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ANALYSIS AND MODELING ON CULTIVATED LAND CONVERSION — Case Study of Hebei Province

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ABSTRACT: With the acceleration of the urbanization and industrialization of China, it is inevitable that cultivated land converts to built-up land for industrial, commercial and residential uses, which would impose pressure both on food security and on the sustainability of urbanization itself for such a country with large population and few cultivated land. Based on the three-time Landsat Thematic Mapper (TM) digital images and statistic data of Hebei Province, the general facts of cultivated land conversion and its driving forces were analyzed by establishing econometric model in this paper. Some conclusions were drawn as the following: during 1985- 2000, the rate of cultivated land converting to built-up area in Hebei was 4.01% or 0.27% per year. Of all the converted cultivated land, 20.96% was converted to built-up area and of all the new built-up areas, 83.4% was converted from cultivated land; meanwhile the conversion is uneven not only in time but also in space; factors such as edge length shared by cultivated land and built-up land, agricultural value per hectare, non-agriculture value per hectare, GDP, total population, farmer's net income per capita and time had significant effects on this conversion.
KEY WORDS: cultivated land conversion; driving forces; econometric model; Hebei Province

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1 INTRODUCTION

With the acceleration of the urbanization and industrialization of China, it is inevitable that cultivated land converts to built-up land for industrial, commercial and residential uses. During 1986-2002 around 168.4×10^3ha cultivated land had converted to non-agriculture use annually (QU et al., 2005). Though the urbanization rate had increased from 17% in the late 1970s to 41% in 2004, China has a long way to go compared with the developed countries whose urbanization rate had exceeded 70% in general. Therefore there would be more cultivated land conversion in the future, which would impose pressure both on food security and on the sustainability of urbanization itself. In view of this, the spatial-temporal characteristics of cultivated land conversion and its driving forces in China were much important to be analyzed.

Cultivated land conversion takes on spatial differentiation in China. For example, the conversion of cultivated land to built-up land mainly concentrated in southeastern coastal area and inland plain area, and the expansion of built-up land for urban and rural use was significant in the Huang-Huai-Hai (Huanghe (Yellow) River, Huaihe River and Haihe River) Plain and the Changjiang (Yangtze) River delta plain area, which accounted for 62% of the total newly increased built-up land and mainly came from high quality cultivated land (LIU et al., 2003). In this paper, Hebei Province has been chosen as a case to analyze its cultivated land conversion.

Studies on cultivated land conversion have been carried out from different aspects such as the development trend, the benefit mechanism, the management system and the driving forces etc. (SKINNER et al., 2001; QU and CHEN, 2001; JIA and ZHANG, 2002; KAREN and ROBERT, 2003). Among them, researches on the driving forces are not only the base and support for other studies, but also the focus currently and in future. As for the driving forces of land conversion, viewpoints held are different, methods adopted are diverse with either qualitative (XU and LI, 2001; CAI and HUO, 2002) or quantitative methods (SHI et al., 2000; GAN et al., 2004), and the data used are either from the statistics (WU et al., 2004) or remote sensing (TAN Ming-hong et

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al., 2004). However, the studies mentioned above still could be improved in general, especially for the present quantitative study, where the annual total cultivated lands instead of the converted cultivated lands usually had been made as the dependant variable in econometric model construction, which more or less weakened the veracity of the model. In addition, there was generally no treatment of spatial characteristics of different land use. In view of these, using remote sensing data an econometric model has been established, where the conversion of two periods was used as the dependent variable and the spatial factor has been added to independent variables to do more accurate factor analysis in this paper. Furthermore, the counties of Hebei Province have been chosen as the sample unit to improve the shortcoming of lack of samples in former studies.

2 STUDY AREA AND DATABASE

2.1 Study Area

Hebei Province is located in 36°05'-42°40'N and 113°27'-119°50' E. The topography of Hebei is high in northwest, low in southeast. The physiognomy is complex with three-physiognomy cells, the Bashang Plateau, Yanshan-Taihang mountainous area and Hebei Plain. The total area of Hebei Province is 187 693km^2, in which Bashang Plateau, a part of Mongolia Plateau, accounts for 8.5%; Hebei Plain, the largest plain in North China Plain, accounts for 43.4%; and the mountainous area accounts for the rest portion. According to administrative divisions, Hebei Province is made up of 11 prefecture-level cities, 23 county- level cities and 115 counties.

At the end of 2003, the total population was 67.694×10^6, and the average population density was 360 persons/km^2. Since China implementing the reform and opening-up policy in 1978, Hebei has experienced profound changes not only in social and economic structure, but also in its surrounding environments. Accompanied by the population growth, economic development and urban construction in past years, the land use pattern and land cover structure has changed greatly. Provided with advantageous location and landscape, Hebei has become one of the main cultivated land loss areas in China.

2.2 Database

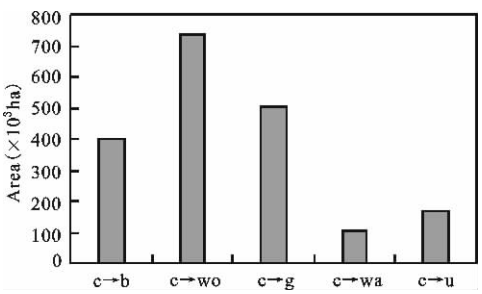
In this study, 1∶100 000 digital land-use data of 1985, 1995 and 2000 were obtained from the Landsat Thematic Mapper (TM) ①. The original map consists of seven classes of land-use types and 27 subclasses. The seven classes include cultivated land, woodland, grassland, water area, residential area, land for industrial and mining sites and unused land. In this paper, built-up land is residential area (urban land and rural settlement) and land for industrial and mining sites.

The social and economic data were from Hebei Economic Statistics in 1949-2001 (HPBS, 2001), Hebei Economic Yearbook (HPPG, 1986-2001) and New Fifty Years of Hebei Province (GOHPPG, 1999).

3 CHARACTERISTICS OF CULTIVATED LAND CONVERSION

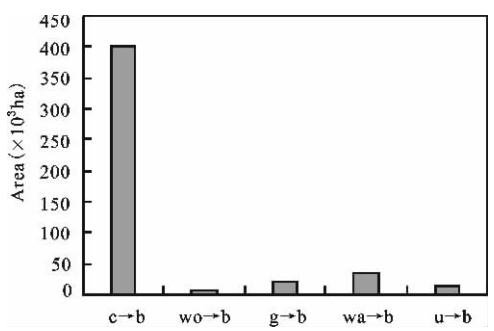
3.1 General Characteristics

By using union function in ESRI's Arcinfo 8.3 to do overlap analysis with the three-time TM remote sensing data at county level of Hebei, the land conversion matrix of 1985-1995, 1995-2000 and 1985-2000 at the province- and county-level were gotten, from which cultivated land conversion and the original areas of built-up land were extracted (Fig. 1, Fig. 2 and Table 1).



c: cultivated land; b: built-up land; wo: woodland; wa: water area; g: grassland; u: unused land

Fig. 1 Cultivated land conversion of Hebei Province in 1985-2000



c: cultivated land; b: built-up land; wo: woodland; wa: water area; g: grassland; u: unused land

Fig. 2 Origin of increased built-up land of Hebei Province in 1985-2000

① The remotely sensed data were interpreted by the Resources and Environment Data Center, Chinese Academy of Sciences

Table 1 Cultivated land conversion and its rate

	1985- 1995	1995- 2000	1985- 2000
Cultivated land→Built-up land (ha)	359419.16	40425.37	399844.53
Annual area of cultivated land conversion (ha)	35941.92	8085.07	26656.30
Rate of cultivated land conversion(%)	3.60	0.45	4.01
Annual rate of cultivated land conversion(%)	0.36	0.09	0.27

According to Fig. 1, cultivated land converting to woodland and grassland were the most, accounting for 38.5% and 26.43% respectively in the total conversion. The areas of cultivated land to built-up land took the third place. Of all the converted arable land, 20.96% was converted to built-up area. According to Fig. 2, in all the newly increased built-up area, 83.4% was converted from cultivated land. In this paper, importance was mainly attached on the conversion from cultivated land to built-up land.

During 1985 - 2000, the total area of cultivated land conversion in Hebei Province was 399 844.53ha, or 26 656.3ha annually. The rate of cultivated land converting to built-up land was 4.01% , or annually 0.27% (Table 1), which was higher than the level of 0.24% for Taiwan in the 1980s and 0.20% for China's mainland during 1991- 1999 (TAN Yong-zhong et al., 2004).

3.2 Spatial-temporal Characteristics

Firstly, cultivated land converting to built-up land was uneven in time. Both the annual acreage and the rate of cultivated land converting during 1985- 1995 were higher than that in 1995- 2000 (Table 1). This could be mainly ascribed to comparatively relaxed regulation policy on cultivated land conversion before 1997, and after that the regulation entered into a strict period.

Secondly, the rates of cultivated land conversion to built-up land were spatially different in Hebei Province. And 149 counties of Hebei Province could be classified into four types by the ratio of cultivated land conversion (Fig. 3): the acute cultivated land loss region (K>10%, K means the ratio of cultivated land converting to built-up land), the severe cultivated land loss region (5%<K≤ 10%), the rapid cultivated land loss region (2%<K≤5%) and the slow cultivated land loss region (K≤2%).

The region of acute cultivated loss is mostly located in prefecture-level cities and regions adjacent to Beijing such as Sanhe and Dachang, where the lost cultivated land were mainly cultivated land and vegetable plot with high quality. This would inevitably induce decline of the whole cultivated land quality. Severe cultivated land loss mainly took place in North China Plain, especially in the counties of Shijiazhuang and Baoding. The rapid cultivated land loss region was mainly in counties of Hengshui, Xingtai, Handan, Qinhuangdao and Tangshan. Slow cultivated land loss mostly took place in high altitude area such as Zhangjiakou and Chengde (Fig. 3).

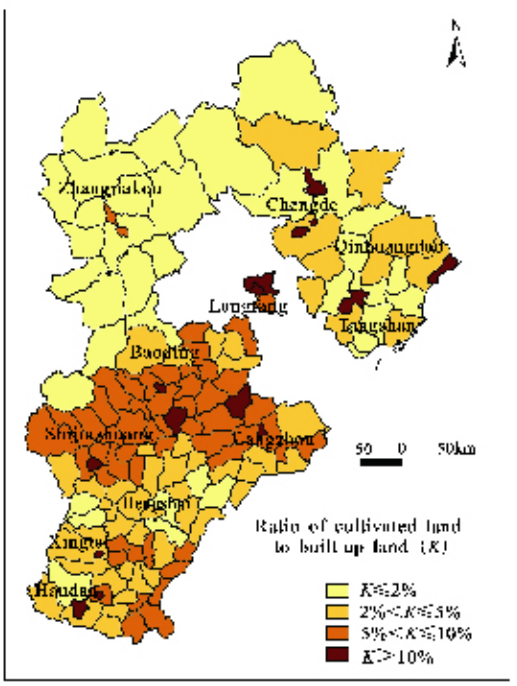


Fig. 3 Distribution of cultivated land conversion ratio at county level

4 ECONOMETRIC MODELING OF DRIVING FORCE OF CULTIVATED LAND CONVERSION

Cultivated land conversion is one part of dynamic land use structure transformation. It was also the result of both natural environmental factors and social economic factors acting together. In the following step, an econometric model was constructed to analyze the driving forces behind cultivated land conversion.

4.1 Establishment of Econometric Model

In this econometric model, data of land use and related economic data were used to explain two sorts of land conversions: land conversion from cultivated land to built-up land, and land conversion from cultivated land and "other" land to built-up land. The dataset used was a pooled time-series cross section. For each sort of land

conversion, remote sensing data for 149 counties of Hebei in two periods, 1985- 1995 and 1995- 2000, were used as dependent variables. Edge length shared by cultivated land and built-up land, agricultural value per hectare, non-agriculture value per hectare, GDP, total population, non-agriculture population, investment level, farmer's net income per capita and time were chosen as independent variables.

An econometric equation with a linear form was established:

$$C_{i,t}=\beta_0+\beta_1X_{1i,t}+\beta_2\Delta X_{2i,t}+\beta_3\Delta X_{3i,t}+\beta_4\Delta X_{4i,t}+\beta_5\Delta X_{5i,t}+\beta_6\Delta X_{6i,t}+\beta_7\Delta X_{7i,t}+\beta_8\Delta X_{8i,t}+\beta_9T_{i,t}+u_{i,t}$$

where, i is the serial number of a county, i=1, 2, 3...,149; t is period, $t=\begin{cases}0 \text{ for } 1985\text{- }1995\\1 \text{ for } 1995\text{- }2000\end{cases}$ and β_0 ..., β_9 are regression coefficients, $u_{i,t}$ is residual error.

(1) The dependent variable ($C_{i,t}$) was conversion area in county i at period t. We estimated the model for two types of conversion: cultivated land to built-up land conversion and all conversion to built-up land.

(2) Edge($X_{1i,t}$): We used remote sensing data and ArcInfo software to create a proxy variable as the perimeter of conversion land subject to conversion pressure at the beginning of each time period. It measured the length of the border shared by cultivated land and built-up land. We would expect the edge to be positively correlated with cultivated land conversion.

(3) Land use profit: measured with the increment of agriculture value per hectare ($\Delta X_{2i,t}$) and the increment of non-agriculture value per hectare ($\Delta X_{3i,t}$). Agriculture value per hectare was the ratio of the value of primary industry to the area of agriculture land. Non-agriculture value per hectare was the ratio of the value of secondary industry and tertiary industry to the area of built-up land. We would expect that cultivated land conversion would be negative to $\Delta X_{2i,t}$ and positive to $\Delta X_{3i,t}$.

(4) Economic development level: reflected by the increment of GDP ($\Delta X_{4i,t}$). The more increase of GDP, the more areas of cultivation conversion.

(5) Urbanization level: reflected by the increment of total population ($\Delta X_{5i,t}$) and the increment of non-agriculture population ($\Delta X_{6i,t}$). The more increase of $\Delta X_{5i,t}$ and $\Delta X_{6i,t}$, the more conversion of cultivated land.

(6) Investment level: reflected by the increment of the whole social investment in fixed assets ($\Delta X_{7i,t}$). We would expect the more increase of $\Delta X_{7i,t}$, the more conversion of cultivated land.

(7) Income level of farmer: it was reflected by the increment of farmer's net income per capita ($\Delta X_{8i,t}$). The more increase of $\Delta X_{8i,t}$, the more areas of cultivated land conversion.

(8) Finally, we added a dummy variable ($T_{i,t}$) to test the differences in area between two periods. As Table 1 showed, there was significantly less annual average conversion in 1995- 2000 than in 1985- 1995. Thus, we would expect that the dummy variable to be negatively correlated with conversion.

4.2 Results of Model

In order to eliminate the effect of multicollinearity, stepwise regression was used to estimate parameters of this model with SPSS 12.0. The results were listed in Table 2.

Table 2 Result of model estimation

Independent variable	Dependent variable (area of land converted)	
	Cultivated land to built-up land	Other land types to built-up land
Edge ($\times10^3$m)	0.522 *	0.803**
	(1.925)	(2.160)
Change in agriculture value per hectare (yuan/ha) (RMB)	- 0.045 **	- 0.057**
	(- 2.680)	(- 2.515)
Change in non-agriculture value per hectare (yuan/ha)	0.002 **	0.003**
	(2.127)	(2.721)
Change in GDP ($\times10^3$yuan)	0.000 **	0.000**
	(2.482)	(2.806)
Change in total population ($\times10^3$)	5.055 *	5.033 *
	(1.932)	(1.928)
Change in farmer's net income per capita (yuan)	0.422 **	0.320
	(2.071)	(1.149)
Dummy variable = 1 in 1995- 2000	- 2014.242 **	- 2543.958
	(- 9.923)	(- 10.659)
Constant	1174.760	1681.978
	(4.222)	(4.5)
R^2	0.504	0.401
F	42.06**	27.688**
N	298	298

Notes: **indicates the test significant at 5% level; *indicates the test significant at 10% level; regression coefficients are out parenthesis and t-test in parenthesis

According to regression results, the model's explaining degree of cultivated land conversion to built-up land was better than that of other land conversion to built-up land, while F statistic tests were both significant.

Edge length, agriculture value per hectare, non-agriculture value per land, GDP and total population were statistically significant in both kinds of conversion. Farmer's net income per capita and time were also passing 5% t-test in the model of cultivated land conversion to built-up land.

Edge was statistically significant at 10% level and positively correlated with conversion from cultivated land to built-up land, which meant the longer of edge, the higher pressure subjected by cultivated land at the urban fringe under urban expansion and the more conversion of cultivated land.

Land use profit was highly significant at 5% level. Agriculture value per hectare negatively correlated with cultivated land conversion, but non-agriculture value per hectare positively correlated with it. It meant different land uses had different profit and the comparative advantage of agriculture land was far lower than that of built-up land. Furthermore, the lower of agriculture land profit and the higher of built-up land profit, the more cultivated land conversion.

The increment of GDP was statistically significant at 5% level and positively correlated with cultivated land conversion. It meant the more increase of GDP, the more area of cultivated land conversion.

Population was statistically significant at 10% level and positively correlated with the conversion. The living space became more and more compressed and the living environment deteriorated because of industrialization and urbanization. The request to improve living condition and environment surrounded led to the expansion of urban built-up area step by step, which induced the occupation of lots of farmland around city. In addition, the increase of population directly led to cultivated land conversion.

Farmer's net income per capita was statistically significant at 5% level. The more increase of that, the more area of cultivated land conversion. The increase of farmer's income directly induced the increasing need of house construction in rural areas by occupying cultivated land.

The dummy variable for the 1995- 2000 period was also statistically significant, but negatively correlated with the conversion. It could be seen form Table 1 that the annual average conversion was larger during 1985- 1995 than that during 1995- 2000.

Based on the analysis of model above, it is indicated that great differences of cultivated land conversion had appeared in different counties of Hebei Province since the diversity in pressures of urbanization, scales of economic development, comparative benefits of land use, speed of population growth and farmer's income per capita etc. Generally, regions with flatter topography, larger urbanization pressure, rapider economic development, higher comparative advantages, quicker population growth and faster increases in farmer's income per capita would be more prone to become the area of cultivated land intensive loss than those regions in the other way around.

5 CONCLUSIONS AND SUGGESTIONS

After the cultivated land conversion and its driving forces have been analyzed during 1985- 2000 in Hebei Province, some results could be reached as follows:

(1) During 1985- 2000, the rate of cultivated land conversion to built-up area in Hebei was 4.01% or annually 0.27%. Of all the converted cultivated land, 20.96% was converted to built-up area and in all the newly increased built-up area, 83.4% was converted from cultivated land.

(2) Cultivated land conversion to built-up land was uneven in time and space. The annual average cultivated land conversion was larger during 1985- 1995 than that during 1995- 2000 and the ratios of cultivated land conversion to built-up land were different in different counties of Hebei Province.

(3) According to econometric model established, factors such as edge length, agriculture value per hectare, non-agriculture value per hectare, GDP, total population, farmer's net income per capita and time had significant effects on such conversion.

In order to achieve reasonable utilization of land resources and sustainable urbanization, some countermeasures should be performed from the following aspects:

(1) To hold correct recognition on the relation between economic development and cultivated land conversion, all the time stand on our current situation of more population with less arable land and food security being of utmost importance and reasonably control the speed and scale of cultivated land conversion.

(2) To make the best of the advantageous guidance to carry out the new rural construction advocated by the country in new era, improve agricultural production condition actively, reduce farm's production costs, raise the comparative benefits of agriculture, and restrain immoderate cultivated land loss.

(3) In view of the investment level being an important factor in cultivated land conversion, to reasonably guide investment, effectively prevent and control blind investment and strictly punish illegal occupation and use of cultivated land.

(4) Based on the irreversible trend of accelerated urbanization, to make great efforts to improve the current level of intensive urban land utilization, formalize the cultivated land conversion in the process of urbanization and make it adapt to urbanization.

(5) To strengthen rural settlement land arrangement and adjust land use scale of rural settlement.

(6) To Adjust land incomes distribution, strengthen supervision on the land governors and users, restrict local government from pursuing huge income by promoting cultivated land conversion unreasonably.

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