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# STUDY ON THE SPATIAL PATTERNS OF LAND-USE CHANGE AND ANALYSES OF DRIVING FORCES IN NORTHEASTERN CHINA DURING 1990 – 2000

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**ABSTRACT:** Land-use change is an important aspect of global environment change. It is, in a sense, the direct result of human activities influencing our physical environment. Supported by the dynamic serving system of national resources, including both the environment database and GIS technology, this paper analyzed the land-use change in northeastern China in the past ten years (1990 – 2000). It divides northeastern China into five land-use zones based on the dynamic degree (DD) of land-use: woodland/grassland – arable land conversion zone, dry land – paddy field conversion zone, urban expansion zone, interlocked zone of farming and pasturing, and reclamation and abandoned zone. In the past ten years, land-use change of northeastern China can be generalized as follows: increase of cropland area was obvious, paddy field and dry land increased by 74. 9 and 276. 0 thousand ha respectively; urban area expanded rapidly, area of town and rural residence increased by 76. 8 thousand ha; area of forest and grassland decreased sharply with the amount of 1399. 0 and 1521. 3 thousand ha respectively; area of water body and unused land increased by 148. 4 and 513. 9 thousand ha respectively. Besides a comprehensive analysis of the spatial patterns of land use, this paper also discusses the driving forces in each land-use dynamic zones. The study shows that some key biophysical factors affect conspicuously the conversion of different land-use types. In this paper, the relationships between land-use conversion and DEM, accumulated temperature( ≥10℃ ) and precipitation were analysed and represented. We conclude that the land-use changes in northeast China resulted from the change of macro social and economic factors and local physical elements. Rapid population growth and management changes, in some sense, can explain the shaping of woodland/grassland – cropland conversion zone. The conversion from dry land to paddy field in the dry land – paddy field conversion zone, apart from the physical elements change promoting the expansion of paddy field, results from two reasons: one is that the implementation of market-economy in China has given farmers the right to decide what they plant and how they plant their crops, the other factor is originated partially from the change of dietary habit with the social and economic development. The conversion from paddy field to dry land is caused primarily by the shortfall of irrigation water, which in turn is caused by poor water allocation managed by local governments. The shaping of the reclamation and abandoned zone is partially due to the lack of environment protection consciousness among pioneer settlers. The reason for the conversion from grassland to cropland is the relatively higher profits of farming than that of pasturing in the interlocked zone of farming and pasturing. In northeastern China, the rapid expansion of built-up areas results from two factors: the first is its small number of towns; the second comes from the huge potential for expansion of existing towns and cities. It is noticeable that urban expansion in the northeastern China is characterized by gentle topographic relief and low population density. Physiognomy, transportation and economy exert great influences on the urban expansion.

**KEY WORDS:** land use, land-use change, spatial pattern, driving force, northeastern China

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## 1 INTRODUCTION

Land-use/coverage change has become an issue of paramount importance in the study of global environmental changes (GEIST and LAMBIN, 2001). As a developing country, China has developed a series of

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policies influencing the land-use change. In addition, due to its varied physical environment and vast land area, China's land-use changes not only influence its social and economic development but also respond concomitantly to the global changes. In order to understand the modern process of land-use change, and to more accurately predict its trends, the Chinese Academy of Sciences(CAS) has built a temporal and spatial data warehouse, with remote sensing data as its main data sources, to study the modern evolution of the terrestrial ecosystem (LIU, 2000). This project, titled National Resources and Environmental Database, is essentially the fundamental work to study the area differentiation of land-use dynamics, and to further analyse the driving forces behind them and to predict future land-use changes. We carry out this study based on 1km grid data in order to eliminate the scale effect of different data sources and to ensure their degrees of accuracy (LIU, 2001).

The study area of the current paper is located in northeastern China, delimited by Sino-Russian and Sino-Korean boundaries to the north and east. Its western boundary is the aridity isoline of 1.2 and merges into the vast temperate grassland of Inner Mongolia. Its southern boundary is the 3200 isotherm of accumulated temperature of ≥10℃ that demarcates the temperature and warm-temperate zones. Northeastern China differs somewhat from northern China whose northern boundary roughly corresponds with the Great Wall. Administratively, northeastern China includes the provinces of Heilongjiang, Jilin and Liaoning and a small part of the Inner Mongolia Autonomous Region. It is one of the most important bases of commercial grains and economic crops (soybeans, sugar beets, etc.), as well as the largest timber and petroleum-producing area in China. Fig. 1 shows the geographical locations of study area(the shaded area).

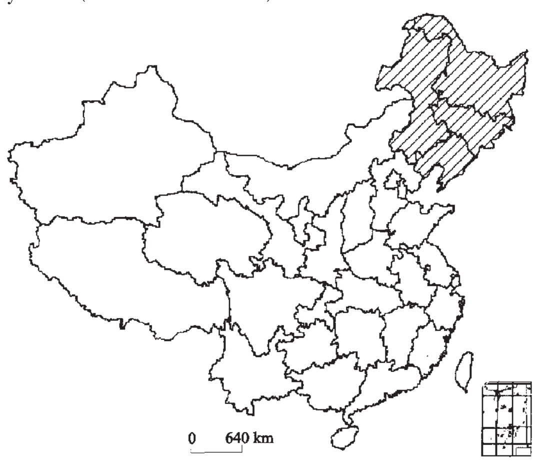


Fig. 1 The location of study area

## 2 DATA PROCESSING

There are two methods to extract land-use change information based on remote sensing data (JOHNSON *et al.*, 1998). The first is based on the classification of input data, and the second is based on the seasonal variation of radiation characteristics of the Earth surface. The former needs accurate classification standards, as well as accuracy and working efforts in data collection. The latter requires rigorous selections of remote sensing data sources and accurate data processing. During the implementation of building the National Resources and Environment Database, we applied the standard classification system, and organized a highly efficient and effective team to interpret remote sensing data in order to guarantee interpretation accuracy. In addition, on the basis of land-use maps at the scale of 1∶100 000 (which relied on Landsat TM data as their data sources and held 6 classes of first level as well as 25 classes of second level of land-use types), we drew the outline of land-use change by comparative analyses of the two-period land-use maps. Based on the above considerations, we extracted the information of land-use change based on the classification system (direct interpretation) designed by ourselves.

Main data sources are the two-period remote sensing data (Landsat-TM digital image). After radiation calibration, the average location errors can be limited to 50 meters (about 2 pixels). The average degree of interpretation accuracy is 98.7%, furthermore, the degree of interpretation accuracy of arable land and urbanization is 99.0%, which guarantees the high interpretation accuracy for each pixel (about 97.6%).

As we all know, supported by the 1km grid global database, IGBP, IHDP and other international research organizations have conducted a series of researches, including land cover dynamics and mechanisms, as well as global and regional models. We believe that the 1km grid data is an effective data integration method that can provide sufficient information for the regional land-use change monitoring, and driving forces analyses and predictions. The methods to generate 1km grid data are not as complicated as we have expected. The first task is to compare the two-period land-use maps and draft the changing patches of land use. We will then intersect the changed patches map and former period land-use maps at grid scale of 1km, and compare the changed areas and conversion areas in each 1km grid. The next task is the statistical analyses and the display of the land-use dynamics based on a vector map with 1km grid scale. The design of this workflow insists on "zero-loss" of information. Due to the lack of information on the thin objects existed in different land-use types, the summary of land-use types only represents the remote sensing investigation areas, which, in some sense, can be called "gross areas".

## 3 MODELS

The area differentiation of land-use dynamics can be represented by the dynamic models of land use (LIU, 2000), i. e.

$$S = \left\{ \sum_{ij}^{n} \left( \Delta S_{i-j} / S_i \right) \right\} \times (1/t) \times W_i \times 100\%$$

$n = 1, 2, 3 \ldots$

where, $S$ is the degree of land-use dynamics, $S_i$ represents area of $i$ (land-use type) at the former stage while $W_i$ is the weight of areas proportion, $\Delta S_{i-j}$ represents the net change of land-use areas from the former stage $i$ to the latter stage $j$, $t$ is the time lag.

Based on the statistics of changing amount of conversions of different land-use types in each grid, we concluded that there exist conspicuous expansion and shrinkage of types of land use. These can be generalized in Fig. 2.

The code system of land-use dynamic patches, theoretically, includes 625 land-use dynamic types ($25 \times 25$) according to the second-level classification system of land use. In order to concentrate on the analyses of the main conversion directions, we simplified the land-use conversion type into 9 categories: $P_1$, $P_2$, $P_3$, $P_4$, $P_5$, $P_6$, $P_7$, $P_8$, $P_9$ (Table 1). We determine the conversion types of each grid in term of the maximal conversion rate of every land-use types, but to classify some grids to "no change" when their maximal conversion rates are less than 0.05%. Among these 9 categories, $P_1$ (arable land – arable land) refers to the conversion between paddy field and dry land; $P_2$ results from reusing land as forest or grassland; $P_3$ represents water body expansion (including river, lake, reservoir, glacier, beach land, etc.); $P_4$ mainly refers to other types of land-use being transformed into built-up area; $P_5$ results from deforestation and reclamation; $P_6$ discloses forests being destroyed into grassland; $P_7$ is about grassland or swampy land being reclaimed; $P_8$ mainly refers to the tree planting and afforestation in grassland or swamp land; and $P_9$ represents the conversion from a body of water to cropland, woodland, grassland or unused land.

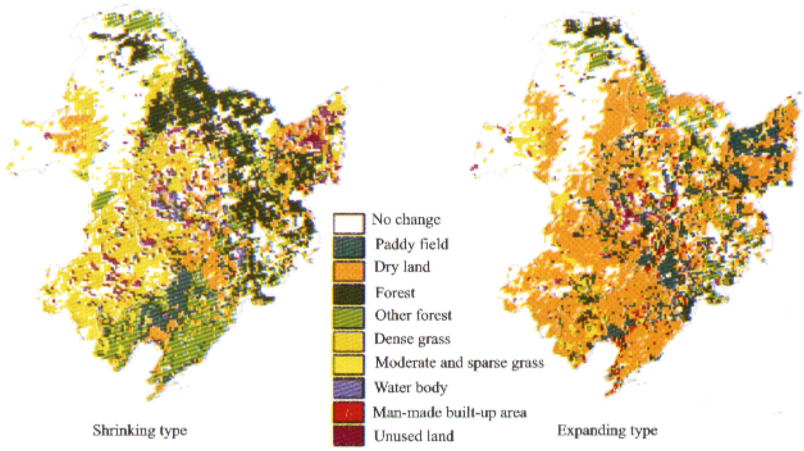


Fig. 2 Land-use types of expansion compared with shrinking in northeastern China

Table 1 Land-use conversion types in northeastern China

| Before conversion | Arable land | Forest area | Grassland and unused land | Water body | Built-up area |
|---|---|---|---|---|---|
| Arable land | $P_1$ | $P_2$ | $P_2$ | $P_3$ | $P_4$ |
| Forest area | $P_5$ | – | $P_6$ | $P_3$ | $P_4$ |
| Grassland and unused land | $P_7$ | $P_8$ | – | $P_3$ | $P_4$ |
| Water body | $P_9$ | $P_9$ | $P_9$ | – | $P_4$ |

## 4 AREA DIFFERENTIATION OF LAND-USE CHANGE

Based on Fig. 3, we subdivided the northeastern China into 5 zones in land-use dynamic types in light of administrative divisions as well as geographical background maps (Fig. 4): 1) woodland/grassland – arable land conversion zone; 2) dry land – paddy field conversion zone; 3) urban expansion zone; 4) interlocked

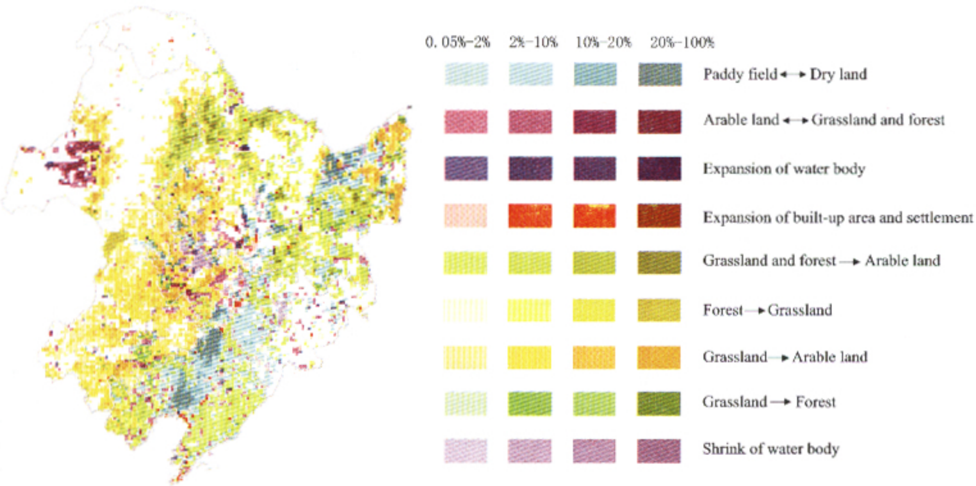


Fig. 3 Spatial distribution of land-use dynamic degree (DD)

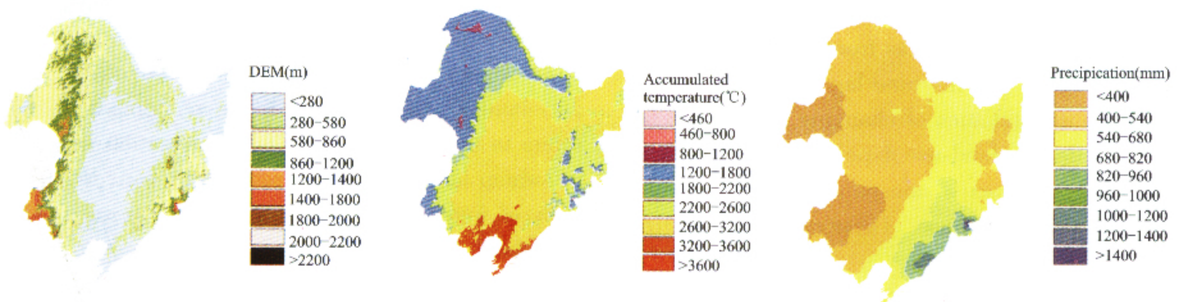


Fig. 4 Chief geographical features of northeastern China

zone of farming and pasturing and; 5) reclamation and abandoned zone (Fig. 5). Chief biophysical factors covering elevation, accumulated temperature and annual precipitation were considered in the first place.

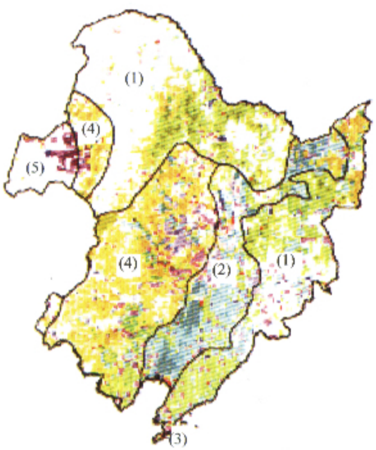


Fig. 5 Division of northeastern China based on land-use/cover change

In the past ten years, land-use change of northeastern China could be generalized as follows (Table 2 and 3): increase of cropland area was obvious, paddy field and dry land increased by 74.9 and 276.0 thousand ha respectively; urban areas expanded rapidly, areas of town and rural residence increased by 76.8 thousand ha; areas of forests and grassland decreased sharply with the amounts of 1399.0 and 1521.3 thousand ha respectively; areas of water body and unused land increased by 148.4 and 513.9 thousand ha respectively. It also shows obvious area differentiation in land-use change of northeastern China. According to the dynamic degree model of land use, we can now analyse the driving forces of land-use change based on the five subdivided zones in northeastern China (Fig. 5).

It is noticeable that there exists conspicuous area differentiation of land-use change in northeastern China (Table 3). Woodland/grassland – arable land conversion zone is located in the interlocked areas of agriculture and forestry, where large area of natural wood (with an area of nearly 108.0 thousand ha) was felled in order to meet the requirement of cropland increase. Dry land – paddy field conversion zone is characterized by the conversion from dry land to paddy field, the increased paddy field totals 294.2 thousand ha. The interlocked zone of farming and pasturing (characterized by the conversion from grassland to cropland) includes

Table 2 Land-use net change during 1990 – 2000(ha)

| Zone | Paddy field | Dry land | Forest area | Grassland | Water body | Built-up area | Unused land |
|---|---|---|---|---|---|---|---|
| 1 | 159071.3 | 1521794.7 | –1083139.0 | –461580.1 | 4899.1 | 22537.2 | –160939.5 |
| 2 | 294150.5 | 78205.0 | –141115.4 | –77376.5 | –51091.3 | 36950.3 | –139706.8 |
| 3 | 0.0 | 5437.8 | –3463.0 | –2075.4 | –19.2 | 23.4 | 96.3 |
| 4 | 295532.6 | 1304445.0 | –170889.3 | –1132203.7 | –111433.4 | 16257.2 | –201701.9 |
| 5 | 0.0 | –150137.4 | –318.0 | 151913.3 | 9183.7 | 1015.3 | –11659.2 |
| Total | 748754.4 | 2759745.1 | –1398924.7 | –1521320.4 | –148461.2 | 76783.4 | –513911.1 |

Table 3 Land-use conversion matrix of northeastern China from 1990 to 2000(ha)

| Zone | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 153528.9 | 70929.2 | 25972.2 | 28111.2 | 1063543.4 | 150249.3 | 693979.5 | 90877.0 | 22437.2 |
| 2 | 1209571.8 | 55027.9 | 21136.9 | 37787.5 | 171838.3 | 13245.2 | 261302.3 | 16850.8 | 68583.0 |
| 3 | 0.0 | 1363.4 | 0.0 | 23.4 | 2213.0 | 2412.6 | 4606.0 | 246.4 | 19.2 |
| 4 | 241958.2 | 297111.8 | 34199.0 | 16429.9 | 177361.9 | 278707.6 | 1702187.6 | 153741.5 | 145676.2 |
| 5 | 0.0 | 167073.3 | 12002.3 | 1015.3 | 0.0 | 524.2 | 17010.8 | 206.2 | 2818.6 |
| Total | 1605058.9 | 591505.5 | 93310.5 | 83367.2 | 1414956.6 | 445138.9 | 2679086.3 | 261921.9 | 238534.2 |

newly reclaimed cropland of nearly 1702.2 thousand ha, among which two thirds come from the conversion of grassland with high shade density, at the same time, areas reused as forests or grassland totals 297.1 thousand ha. Therefore, this area, in other words, took on the characteristics of cropland expansion and grassland shrinking. The reclaimed and abandoned zones are mainly located in the arid and sub-arid area, where the interlaced distribution of reclaimed and abandoned zones is common. During the past 10 years, the cropland increased by a total of 17.01 thousand ha, while the grassland decreased by 30.23 thousand ha. As a whole, there are two directions for grassland conversion: one is cropland, the other is wildness, and the probabilities for the two directions are nearly equal. The urban expansion zone, traditionally, is the farming belt, which is characterized by the conspicuous expansion of urbanization. This increased built-up area totals 23.4ha, though the total area of the zone is small, less than 1.09 thousand ha.

## 5 ANALYSES OF DRIVING FORCES OF LAND-USE CHANGE

Land-use/coverage change is an important indicator of mankind activities that have direct bearings on natural resources and the environment (ERIC LAMBIN *et al.*, 2001; KLEPEIS and TURNER, 2001). There are two premises for mankind to carry out their land-use activities. One is the favorable environment and resources, and the other is the ability to carry out human activities. Environment and resources comprise regional elevation, annual precipitation, accumulated temperature, etc. Fig. 4 has shown the area differentiation of main physical indexes of northeastern China. After analyzing them carefully, we can conclude that some key biogeophisical factors affect conspicuously the conversion of different land-use types (Fig. 6, 7 and 8). Fig. 6 tells us that when comparing between conversion from "dry land to paddy field" and "other land-use types to built-up areas" and "woodland to cropland", the former responds more strongly than the other types to elevation gradation. For the conversion from dry land to paddy field, an elevation of 127m above sea level would be perfect and easy to convert. For conversion of "other land-use types to built-up areas", the best elevation would be 150m, and the conversion of "woodland to cropland", 350m. Except for the more advantageous elevation values, the trend to descend with curvilinear style is conspicuous for these three kinds of conversion. Based on Fig. 7, we can find that, as a whole, with the increase of accumulated temperature of ≥10℃, each kind of conversion shows a trend to increase. Yet, conversion from paddy field to dry land and other land-use types to built-up area, and the water body expansion climbs up to maximal amount with the accumulated temperature of ≥10℃ of 3138.9, 1491.4 and 2210.3 ℃ respectively. Comparatively speaking, the increase of annual precipitation affects significantly the conversion from other kinds of land-use to built-up areas, dry land to paddy land, and woodland to cropland. Furthermore, with the increase of annual precipitation, the fluctuation of conversion amounts tends to be more conspicuous, until it stays at an annual precipitation of 427.2, 357.3 and 532.2mm and gets its corresponding maximal value respectively.

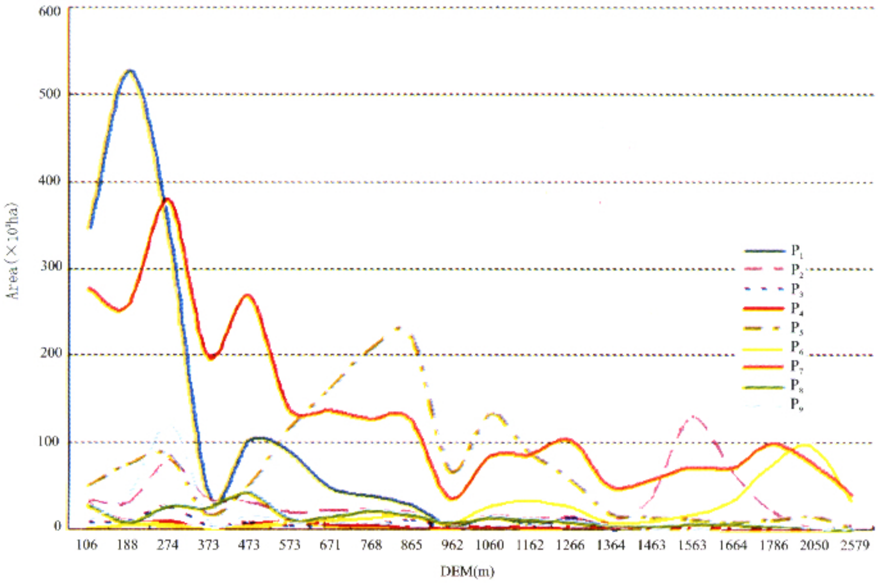


Fig. 6 Relationships between conversion of land-use types and elevation gradations in northeastern China

Notes: Values listed in the X axis are the breakpoints calculated by the division of the range of DEM value based on the statistical formula (Jenk's optimization) which made the sum of the variance with each of classes minimal; areas summarized based on each classes were calculated and represented in the Y axis.

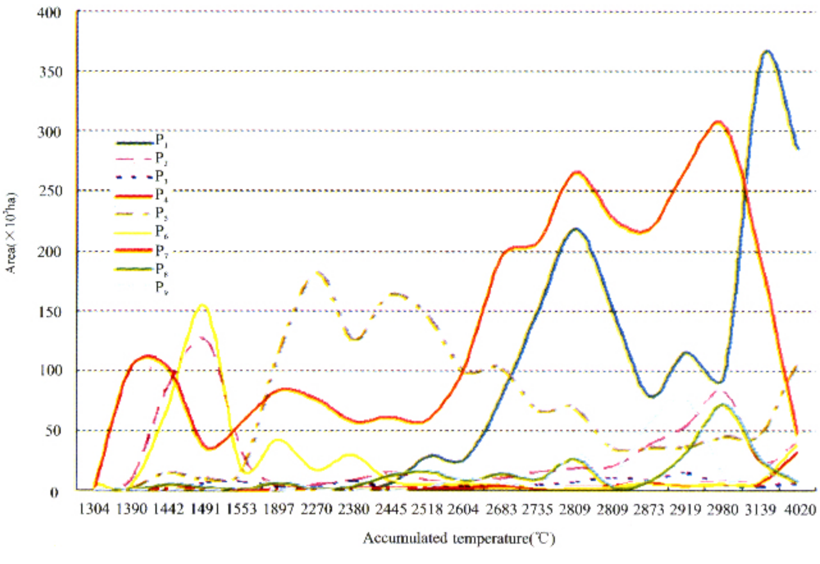


Fig. 7 Relationships between conversion of land-use types and accumulated temperature in northeastern China

Notes: Values listed in the X axis are the breakpoints calculated by the division of the range of accumulated temperature (≥10℃) value based on the statistical formula (Jenk's optimization) which made the sum of the variance with each of classes minimal; areas summarized based on each classes were calculated and represented in the Y axis.

Until only a few decades ago, all areas north of Changchun were called the Great Northern Wilderness (Beidahuang) because of the immense sea of forest on montane areas and grasses on undulating plains. All these areas have been part of Chinese cultural orbit since the Soshin tribes hunted and fished there in ancient times. In the third century A. D., the Chinese government introduced farming into the region. And in 1858 A. D., the Qing imperial government was finally forced to give up its prohibition for Chinese farmers moving into the region. Yet, up to 1897, there were only about 5300ha of croplands and 25 000 inhabitants in the whole Heilongjiang Province. Between 1897 and 1949, pioneer settlement established by small holding

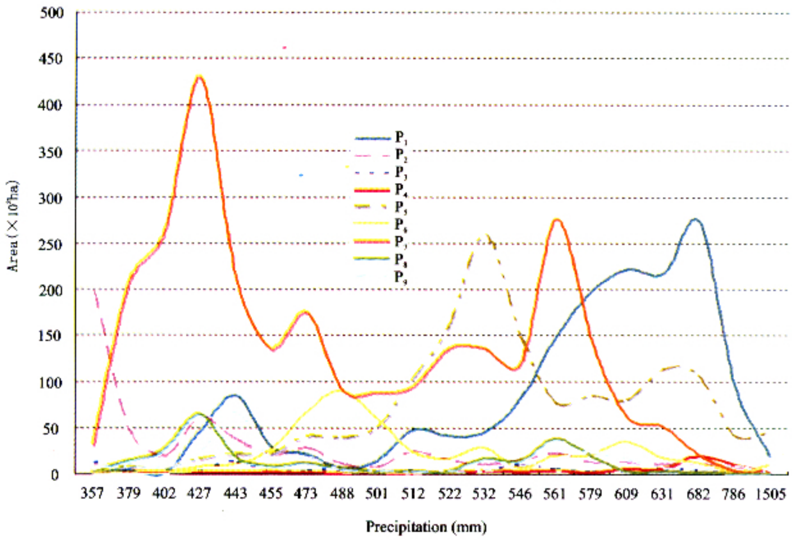


Fig. 8 Relationships between conversion of land-use types and precipitation in northeastern China

Notes: Values listed in the X axis are the breakpoints calculated by the division of the range of precipitation value based on the statistical formula (Jenk's optimization) which made the sum of the variance with each of classes minimal; areas summarized based on each classes were calculated and represented in the Y axis.

framers developed rapidly. In 1930, Heilongjiang Province had already a total cropland area of 3. 85 million ha and a population of 3. 7 million. In 1949, the cropland had reached a new level of 5. 7 million ha. In more than 50 years after 1949, the cropland increased rapidly, occupying about 35 percent of the total land area in the province.

In the past ten years (1990 – 2000), great changes have taken place in land-use of northeastern China. Besides the restricting factors of physical elements, both social and economic factors exert profound influences on the land-use change there. Just like the spatial distribution of land-use change, the social and economic driving forces also take on the area differentiation corresponding to the land-use change. We will use Canonical Correlation Analysis (CCA) to explain the land-use change, considering its necessity and academic significance. CCA aims to determine the significant correlations between two groups of variables. In order to seek the correlation between two groups of variables, their linear combinations should be, firstly, determined, making the maximal correlation exist. Their linear combinations, however, are underlying, and hard to be noticed, working as unknown variables and named after canonical variables. The significant correlation of the two canonical variables is the canonical correlation and is always represented as "ρ". The mathematical expression of CCA is as follows.

$$A_1 Y_1 + A_2 Y_2 + A_3 Y_3 + \ldots + A_k Y_k$$
$$= B_0 + B_1 X_1 + B_2 X_2 + B_3 X_3 + \ldots B_k X_k$$

In this study, we use the social-economic factors as the independent variables, covering total population growth (TPG), agricultural population growth (APG), gross output of meat (GOMe), gross output of milk (GOMi), acreage planted of cereal (APC) and gross output of cereal (GOC). In the meantime, we use the typical land-use conversion categories as dependent variables, applying CCA method to find out the relationship between them. Correspondingly, the conversion from dry land to paddy, arable land to built-up areas, forest area to arable land, forest area to built-up area, grassland to arable land, grassland to built-up areas, remaining area to arable land, remaining areas to forest area, and remaining area to grassland, are abbreviated as ALcAL, ALcBuA, FAcAL, FAcBuA, GRcAL, GRcBuA, RAcAL, RAcFA and RAcGR respectively. In order to better analyze the land-use conversion in northeastern China, the emphases have been shifted to the above-mentioned conversion categories. Table 4 is the summary table of CCA for the selected socio-economic indices.

Based on Table 4, the following conclusions can be safely drawn: 1) All three selected canonical coefficients are significant at the observed significance level (less than 0. 05). The first, second and third canonical coefficients are 0. 739, 0. 577 and 0. 522 respectively. The six independent variables chiefly influence the dependent variables via the three canonical coefficients. 2) The first canonical component ($X_1$) can explain 54. 6% of the variance of the first component ($Y_1$) of

Table 4 Summary table of CAA for selected socio-economic indices

| Independent variable | $X_1$ | $X_2$ | $X_3$ | Depend variable | $X_1$ | $X_2$ | $X_3$ |
|---|---|---|---|---|---|---|---|
| TPG | 0.615 | 0.053 | 0.713 | ALcAL | −0.486 | −0.160 | −0.498 |
| APG | 0.699 | 0.181 | 0.614 | ALcBuA | −0.369 | −0.665 | 0.612 |
| GOMe | −0.468 | −0.206 | −0.175 | FAcAL | 0.381 | −0.575 | −0.363 |
| GOMi | 0.190 | 0.060 | −0.045 | FAcBuA | 0.169 | −0.630 | −0.506 |
| APC | 0.641 | −0.670 | −0.188 | GRcAL | 0.672 | −0.220 | −0.286 |
| GOC | −0.223 | −0.195 | −0.294 | GRcBuA | 0.603 | −0.139 | −0.283 |
| | | | | RAcAL | 0.382 | −0.124 | −0.149 |
| | | | | RAcFA | 0.112 | 0.037 | −0.038 |
| | | | | RAcGR | 0.237 | 0.072 | −0.074 |
| Pct Var CO | 0.26355 | 0.09483 | 0.17321 | Pct Var DE | 0.17506 | 0.14274 | 0.13351 |
| Pct Var DE | 0.14390 | 0.03159 | 0.04711 | Pct Var CO | 0.09559 | 0.04755 | 0.03631 |
| | | | | Sq. Cor. | 0.546 | 0.333 | 0.272 |
| | | | | Canon Cor. | 0.739 | 0.577 | 0.522 |

dependent variables. The first component of the dependent variables, however, can explain 17.506% of the variance of dependent variables. This means that the independent variables by the first canonical components ($X_1$ & $Y_1$) can explain 9.559% of the variance of the dependent variables due to the existence of overlapping value (9.559%; abbreviated by Pct Var CO in Table 4, the same below). 3) The second canonical component ($X_2$) can explain 33.3% of the variance of the second component ($Y_2$) of dependent variables. In contrast, the first component of dependent variables, however, can explain 14.274% of the variance of dependent variables, i.e. the independent variables by the second canonical components ($X_2$ & $Y_2$) can explain 4.755% of the variance of the dependent variables due to the existence of overlapping value (4.755%). 4) The third canonical component ($X_3$) can explain 27.2% of the variance of the third component ($Y_3$) of the dependent variables. The third component of the dependent variables, however, can explain 13.351% of the variance of the dependent variables, i.e. independent variables by the third canonical components ($X_3$ & $Y_3$) can explain 3.631% of the variance of the dependent variables due to the existence of overlapping value (3.631%). 5) The overlapping value aggregated from the three canonical components totals 17.945%. In other words, the six independent variables can explain 17.945% of the total variance of the dependent variables via the three pairs of canonical components ($X_1$ & $Y_1$; $X_2$ & $Y_2$; $X_3$ & $Y_3$). Therefore, a reasonable conclusion can be safely made that some typical conversion categories have been driven by the selected indices. It is noticeable that the regression coefficient among ALcBuA, TPG and APG (Fig. 9), as well as FAcAL, FAcBuA, GRcAL, GRcBuA with APC (Fig. 10), has passed the $t$ test ($p < 0.001$)

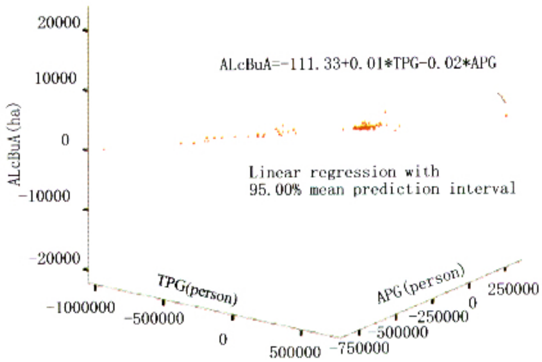


Fig. 9 Significant correlations among ALcBuA, TPG and APG

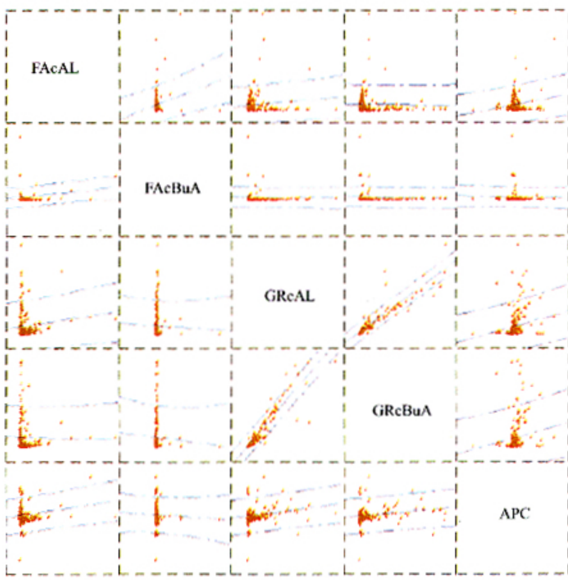


Fig. 10 Correlative matrixes among FAcAL, FAcBuA, GRcAL, GRcBuA and APC

as means population growth, especially the agricultural population growth, together with the increase of acreage planted areas.

Rapid population growth and management changes can explain the shaping of woodland/grassland – cropland conversion zone. Yet, the differentiation between its northern and southern regions should also be noticed. Its northern region has become one of the most concentrated areas of "out-census" population. Since the family planning policy was implemented in the 1970s, large numbers of farmers from China's other provinces converged here with the aspiration to have more sons, so as to ensure their old age security as there was no effective social security system in rural China. And now, their "sons" have grown up, with nearly identical life style as their fathers—to fell trees or reclaim grassland illegally, which led to the decrease of woodland and grassland areas and the consequential increases of cropland areas.

The southern region of the northeastern China, however, with its dense forest centers, has different developments. After the government carried out "forestry protection" policies, large number of farmers was forced to abandon farmland inside protected zones. Some farmer began to reclaim land outside the forest centers, with the conspicuous trend to stretch their farmland toward forestry centers until they encroached upon the protected forests. In addition, some forestry centers have no other industries to develop but to continue to organize laid-off workers to reclaim marginal land. The above-mentioned reasons led directly to the conversion from forestry and grassland to cropland.

There are two kinds of conversion from paddy field and dry land: conversion from dry land to paddy field as well as from paddy to dry land in the dry land – paddy field conversion zone. The former, apart from the physical elements change promoting the expansion of paddy field, results from two reasons: one is that the implementation of market-economy in China has given farmers the right to decide what they plant and how they plant their crops. Since the market prices of rice are higher than those of corn and wheat, more and more farmer chose to convert their dry land to paddy field. Another factor in this change originated partially from the change of dietary habit that along with the social and economic development. More and more people begin to consume rice over wheat, which leads to the increased demands of rice in grain markets, consequently further promote the conversion from dry land to paddy field. The conversion from paddy field to dry land is caused primarily by the shortfall of irrigation water, which in turn is caused by poor water allocation managed by local governments. It can be imaged: if farmers in the upper reaches of a river use most of available river water, those in the middle and lower reaches can only depend on rains to irrigate their paddy. In arid seasons or a dry year, these farmers in the middle and lower reaches would have to convert their paddy field to dry farming, that is, replacing rice with wheat or corn to assure their harvest. As a whole, the above-mentioned situations have resulted in the shaping of the paddy field – dry land conversion zone.

The shaping of the reclaimed and abandoned zone is partially due to the lack of environment protection consciousness among pioneer settlers. As we all know, the population density in the northeastern China is comparatively lower than the national average. The early settled pioneers could engage in wonton deforestation and land reclamation. The black earth abundant with humus could assure good harvest for several years. Yet it is also liable to lose fertility without continual fertilization. The local settlers always abandoned their land after exhausting its fertility, and turned to reclaim new black earth somewhere else. This, undoubtedly, led to the increases of abandoned cropland. In addition, the lack of supervision and directions from the government further speed up the process of illegal reclamation and irrational abandonment of cropland.

Comparing profits received from farming with pasturing, the former is 179 times higher than the latter. The reason for the conversion from grassland to cropland is the relatively higher profits of farming than that of pasturing in the interlocked zone of farming and pasturing. Again, benefiting from the implementation of the market-economy, some "herdsman" begin to throw away whips and pick up hoes to regain more profit, which leads to the conversion from grassland to cropland. Another reason is the existence of population pressure in the transitional zone of farming and pasturing. As we know, pasturing has lower population carrying capacity than farming. This further induces, or promotes, the conversion from grassland to cropland. Besides, the variation of air temperature and precipitation is another factor in determining this kind of conversion.

Urbanization, in some sense, is a necessity accompanying social and economic developments (KRAUSMANN, 2001). Since China is one of the largest developing countries in the world, the expansion of built-up or resident areas will last for a long time to come. In northeasern China, the rapid expansion of built-up areas results from two factors: the first is its small number of towns; the second comes from the huge potential for expansion of existing towns and cities. It is noticeable that urban expansions in northeastern China are characterized by gentle topographic relief and low population density. Physiognomy, transportation and economy exert great influences on the urban expansion.

## 6 DISCUSSION

There exists conspicuous area differentiation in land-use change of northeastern China during the ten years of 1990 – 2000, and the area differentiation of land-use dynamics reveal the features of land-use change patterns and their hidden driving forces. The regional land-use change is a collective outcome influenced by physical environment, global change and human activities. Consequently, great emphases should be laid on the following aspects: monitoring land-use change, analyzing the driving forces affecting the changes, identifying global changes influencing land-use, model-building for predicting of land-use change, and studying the effect of land-use change on the biogeochemical cycles of terrestrial ecosystem. For the moment, we have set up a continual and long-term monitoring system of land-use change, with multiple tasks been incorporated, e. g. study the influence of human activities on land-use change and on global environment, and study their corresponding biogeochemical cycles supported by our abundant data accumulation.

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