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Land use change in Bohai Rim: a spatial-temporal analysis

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Abstract: Based on RS and GIS methods, land use information for 1985 and 1995 was acquired from TM images and analyzed. Then on both spatial and temporal aspects, this paper analyzes land use change in three provinces of Hebei, Shandong and Liaoning and two municipalities of Beijing and Tianjin in the Bohai Rim covering the period of 1985 to 1995. The extent, rate, areal difference and trend of various types of land use changes in the region, as well as spatial changes of major types of land use, their distribution characteristics and regional orientation are revealed. The regional characteristics of land use are elaborated, so as to provide effective policy support for sustainable land use in the area around the Bohai Bay.

Land use change in Bohai Rim: a spatial-temporal analysis ZHU Hui-yi, LI Xiu-bin, HE Shu-jin, ZHANG Ming (Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) Land use change is one of the important aspects of global change[1-3]. The Bohai Rim is a hot spot of economic development in China, where land use changes remarkably. Analyzing land use change in this area is significant to the research of global change and regional sustainable land use. Although there has been much work undertaken on regional land use change in China, it was mainly on urban land use change[4-11], and few researches integrated remote sensing and GIS method. Based on data from RS investigation, this paper deals with the temporal and spatial characteristics of land use change from 1985 to 1995 in the Bohai Rim by means of RS, GIS and statistical analysis. 1 Research area, methods and data source 1.1 Research area The Bohai Rim includes Beijing, Tianjin, part of Hebei, Shandong, and Liaoning provinces, consisting of 152 counties under jurisdiction of 24 prefectures and covering a total area of 233,630 km². 1.2 Methods Remote sensing, GIS and statistical analysis are used to collect and process data. The interpretation of land use information from TM images was based on computer-aided interpretation method. The images was transformed into a computer, then interpreted on the screen. The result is in vector format and then transformed into ARC/INFO format. In ARC/INFO environment, the data interpreted from two period images were processed using overlay function. Based on the results of spatial analysis, the data of land use change were extracted from the attribute tables and statistically analyzed. 1.3 Data source The data are mainly from the state investigation of land resources using remote sensing during the 8th and 9th five-year plan periods. The first period data come from 1984-1985 TM images, while the second period data come from 1994-1995 TM images. The duration is ten years. However, the scale of the first period data is 1:250,000, and the scale of the second period data is 1:100,000. In order to match the two sets of data, the second period data were simplified in GIS environment. Polygons of land use which cannot be reflected on 1:250,000 scale were eliminated from the coverage on the scale of 1:100,000. 1.4 Land use classification According to attributes, land use is classified into six main types in remote sensing investigation. They are cultivated land, forestland, grassland, water area, urban and rural housing construction land, and unutilized land. They are further classified into 22 sub-types, including paddy field, dry land; woodland, shrubby land, sparse woodland, other woodland; high coverage grassland, middle coverage grassland, low coverage grassland; river/dyke, lake, reservoir/pond, permanent glacier or snow-capped land, floodland; land for urban construction, rural residential area, land for other construction purpose; sandy land, Gobi, saline-alkali land, wetland, barren land. The sub-types are adopted in the process of spatial overlay analysis on graphic data in GIS environment. In statistical analysis, the main types are adopted. Figure 1 Land use map of the Bohai Rim, 1985 2 Quantitative land use change in the Bohai Rim 2.1 Extent of land use change Regional land use change includes quantitative, spatial and qualitative changes of diverse land use types. The change in amount is firstly reflected in the chan

ge of the total amount of diverse land use types. By analyzing change in the total amount of different types, the situation of land use change and land use structure can be figured out. Based on the materials described above, the graphic data of land use in the Bohai Rim (Figures 1 and 2) are statistically analyzed. The result (Table 1) is shown as follows: From the table one can find that: (1) cultivated land decreased by more than 1,800,000 ha in 10 years; (2) forestland increased by 600,389 ha, of which garden area (including orchard) increased substantially by 364,607 ha, or more than 60% of the increased area of forestland; (3) the area of grassland decreased to a less extent; (4) the area of land devoting to urban and rural housing construction increased to a great extent with most remarkable expansion in rural residential area due to pressure of population growth and development of urbanization; and (5) the area of pond got enlarged thanks to the development of aquiculture. Figure 2 Land use map of the Bohai Rim, 1995 Table 1 Area changes of classified land use in the Bohai Rim in recent 10 years (unit: ha)

2.2 Rate of land use change

Land use dynamic degree can be used to quantitatively describe the rate of regional land use change. It is meaningful for comparing regional differences in land use change and prognosticating the trend of in future land use change[12]. Land use dynamic degree for single land use type can quantitatively express change of a certain land use type. It is calculated with the following formula: where U_a is the area of a certain land use type at the beginning of the research period, U_b is the area of the land use type at the end of the research period, and T is the research period of time. When the unit of T is set as year, K is the yearly rate of land use change of a certain land type in the research period. Integrated land use dynamic degree can be used to generally describe the rate of regional land use change. It is calculated with the formula below: where LUI is the area of land use type i at the beginning of the research period, ΔLUI_{i-j} is the absolute value of area of land use type i turned to type j in the period, and T is the research period of time. When the unit of T is set as year, LC is the yearly rate of land use change in the region. Table 2 Yearly change rate of classified land use in the Bohai Rim (unit: ha)

According to Formulas 1 and 2, we calculated the yearly rate of land use change for six land types. The results, which are shown in Table 2, imply that the rate of land use change in the Bohai Rim is very high in 10 years with a yearly rate up to 0.85%. Among the changes, the yearly change rate of land devoting to urban and rural housing construction and surface area of water bodies is the greatest, reaching 6.40% and 6.59% respectively. The change rate of cultivated land is only 1.26%, because of its relative large total area and relative small portion changed in land use. The above results neglect the internal process of land use change in the region, but only reflect quantitative change rate in land use.

2.3 Regional differences of land use change

The relative change rate of a single land use type is introduced here to elaborate the regional difference in land use change. It can be calculated with the following formula: where K_a is the area of a certain land use type in a sub-region at the beginning of the research period, K_b is the area of the same land use type in the sub-region at the end of the research period, C_a is the area of the same land use type in the whole region at the beginning of the research period, and C_b is the area of the land use type in the whole region at the end of the research period. Based on Formulas 2 and 3, we calculated the relative change rate of different land use types for Beijing, Tianjin, Hebei (partly), Shandong (partly) and Liaoning (partly) in the Bohai Rim. The results are listed in Table 3. It is clear that land use change in the Bohai Rim has remarkable regional differences. Cultivated land changed most apparently in Beijing and Liaoning, with a relative change rate up to 1.53 and 1.36 respectively. Forestland changed most evidently in Beijing and Tianjin, and grassland in Beijing and Liaoning. Land for rural and urban housing construction changed most obviously in Liaoning and Beijing. Shandong and Hebei has a remarkable change in unutilized land. If the value in Table 3 is bigger than 1, it implies that the change of a land use type in a sub-region is greater than that in the whole region and vice versa. Table 3 Relative change rate of various land use types in sub-regions of the Bohai Rim (%)

3 Spatial change of land use in the Bohai Rim

3.1 Land use conversion

After overlaying the graphic data sets of land use for the whole region, we can statistically analyze the attribute data and sequence the results (Table 4). It is found that 70% of the total area kept the same land use pattern, while the remaining 30% changed its land use pattern. Among the changes, the greatest is conversion of cultivated land to that for urban-rural housing construction, the second is conversion of cultivated land to forestland including orchard, woodland and shrubby land, and the third from cultivated land to grassland. Compared to the results of quantitative land use change, the statistical results of spatial data reflect the initial process of land use change in the region. Table 4 Areal change of the major types of land use in the Bohai Rim

3.2 Spatial distribution of land use change

From the analytical method of land spatial structure[13], we advance the conception of frequency, importance degree and their calculation methods to express the spatial distribution and regional direction of land use change. The frequency of a certain land use type indicates the number of polygons of this particular land use type in a region, which can be used to quantitatively describe the spatial distribution of land use change. It can be calculated with the following formula. where D is the frequency of

a certain type of land use change, N_i is the number of polygons of this type, and N is the number of polygons of all types of land use in the region. Based on Formula 4, the frequency of major types of land use change in the Bohai Rim was calculated (Table 5). The results imply that cultivated land converted to forestland and to urban-rural construction land is widespread in the region, which occupies more than 10% of the land use polygons. After detailed analysis on the land use map, it is found that cultivated land converted to forestland is mainly distributed in the interlaced area of mountains and plains while discretely distributed in plains with cultivated land converting to garden plots. Meanwhile, cultivated land turned to urban-rural construction land is mainly distributed at the edge of cities and near villages. The analysis also shows that the spatial distribution of diverse types of land use change is quite different in various regions. For Tianjin, Hebei (partly) and Shandong (partly), cultivated land converting to urban-rural construction land spreads most widely while for Liaoning (partly) and Beijing, the case of cultivated land to forestland spreads most widely. From the analysis, we can even conclude that the distribution of the same type of land use change differs in different sub-regions. This is obvious in the distribution of cultivated land converting to urban-rural construction land in Beijing, Tianjin and other sub-regions.

Table 5 Frequency of the major types of land use change in the Bohai Rim (%)

3.3 Trend of regional land use change

The importance degree can quantitatively express the importance of a type of land use change in a certain region, and it can be used to ascertain the trend of regional land use change. As a composite reflection of frequency and area proportion, it is calculated with the following formula. where IV is the importance degree of a certain type of land use change, D is the frequency of the same type of land use change, and B is the area proportion. Table 6 lists the calculation results of importance degree of land-use change types. From the table, it is clear that the main direction of land use change in the Bohai Rim is the land expansion for urban-rural housing construction by occupying cultivated land and the conversion between forestland and cultivated land in different regions. Beijing's main direction of land use change is the conversion between forestland and grassland and the land expansion for urban-rural housing construction. For Tianjin, it is the land expansion for urban-rural housing construction and water area, and cultivated land adjustment. For Hebei, it is the land expansion for urban-rural housing construction and garden plots, and cultivated land adjustment. For Liaoning, it is the conversion between cultivated land and forestland, and the land expansion for urban-rural housing construction. For Shandong, it is the land expansion for urban-rural housing construction, cultivated land adjustment and land degradation.

Table 6 Importance degree of the major types of land use change in the Bohai Rim (%)

4 Conclusions

- 1) Land use changed greatly in the Bohai Rim in 1985-1995. The cultivated land decreased by 1,800,000 ha, forestland increased by 600,389 ha, housing and construction land increased remarkably.
- 2) The rate of land use change is up to 0.85% per year. The cultivated land decreased at a rate of 1.26% per year. Dwelling and construction land, water area, forestland increased at different rates, 6.40% for housing land and 6.95% for water area.
- 3) There are notable differences in land use change among the sub regions. Cultivated land change is most obvious in Beijing and Liaoning (partly), and least obvious in Hebei (partly). Housing and construction land change is obvious in Liaoning (partly) and Beijing, and least in Tianjin.
- 4) About 30% of the study area has undergone land use change, mainly cultivated land converting to urban-rural housing construction land or to forestland and grassland. They are distributed widely and differently near the mountains and in the areas joining the town and country.
- 5) The direction of land use change is the expansion of cultivated land, housing construction land, and the conversion between forestland and cultivated land.
- 6) Population growth, urbanization and adjustment of agricultural production structure are the direct causes for land use change in the Bohai Rim.

关键词: Bohai Rim; land use change; spatio-temporal analysis