J. Geogr. Sci. 2012, 22(3): 548-562
DOI: 10.1007/s11442-012-0946-x

The coupling characteristics and mechanism of farmland and rural housing land transition in China

LONG Hualou[1,2], LI Tingting[1,2,3]

1. Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China;
2. Key Laboratory of Regional Sustainable Development Modeling, CAS, Beijing 100101, China;
3. Graduate University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Land use transition refers to the changes in land use morphology (both dominant morphology and recessive morphology) of a certain region over a certain period of time driven by socio-economic change and innovation, and it usually corresponds to the transition of socio-economic development phase. In China, farmland and rural housing land are the two major sources of land use transition. This paper analyzes the spatio-temporal coupling characteristics of farmland and rural housing land transition in China, using high-resolution Landsat TM (Thematic Mapper) data in 2000 and 2008, and the data from the Ministry of Land and Resources of China. The outcomes indicated that: (1) during 2000–2008, the correlation coefficient of farmland vs. rural housing land change is –0.921, and it shows that the change pattern of farmland and rural housing land is uncoordinated; (2) the result of Spearman rank correlation analysis shows that rural housing land change has played a major role in the mutual transformation of farmland and rural housing land; and (3) it shows a high-degree spatial coupling between farmland and rural housing land change in southeast China during 2000–2008. In general, farmland and rural housing land transition in China is driven by socio-economic, bio-physical and managerial three-dimensional driving factors through the interactions among rural population, farmland and rural housing land. However, the spatio-temporal coupling phenomenon and mechanism of farmland and rural housing land transition in China are largely due to the "dual-track" structure of rural-urban development.

Keywords: land use transition; farmland; rural housing land; coupling mechanism; rural transformation development; China

1 Introduction

Land use transition is one of the manifestations of land-use change (Long *et al*., 2007a), and

Received: 2011-12-09 **Accepted:** 2012-01-15
Foundation: National Natural Science Foundation of China, No.41171149; No.41130748; Knowledge Innovation Program of the Chinese Academy of Sciences, No.KZCX2-YW-QN304
Author: Long Hualou (1971–), Ph.D and Professor, specialized in land change science and rural transformation development. E-mail: longhl@igsnrr.ac.cn

is also one of the major research contents of Global Land Project (GLP), a joint research agenda of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP) to improve the understanding of land system dynamics (GLP, 2005). Land use transition was put forward by Grainger (1986, 1995) based on his study on the land use in forested countries. From then on, the research concerning land use transition has been carried out vigorously, but which mainly focused on forest transition (Foster *et al.*, 1998; Mather *et al.*, 1999; Meyfroidt and Lambin, 2008a, 2008b; Barbier *et al.*, 2010; Pfaff and Walker, 2010; Rudel *et al.*, 2010). Recently, related research on land use transition combining with the characteristics of China's socio-economic development has been carried out rapidly since the research field of land use transition was introduced to China (Long and Li, 2002; Long, 2003a). Over the last decade, the research on land use transition has flourished in China and mainly involved the following aspects, e.g., related concept (Lu *et al.*, 2006), the laws (Cai *et al.*, 2009), and the theory and hypotheses (Long *et al*., 2007a; Li, 2008) of land use transition, the transition of the land use mode and structure (Guo and Zhang, 2008; Yang and Yang, 2009; Wu, 2010), the transition of a particular land-use type (Liu and Li, 2006, 2010; Long *et al.*, 2007a; Ma, 2009) and the relationship between land use transition and other land-use activity (Long, 2003b).

Land-use and land-cover change, as the core of coupled human-environment systems, has become a potential field of land change science (LCS) in the study of global environmental change (Liu *et al.*, 2010a). The goal of GLP is to measure, model and understand the coupled socio-environmental terrestrial system, which is also referred to as "land system" (GLP, 2005). In this kind of land system, farmland and rural housing land are tightly inter-related with human production activities, and are treated as the two most important land-use types depicting urban-rural development in China (Long *et al.*, 2009). Currently, farmland and rural housing land change in China has attracted the interest in academic circles, ranging from farmland loss due to urbanization and farmland preservation (Tan *et al.*, 2009, 2011; Wang *et al.*, 2010; Gong *et al.*, 2012; Xi *et al.*, 2012), rural settlement and housing land expansion (Peng *et al.*, 2008; Su *et al.*, 2011; Xu *et al.*, 2010), spatio-temporal dynamic pattern of land-use change (Tian *et al.*, 2007; Liu *et al.*, 2008, 2010a; Long *et al.*, 2009), to driving forces analysis and simulation (Xie *et al.*, 2007; Liu *et al.*, 2010b; Zhan *et al.*, 2010). However, the research on the coupling interaction of farmland and rural housing land transition has found much less attention.

Since the turn of the new millennium, the implementation of a series of socio-economic and regional development policies has resulted in accelerated economic growth and hence caused considerable land-use change in China, which was characterized by the reduction of farmland and the rapid expansion of urban-rural construction land, two-thirds of which are rural housing land (Long *et al.*, 2009, 2010; Liu *et al.*, 2010a). Accordingly, it may be hypothesized that, to some extent, there is a coupling relationship between farmland and rural housing land transition in the early 21st century in China. The aims of this paper are: (1) to develop the concept and connotation of land use morphology and conceptualize land use transition; (2) to examine the coupling relationship between farmland and rural housing land transition in the early 21st century in China; and (3) to investigate the coupling mechanism of farmland and rural housing land transition.

2 The major sources of land use transition: farmland and rural housing land

Land use transition is the changes in land use morphology, the overall pattern of actual land cover in a region at a given time, over time (Grainger, 1995). Land use morphology is the key content of land use transition research. Driven by socio-economic change and innovation, only focusing on the quantity and spatial structure characteristics of land use morphology cannot meet the demands of the research on land use transition (Lambin and Meyfroidt, 2010). As such, the concept and connotation of land use morphology needs to be developed continuously with the in-depth research and socio-economic change and innovation. Basing on the analysis of the evolvement of the concept and connotation of land use morphology, we argue that there are two formats for depicting land use morphology: one is dominant morphology, another is recessive morphology. The dominant land use morphology refers to the quantity, structure and spatial pattern of land use, and the recessive land use morphology includes the land-use features in the aspects of quality, property rights, management mode, fixed input and productive ability, etc. So, the conception of land use transition may be further developed as follows: land use transition refers to the changes in land use morphology, including dominant morphology and recessive morphology, of a certain region over a certain period of time driven by socio-economic change and innovation, and it usually corresponds to the transition of socio-economic development phase (Long, 2012). Figure 1 shows the conceptualization of the models of land use transition. The land use morphology at a time point (e.g., time point B) is not only the result of land use transition in last period of time (from A to B), but also the beginning of land use transition in the next period of time (from B to C) (Figure 1). Land use transition is a continuous evolution process of land use morphology instead of aiming at forming a fixed or deterministic land-use pattern.

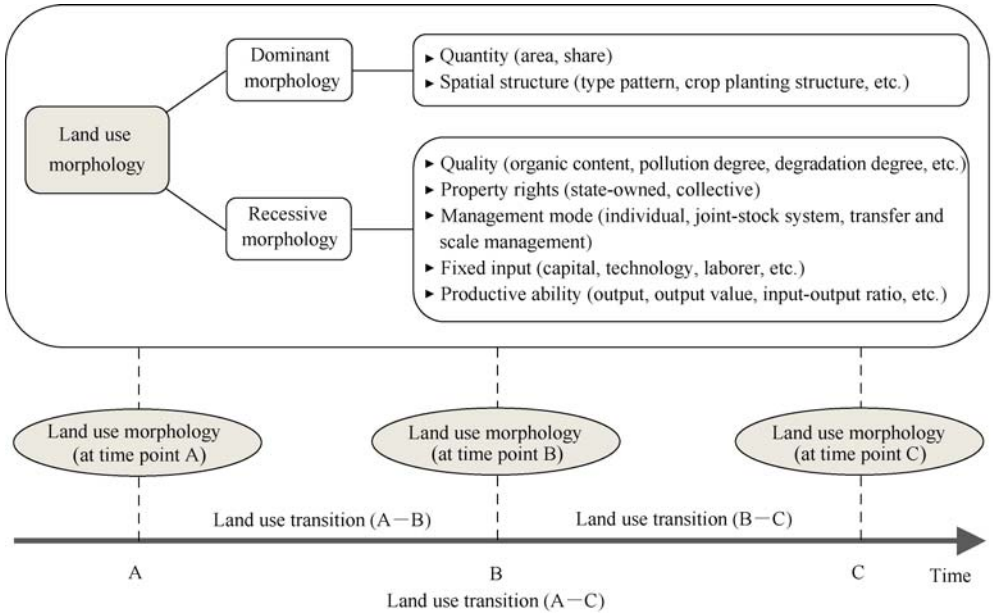

Figure 1 A conceptualization of the models of land use transition

Farmland and rural housing land are the two major land-use types closely related to human livelihood and production activities. It is well known that the urban is originally developed from the rural, and its formation and further development is closely linked with the transition of farmland and rural housing land. In general, socio-economic development affects land use morphology, which also makes a counteraction to socio-economic development. The interaction between land use morphology and socio-economic development facilitates the land use transition. Therefore, the changes of the regional land use morphology may be basically reflected by the changes of farmland and rural housing land, two major land-use types affecting human production activities. Farmland and rural housing land, as the two major sources of land use transition, play an important role in the process of facilitating land use transition. That is also the main reason why this paper focuses on the analysis of farmland transition and rural housing land transition. Undoubtedly, analyzing the spatio-temporal coupling characteristics and mechanism of farmland and rural housing land transition, to a great extent, will be helpful in promoting the understanding the coupled "land system".

3 Materials and methods

3.1 Data source

This paper analyzes the spatial and temporal coupling characteristics of farmland and rural housing land transition using high-resolution Landsat TM (Thematic Mapper) data in 2000 and 2008 (lack of the data of Shaanxi and Qinghai provinces) from the Ministry of Environmental Protection of China, as well as the data from Reports on China's Land-use Survey and Update at the provincial level from 2000 to 2008 released by the Ministry of Land and Resources of China. The two sets of data collected from different sources have their respective advantages in revealing the spatio-temporal laws of land use transition. The integrated application of the analysis results from the two sets of data is beneficial to explore the spatio-temporal coupling characteristics of farmland and rural housing land transition.

3.2 Methods

3.2.1 Spearman rank correlation analysis

The correlation coefficient of farmland vs. rural housing land change reflects the coordinative relation of farmland and rural housing land change over a certain period of time. The higher the absolute value of the coefficient, the stronger the coordinative relation of farmland and rural housing land change, and vice versa. When it is negative or positive, the change of the farmland and rural housing land shows a negative correlation or positive correlation, respectively. Spearman rank correlation coefficient is used to measure the correlationship between the ordinal variables and its range is [–1, 1]. The positive value of the spearman rank correlation coefficient illustrates the positive rank correlation, and vice versa. The higher the value is, the higher the rank. When the value equals 1 or –1, the rank of two variables is equal or totally different, respectively. In this paper, Spearman rank correlation analysis is used to analyze the correlationship between the change rate of rural housing land and the correlation coefficient of farmland vs. rural housing land change.

3.2.2 Coupling coefficient of the farmland and rural housing land change

In order to quantitatively analyze the coupling relationship of the farmland and rural housing land transition, this paper calculates the proportion of mutual transformation area between farmland and rural housing land to the total area of farmland change and rural housing land change during the study period. Therefore, the paper uses the coupling coefficient of farmland and rural housing land change (*FHCC*) to reflect the spatial coupling degree of the farmland and rural housing land transition, according to Equation (1):

$$FHCC = \frac{C_{FH} + C_{HF}}{C_F + C_H - C_{FH} - C_{HF}} \times 100\% \quad (1)$$

where *FHCC* is the coupling coefficient of farmland and rural housing land change; C_{FH} is the area of farmland transformed to rural housing land; C_{HF} is the area of rural housing land transformed to farmland; C_F or C_H is the total area of the changed patches whose attribute information in the early period and later period of the research contains farmland or rural housing land, respectively. The higher the value of coupling coefficient is, the higher the spatial coupling degree of farmland and rural housing land change.

Geographic information system (GIS) analysis was adopted for the research. In particular, the ESRI's ArcGIS 9.2 spatial analysis module was used to aggregate, synthesize and analyze the databases, and to identify spatial relationships.

4 Results

4.1 Temporal coupling of farmland and rural housing land transition

The result of the correlation analysis of China's farmland and rural housing land change during 2000–2008 indicates that: during 2000–2005, the area of farmland decreased dramatically, but the area of rural housing land had an obvious increase; during 2005–2008, the area change of farmland and rural housing land gradually tended to be stable and the area of rural housing land even had a small decrease; during 2000–2008, the correlation coefficient of farmland vs. rural housing land change is –0.921, which shows that the change pattern of farmland and rural housing land is uncoordinated (Figure 2).

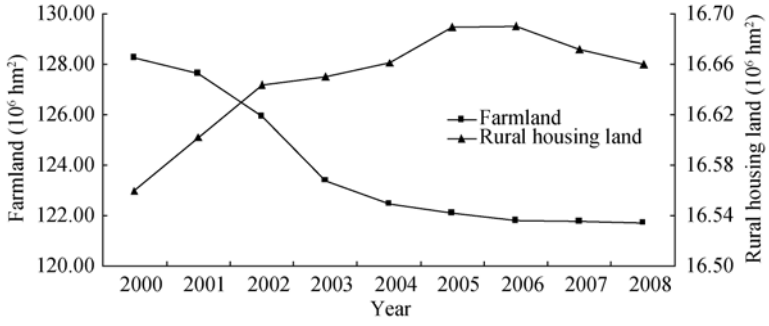

Figure 2 The change of China's farmland and rural housing land during 2000–2008

To carry out the Spearman rank correlation analysis of the change rate of rural housing land and the correlation coefficient of farmland vs. rural housing land change, it is needed to ensure the rank order of the two variables. Because there is a negative correlation between

farmland and rural housing land change in China, it assumed that the lower the value of correlation coefficient of farmland vs. rural housing land change, the stronger the correlation and the higher the rank. The rank of the change rate of rural housing land is determined by its value in descending order, and the higher the value, the higher the rank. Table 1 shows the ranks of the two variables.

Table 1 The change rate of rural housing land and the correlation coefficient of farmland vs. rural housing land change

Province	Correlation coefficient of farmland vs. rural housing land change	Rank of correlation coefficient	The change rate of rural housing land (%)	Rank of the change rate
Beijing	–0.017	17	0.01	19
Tianjin	–0.988	1	1.14	1
Hebei	–0.889	9	0.44	7
Shanxi	–0.936	7	0.30	8
Inner Mongolia	–0.791	10	0.10	16
Liaoning	–0.712	13	0.14	15
Jilin	0.696	27	–0.07	23
Heilongjiang	0.275	21	0.06	17
Shanghai	0.462	23	–0.90	31
Jiangsu	0.201	19	0.02	18
Zhejiang	–0.919	8	0.47	6
Anhui	0.752	29	–0.20	27
Fujian	–0.736	12	0.24	11
Jiangxi	0.618	25	–0.20	28
Shandong	0.257	20	–0.06	22
Henan	0.712	28	–0.08	25
Hubei	–0.760	11	0.17	12
Hunan	0.548	24	–0.03	21
Guangdong	–0.968	3	0.17	13
Guangxi	–0.939	6	0.28	9
Hainan	–0.651	14	0.00	20
Chongqing	0.911	31	–0.21	30
Sichuan	0.410	22	–0.07	24
Guizhou	–0.946	5	0.16	14
Yunnan	–0.974	2	0.28	10
Tibet	–0.513	15	0.48	5
Shaanxi	0.650	26	–0.14	26
Gansu	0.837	30	–0.20	29
Qinghai	0.141	18	0.94	2
Ningxia	–0.959	4	0.94	3
Xinjiang	–0.407	16	0.79	4

The result of Spearman rank correlation analysis using the two sets of rank series data shows that the Spearman rank correlation coefficient of the two variables is 0.808, which is

close to 1 and is significant at the 1% level (Table 2). So, it can be concluded that there is a significant positive rank correlation between the two variables. The higher the change rate of rural housing land, the lower the correlation coefficient of farmland vs. rural housing land change (the higher its rank is) and the stronger the correlation between farmland and rural housing land change. The result also shows that rural housing land change has played a major role in the mutual transformation of farmland and rural housing land.

Table 2 Spearman rank correlation coefficient and related test

		Correlation coefficient of farmland vs. rural housing land change	The change rate of rural housing land
Correlation coefficient of farmland vs. rural housing land change	Correlation coefficient	1.000	0.808**
	Two-tailed test of significance		0.000
	Number of samples	31	31
The change rate of rural housing land	Correlation coefficient	0.808**	1.000
	Two-tailed test of significance	0.000	
	Number of samples	31	31

** represents statistically significant at 1%.

4.2 Spatial coupling characteristics of farmland and rural housing land transition

Basing on the calculation of the coupling coefficient of farmland and rural housing land change at provincial level, it shows a high-degree spatial coupling between farmland and rural housing land change in the southeast of "HU Huanyong Line" during 2000–2008 (Figure 3). The inclined line in Figure 3 is called "HU Huanyong Line", a "geo-demographic demarcation line" discovered by Chinese population geographer HU Huanyong in 1935. The imaginary Heihe (in Heilongjiang)-Tengchong (in Yunnan) Line divides the territory of China into two parts: northwest of the line covers 64% of the total area but only 4% of the population; however, southeast of the line covers 36% of the total area but 96% of the

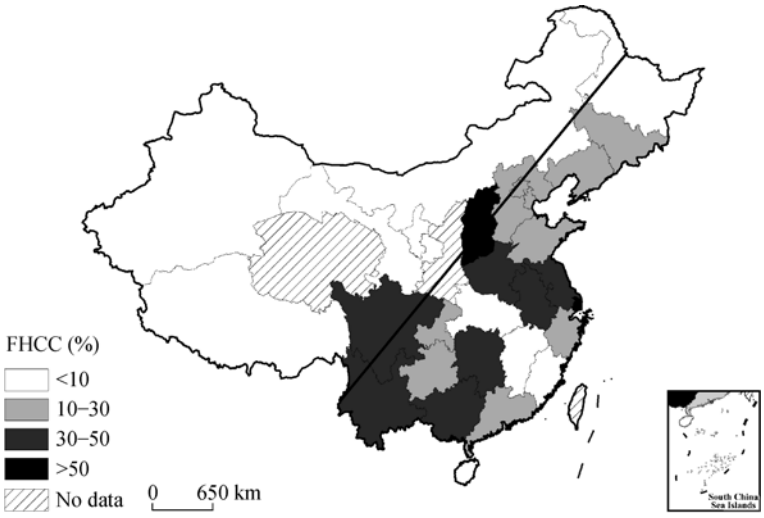

Figure 3 The coupling coefficient of China's farmland and rural housing land change at provincial level (%)

population (Hu, 1935). The southeast of "HU Huanyong Line" has been affected by the most frequent human activities, which caused obvious spatio-temporal coupling relationship between agricultural laborer transfer and farmland transition (Liu and Li, 2010). Shanxi and Shanghai have the highest coupling coefficients of farmland and rural housing land change, which are more than 50% (Figure 4).

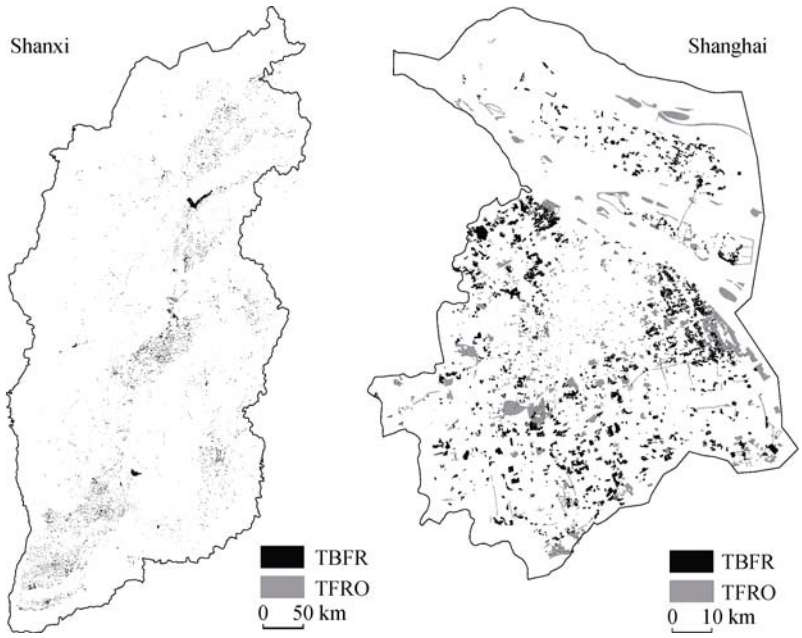

Figure 4 The coupling of farmland and rural housing land change during 2000–2008 in Shanxi and Shanghai basing on interpreted remote sensing data
"TBFR" refers to transformation between farmland and rural housing land; "TFRO" refers to transformation of farmland or rural housing land from/to other land-use types.

4.3 Coupling mechanism of farmland and rural housing land transition

4.3.1 The driving forces of farmland and rural housing land transition

Usually, land-use change is driven by socio-economic, bio-physical and managerial three-dimensional driving factors (Turner *et al.*, 1995). It is better to divide the driving factors into three driving forces according to the three dimensions mentioned above to analyze the coupling mechanism of farmland and rural housing land transition, by examining how the driving factors interact with each other and finally drive land use transition through the socio-economic, bio-physical and managerial three-dimensional dynamical mechanism (Li, 2002).

(1) Socio-economic driving forces

1) Economic growth and population change. Industrialization and urbanization are two different processes of modern socio-economic development. The process of industrialization and urbanization in China has been gradually accelerated with the reform of rural economic system and the adjustment of urbanization strategy. It was reported that (Lu, 2007): during 1996–2001, China's urbanization level increased by about 1.43% per year; during 2000–2005, the urban population increased from 456 million to 562 million, an increment of

106 million and an average annual increment of 21 million; during 1997–2000, the average annual area of farmland occupied by construction land was 1800 km^2, and the annual area amounted to 2187 km^2 during 2001–2005. The reasons for this phenomenon can be summarized into two aspects. On the one hand, the existing urban planning is unreasonable because it did not fully take the coordinated development of rural-urban area and industry-agriculture production into account, which caused low-efficient urban expansion and unnecessary non-agriculturalization of farmland. On the other hand, the potential of stock land has not been well tapped, which leads to a serious waste of urban land and aggravates the non-agriculturalization of farmland. Recently, the flourish of the "development zone fever" and "new district fever" is a major aspect of industrialization and urbanization. It is worth mentioning that the lost farmland due to industrialization and urbanization was usually located at densely populated area or along the trunk roads, with a high quality. In addition, with rapid industrialization and urbanization, farmer's income has been greatly raised, which promoted the expansion of rural housing land. Low opportunity cost of occupying farmland further leads to the loss of farmland. The demographic structure change and migration will bring a series of influences on land-use change, especially on farmland and rural housing land change. Since the adoption of economic reform and open-door policy, the change of farmland and rural housing land has been greatly affected by the miniaturization of rural household scale, the flow of the rural population between the rural and the urban, and the rural migrant's settling down in the city.

2) Social behavior and subjective behavior of land user. In the early 1990s, the phenomena of "development zone fever" and "real estate fever" caused a lot of farmland was transformed to construction land. Then the "macro urban planning fever" was flourished although the farmland loss issues mentioned above have not yet been solved. Recently, the "new district fever"[1] and "urban agglomeration fever"[2] have sprung up. To some extent, these "fevers" as a kind of social behavior have exerted great influences on national or regional land-use change.

The subjective behavior of land user, such as the understanding and application of related policies, the choice of industry, allocation of funds and how to coordinate the relationship with the community and the government, also has a great impact on land-use change. For example, some counties did not follow the land-use planning when they changed the land-use mode and failed to form an effective management mechanism to the planning and distribution of non-agricultural construction land, which resulted in the orderless expansion of urban and rural construction land. Some local governments take the penalties for illegal

[1] The national level "new district" approved by the State Council refers to the regions with national special preferential policy in urban planning area. They have the property of governmental functional departments and are deputy provincial units. According to China's related industrial policy, the tax relief and other preferential policies for encouraging projects of the direct investment enterprises, are issued to attract various capital and entity investment to set up factories or companies. Usually, the planning areas of these new districts are relatively large, and the supporting facilities are completed. In these areas, attracting investment can improve the local economy development. Currently, there are five new districts, i.e., Shanghai Pudong New District, Tianjin Binhai New District, Chongqing Liangjiang New Area, Zhejiang Zhoushan Islands New District, and Xi'an-Xianyang New District.

[2] For example, some urban agglomerations have been approved by the State Council recently, such as Wuhan urban agglomeration, Changsha-Zhuzhou-Xiangtan urban agglomeration, Wanjiang urban Belt, and so on.

land occupancy and over-standard house-building as a source of revenue, which caused some wealthy farmers take the opportunity to take up more land.

3) Technology development. The land-use structure is determined by the socio-economic and technological conditions, and by the rationality, feasibility and assurance degree of technology application. Basing on the development of science and technology, it is meaningful to protect and manage the existing land, improve its productivity and appropriately develop reserved land resources, so as to mitigate the human-land contradiction, and make the land-use change coordinated with local socio-economic development.

(2) Bio-physical driving forces. In the short term, the bio-physical driving factors influencing land-use change mainly refer to the natural disasters, topography and slope.

1) Natural disasters. Usually, desertification, flooding and soil erosion are the major natural disasters influencing farmland use. In China, desertification leads to the lower farmland productivity and large-scale farmland degradation. Reclamation of lake results in environmental degradation of the lake and poor buffer capacity for flood prevention, and increases the hazards of flooding. Unreasonable reclamation of the upper reaches leads to soil erosion and siltation of reservoir and riverway, which increase the burden of flood control. According to the analysis and estimate, farmland destroyed by natural disasters reached 1.662 million hm^2, and the direct grain production loss reached 6.055 million t during 1988–2008 in China (Long and Zou, 2010).

2) Topography and slope. The reclamation of marginal land mainly occurred in some regions with special physical factors, e.g., topography and slope. In the process of implementing the "Grain for Green" program in China, topography and slope the two physical factors are mainly taken into account for the selection of farmland to be returned to forest or grassland. In addition, the expansion of rural housing land in China, to some extent, is affected by topography and slope (Long *et al.*, 2012).

(3) Land management driving force. Land management, the direct decision-making factor of land use, drives land-use change through property rights system, price system and land managerial policy.

1) Property rights system. The land property rights system plays a basic role in driving land-use change. Since the 1980s, with the deepening of reform, the existing unstandardized and unstable farmland property rights system has led to some problems exposed (Ding, 2007; Zhou, 2007), such as the incomplete land ownership, ambiguous land-use right, unrealized land transfer right and so on, which affect land-use change in China to a great extent. Currently, the farmer only has the right of use instead of dealing with his house, which resulted in the difficulty in transferring and exchanging his house, also the difficulty in implementing new village construction planning. That is an important factor causing the phenomenon of hollowed villages (Long *et al.*, 2012).

2) Price system. One of the characteristics of market economy is profit maximization, which makes the allocation of resources affected by the price system. The change of farmland is also affected by the price system. Recently, industrialization and urbanization in China have apparently triggered massive farmland loss for the benefits of market-oriented farming and non-agricultural development (Long *et al.*, 2007b).

The market mechanism only concerns the economic benefit, instead of environmental benefit and social benefit. As such, it is inevitable that the farmland with low comparative

benefit will be occupied if the market mechanism is allowed to work blindly. The farmland transition is promoted by the disparity of comparative benefit in two aspects (Li, 2002, 2008): firstly, it induces the transfer of agricultural laborer force to second or tertiary industry, which creates conditions for farmland transfer; secondly, according to market rules, competition among various economic departments drives land-use change.

3) Land managerial policy. The current land managerial mechanism in China is distempered even somewhat unreasonable. The unreasonable land income distribution forms a mechanism that different groups vie with each other to occupy more farmland. In 1999, the Ministry of Finance of China and the Ministry of Land and Resources of China jointly enacted "Measures for the Administration of the Collection and Use of Land-Use Fees for Newly Added Construction Land", in which 70% of the land-use fees for newly added construction land belongs to local governments. Hereafter, 60% or 70% revenue of China's local governments is from land deals (Zhou, 2007).

Therefore, the city, county and township governments try their best to benefit more from land deals through requisitioning and selling farmland. Current distempered land managerial mechanism in China made it difficult for the central government to restrict the land-use behavior of local government through implementing farmland protection policy. Driven by the partial and local interests, even individual interests, local governments and officials tend to convert farmland to construction land, causing massive farmland loss. Currently, lack of related rules and regulations aiming at dealing with idle or vacant rural houses and the distempered examination and approval institution for new rural housing site made it difficult for the governments to supervise and adjust rural housing land.

4.3.2 The coupling mechanism of farmland and rural housing land transition

In general, farmland and rural housing land transition in China is driven by socio-economic, bio-physical and managerial three-dimensional driving factors through the interactions among rural population, farmland and rural housing land.

At the beginning of the economic reform in China, the great demand for rural housing increased with the development of rural economy and the increase of rural population, which caused the expansion of rural housing land. The farmers usually prefer the flat terrain with convenient facilities to build rural houses, where are often the distribution area of high-quality farmland. Together with the relaxed land managerial policies and low opportunity cost of farmland occupation, a large number of farmland has been occupied by rural housing construction. Meanwhile, driven by the social behavior of blindly developing "new town", "new district" and "urban agglomeration", as well as the low price of farmland requisition, much farmland was occupied by urban construction. Under the nibbling of rural-urban construction, the farmland tends to be fragmental, which is not in favor of scale management and causes the decrease of comparative benefit of farming. With the rapid urbanization in China, massive rural laborers migrate to urban area. That leads to the farmland management transferred to an extensive model even abandoned model, and the morphology of farmland is transformed from A to B (Figure 5). With the rural population migrating to the city, due to the distempered withdrawing mechanism of rural housing land and the defect of property rights system, the morphology of rural housing land is transformed from A to B (Figure 5), accompanied with the phenomenon of village-hollowing. When the issue of food

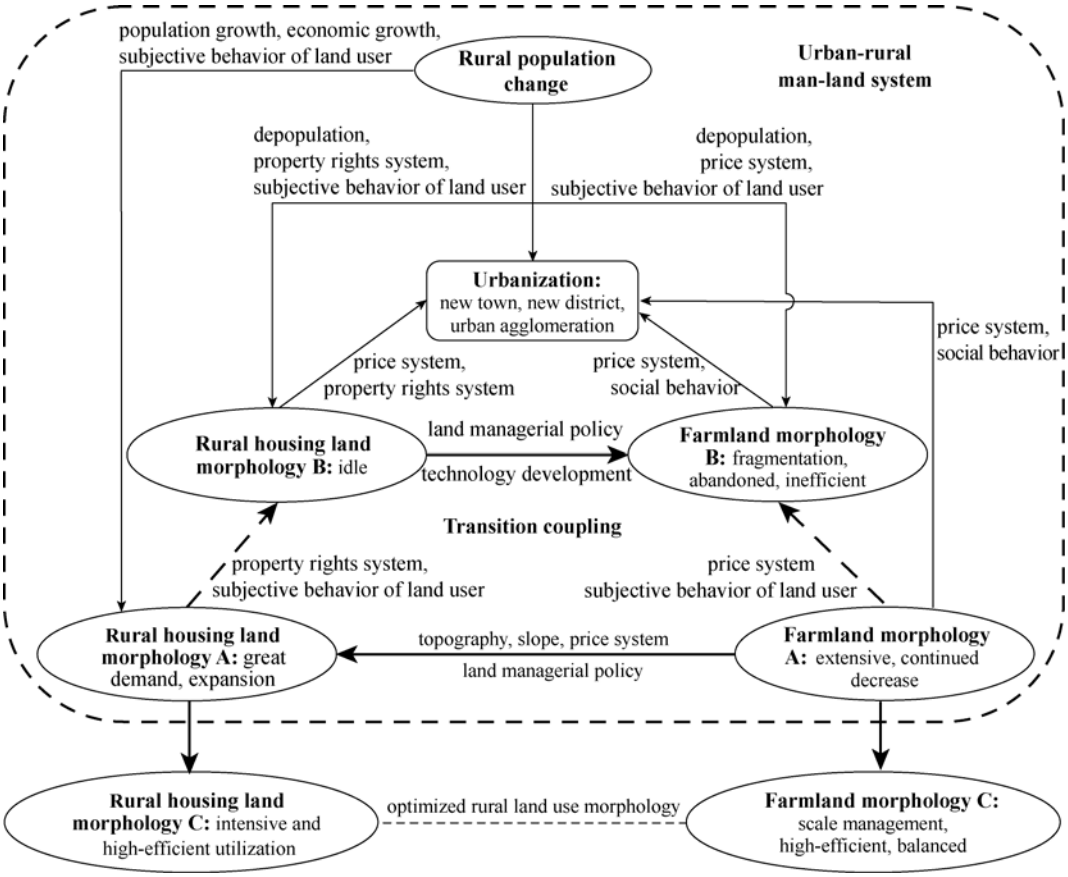

Figure 5 The coupling mechanism of farmland and rural housing land transition in the process of rural transformation development in China

security threatened by the continued decrease of farmland is severe enough to draw the public's concern, the institutional system will adjust the rural-urban land-use pattern through the resources and environmental managerial instruments, e.g., laws, regulations and policies. Aiming at dealing with idle rural housing land and the contradiction between the demand and supply of urban construction land, several powerful policies related to optimally allocating idle rural housing land have been enacted, such as "homestead exchange for house", "reconstruction of villages-in-the-city", and "increasing vs. decreasing balance" land-use policy to balance increases in urban construction land with a reduction in rural construction land (Long *et al.*, 2012). Part of the suburban idle rural housing land has been transformed into urban construction land, but most of them have been converted to farmland through carrying out land consolidation and reclamation. As such, by building new rural houses with unified planning and making full use of the original site, the morphology of rural housing land is transformed to an intensive and high efficient one (C) (Figure 5). With the implementation of rural housing land reclamation project and high-standard farmland construction project, the fragmented farmland and abandoned rural housing land are converted to high-standard farmland, which cause the morphology of farmland transformed to a scale management, high-efficient, and balanced one (C) (Figure 5). The coupling of farmland and rural housing land transition in urban-rural man-land system made rural land use morphol-

ogy further optimized, as evidenced by that the area change of farmland and rural housing land gradually tended to be stable and the area of rural housing land even had a little decrease during 2005–2008 (Figure 2), which will smoothly promote the rural transformation development (Figure 5).

5 Conclusions and discussion

(1) Land use transition refers to the changes in land use morphology (both dominant morphology and recessive morphology) of a certain region over a certain period of time driven by socio-economic change and innovation, and it usually corresponds to the transition of socio-economic development phase. Farmland and rural housing land, as the two major sources of land use transition, play an important role in the process of facilitating land use transition.

(2) During 2000–2008, the correlation coefficient of farmland vs. rural housing land change is –0.921, and it shows that the change pattern of farmland and rural housing land is uncoordinated. The result of Spearman rank correlation analysis of the change rate of rural housing land and the correlation coefficient of farmland vs. rural housing land change shows that rural housing land change has played a major role in the mutual transformation of farmland and rural housing land. During 2000–2008, a high-degree spatial coupling between farmland and rural housing land change occurred in Southeast China, based on the calculation of the coupling coefficient of farmland and rural housing land change at provincial level. In general, there are obvious spatio-temporal coupling characteristics of farmland and rural housing land transition during the research period.

(3) Land use transition is closely related to the change of social and bio-physical system, and its driving forces mainly come from socio-economic change and innovation. The interdependence and mutual restriction between the driving factors and the process of land use change may result in a dynamic coupling phenomenon of land use transition. In general, farmland and rural housing land transition in China is driven by socio-economic, bio-physical and managerial three-dimensional driving factors through the interactions among rural population, farmland and rural housing land. However, the spatio-temporal coupling phenomenon and mechanism of farmland and rural housing land transition in China are largely due to the "dual-track" structure of rural-urban development.

References

Barbier E B, Burgess J C, Grainger A, 2010. The forest transition: Towards a more comprehensive theoretical framework. *Land Use Policy*, 27(2): 98–107.

Cai Yunlong, Wang Yong, Li Yuping, 2009. Study on changing relationship of demand and supply of cultivated land in China. *China Land Science*, 23(3): 11–18, 31. (in Chinese)

Ding C R, 2007. Policy and praxis of land acquisition in China. *Land Use Policy*, 24(1): 1–13.

Foster D R, Motzkin G, Slater B, 1998. Land-use history as long-term broad-scale disturbance: Regional forest dynamics in Central New England. *Ecosystems*, 1(1): 96–119.

Global Land Project (GLP), 2005. Science Plan and Implementation Strategy. IGBP Report No.53/IHDP Report No.19. IGBP Secretariat, Stockholm.

Gong Jianzhou, Liu Yansui, Chen Wenli, 2012. Optimal land use allocation of urban fringe in Guangzhou. *Jour-*

nal of Geographical Sciences, 22(1): 179–191.

Grainger A, 1986. The future role of the tropical rain forests in the world forest economy. Philosophy Dissertation, Department of Plant Sciences, University of Oxford.

Grainger A, 1995. National land use morphology: Patterns and possibilities. *Geography*, 80(3): 235–245.

Guo Sujun, Zhang Peigang, 2008. The need for land use transition near Shenzhen Special Economic Zone from Guanlan. *Planners*, 24(8): 72–77. (in Chinese)

Hu Huanyong, 1935. The distribution of population in China. *Acta Geographica Sinica*, 2(2): 33-74. (in Chinese)

Lambin E F, Meyfroidt P, 2010. Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy*, 27(2): 108-118.

Li Xiubin, 2002. Explanation of land use changes. *Progress in Geography*, 21(3): 195-203. (in Chinese)

Li Xiubin, 2008. Theoretical hypotheses about agricultural land use changes and the relevant propositions about environmental impacts. *Advances in Earth Science*, 23(11): 1124-1129. (in Chinese)

Liu Chengwu, Li Xiubin, 2006. Regional differences in the changes of the agricultural land use in China during 1980-2002. *Acta Geographica Sinica*, 61(2): 139–145. (in Chinese)

Liu Jiyuan, Zhang Zengxiang, Xu Xinliang *et al*., 2010a. Spatial patterns and driving forces of land use change in China during the early 21st century. *Journal of Geographical Sciences*, 20(4): 483–494.

Liu Yansui, Li Yurui, 2010. Spatio-temporal coupling relationship between farmland and agricultural labor changes at county level in China. *Acta Geographica Sinica*, 65(12): 1602–1612. (in Chinese)

Liu Yansui, Liu Yu, Chen Yangfen *et al*., 2010b. The process and driving forces of rural hollowing in China under rapid urbanization. *Journal of Geographical Sciences*, 20(6): 876–888.

Liu Yansui, Wang Lijuan, Long Hualou, 2008. Spatio-temporal analysis of land-use conversion in the eastern coastal China during 1996–2005. *Journal of Geographical Sciences*, 18(3): 274–282

Long Hualou, 2003a. Land use transition: A new integrated approach of land use/cover change study. *Geography and Geo-information Science*, 19(1): 87–90. (in Chinese)

Long Hualou, 2003b. Land rehabilitation and regional land use transition. *Progress in Geography*, 22(2): 133–140. (in Chinese)

Long Hualou, 2012. Land use transition and rural transformation development. *Progress in Geography*, 31(2): 131–138. (in Chinese)

Long Hualou, Heilig G K, Li Xiubin *et al*., 2007a. Socio-economic development and land-use change: Analysis of rural housing land transition in the transect of the Yangtse River, China. *Land Use Policy*, 24(1): 141–153.

Long Hualou, Li Xiubin, 2002. Analysis of regional land use transition: A case study in the transect of the Yangtse River. *Journal of Natural Resources*, 17(2): 144–149. (in Chinese)

Long Hualou, Li Yurui, Liu Yansui *et al*., 2012. Accelerated restructuring in rural China fueled by 'increasing vs. decreasing balance' land-use policy for dealing with hollowed villages. *Land Use Policy*, 29(1): 11–22.

Long Hualou, Liu Yansui, Li Xiubin *et al*., 2010. Building new countryside in China: A geographical perspective. *Land Use Policy*, 27(2): 457–470.

Long Hualou, Liu Yansui, Wu Xiuqin *et al*., 2009. Spatio-temporal dynamic patterns of farmland and rural settlements in Su-Xi-Chang region: Implications for building a new countryside in coastal China. *Land Use Policy*, 26(2): 322–333.

Long Hualou, Tang Guoping, Li Xiubin *et al*., 2007b. Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta Economic Area of China. *Journal of Environmental Management*, 83(3): 351–364.

Long Hualou, Zou Jian, 2010. Farmland destroyed by natural hazards in China: Spatio-temporal pattern and integrated prevention and treatment system. *Disaster Advances*, 3(4): 592–597.

Lu Dadao, 2007. Urbanization process and spatial expansion in China. *China Urban Economy*, (10): 14–17. (in Chinese)

Lu Dadao, Shi Peijun, Dong Guangqi, 2006. Important ideas embodying land use transition. China *Land and Resources News*, 2006/07/17/005. (in Chinese)

Ma Jihong, 2009. Analysis of mechanism in cultivated land transition in Nong'an County [D]. Changchun: Northeast Normal University. (in Chinese)

Mather A S, Fairbairn J, Needle C L, 1999. The course and drivers of the forest transition: The case of France. *Journal of Rural Studies*, 15(1): 65–90.

Meyfroidt P, Lambin E F, 2008a. The causes of the reforestation in Vietnam. *Land Use Policy*, 25(2): 182–197.

Meyfroidt P, Lambin E F, 2008b. Forest transition in Vietnam and its environmental impacts. *Global Change Biology*, 14(6): 1319–1336.

Peng Jian, Wu Jiansheng, Yin He *et al*., 2008. Rural land use change during 1986–2002 in Lijiang, China, based on remote sensing and GIS data. *Sensors*, 8(12): 8201–8223.

Pfaff A, Walker R, 2010. Regional interdependence and forest "transitions": Substitute deforestation limits the relevance of local reversals. *Land Use Policy*, 27(2): 119–129.

Rudel T K, Schneider L, Uriarte M, 2010. Forest transitions: An introduction. *Land Use Policy*, 27(2): 95–97.

Su Shiliang, Zhang Qi, Zhang Zhonghao *et al*., 2011. Rural settlement expansion and paddy soil loss across an ex-urbanizing watershed in eastern coastal China during market transition. *Regional Environmental Change*, 11: 651–662.

Tan Minghong, Robinson G M, Li Xiubin, 2011. Urban spatial development and land use in Beijing: Implications from London's experiences. *Journal of Geographical Sciences*, 21(1): 49–64.

Tan R, Beckmann V, van den Berg L *et al*., 2009. Governing Farmland Conversion: Comparing China with the Netherlands and Germany. *Land Use Policy*, 26(4): 961–974.

Tian Guangjin, Yang Zhifeng, Zhang Yaoqi, 2007. The spatio-temporal dynamic pattern of rural residential land in China in the 1990s using Landsat TM images and GIS. *Environmental Management*, 40: 803–813.

Turner II B L, Skole D, Sanderson S *et al*., 1995. Land-Use and Land-Cover Change Science/Research Plan. IGBP Report No.35 and HDP Report No.7. Stochkholm: IGBP.

Wang Hui, Tao Ran, Wang Lanlan *et al*., 2010. Farmland preservation and land development rights trading in Zhejiang, China. *Habitat International*, 34(4): 454–463.

Wu Junfan, 2010. Modern land use mode transition in Shanghai: A case of river bank resources. *Researches in Chinese Economic History*, (3): 43–53. (in Chinese)

Xi F M, He H S, Clarke K C *et al*., 2012. The potential impacts of sprawl on farmland in Northeast China: Evaluating a new strategy for rural development. *Landscape and Urban Planning*, 104: 34–46.

Xie Y C, Batty M, Zhao K, 2007. Simulating emergent urban form using agentbased modeling: Desakota in the Suzhou–Wuxian region in China. *Annals of the Association of American Geographers*, 97: 477–495.

Xu Chi, Liu Maosong, Yang Xuejiao *et al*., 2010. Detecting the spatial differentiation in settlement change rates during rapid urbanization in the Nanjing metropolitan region, China. *Environmental Monitoring and Assessment*, 171: 457–470.

Yang Yongchun, Yang Xiaojuan, 2009. Research on urban spatial expansion and land use inner structure transformation of the large valley-basin cities in China from 1949 to 2005: A case study of Lanzhou. *Journal of Natural Resources*, 24(1): 37–49. (in Chinese)

Zhan Jinyan, Shi Nana, He Shujin *et al*., 2010. Factors and mechanism driving the land-use conversion in Jiangxi Province. *Journal of Geographical Sciences*, 20(4): 525–539.

Zhou Feizhou, 2007. The role of government and farmers in land development and transfer. *Sociological Studies*, 22(1): 49–82. (in Chinese)