

LAND USE/COVER CHANGE AND DRIVING FORCES IN SOUTHERN LIAONING PROVINCE SINCE 1950S

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ABSTRACT: Land use/cover change (LUCC) is a key aspect of global environment change, and in a sense indicates the influence of human activities on natural environment. Regional case study is the core of LUCC research. Taking the southern Liaoning Province, a coastal area facing the Bohai Sea and the Huanghai Sea, as an example, supported by ARCVIEW and ARC/INFO, this paper reconstructed LUCC patterns in three periods of 1954, 1976 and 2000, and analyzed their spatial-temporal changes from 1954 to 2000. On the base of these, it also studied the LUCC's driving mechanism. The results show that the land transformation mainly occurs among cultivated land, forestland and urban and industrial land. Industrialization and urbanization in rural area are the major driving forces for cultivated land change, and the extension of the built-up area in cities is mainly the result of economic development and tertiary industry development, etc., which is at expense of cultivated land.

KEY WORDS: land use/cover change (LUCC); spatial-temporal pattern; driving mechanism; southern Liaoning Province

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1 INTRODUCTION

Land is the most essential physical resources and material basis for people's life (LIU, 1996). Land use/cover change (LUCC) is a key aspect of global environment change, and indicates the influence of human activities on physical environment. As we all know, International Geosphere-Biosphere Program (IGBP) and International Human Dimensions Program (IHDP) have drew up a plan of "Land Use/Cover Change (LUCC)" in 1995, so that LUCC has been the advanced and hot subject in global environment change research (LI, 1995; CHEN and YANG, 2001; GEIST and LAMBIN, 2001).

By taking a comprehensive view of the international study about LUCC, it can be reduced to three cores: the dynamic analysis of process, the driving forces, and the global and regional models of LUCC (LI, 1995). The international global change study organizations, such as IGBP and IHDP, have conducted a series of researches, including dynamics, mechanisms and global and regional models in LUCC, which take 1km-grid global database as the background (GEIST and LAMBIN, 2001; TURNER *et al.*, 1990). In recent years, seeing

the huge land use changes caused by fast growing economy and the accelerated industrialization and urbanization, scholars in China have launched the territorial land use change research, mainly focusing on two aspects: the dynamic analysis of process in LUCC, and the mechanism of driving forces in LUCC (SHI and GONG, 2000; SHI *et al.*, 2000).

As a very complicated process, LUCC subjects to natural factors and human factors at the same time (YU and TANG, 2003; ZHANG and ZHAO, 1999; WANG *et al.*, 2002). The natural environment is the foundation of land use change, and controls the change partly. While the human factors such as society, economy, technology and policy, etc. are the inducements and play a decisive role in some degree. Analyzing the spatial-temporal patterns of LUCC is the basic premise of the monitoring and driving forces analysis and even more prediction of regional land use change (DENG, 2002; LIU and BUHE, 2000).

The southern Liaoning has a long coast. It is the most active area in Liaoning Province and enjoys the fastest economic development. For a long time, the region has been aiming at economic growth chiefly and ignoring

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reasonable adjustment of land use structure and effective protection of ecological environment. So the urban environment deteriorates day by day and land resources suffer from being wasted. And all of these potential disadvantages are threatening urban ecological environment and sustainable economic growth (SHI *et al.*, 1996; SHI and CHEN, 1996). The conflict between the less and less cultivated land area and human's more and more requirements of land is getting prominent. The acceleration of rural industrialization and urbanization process has deep influence on the land use change in the southern Liaoning, which is typical in the coastal area. Taking the southern Liaoning as the study area, supported by the techniques of Remote Sensing and GIS, LUCC patterns in three periods are reconstructed in this paper and spatial-temporal changes are also analyzed from 1954 to 2000. Based on this, major driving mechanism is analyzed. The study provides a better research case in revealing LUCC in industrialization and urbanization process in coastal region and also possesses the important meaning to promoting the development and region planning in the southern Liaoning Province.

2 STUDY AREA AND METHOD

2.1 Study Area

The study area is located in the southmost part of northeast economic zone (Fig. 1), and is the important door that northeast economic zone contacts with the external. It governs two prefecture-level cities (Dalian and Yingkou) and six cities or counties under these two cities (Wafangdian, Pulandian, Zhuanghe, Changhaixian, Dashiqiao and Gaizhou). The regional natural conditions is of superiority, and possesses both the characteristic of temperate continental monsoon climate and some characteristics of maritime climate, with warm climate, clear seasons, moderate precipitation and ample sunshine, therefore it is a suitable place for human being to live and carry on all social economic activities. Among the 7.8638×10^6 people in this area at 2002 year-end, about 18.92% of the total population of Liaoning Province, 3.8464×10^6 were living in urban areas, about 48.93% of the region. At 2002 year-end, GDP reached 162.373×10^9 yuan (RMB). And gross output value of industry was 147.391×10^9 yuan, while value of retail of consumer goods was 66.3×10^9 yuan. In 2002, the total land area was $17\,939.31 \text{ km}^2$, of which 3893.94 km^2 were cultivated land, accounting for 21.71% of the total area, and 6640.56 km^2 were forestland 37.01% of the total area, and 3239.37 km^2 were built-up land, 18.01% of the total area.

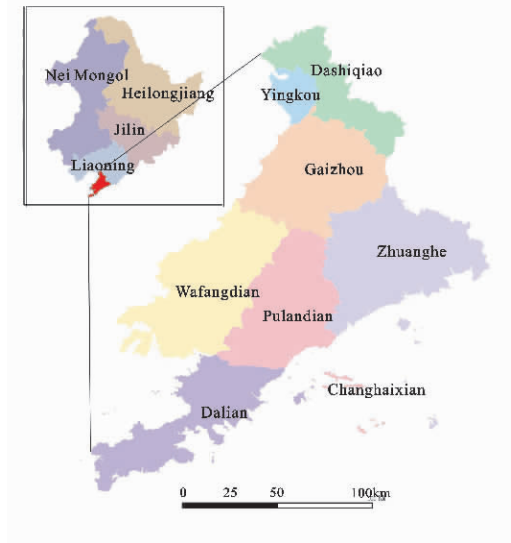


Fig. 1 Location of study area

At present, the regional land use intensive degree is relatively high, but the cultivated land per capita is relatively small, and the land productivity potentiality is low. Meanwhile, the reserved land resources are limited, and spatial land distribution is unbalanced. Taking Dalian City as an example, the land use rate is 92.72%, while cultivated land per capita is only 0.07ha, which is about 67% of the whole China's average and 63% of Liaoning Province's average. In terms of the used land, garden plot, beach, residential area and urban and industry land hold a large proportion, weighing high in Liaoning Province. The reservation lands are mostly weeds land, bare land, saline land, unused beach, which is hard to be cultivated.

2.2 Data Sources and Method

The data used in the paper spans 50 year and can be divided into the years of 1954, 1976 and 2000. The basic data sources are the remote sensing data in 2000 and the Landsat MSS image in 1976 and the topographic map in 1954. And we also take the relevant cities' and counties' statistic yearbooks and the land alteration data in consideration. We adopt different methods to different data sources. We gauge the landsat ETM+ data on the basis of topographic map at the scale of 1:100 000, and establish interpretation indications with the help of ARCVIEW. Then we get the LUCC information of the southern Liaoning Province. Adopting the MSS data in 1976 and on the basis of the ETM+ image in 2000, we obtain the LUCC information after mending the data of 1976. We distill the topographic map data on the basis of the boundary of land use type except the type that has clear boundary, and paint the places with no boundary

of land-use type along the lowest contour. After storing the three-period data in COVERAGE format and establishing a graphic database, we finally obtain the data of current use of land and the corresponding 100m-grid analyzed data.

3 LAND USE/COVER CHANGES

3.1 Quantitative Character of Land Use/Cover Change

Through analyzing the key three-period land use/cover data, we can get the character of the land use structure of the southern Liaoning.

(1) Unbalanced distribution of land use types. Mountains and hills cover most areas of the study area, and only in the coastal part the change of hypsography is moderate. Therefore, the six land use types are distributed unbalancedly, among which cultivated land and forestland hold a higher percent than the water area and urban and industrial land do (Table 1).

Table 1 Land use structure in the study area (%)

Land use type	1954	1976	2000
Cultivated land	46.43	41.71	43.17
Forestland	43.84	41.30	39.04
Grassland	1.40	1.51	1.07
Water area	2.36	2.19	2.72
Urban and industrial land	5.08	12.66	13.69
Unused land	0.89	0.64	0.31

(2) The number of all types of land fluctuated in the past 50 years (Fig. 2). From 1954 to 1976, cultivated land, forestland, water area and unused land reduced by 10.89%, 6.54%, 7.89% and 28.92%, respectively; but urban and industrial land increased notably with the rising rate of 147.03%, and the area of grassland had increased by 6.82%. From 1976 to 2000, the area of cultivated land had increased to some extent with the increasing rate of 4.11%, most of which come from the forestland and grassland; the urban and industrial land kept growing but only increased a little by 8.78%; water

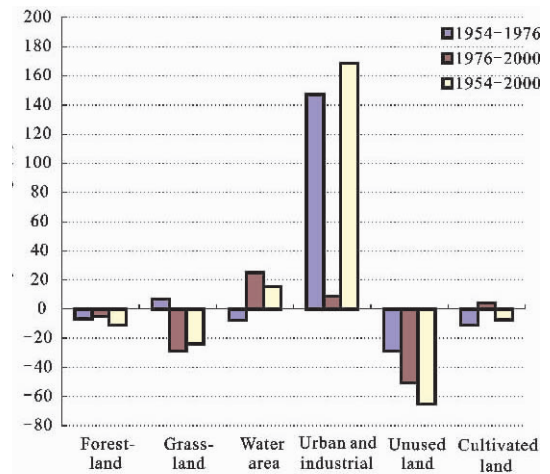


Fig. 2 Land use dynamic change of study area

area has increased by 25.08%; the forestland and grassland reduced respectively by 28.76% and 4.93%; and the unused land area decreased dramatically by 50.88%. Generally speaking, the LUCC trend of the Southern Liaoning from 1954 to 2000 is that the increase rate of urban and industrial land was the greatest, and water area took the second place, on the contrary, unused land and grassland showed obvious reduction trend, and cultivated land and forestland declined a little.

(3) Net land use/cover change. Through the analysis of the three-period LUCC data in different regions, we can reach the following conclusions. In all the regions (two prefecture-level cities and six county-level cities and counties), the urban and industrial land increased universally, and water area rose except Dashiqiao County. Except for large numbers in Yingkou as a result of closing hillsides to facilitate forestations, forestland in others all decreased, and cultivated land grew up in Zhuanghe and Pulandian but down in others. The grassland increases notably in Gaizhou and Zhuanghe but fell in other counties (Table 2).

3.2 Spatial Character of Land Use/Cover Change

Based on Fig. 3, we conclude that the LUCC in the

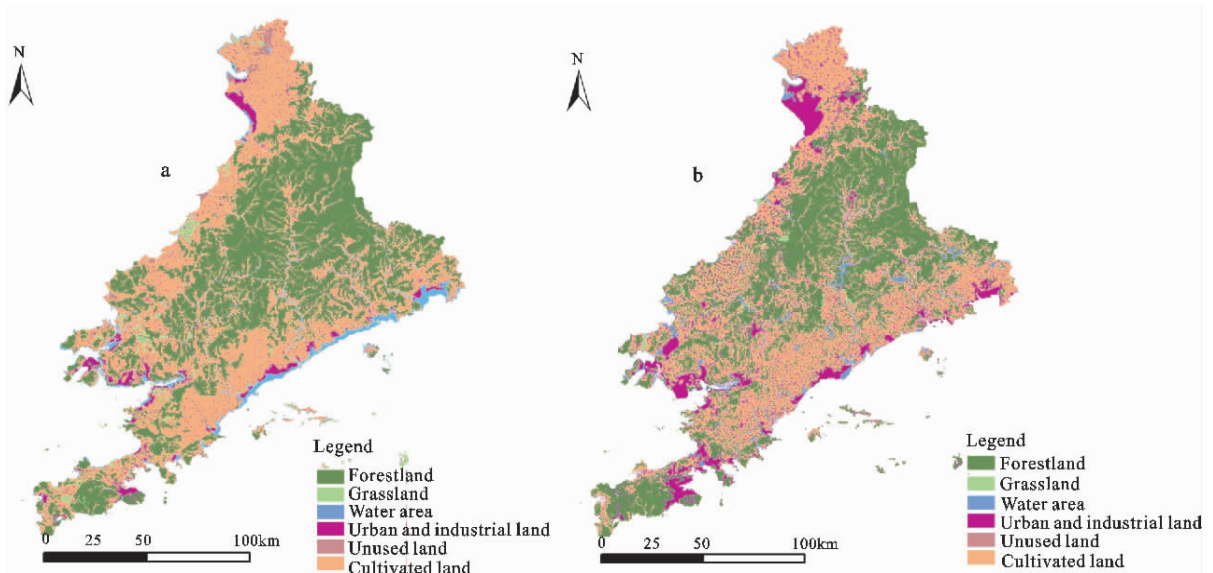
Table 2 Land use net change rate from 1954 to 2000 in southern Liaoning (%)

	Cultivated land	Forestland	Grassland	Water area	Urban and industrial land	Unused land
Dashiqiao	-2.36	-4.44	-65.10	-46.13	+206.87	-80.28
Gaizhou	-16.91	-0.46	+132.45	+126.58	+275.44	-89.03
Yingkou	-54.08	+1664.27	-23.06	+5.28	+169.28	-33.93
Changhaixian	+2.45	-98.35	-39.36	+7.28	+155.21	-28.66
Zhuanghe	+11.32	-24.40	+228.63	+4.17	+160.99	+10.39
Pulandian	+10.81	-30.07	-58.14	+11.86	+165.07	+190.07
Wafangdian	-7.88	-7.74	-40.19	+24.24	+133.67	-82.90
Dalian	-30.49	+12.79	-86.78	+36.19	+170.98	-72.58

three periods is chiefly embodied by the gradual landscape fragmentation, from the typical agricultural landscape in 1954 changing into the urban and rural mixed landscape, causing the urban and industrial land to expand rapidly. In the process of land-use change, the cultivated land patches show ceaseless fragmental and dispersive. The fragmentation degree of forestland and grassland enlarges, and part of them turn into cultivated land, causing the patches area to decrease, so that the forestland and grassland are distributed across with cultivated land. With constant economic development, the patch number and patch area of urban and industrial land keep increasing, and show central spatial distribution pattern relying on the port district and the main line of communication, basically spreading along the port agglomeration at the bank of the Huanghai Sea and the Bohai Sea and along the Ha-Da (Harbin-Dalian) railway.

3.3 Transformation of Land Use/Cover

Analyzed on the basis of the transformation matrix of the land use/cover, the land use transformation mainly occurs in cultivated land, urban and industrial land and grassland, and the transformation rates among grassland, water area and unused land are some small. In almost half a century, about 16.68% of cultivated land of 1954 has turned into urban and industrial land, which explains that the enlargement of the urban land is at the price of invading and occupying the cultivated land. About 35.54% of water area of 1954 have been transformed into urban and industrial land, which shows that the city expands to the coastal zones. The transformation area is small from forestland, grassland and unused land to urban and industrial land. The transformation of cultivated land come from unused land, grass land, forestland and water area, which unpuzzles why the change of cultivated land is little (Table 3).



Source: Center for Application and Research of Geography and Remote Sensing Technology, Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences

Fig. 3 Land use and land cover map of 1954 (a) and 2000 (b)

Table 3 Land use/cover change matrix between 1954 and 2000 (%)

1954	2000					
	Cultivated land	Forestland	Grassland	Water area	Urban and industrial land	Unused land
Cultivated land	–	13.53	0.71	3.04	16.68	0.29
Forestland	23.59	–	1.49	0.38	3.06	0.07
Grassland	27.26	63.48	–	0.84	7.04	0.24
Water area	20.50	6.37	0.50	–	35.54	3.46
Urban and industrial land	16.15	5.57	0.19	3.47	–	0.19
Unused land	60.82	6.34	4.78	12.75	9.14	–

4 DRIVING FORCES OF LAND USE/COVER CHANGE

4.1 Immanent Factor of Resources

Land resources throw certain restriction on LUCC (ZHANG, 1998). Influenced by topography, the territorial differentiation of land resources in the southern Liaoning is obvious. In the coastal area of southeastern Dalian and the plain area of the western Yingkou, the topography is low and gentle with large area of cultivated land, which is suitable for agricultural production. In the hilly land of the central and northern area, forestry production is feasible. Because of its gentle territory and feasibility to human activities, the urbanization level at coastal area is high, and the urban land increase fast with centralized trend. The expansion of urban and industrial land is at the expense of cultivated land, thus making large area of high-quality cultivated land change into built-up land and the area of cultivated land in suburban decrease. The land use structure in suburban area has been optimized further, and land for big agricultural is changing gradually into the suburban-type agricultural land, such as building vegetables bases, melon and fruit bases and flowers bases, etc. Because of its high traffic accessibility, large area of land around major traffic arteries at the city and town's periphery area has been changed into urban and rural construction land.

4.2 Social and Economic Factors

The land resources themselves are the foundation background of LUCC, while human impacts on natural environment are direct causes (ZHANG and ZHOU, 1999; WANG and HE, 2002; LIU *et al.*, 2002). Therefore the intricate social economic factors become the major causes of LUCC. Owing to the important effect of cultivated land and built-up land to mankind's economic development, according to the general analysis of social economic factors as well as available data, this paper chooses 10 indexes, such as total population, GDP and urbanization level, etc. to analyze their influences on cultivated land and urban land changes.

When developing the multiple linear regression model of cultivated land change, we choose the area of cultivated land (y_1) as the dependent variable, total population (x_1), GDP (x_2), urbanization level (x_3), gross value of industry output (x_4), gross investment in fixed assets (x_5), proportion of secondary industry (x_6) and proportion of tertiary industry (x_7), etc. as independent variable, and the regression analysis results are as follows:

$$y_1 = 441.6 - 0.1x_5 - 0.71x_6 \quad (1)$$

$$(R^2 = 0.812, \text{significance level is } 0.001)$$

Formula (1) indicates that industrialization and industrial enterprises' building are the major social economic driving forces of cultivated land change. Because cultivated land is chiefly distributed along coastal plain zones with flat terrain, human production and life activities are inclined to the plain area; therefore, the impacts of human social economic activities on the cultivated land are very remarkable. After the founding of the People's Republic of China in 1949, the industrialization in the study area has occurred mostly at the plain zones where large area of cultivated land is distributed. A large number of industrial enterprises were concentrated on the area, so, the active regional economy drove the regional development and people concentrated gradually in the area. Large area of cultivated land had changed into urban construction land for the increase of industrial enterprises' building land. To sum up, the production and construction of industry enterprises exerted deep influences on the cultivated land decrease.

When developing the multiple linear regression model of urban construction land change, we choose the built-up area as dependent variable (y_2), the total population (x_1), GDP (x_2), nonagricultural population (x_3), value of capital actually used from foreign countries (x_4), proportion of primary industry (x_5), proportion of secondary industry (x_6) and proportion of tertiary industry (x_7), etc. as independent variables, and the regression analysis results are as follows:

$$y_2 = -1154.54 - 0.21x_2 + 3.77x_3 + 8.38x_7 \quad (2)$$

$$(R^2 = 0.966, \text{significance level is } 0.001)$$

Formula (2) indicates that the increase of urban construction land chiefly depends on the social economic factors such as the development of tertiary industry and the increase of nonagricultural population and the rising of GDP.

Since the reform and opening up in the late 1970s, the regional industrial structure adjustment has laid stress on the development of secondary and tertiary industries, and regional industrial development has been transformed from labor-intensive to fund- and knowledge-intensive. In the process of industrial structure adjustment, enterprises thought more about the land use cost, economic income and competitive ability in rent. Related calculation shows that a reasonable urban industrial layout and structure can economize 10%–20% of urban land and decrease 10%–20% of the cost of industrial land use. The layout of the new industries of economic development such as tertiary industry and high-tech industry makes the urban land expand to new space, showing an obvious industry-leading character of urban

land-use, and the layout of urban land tends to be more marketable and rational.

5 CONCLUSIONS

(1) In recent years, rural industrialization and urbanization have been accelerated owing to the development of regional economy, which has made LUCC extensively and diversely. Through analyzing the data of the study area, we can find that the distribution of the land use types in the area is unbalanced, among which cultivated land and forestland hold a higher percent than others. In the past 50 years, the area of all types of land fluctuated, the urban and industrial land expanded faster than others.

(2) The results show that the LUCC in the three periods is chiefly embodied by the gradual landscape fragmentation, from the typical agricultural landscape in 1954 changing into the urban and rural mixed landscape. In terms of space distribution, urban and industrial land is arranged chiefly along the main line of transportation and around the port district in band and group pattern.

(3) Analyzing the driving forces of the land use/cover change in the study area, we can see that the urbanization and industrialization in rural area are the major driving forces for cultivated land change and the extension of the built-up area is the result of economic growth and the rapid development of the tertiary industry, characterized by land for industrial use having occupied a large number of cultivated land. In addition, port position, traffic conditions, topographical conditions, early land use mode and other inherent factors can influence and restrict the land use/cover change. Among them, the functions of the port position and the traffic conditions are particularly outstanding.

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