LANDSCAPE PATTERNS

Previous studies often use variable indices to describe the quantity of land use and spatial pattern [19-23]. Study on spatial pattern change of planning to choose part of the landscape index in the study area, the calculation method and the ecological meaning (following Table 1).

TABLE 1 Indices of landscape patterns utilized in this study

Index	Calculation formula	Meaning
Nearly circular index	$SIC_i = \frac{4\pi}{A_i}\sum_{j=1}^{N_i}(\frac{A_{ij}}{P_{ij}})^2$	The range of nearly circular index in (0, 1), patch shape is more compact, more close to round, nearly round index is close to 1, patch near circular index is smaller and the patch shape is more complex.
Square index	$SIS_i = \frac{1}{4A_i}\sum_{j=1}^{N_i} P_{ij}A_{ij}$	Square index values greater than or equal to 1, the shape index is close to 1,meaning that the land use patch shape is more close to the square, and the numerical value is greater that the patch shape is more complex and far from the square.
Fractal dimension	$D = \frac{2\ln(\frac{P_i}{4})}{\ln(A_i)}$	The complexity in the scale of observation of certain land use patch edge, theoretical value of D is 1~2, the value of the smaller plaques self-similarity is more strong, plaque geometry is close to simple and more regularly.
Distance index	$D_i = \frac{1}{2}\times\sqrt{\frac{N_i}{A}}$	Average minimum distance of description plaque in the spatial distribution.

(**Note:** SIC_i, A_i, N_i denote the I class nearly circular index, type of land use patch area and the number, A_{ij}, P_{ij} represents the I class land use type of J patch area and perimeter, SIS_i represent the I types of land use patch square index, P_i represent patch perimeter of the I class, D_i represent the distance index of the I types of land use, A represent the total area).

4 Results

4.1 THE CHANGE OF LAND USE PATTERN

Based on the analyses of Figure 3, we conclude that the land use change was dramatic during 1991~1995, mainly concentrated in the forestland, cultivated land and grassland. Between 1995 and 2000, the land use change was stable. The land use change of Changling County in these years was a consequence of the combined actions of natural factors and socio-economic factors. During 1991~ 1995, the land use change was dramatic, mainly concentrated in the cultivated land, forestland land and grassland. In this period, the population of Changling County increases from 567513 to 601152. The demand for food increased greatly under the pressure of population growth, and it should be the main reason of cultivated land area growth of 523.68 km2 in these five years. Destroying the forest to farm and turning the pasture to farmland is the main source of the increase of cultivated area.

The growth of the population and the development of social economy promoted the growth of the residential area. The newly cultivated farmland was mostly barren, which would be given up cultivating after one or two years frequently even if it has been reclaimed. In addition, due to the excessive grazing, the grassland has degenerated, which was the main reason for the increase of unused land area, this also was the loss direction of the grassland area. Simultaneously, water body had increased a little, compared with the fishery area, whose income was continuously growing, we may know that the aquatic products breeding had caused the growth of water area. Overall, the status of land use had been changed greatly in the first 5 years, forestland and grassland area sharply decreased, while the cultivated land and unused land increased rapidly. During 1995 and 2000, the status of land use changed slowly; while the main performance was the reduction of cultivated land and the increase of forestland.

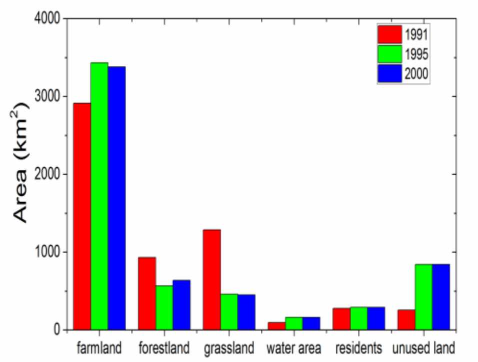


FIGURE 3 Areas of different land-use types in 1991, 1995 and 2000

4.2 MECHANISM BETWEEN PATCH SIZE AND SHAPE FEATURES

Different land use indices, including nearly circular index, type of square index, fractal dimension and plaque area were estimated and obtained, it shows that the relationship between land use patch size and shape feature types is rather different (following Table 2).

The C value and C1 value of residential land and forestland are slightly higher than that of cultivated land, water areas, grassland and unused land, and residential land and forestland by human applied forces lead its tendency is also higher than other land use types. By calculating the correlation of nearly circular index, type of square index and fractal dimension square shape index and fractal dimension index, we found the map under human disturbance is strong, its C value and C1 value is higher; this indicates that the C value and C1 value reflect the land use patch size of human driving force.

The C2, C3 and C4 values display plaque size to interference degree of nearly circular index, square shape index and fractal dimension. The square index and fractal dimension of forestland, grassland and unused increases with the area increases, however, nearly circular index is decreasing, which shows that increased plaque area caused by complicated fringe, and its irregular shape and square or circular gap increased. But for the residential area caused by the change of the shape index and fractal dimension change is much lower, and the C2, C3 and C4 values of forestland, grassland and unused land relative to the other match. This suggests that various types of land use exists between the relationship of mutual transformations of different directions and different rates change in the natural and human factors.

TABLE 2 Correlation coefficients among the landscape indices in 2000

Types	Grassland	Forestland	Grassland	Water area	Residents	Unused land
Correlation coefficient of nearly circular index and fractal dimension (C)	-0.922	-0.973	0.439	-0.548	-0.987	-0.449
Correlation coefficient of square shape index and fractal dimension (C1)	0.724	0.931	-0.397	0.501	0.986	0.413
Correlation coefficient of fractal dimension and plaque area (C2)	0.884	0.393	0.581	0.279	0.298	0.392
Correlation coefficient of circular index and patch area. (C3)	-0.1853	-0.305	-0.961	-0.329	-0.321	-0.316
Correlation coefficient square index and patch area (C4)	0.392	0.638	0.933	0.569	0.372	0.592

4.3 CONSTRUCTION OF GRAPHIC INFORMATION AND LAND USE CHANGE MODEL

4.3.1 Correlation analysis of graphic information and the driving factor

We chose the total population (A1), the agricultural population (A2), the net population rate (A3), the production value of farming (A4), animal husbandry production output (A5), forestry production value (A6), total grain production (A7), number of large livestock (A8) as the socio-economic factors that affects land use change, because they reflected the changes in the socio-economic conditions. The study also selected the annual average temperature (A9), the annual precipitation (A10), the annual evaporation (A11), the flood area (A12), the drought area (A13) as the driving factors. Based on the land use spatial database, we prosecuted the correlation analysis of the driving factors of the quantitative indicators and types of graphics features characterization of land use (following Table 3). We found that the different graphics index of the same kind is affected by different factors at different levels, suggesting different graphic index reflects land use different stress conditions; the same graphic index of different classes by different driving factors of influence is also different, which indicates that the figure index reflects the driving factors of land use change.

The related degree of farmland, forestland and shape index and the total population, agriculture population and plant output was significantly higher than that of water, grassland and unused land and the social economic factors correlation. From one side it shows the shape index can well reflect the transformation of LUCC. It is feasible to take the land use change as the dependent variables, and use the landscape index for argument construction land use change model. Through the graphic information of land use, we can not only obtain transfer direction and quantity of land use, but can also analyze land use driving mechanism changes.

TABLE 3 Correlation coefficient matrix of land use driving factors and landscape index

a: grassland

Types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Nearly circular index	-0.883	-0.908	0.638	-0.957	-0.792	-0.851	-0.930	0.988	0.014	-0.640	-0.443	0.688	-0.753
Square index	0.851	0.821	-0.987	0.735	0.927	0.883	0.787	-0.634	-0.870	-0.340	-0.550	0.278	-0.186
Fractal dimension	0.983	0.992	-0.838	1.000	0.938	0.969	0.997	-0.989	-0.311	0.382	0.156	-0.440	0.524
Distance index	-0.990	-0.997	0.931	-0.978	-0.989	-0.999	-0.991	0.939	0.497	-0.186	0.048	0.249	-0.340

b: forestland

Types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Nearly circular index	0.847	0.875	-0.581	0.933	0.746	0.811	0.902	-0.974	0.058	0.693	0.506	-0.738	0.799
Square index	-0.862	-0.889	0.605	-0.944	-0.765	-0.828	-0.914	0.980	-0.028	-0.671	-0.480	0.718	-0.781
Fractal dimension	-0.643	-0.685	0.303	-0.778	-0.506	-0.592	-0.725	0.858	-0.362	-0.881	-0.746	0.910	-0.945
Distance index	0.921	0.898	-0.900	0.829	0.973	0.944	0.871	-0.744	-0.785	-0.193	-0.417	0.130	-0.035

c: grassland

Types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Nearly circular index	0.847	0.875	-0.581	0.933	0.746	0.811	0.902	-0.974	0.058	0.693	0.506	-0.738	0.799
Square index	-0.862	-0.889	0.605	-0.944	-0.765	-0.828	-0.914	0.980	-0.028	-0.671	-0.480	0.718	-0.781
Fractal dimension	0.831	0.861	-0.556	0.922	0.726	0.793	0.888	-0.967	0.088	0.715	0.532	-0.758	0.817
Distance index	0.706	0.719	0.319	-0.345	-0.945	-0.416	-0.322	0.309	0.315	0.116	0.334	0.168	0.304

d:water area

Types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Nearly circular index	-0.876	-0.902	0.626	-0.952	-0.783	-0.843	-0.925	0.385	-0.001	-0.651	-0.456	0.698	-0.763
Square index	0.876	0.902	-0.627	0.953	0.783	0.844	0.925	-0.186	0.000	0.650	0.455	-0.698	0.762
Fractal dimension	-0.828	-0.858	0.552	-0.920	-0.722	-0.790	-0.886	0.366	-0.093	-0.718	-0.536	0.761	-0.819
Distance index	-0.845	-0.854	0.349	-0.896	-0.694	-0.798	-0.924	0.369	-0.006	-0.578	-0.458	-0.657	-0.692

e: residents

Types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Nearly circular index	0.877	0.902	-0.628	0.953	0.784	0.844	0.925	-0.986	0.000	0.650	0.455	-0.697	0.762
Square index	-0.874	-0.900	0.624	-0.951	-0.780	-0.841	-0.923	0.985	-0.005	-0.654	-0.459	0.701	-0.766
Fractal dimension	-0.877	-0.902	0.628	-0.953	-0.784	-0.844	-0.925	0.986	0.000	-0.650	-0.455	0.697	-0.762
Distance index	-0.785	-0.597	0.671	-0.897	-0.788	-0.852	-0.922	0.977	0.004	-0.234	-0.456	0.687	-0.729

f: unused land

Types	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
Nearly circular index	-0.861	-0.888	0.603	-0.943	-0.764	-0.827	-0.913	0.980	-0.031	-0.673	-0.483	0.720	-0.782
Square index	0.646	0.688	-0.306	0.780	0.509	0.595	0.728	-0.859	0.358	0.879	0.744	-0.908	0.944
Fractal dimension	0.879	0.904	-0.631	0.954	0.786	0.846	0.927	-0.986	-0.005	0.646	0.451	-0.694	0.759
Distance index	-0.872	-0.796	0.705	-0.924	-0.781	-0.833	-0.901	0.957	-0.011	-0.621	-0.476	-0.712	-0.569

4.3.2 Land use change driving model

Linear fit through the graphical information for three years in Changling county land use, land use change model was used to analyze the land use change as the dependent variable, variables of all kinds of shape index. Among them, Yi expresses the land use change index types, SI1 expresses nearly circular index, SI2 expresses square index, F expresses fractal dimension, DI expresses distance index.

1) The farmland change model is as follows:
Y1=4801.165+1113644SI1+0.974593SI2+654.858F+458.347DI

R2=0.997, R value indicate accuracy of the regression equation. By F test, significant probability value P=4.56E-05<0.05, a significant regression equation.

2) The forestland change model is given as:
Y2=4489.8-19440SI1-46.6498SI2+289.9587F+0.9457DI

R2=0.945, R value indicate accuracy of the regression equation. By F test, significant probability value P=2.36E-05<0.05, a significant regression equation.

3) The grassland change model is written as:
Y3=–3525.87+4385.212SI1–31.7916SI2+3320.089F+456.448DI

R2 = 0.925, R value indicate accuracy of the regression equation. By F test, significant probability value P=5.36E-04<0.05, a significant regression equation.

4) The water area change model is written as:
Y4=255.4497–832.929SI1–5.19186SI2+221.1461F+62.497DI

R2=0.995, R value indicate accuracy of the regression equation. By F test, significant probability value P=.36E-05<0.05, a significant regression equation.

5) The residents change model is written as:
Y5=659.318+421.708SI1–287.405SI2–582.652F+638.479DI

R2=0.969, R value indicate accuracy of the regression equation. By F test, significant probability value P=3.2E-04<0.05, a significant regression equation.

6) The unused land change model is written as:
Y6=422.1319+3453.382*SI1+1.018694*SI2+451.1894*F+385.292*DI

R2 = 0.987, R value indicate accuracy of the regression equation; By F test, significant probability value P = 5.36E-04 < 0.05, a significant regression equation.

After testing, high precision of the regression equation has been achieved, fitting well the 1991~ 2000 land use change and its internal relationship graph information. The results show that the prediction and forecasting precision are preferable in a decade. Each land use type and various driving factor data of the model are obtained according to the land use vector around the patch on the graph shape feature extraction or calculation, and land use map can be obtained according to the interpretation of remote sensing data, so the whole process with respect to the use of human factors and reduce the influence of subjective factors. Based on the model and according to the characteristics of land use patterns, the evolution trend of land use can be well predicted.

5 Conclusions

Land use pattern and spatial pattern of plaque is the interactive results between human and natural activities. Through calculating various quantitative indices related to the land use graphical information of Changling County land use graphical information of various quantitative index calculation, we found that the graphic features of different kinds of land have obvious differences, which can be seen as a manifestation of the spatio-temporal evolution of land use development features. Based on the support of ARCGIS spatial and SPSS statistical analysis function, the mechanism of graphic information of land use and land has been studied in Changling County.

According to the Changling County land use patches near roundness, square index, fractal dimension and the distance index statistical analysis, the results shows that the land use patch shape is the result of interaction between nature and human. Human weak interference patches to maintain the original natural force is formed, when the state fractal dimension is large, shape index is low, however, Affected by human strong interference, patches inclined to maintain neat edge and shape rules, when the state fractal dimension is low and the shape index is high.

Different types of land for use are in the shape of human land cover transformation results, Land use map can reflect both the characteristics of the shape and force direction and the nature of its formation in the process of interaction between various driving forces. Therefore, we can study the changes of the driving mechanism of land use using shape features of land maps.

We constructed the linear fitting of the graphic information of land use in Changling County and made land use change as the dependent variable, with all sorts of shape index of land use change model variables. In the process of modeling reduction and the influence of subjective factors, using the graphical features of land change for predicting the evolution tendency of land use is a new attempt to supplement the description and analyzes of these land use/cover temporal-spatial processes.

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