CHINESE GEOGRAPHICAL SCIENCE
Volume 12, Number 2, pp. 107 – 113, 2002
Science Press, Beijing, China

ANALYSIS ON SPATIAL FEATURES OF LUCC BASED ON REMOTE SENSING AND GIS IN CHINA

GAO Zhi-qiang, DENG Xiang-zheng
(*Institute of Geographic Sciences and Natural Resources Research, the Chinese Academy of Sciences, Beijing 100101, P. R. China*)

ABSTRACT: In view of the large quantities of areas, complex landform and dynamic change of resources and environment in China, China has already funded abundantly a series of macro remote sensing investigation projects in land use/cover change(LUCC) since 1990. Supported by the achievements of such projects, Chinese resources, environmental and remote sensing database (CRERS) was created. In this paper, we standardized the LUCC dataset of CRERS at scale of 1km, which facilitated the study of spatial features of LUCC in China. The analysis on the spatial features of LUCC and their causes of formation in China are based on the CRERS supported by the technologies of Geographic Information System (GIS). The whole research was based on the grade index of land use, ecological environmental index and index of population density. Based on the correlation analysis, we found that the special features of LUCC were closely related with those of ecological environment and population density, which resulted from that areas with better ecological environment and high production potential of land were easy and convenient for human being to live, which, furthermore, led to the aggravation of excessive exploitation of land resources there.

KEY WORDS: LUCC, 1km data, grade index, remote sensing

CLC number: F301.24 Document code: A Article ID: 1002-0063(2002)02-0107-07

1 INTRODUCTION

Over the coming decades, the global effects of land use/cover change(LUCC) may be as significant, or more so, than those associated with potential climate change. Unlike climate change per se, LUCC are known and undisputed aspects of global environmental change. These changes and their impacts are with us now, ranging from potential climate warming to land degradation and biodiversity loss and from food production to spread of infectious diseases(LI, 1996).

Over recent years, researchers have increasingly turned to remotely sensed data to improve the accuracy of datasets that describe the geographic distribution of land cover at regional and global scales (TOWNSHEND *et al.*, 1991; DEFRIES *et al.*, 1994). Continental scale land cover classifications using Global Vegetation Index data at 15 – 20km resolution (TUCKER *et al.*, 1985; TOWNSHEND *et al.*, 1987) discriminated between land cover types based on temporal dynamics in the greenness of vegetation throughout the year. This principle was applied to derive a coarse-resolution land cover dataset at a global scale (DEFRIES *et al.*, 1994; 1995), as well as a classification using Advanced Very High Resolution Radiometer (AVHRR) 1km data for the conterminous United States.

In view of the large quantities of areas, complex landform and dynamic change of resources and environment in China, it is necessary to dynamically monitor periodically the status of LUCC and environment and update their basic data duly, which is significant for government to manage land and environment(LIU, 1996). Taking the advantage of high effectiveness and accurateness of remote sensing technology for investigating LUCC and environment, Chinese government has already funded abundantly the macro remote sensing investigation of LUCC of China since 1990 and created Chinese resources, environmental and remote sensing database (CRERS, http://crers.irsa.ac.cn), which supplied government with data for the management and

Received date: 2001-11-15
Foundation item: Under the auspices of the Knowledge Innovation Project of the Chinese Academy of Sciences(KZCX1-Y-02).
Biography: GAO Zhi-qiang (1966 –), male, a native of Shandong Province, Ph. D., associate professor. His research interests include data modernization and application researches of remote sensing in geography.

decision making in relative areas.

The analysis on the spatial features of LUCC and their cause of formation in China are based on the CRERS and with technologies of Geographic Information System (GIS) and database.

2 STUDIED AREAS

With a vast territory, China is located in the Northern Hemisphere and the north of the Equator and spanned from 3°59′N to 53°32′N in latitude and 135°05′E to 73°40′E in longitude. Resulted from the difference of the latitudes and their distance to different seas, distribution of temperature zones ranges from the equatorial to tropical, subtropical, warm-temperate, temperate and frigid zones from the south to north. Due to the difference of moisture conditions, it can be divided into humid, sub-humid, semiarid and arid zones from southeast to northwest of China (LIU, 1996).

It is high in the west and low in the east in topography with the distribution of three steps. Qinghai-Xizang(Tibet) Plateau with an altitude of 4000m is the first step. Passing the Kunlun lines eastward and northward, the plateaus and basins with the altitude of 1000m to 2000m are the second step. The east of Hinggan line belongs to the third step, which is covered by low hills and plains with the altitude of less than 1000m and 200m respectively (WU and GAO, 1994).

In climate, most of areas lie in the temperate or subtropical zones controlled by monsoon climate and their precipitation change with the quantity of heat and show obviously seasonal variation in a year. But there are distinct difference among different areas: south of Qinling Mountains and the Huaihe River belongs to the subtropical or tropical while north of them belongs to the warm-temperate or temperate; based on the line from Da Hinggan Mountains to Zhangbei, Yulin, Lanzhou till the southeast fringe of Qinghai-Xizang(Tibet) Plateau, the east belongs to humid or sub-humid zones while the west belongs to semiarid or arid zones. In topography, the east owns more hills and plains while the west more high mountains, plateaus and basins. All of the above result in the complex and various LUCC and the different conditions and types in land use.

3 DATA PROCESSING AND REMOTE SENSING INTERPRETATION

The development of remote sensing technology benefits the realization of macro investigation of land use. The remote sensing investigation in LUCC carried out by IRSA (Institute of Remote Sensing and Application, the Chinese Academy of Sciences) and entrusted by the Chinese Government in 1996 used the remote sensing data of 1995 – 1996 Landsat TM. TM images used in the project amounted up to 300 scenes for east of China and some important areas of west, images used were 200 scenes for the subsidiary areas of the west. The whole investigation is a complex systematic project including the remote sensing images processing, abstraction of information, handling and analysis of data, creation of database and qualification management of the whole project (LIU, 1996).

(1) Scenario design of remote sensing classification. The scenario design is pivotal for the final realization of the whole project. Experts from geography, remote sensing, ecology and agrology were invited and cooperated with each other during the course of scenario design. Based on the comprehensive research and extensive investigation, a classification scenario including 6 types and 25 subtypes was set up.

(2) Selection of remote sensing data. The main information resources came from Landsat TM. Considering making full use of the TM information of China, which received by the Remote Sensing Satellite Earth Station of Chinese Academy of Sciences (Beijing), selection of image was based on the quality of TM information in the research areas. Based on the principle of making instantaneous image reflect ground information maximally, in Northeast China, we selected the TM images of the last ten days of May to the middle ten days of June or the last ten days of October to the middle ten days of September; in North China, we selected those of the last ten days of May or the first ten days of September; in Central China, East China and Southwest China, we selected those of the first ten days of March or the last ten days of October; in the main part of South China and the northern part of Southwest China, we selected those of winter; in the Northwest China, we selected those of the first month of summer or the first month of autumn.

(3) Rectification of remote sensing data. The whole work was carried out in the environment of MGE of Intergraph. There were three steps to follow. 1) The creation of grids of Albers projection was the mathematics basis of the whole work. 2) Scanned images of the relief map with the scale of 1∶100 000 were rectified to the grids with the scale of 1∶100 000 based on 4 contour points. 3) Regarding the rectified relief map of China with scale of 1: 100 000 as the orientation standard to collect GCP(ground control point), based on the points with the same name to collect GCP in remote

sensing images of China, after their further rectification according to the technological standards, remote images of China would be inlayed in term of the request of different determination of images.

(4) Classified interpretation using remote sensing. The interpretation was carried out by the manual power aided by computers, in which nearly 100 persons employed involved in 12 institutions of the Chinese Academy of Sciences (CAS) and more than 18 months were spent. The whole interpretation was finished in the environment of CorelDraw 6.0 and MGE of Intergraph.

(5) Compilation of interpretation data. The classified interpretation data were transformed to coverage of Arc/Info 7.0 from DXF. The compilation of interpretation data was carried out based on the studied areas: editing within different research areas and realizing their edge match, then continuing the edge match among different research areas, finally creating the vector data of standard Arc/Info coverage. All the data would be integrated into Chinese resources, environment and remote sensing database, which would have benefited the LUCC research of China.

(6) Creation of 1km LUCC data. In order to research quantitatively the temporal and spatial variation of LUCC in China, the LUCC data had to be standardized with the scale of 1km. In term of the 1km × 1km, the classified information of LUCC with the scale of 1: 100 000 would be extracted by percentages in different layers, each layer created one kind of LUCC data in light of percentage distribution. The creation of 1km LUCC data is the operation database for the research of the temporal and spatial changes of LUCC in China.

4 RESEARCH METHODS

Based on the 1km LUCC database, using the grade index of land use, the environmental index and population density, the paper analyzes the spatial features of LUCC and their causes of formation in China.

4.1 Creation of Grade Index of LUCC

The grade of land use reflects the deepness and scope of land use. The upper most grade of land use was defined as the towns and residential areas where the natural environmental systems were destroyed drastically, while the bottom most grade as the undeveloped areas or those hard to develop based on present economic conditions and technology where the original resources had not been disturbed by human activities. In light of such principle, the grade index of land use was defined as follows (ZHUANG and LIU, 1997):

$$\text{UINDEX} = 100 * \sum_{i=1}^{n} A_i * C_i$$

$$\text{UINDEX} \in [00,400]$$

where UINDEX stands for the united grade index of land use, A_i stands for the grade index of land use of i level, C_i stands for the area percentage of land use of i level.

In Table 1, the four kinds of land use grades were unpractical. In effect, they existed with different percentages in a certain area and resulted in different grade indexes of the area by different weights. Based on the above formula, we could calculate grade indexes of land use by pixel to pixel of 1km × 1km in China, we created the map of grade index of land use (Fig. 1), which could reflect the integrated levels of different areas.

Table 1 Types and grades of land use in China

Grades	Grade of undeveloped land	Grade of forestry, grassland and water	Grade of agricultural land	Grade of towns and residential areas
Types of land use	Undeveloped or hard to be used land	Forestry, grassland and water	Arable land, garden plot and artificial grassland	Towns, residential areas and industrial and mining land
Indexes of levels	1	2	3	4

4.2 Creation of Ecological Environmental Index

The factors affecting land use were various. We selected four groups of indexes including moisture and temperature, terrain and relief, soil and vegetation and land covers.

Moisture and temperatured included the accumulated temperature above 0℃, annual average temperature, annual precipitation and moisture degree. Terrain and relief include mean height above sea level, gradient, aspect of slope and relief types. Soil and vegetation include soil types and vegetation types. Land cover referred to Normalized Difference Vegetation Index (NDVI). That is, we selected 11 indexes to evaluate the ecological environmental quality of land-use, so as to realize the objectives of evaluation (GAO and LIU, 1998).

During the course of ecological environmental evaluation, the selecting of index's weights was important which determined whether the evaluation result was the same as the reality. In recent years, the Analytic Hi-

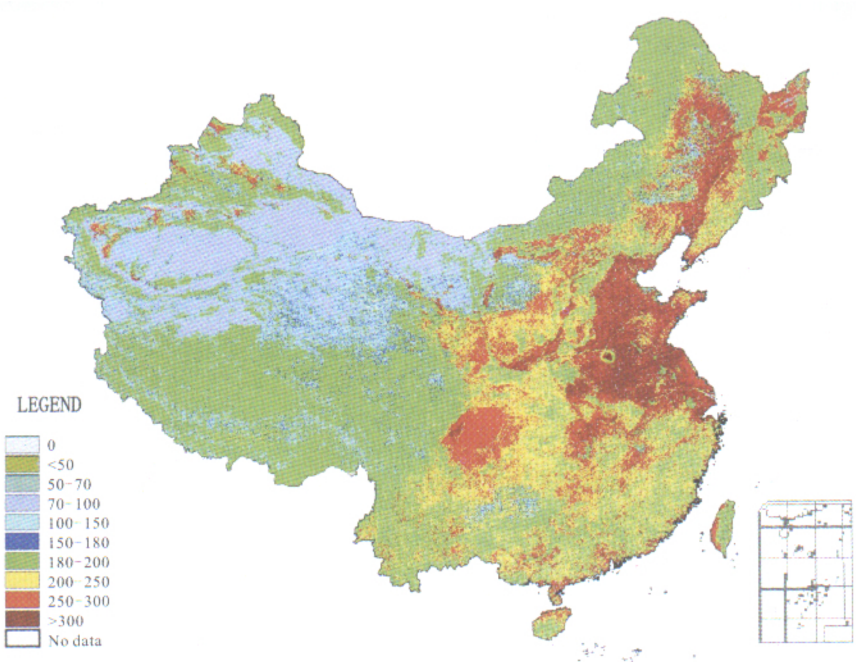

Fig. 1 Map of grade index of land use in China

erarchy Process (AHP) was used to decide weights. In the project, we decided weights of different ecological environmental factors according to the principle and steps of AHP.

Based on the above, we divided the whole ecological environment system into four subsystems: moisture and temperature, terrain and relief, soil and vegetation and land cover. In light of the mutual relationship between subsystems, grade values and weights of different indexes, we used the below formula to calculate index values of different subsystems respectively, finally got the ecological environmental integrated indexes of China and the map of ecological environmental integrated evaluation indexes of China (Fig. 2).

$$\text{index} = \sum_{i=1}^{n} W_i * C_i$$

where, W stands for index value, C refers to the relative weights, i was the index number of some subsystem.

4.3 Population Density Index of China

Using the data of population census in 1995 in China, regarding counties as basic statistic units, we calculated indexes of population density of China for each county and related them to the code of every counties and created map in the Arc/Info environment (Fig. 3).

5 RESULT ANALYSES

Since there is large quality of areas in China and environmental conditions are obviously different for different areas, it is self-evident that the grade indexes of land use differ from each other.

In Fig. 1, we divided the grade indexes of land use in China into 8 levels from 100 to 400 and evaluated each with a color value. We could find that counties with the grade indexes of land use over or equal to 300 are mainly distributed in the Huang-Huai-Hai Plain, the Changjiang River Delta, the Zhujiang River Delta, Sichuan Basin, where ecological environment is the best and arable land is centralized; counties with the grade indexes of land use below 200 centralizes in the west of Inner Mongolia, Xinjiang, Qinghai and Xizang, in which ecological environment is abominable and hard to live for human beings; provinces with high grade indexes of land use concerned Shanghai(303), Shandong(301.96), Jiangsu(296.24), Tianjin(291.36), Henan(284.77), which are covered by fluvial plains. We also could find that land with the grade indexes of land use over or equal to 225 amounted to 262 015km^2 which accounted for 27.48 percent of the whole country and main arable land resources of China lie there. The grains, cotton and cooking oil production bases are distributed in plains, basins and alluvial fans with the grade indexes of land use over or equal to 275, which

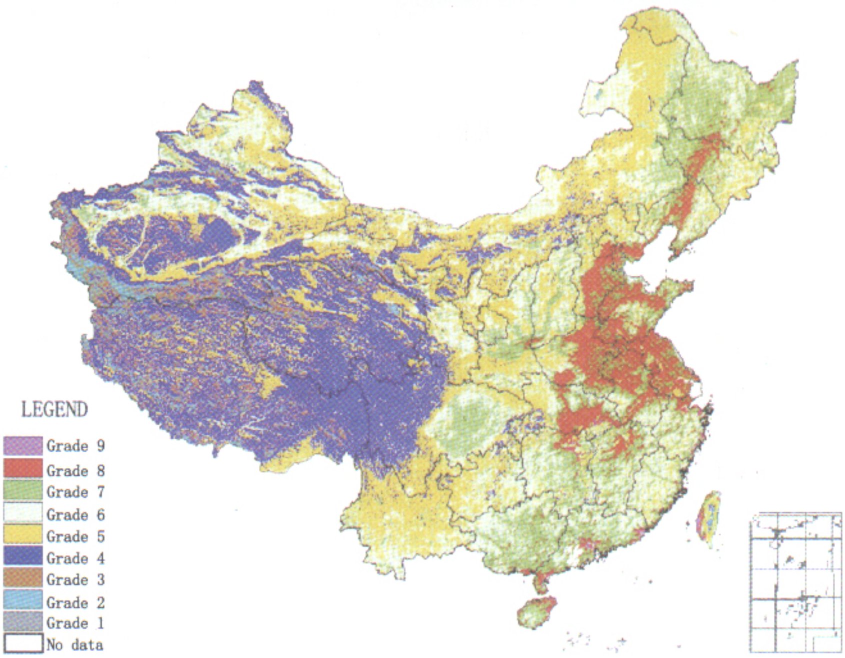

Fig. 2 Map of ecological environmental integrated evaluation indexes of China

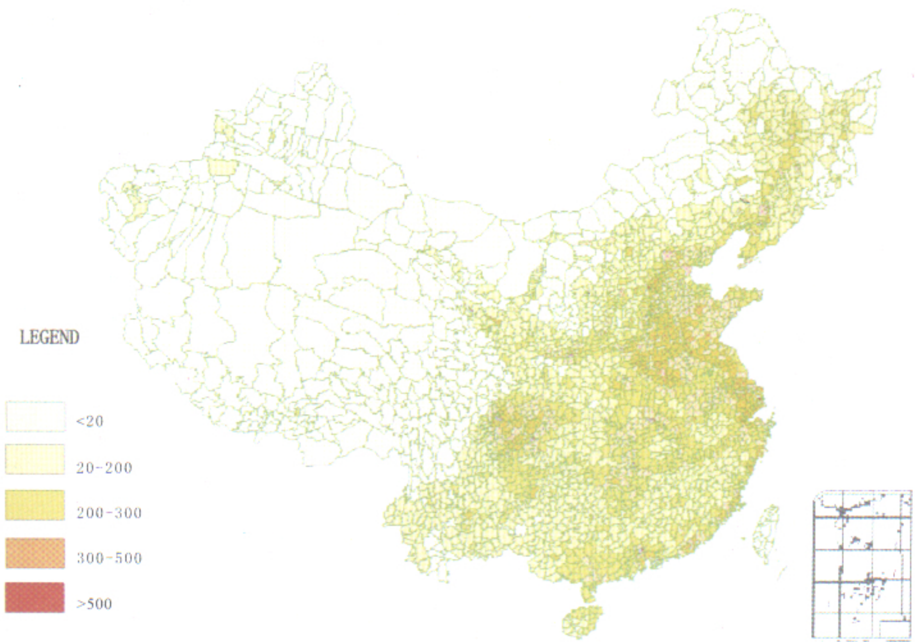

Fig. 3 Map of population density index (persons/km^2)

amounts to 862 438km^2, accounting for 9.05 percent of the whole land in China and belonging to high exploited areas over loading population. So it was necessary to exploit land resources with sufficiency and rationalization and protect arable land and develop built-up areas as scheduled there (GAO and LIU, 1999).

In Fig. 2, we divided the ecological environmental quality into three groups: group A with levels numbered 7, 8, 9; group B with levels of 5, 6 and 7; group C with levels numbered 1, 2, 3, 4. Group A except Sichuan Basin is distributed in the first step of topography in China; main part of Group B is distributed in the second step of topography in the three provinces of the Northeast China, the rest of Group B is distributed in the first step of topography; Group C is distributed in the second and third steps. Seen from Fig. 2, level 8 and level 9 are with the best ecological environmental quality and distributed in the southeast coast areas and Sichuan Basin covered by subtropical and warm temperate zones, where the population density and grade indexes of land use are high.

Seen from the map of population density (Fig. 3), the spatial features of population distribution are as follows: areas with high population density are centralized in the plains and hills of the east coast areas and Sichuan Basin with the population density over 300 persons per square kilometers. The isohyetal line of 400mm is the division line of sub-humid and humid zones as well as the obvious division line of population distribution in China, east of the line is the areas with population density over 200 persons per square kilometers where population is centralized obviously, while west of the line is the areas with the population below 200 persons per square kilometers with sparse population.

Comparing Fig. 1, Fig. 2, Fig. 3 with Fig. 4, we found that where the ecological environmental qualities are the best are the areas of which the population density and the grade indexes of land use are high. So we draw the conclusion that the grade indexes of land use are closely related with the ecological environmental quality and population density. We made each province as unit and used following formula to calculate their correlation coefficients.

$$r = \frac{(1/n) * \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\partial x * \partial y}$$

$$\partial x = \sqrt{\sum x_i^2 / n - \bar{x}^2}$$

$$\partial y = \sqrt{\sum y_i^2 / n - \bar{y}^2}$$

where, ∂_x and ∂_y are the standard deviations of x and y.

We found that the correlation coefficient of grade index of land use (uindex) and population density (pden) is $r_{ud} = 0.7643$, ($F_{ed}(1, 30) = 40.7744$), the correlation coefficient of grade index of land use (uindex) and ecological environmental quality (enindex) is $r_{ue} = 0.9058$, all the values of coefficients are over 0.7. Based on the principle of statistics, we concluded that they were correlative with each other.

6 CONCLUSIONS

The research of spatial features of LUCC in China was based on the Chinese environmental and remote sensing database (CRERS). Combined with the ecological environmental data and the data from census, we analyzed the relationship of environmental feature and population distribution. In view of the large numbers of data from TM imag, the project had to depend on the technology of remote sensing and GIS as well as the serious management. The creation of LUCC data with the scale of 1km laid the data foundation for the research of temporal and spatial variation, which made the project to be carried out continuously.

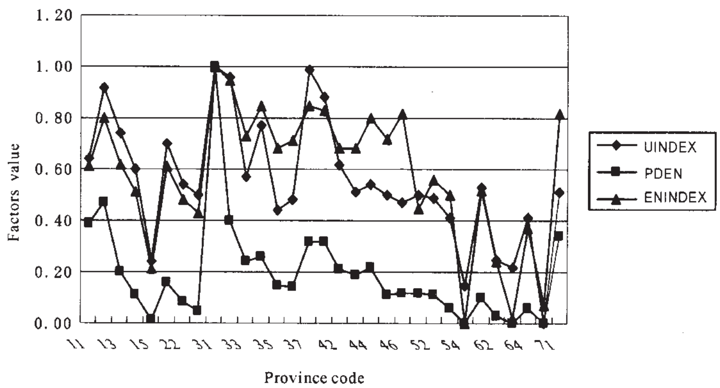

Fig. 4 The index curves of land-use grade (blue), environmental grade (green) and population density (red)

The spatial distribution features of LUCC were closely related to those of ecological environment and the distribution of population. The whole research was carried out based on the grade index of land use, ecological environmental index and index of population density. Using the methods of correlation analysis, we disclosed the relationship of spatial features of grade of land use, ecological environment and population distribution.

The close relationship between the spatial features of LUCC and ecological environment and population distribution resulted from that areas with better ecological environment and high production potential of land had led to the easiness of human beings living and development while the increase of population density had further accelerated the development of land there, which was the essential cause for such relationship exited.

ACKNOWLEDGMENTS

The authors are grateful to Prof. LIU Ji-yuan of Institute of Geographic Sciences and Natural Resources Research, CAS, Prof. LIU has given more instructions and helps to the work. And the authors are also thankful to Dr. Dennis Ojima (Natural Resource Ecology Laboratory, Colorado State University, USA) for providing helps in this work.

REFERENCES

DEFRIES R, HANSEN M, TOWNSHEND J, 1994. NDVI-derived land cover classification at global scales[J]. *International Journal of Remote Sensing*, 15, 3567 – 3586.

DEFRIES R, HANSEN M, TOWNSHEND J, 1995. Global discrimination of land cover types from metrics derived from AVHRR pathfinder data[J]. *Remote Sensing of Environment*, 54, 209 – 222.

GAO Zhi-qiang, LIU Ji-yuan, 1998. The relations between ecological environmental background and land-use degree in China[J]. *Acta Geographica Sinica*, 53: 189 – 196. (in Chinese)

GAO Zhi-qiang, LIU Ji-yuan, 1999, The study of Chinese land-use/land-cover present situations[J]. *Journal of Remote Sensing*. 3: 121 – 128. (in Chinese)

LI Xiu-bin, 1996. The core field of global environmental changes study[J]. *Acta Geographica Sinica*, 51: 231 – 242. (in Chinese)

LIU Ji-yuan, 1996. *Macro-Scale Survey and Dynamic Study of Natural Resources and Environment of Chinese by Remote Sensing*[M]. Beijing: Chinese Science & Technology Press, 262 – 275.

TOWNSHEND J R G, JUSTICE C O, KALB V T, 1987. Characterization and classification of South American land cover types using satellite data[J]. *International Journal of Remote Sensing*, 8: 1189 – 1207.

TOWNSHEND J R G, JUSTICE C O, LI W, MCMANUS J, 1991. Global land cover classification by remote sensing: present capabilities and future possibilities[J]. *Remote Sensing of Environment*, 35: 243 – 256.

TUCKER C J, TOWNSHEND J R G, GOFF T E, 1985. African land-cover classification using satellite data[J]. *Science*, 227: 369 – 375.

WU Chuan-jun, GUO Huang-cheng, 1994. *Chinese Land Use*[M]. Beijing: Chinese Science & Technology Press, 1 – 171. (in Chinese)

ZHUANG Da-fang, LIU Ji-yuan, 1997. The regional model study of Chinese land use degree[J]. *Journal of Natural Resources*, 12(1): 30 – 36.