J. Geogr. Sci. 2019, 29(2): 163-179
**DOI: https://doi.org/10.1007/s11442-019-1590-5**



# Agricultural labor changes and agricultural economic development in China and their implications for rural vitalization

MA Li[1,2], *LONG Hualou[1], ZHANG Yingnan[1,2], TU Shuangshuang[1,3], GE Dazhuan[4], *TU Xiaosong[1,5]

1. Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China;
2. University of Chinese Academy of Sciences, Beijing 100049, China;
3. Key Laboratory of Environment Change and Resources Use in Beibu Gulf, the Ministry of Education, Guangxi Teachers Education University, Nanning 530001, China;
4. College of Rural Vitalization, Nanjing Normal University, Nanjing 210023, China;
5. School of Tourism & Urban Management, Jiangxi University of Finance & Economics, Nanchang 330013, China

**Abstract:** Based on panel data from 1991, 2000 and 2010 at the county level in China, this study analyzed the coupling characteristics and spatio-temporal patterns of agricultural labor changes and economic development under rapid urbanization using quantitative and GIS spatial analysis methods. Three primary conclusions were obtained. (1) During 1991–2010, China's agricultural labor at the county level showed a decreasing trend, down 4.91% from 1991 to 2000 and 15.50% from 2000 to 2010. In spatial distribution, agricultural labor force has evolved by decreasing eastward and increasing westward. (2) During 1991–2010, China's agricultural economy at the county level showed a sustained growth trend, with a total increase of 140.13%, but with clear regional differences. The proportion of agricultural output in national GDP gradually decreased, characterized by decreases in eastern China and increases in western China. (3) The coupling types of economic-labor elasticity coefficient are mainly growth in northwest China, for both the agricultural economy and labor, and are intensive in southeast China, with growth of the agricultural economy and reduction of agricultural labor. Regions with lagged, fading, and declining coupling types are generally coincident with the high incidence of poverty in China. However, different coupling types had a positive developing trend for 1991–2010. Finally, based on the coupling types and spatial distribution characteristics of economic-labor elasticity coefficients, some policy suggestions are proposed to promote the integration of the primary, secondary, and tertiary industries and the vitalization of rural economies.

**Keywords: agricultural labor change; agricultural economic development; economic-labor elasticity coefficient; spatio-temporal coupling; rural vitalization**

**Received:** 2018-08-18 **Accepted:** 2018-09-25
**Foundation:** Key Program of National Natural Science Foundation of China, No.41731286; The Postdoctoral Science Foundation of China, No.2018M630197
**Author:** Ma Li (1991–), PhD, specialized in urban-rural development and land use. E-mail: mal.17b@igsnrr.ac.cn.
***Corresponding author:** Long Hualou, Professor, E-mail: longhl@igsnrr.ac.cn;
Tu Xiaosong, PhD, E-mail: tuxiaosong@jxufe.edu.cn

## 1 Introduction

Since the reform and opening up, China's economic development level has been continuously improving, and the per capita disposable income of urban residents increased from 343.4 yuan in 1978 to 33,616 yuan in 2016; the per capita net income of rural residents increased from 133.6 yuan in 1978 to 12,363 yuan in 2016. However, the large gap in urban and rural development and uneven development of the eastern and western regions remain as large problems. Due to mobility, poverty, policy bias, and poor land management, the countryside is being abandoned and villages face challenges, such as labor shortage, economic recession, and weakening of mainstream of rural development (Long, 2014; Liu and Li, 2017; Tu and Long, 2017; Tu *et al*., 2018). The Report of the 19th National Congress of the Communist Party of China (2017) highlighted the necessity of implementing a rural vitalization strategy, prioritizing the development of agriculture and rural areas, and addressing the problems related to farmers, agriculture, and rural areas (termed "San Nong Wen Ti" in Chinese) as the top priority of the whole party. Improving the vitality of rural areas, reconstructing the rural economy, and reversing the primitive nature of rural development is an urgent problem (Sato, 2013; Li *et al*., 2014; Chen *et al*., 2017).

As the basic industry of the national economy, agriculture bears the function of employment and development of vast peasant population in China. Agricultural development has important practical significance for ensuring food security, alleviating poverty, narrowing the gap between urban and rural areas and building a successful society (Ge *et al*., 2018a, 2018b; Matos *et al*., 2018). The transfer of agricultural labor promotes economic growth, improves agricultural production efficiency, completely transforms agricultural production modes, and achieves agricultural transformation (Tan, 2014; Li *et al*., 2016; Ge *et al*., 2018a). At present, many empirical studies have investigated the impact of agricultural labor transfer on rural economic development, including the potential and trends (Li *et al*., 2017a), impacts on rural development and their relationships (Long *et al*., 2016), and from macroscopic and meso perspectives (Mcarthur and Mccord, 2017; Long *et al*., 2016; Li *et al*., 2017b). However, relatively few studies have focused on the coupling relationship between agricultural labor transfer and agricultural economy (Li and Fang, 2018), and analyses focusing on both theoretical and empirical levels are relatively scarce. At present, most current research areas are based on provinces and cities, and there is limited research at the county level although the importance of the county economy in China's economic development is becoming increasingly prominent (Yu *et al*., 2018). To address these data deficiencies, this study uses data for 1991, 2000, and 2010 at the county level to analyze the interactions between the agricultural labor force and agricultural economic development in different regions of the country and their spatio-temporal coupling patterns. This work can be used as a reference for coordinating man-land interrelations and promoting industrial structure transformation and rural economic vitalization.

## 2 The mechanisms driving agricultural labor changes and economic development

This study establishes a theoretical framework to characterize the mechanisms driving agricultural labor changes and economic development. We use this framework to explore the

regularity and coupling pattern of agricultural labor change and economic development in China to optimize the industrial and employment structure and promote vitalization of rural economies (Figure 1).

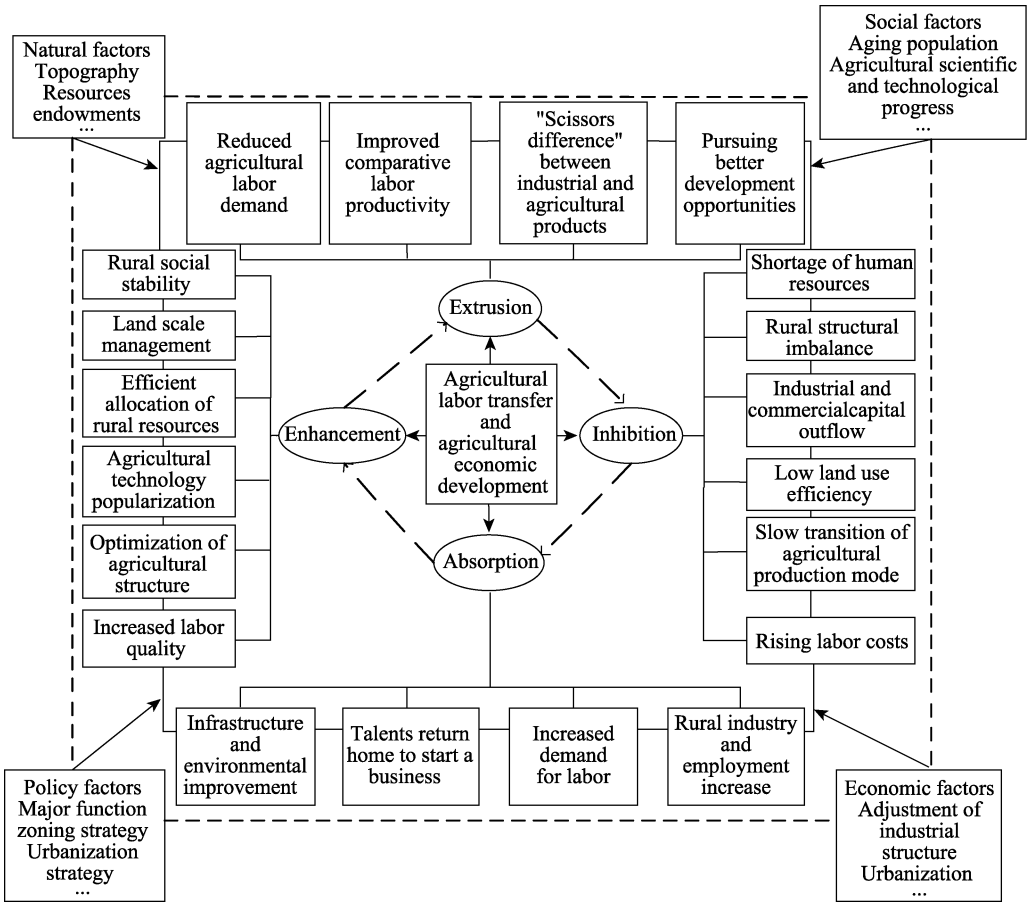


**Figure 1** The mechanisms driving agricultural labor changes and economic development

(1) Agricultural labor transfer can both facilitate and inhibit agricultural economic development. The transfer of agricultural labor is conducive to farmers accepting more advanced ideas and education, which can improve the quality of labor, popularize agricultural technology, and increase farmers' income. Wealthier farmers will also increase investments in education and other intellectual resources and improve the overall quality of life; this has a multiply effect that further promotes the development of the agricultural economy (Long *et al*., 2016). In addition, the transfer of the agricultural labor force facilitates the rational allocation of rural resource elements, optimizing the agricultural production structure, realizing land scale management, improving agricultural productivity, and promoting rural social stability (Li *et al*., 2017b; Eberhardt and Vollrath, 2018; Long and Qu, 2018). Ultimately, these factors are key in promoting the development of the agricultural economy. Nonetheless, there are some drawbacks to the transfer of the agricultural labor force because the moving population is generally well-educated: the weak labor force remains in the countryside, causing such problems as a rural human resource shortage, capital outflow, difficulty in promoting agricultural technology, and imbalances in population and industrial structure. In

addition, the transfer of a more educated labor force inhibits the replacement of agricultural traditional production factors for modern ones, which increases labor costs, creates inefficient use of land and land abandonment, and thus inhibits the development of the agricultural economy (Leng *et al*., 2018; Ge *et al*., 2018a).

(2) The development of the agricultural economy results in the absorption and extrusion of the agricultural labor force. As the development of labor-intensive industries has shifted from east to west, the development and expansion of rural industries and new business entities and the division of labor in agriculture and rural areas has become more clear; therefore, promoting employment opportunities has become easier, resulting in a transfer of agricultural labor (Emran and Shilpi, 2018). In addition, in the context of rural infrastructure improvement and strong policy support, there is greater potential for rural development. Capable farmers can actively return to their hometowns for employment and entrepreneurship, and further promote rural industrial development and economic restructuring. However, with the development of the agricultural economy, agricultural mechanization and labor productivity have increased. As a result, a declining demand for agricultural labor promotes the transfer of agricultural labor to non-agricultural industries. In addition, the importance of the industrial sector has been overemphasized for a long time, while the role of the agricultural sector has been ignored. Furthermore, the "scissors difference" between industrial and agricultural products has always existed, accelerating the transfer of agricultural to non-agricultural labor (Long *et al*., 2010). Some farmers have also chosen to move to the city to seek better development opportunities after their economic conditions have reached a certain level.

(3) Changes in the agricultural labor force and development of agricultural economy are mutually influencing, but external factors also play a role in their trajectories. For example, natural, socio-economic, and policy factors, such as resource endowments, geographic conditions, aging population, new urbanization innovations, agricultural scientific and technological progress, industrial structure adjustments, and major function zoning will have impacts. Generally, good natural resource endowments and geographic location are conducive to the development of a regional agricultural economy and promote the transfer of agricultural labor. However, in areas with relatively poor conditions, the level of agricultural economic development and urbanization are often low. An aging rural population will inhibit the transfer of agricultural labor and the development of agricultural economy. Furthermore, with the acceleration of innovations in urbanization and an increase in urban employment opportunities, the non-agricultural transfer of agricultural labor will continue to increase. Concurrently, the development of agricultural science and technology accompanied by the urbanization process will effectively improve the level of agricultural economic development. The impact of industrial structure adjustment and major function zoning on the development of the agricultural economy varies across different regions. For example, restricted or prohibited development zones focusing on ecological protection will inhibit the development of local agricultural economy. However, key development zones for sustainable development of China's economy will promote the transfer of agricultural labor to non-agricultural positions and the improvement of the agricultural economy (Fan, 2015).

In summary, under the combined effect of various factors, agricultural labor transfer and economic development have evolved with regional characteristics and taken on special development law.

## 3 Data sources and research method

### 3.1 Data sources

The basic geographic data incorporated in this study were obtained from the Resource and Environmental Science Data Center of the Chinese Academy of Sciences. Statistical data at county level for 1991, 2000, and 2010 were obtained from the China Natural Resources Data Center (http://www.data.ac.cn) and China County (City) Social and Economic Statistical Yearbook; data include regional GDP, total agricultural output, and agricultural labor populations. In processing the data, missing values for some counties were interpolated using statistical yearbooks for corresponding provinces in corresponding years. In total, 2024 valid statistical units were obtained. To make data for different years comparable, and accurately reflect the true development of the rural economy and eliminate the impact of price changes on analyses, economic data were converted to 1990 equivalent values.

### 3.2 Research method

#### 3.2.1 The economic-labor elasticity coefficient (ELEC)

Elasticity in economics refers to the sensitivity degree of the change, which is reflected by the change percentage of one variable relative to that of another variable. The magnitude of the elasticity can be measured using elasticity coefficient; this study uses the labor-farmland elasticity coefficient (Liu and Li, 2010), to establish the economic-labor elasticity coefficient (ELEC) to reflect the sensitivity degree of the change in the agricultural labor population relative to the change in the development of the agricultural economy. It is defined as the ratio of the rate of change in agricultural economic development to the rate of change in the agricultural labor population for a given period. A larger absolute value for the elasticity coefficient reflects a higher sensitivity between the changes in the two variables and vice versa. The ELEC is calculated from the following equation:

$$ELEC_{mn} = \frac{ECR_{mn}}{LCR_{mn}} = \frac{(E_{mn} - E_{m0})/E_{m0}}{(L_{mn} - L_{m0})/L_{m0}} \quad (1)$$

where $ECR_{mn}$ and $LCR_{mn}$ represent the rates of change for agricultural economic development level and agricultural labor population for county $m$ in year $n$, respectively. Similarly, $E_{mn}$ and $L_{mn}$ refer to the agricultural economic development level and agricultural labor population for county $m$ in year $n$, respectively; while $E_{m0}$ and $Lm_0$ refer to the agricultural economic development level and agricultural labor population for county $m$ in the base year.

#### 3.2.2 The coupling relation modes between agricultural labor changes and economic development

Based on the analyses of the changes in $ELEC_{mn}$, this study divides the coupling between agricultural labor change and economic development into six types: growth, extensive, intensive, lagged, fading, and declining (Table 1). The specific descriptions are as follows. (1) $ECR_{mn} > 0$, $LCR_{mn} > 0$ indicates that the increase in the agricultural labor population has played a positive role in promoting rural economic development. $ELEC_{mn} > 1$ indicates that the growth rate for the agricultural economy is higher than that of the agricultural labor population, and characterizes the growth type. $0 < ELEC_{mn} < 1$ indicates that the growth rate of agricultural economy is lower than that of the agricultural labor population, and charac-

terizes the extensive type. (2) $ECR_{mn} > 0$, $LCR_{mn} < 0$ indicates that while the agricultural labor population is decreasing, the level of agricultural economic development is increasing, and the reduction in the agricultural labor population has played a positive role in promoting agricultural economic development, which characterizes the intensive type. (3) $ECR_{mn} < 0$, $LCR_{mn} > 0$ indicates that while the agricultural labor population is increasing, the level of agricultural economic development is declining, and the increase in the agricultural labor population has a reversed suppression effect on agricultural economic development, which characterizes the lagged type. (4) $ECR_{mn} < 0$, $LCR_{mn} < 0$ indicates that the agricultural labor population has decreased with the level of agricultural economic development. $ELEC_{mn} > 1$ indicates that the decline in agricultural economic development is faster than that of the agricultural labor population, which characterizes the fading type. Finally, $0 < ELEC_{mn} < 1$ indicates that the decline in agricultural economic development is slower than that of the agricultural labor population, which characterizes the declining type.

**Table 1** The coupling relationship types between agricultural labor change and economic development

| Type | $ECR_{mn}$ | $LCR_{mn}$ | $ELEC_{mn}$ | ELEC characteristics |
|---|---|---|---|---|
| Growth | $ECR_{mn} > 0$ | $LCR_{mn} > 0$ | $ELEC_{mn} > 1$ | The agricultural economy grows faster than the agricultural labor population |
| Extensive | $ECR_{mn} > 0$ | $LCR_{mn} > 0$ | $0 < ELEC_{mn} < 1$ | The agricultural economy grows slower than the agricultural labor population |
| Intensive | $ECR_{mn} > 0$ | $LCR_{mn} < 0$ | $ELEC_{mn} < 0$ | The agricultural economy grows, but the agricultural labor population decreases |
| Lagged | $ECR_{mn} < 0$ | $LCR_{mn} > 0$ | $ELEC_{mn} < 0$ | The agricultural economy declines, but the agricultural labor population increases |
| Fading | $ECR_{mn} < 0$ | $LCR_{mn} < 0$ | $ELEC_{mn} > 1$ | The agricultural economy declines faster than the agricultural labor population |
| Declining | $EC_{Rmn} < 0$ | $LCR_{mn} < 0$ | $0 < ELEC_{mn} < 1$ | The agricultural labor population declines faster than the agricultural economy |

At present, China is best represented by the intensive coupling relationship mode. The continued non-agricultural transfer is conducive to improving man-land interrelations, increasing farmers' income, and improving agricultural labor productivity, thereby promoting rural economic development. The growth and extensive coupling modes contribute less to rural development than the intensive coupling mode. However, the lagged coupling relation mode will inhibit rural development, and the agricultural labor force remaining in rural areas will affect improvements in agricultural productivity, which is not conducive to the transformation of traditional agriculture and increases in farmers' income (Inwood, 2017; Zhang *et al*., 2017). In addition, the fading and declining coupling mode should receive more attention to avoid the problems of rural hollowing (Liu *et al*., 2010; Long *et al*., 2012), farmland abandonment (Li and Li, 2017; Shao *et al*., 2018), and lack of vitality in rural areas due to high-quality labor transfer and capital outflow (Kumwimba *et al*., 2018).

## 4 Results

### 4.1 The spatio-temporal changes in agricultural labor

Generally, for 1991–2010, the agricultural labor population in China gradually decreased. The data analysis shows that the agricultural labor population at the county level both in-

creased or decreased with clear spatial differences (Figure 2).

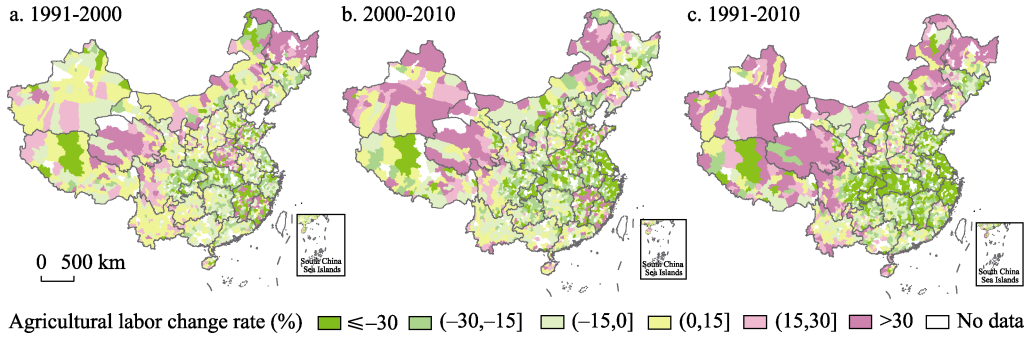


**Figure 2** Spatio-temporal patterns of agricultural labor change at the county level in China for 1991–2010

Between 1991 and 2000, the agricultural labor population in 52.57% of the counties decreased, and decreased at a higher rate over 2000–2010. Counties with decreases in the agricultural labor population accounted for 64.97% of all counties, and 251 counties with reduced agricultural labor were added. The agricultural labor presents an opposite trend, which tends to decrease in the east part and is prone to increase in the western part of China. From 1991 to 2010, 64.72% of the counties had an agricultural labor force with a decreasing trend, and 35.28% counties had an increase in the agricultural labor population, with clear territorial differences. The areas with a decrease in agricultural labor were mainly distributed in southeastern China, including most of the counties in the Huang-Huai-Hai Plain, Yangtze River Delta, Pearl River Delta, middle and lower reaches of the Yangtze River, southern China, and most counties in southwestern China. The areas with increased agricultural labor were mainly distributed in northwestern and northeastern China, including the Loess Plateau Region, Inner Mongolia Autonomous Region, Gansu-Xinjiang Region, Qinghai-Tibet Region, and northeastern China. Among them, the agricultural labor populations in Qinghai-Tibet and Gansu-Xinjiang regions increased significantly, and there were 33 counties with a more than doubling increase, mainly distributed in Qinghai and Xinjiang.

## 4.2 Spatio-temporal changes in agricultural economic development

For 1991–2010, the development of the agricultural economy in China's counties generally continued to increase; only a small number of counties showed a declining trend, and the spatial differences were clear (Figure 3).

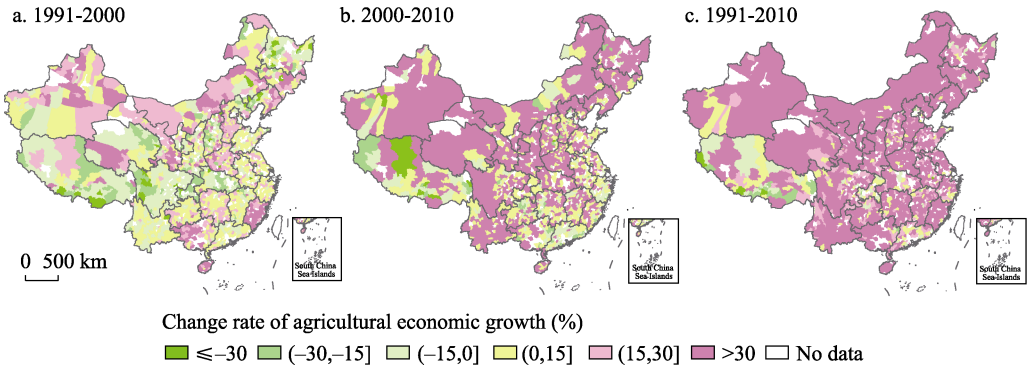


**Figure 3** Spatio-temporal patterns of agricultural economic growth at the county level in China for 1991–2010

From 1991 to 2000, 1841 counties, or 90.96% of the total number of counties, experienced growth in the agricultural economy; only 9.04% of counties showed a slight decline in the agricultural economy. The regions with reduced agricultural economy were mainly distributed in western Sichuan, southern Tibet and northeastern China. The regions with increased agricultural economy were widely scattered across most of China's counties; the agricultural economic growth rates of most counties in seven provinces, including Fujian, Henan, and Hebei, were over 60%. The spatial distribution of agricultural economic growth was characteristically fast in northern and southeastern China and lagged in southwestern China. Between 2000 and 2010, 1947 counties in China, or 96.20% of the total counties, experienced growth in their agricultural economy; only 3.80% of the counties showed a decline. In addition, regions with rapid growth in their agricultural economy started to trend westward. Counties on both sides of the Hu Huanyong Line and the Gansu-Xinjiang region became hot spots for rapid growth. Regions with declining agricultural economies were primarily distributed in Tibet; other regions showed a growth trend, but with clear spatial differences in growth. Growth rates of the agricultural economy in the central and western regions were faster than in the southeastern coastal regions. In general, between 1991 and 2010, agricultural economies for 98.57% of the counties showed growth, of which 75.44% increased more than 90%; only 1.43% of the counties had a downward trend in their agricultural economic development and most were located in southwestern Tibet.

### 4.3 ELEC coupling characteristics

#### 4.3.1 ELEC spatio-temporal patterns

Based on formula (1) and the classification criteria for coupling relation types between agricultural labor change and economic development (Table 1), the changes in ELEC and the corresponding coupling types at the county level in China for 1991–2010 were obtained (Table 2). According to the two types of agricultural economic growth and reduction zones, the coupling relationships between agricultural labor changes and agricultural economic development at the county level in China were further analyzed (Figures 4–6).

**Table 2** Changes in the ELEC and corresponding coupling types at the county level in China for 1991–2010

| *ECR* | Coupling type | *LCR* | *ELEC* | 1991–2000 | 2000–2010 | 1991–2010 |
|---|---|---|---|---|---|---|
| $ECR > 0$ | Growth | $LCR > 0$ | $ELEC > 1$ | 701 (34.63%) | 607 (29.99%) | 669 (33.05%) |
| | Extensive | $LCR > 0$ | $0 < ELEC < 1$ | 160 (7.91%) | 83 (4.1%) | 34 (1.68%) |
| | Intensive | $LCR < 0$ | $ELEC < 0$ | 980 (48.42%) | 1257 (62.1%) | 1292 (63.83%) |
| $ECR < 0$ | Lagged | $LCR > 0$ | $ELEC < 0$ | 99 (4.89%) | 18 (0.89%) | 9 (0.44%) |
| | Fading | $LCR < 0$ | $ELEC > 1$ | 23 (1.14%) | 22 (1.09%) | 8 (0.4%) |
| | Declining | $LCR < 0$ | $0 < ELEC < 1$ | 61 (3.01%) | 37 (1.83%) | 12 (0.59%) |

Note: Data outside the parentheses refers to the number of counties belonging to a certain type; data inside the parentheses refers to the proportion of counties belonging to a certain type relative to the total number of counties.

Several observations were made from Figure 4. First, in counties with increases in the agricultural economy, 701 counties had agricultural economies with faster growth than the increase in the agricultural labor population (LCR > 0, ELEC > 1), i.e., the growth type, mainly distributed in Yunnan, Xinjiang, Qinghai, and Inner Mongolia. Agricultural eco-

nomic growth rates were smaller than that of the agricultural labor population (LCR > 0, 0 < ELEC < 1), i.e., the extensive type, in 160 counties primarily distributed in the western part of Sichuan Basin, Qinghai, Tibet, Jiangxi, Henan, Heilongjiang, and some counties in southern Xinjiang. There were 980 counties showed agricultural economic growth but decreases in the agricultural labor population (LCR < 0, ELEC < 0), i.e., the intensive type, mainly distributed in the middle and lower reaches of the Yangtze River, South China, Pearl River Delta, Yangtze River Delta, and Huang-Huai-Hai Plain. Second, in the counties with decreases in the agricultural economy, 99 counties showed growth in agricultural labor and a decrease in agricultural economic growth (LCR > 0, ELEC < 0), i.e., the lagged type, mainly distributed in counties in the western Sichuan Basin, Tibet, Xinjiang, Qinghai, Shanxi, Hebei, Liaoning, and Heilongjiang. The agricultural economy declined faster than the agricultural labor population (LCR < 0, ELEC > 1), i.e., the fading type, in 23 counties mainly distributed on both sides of the Hu Huanyong Line. The agricultural economy declined slower than the agricultural labor population decreased (LCR < 0, 0 < ELEC < 1), i.e., the declining type, in 61 counties mainly distributed in Hubei and Chongqing.

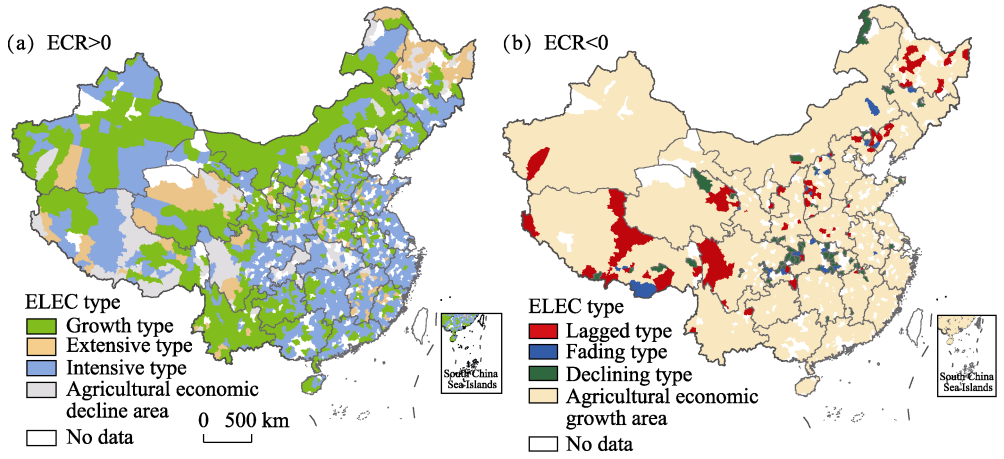


**Figure 4** ELEC spatio-temporal patterns at the county level in China for 1991–2000 (a. ECR>0; b. ECR<0)

Several observations can be clearly reflected from Figure 5. First, in the counties with an increase in agricultural economy, 607 counties had faster agricultural economic growth than the increase in the agricultural labor population (LCR > 0, ELEC > 1), i.e., the growth type, mainly distributed in Sichuan, Gansu-Xinjiang, Qinghai-Tibet, Inner Mongolia, and northeastern regions. In comparison, 83 counties had slower agricultural economic growth rates than that of the agricultural labor population (LCR > 0, 0 < ELEC < 1), i.e., the extensive type, distributed in the Qinghai-Tibet and Gansu-Xinjiang regions and the Pearl River Delta. Growth of agricultural economy with a decrease in the agricultural labor population (LCR < 0, ELEC < 0), i.e., the intensive type, occurred in 1257 counties mainly distributed in the Huang-Huai-Hai Plain, Yangtze River Delta, Pearl River Delta, middle and lower reaches of the Yangtze River, Sichuan-Chongqing, Inner Mongolia, and parts of the Loess Plateau. Second, in the counties with declining agricultural economies, 18 counties showed growth in the agricultural labor and a decrease in agricultural economic growth (LCR > 0, ELEC < 0), i.e., the lagged type, mainly distributed in Tibet, Xinjiang, and the southeastern coastal areas. The agricultural economy declined faster than the agricultural labor population (LCR < 0,

ELEC > 1), i.e., the fading type, in 22 counties mainly distributed in Tibet. The agricultural economy declined slower than the agricultural labor population decreased (LCR < 0, 0 < ELEC < 1), i.e., the declining type, in 37 counties mainly scattered in Tibet and Inner Mongolia.

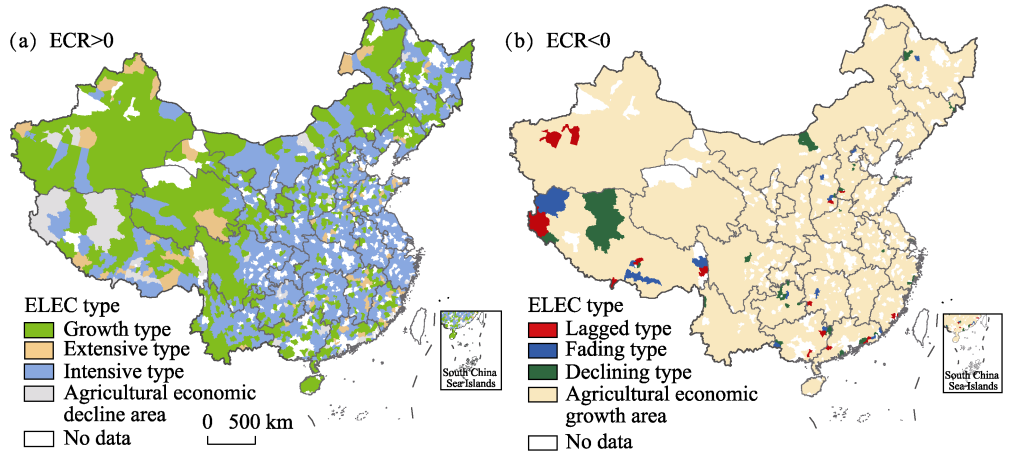


**Figure 5** ELEC spatio-temporal pattern at the county level in China for 2000–2010

From Figure 6, during 1991–2010, growth and intensive type coupling mode counties accounted for 96.88% of the total, and declining and fading type coupling mode counties decreased from 84 during 1991–2000 to 20 during 1991–2010, indicating a general positive development trend. First, in counties with improvements in the agricultural economy, 669 counties showed faster agricultural economic growth than the increase in agricultural labor population (LCR > 0, ELEC > 1), i.e., the growth type, mainly distributed in western Sichuan, Gansu-Xinjiang, Qinghai-Tibet, Inner Mongolia, and northeastern China regions. Agricultural economic growth rates were slower than that of the agricultural labor population (LCR > 0, 0 < ELEC < 1), i.e., the extensive type, in 34 counties mainly distributed in western Sichuan, Qinghai-Tibet, Xinjiang, and Heilongjiang; their grouping shows obvious regional agglomeration characteristics. Growth in the agricultural economy and declines in the agricultural labor population (LCR < 0, ELEC < 0), i.e., the intensive type, was observed in 1292 counties mainly distributed in the Huang-Huai-Hai Plain, Yangtze River Delta, middle and lower reaches of the Yangtze River, Sichuan-Chongqing, and parts of the Loess Plateau. Second, during this period, only 29 counties showed a declining agricultural economy; 9, 8, and 12 counties respectively belonged to the lagged type (LCR > 0, ELEC < 0), fading type (LCR < 0, ELEC > 1), and declining type (LCR < 0, 0 < ELEC < 1) concentrated in Tibet.

**4.3.2** The transformation characteristics of the coupling types between agricultural labor changes and economic development

During 1991–2000, the ELEC types within counties changed from each other (Table 3). During the split periods of 1991–2000 and 2000–2010, intensive counties showed a net increase of 13.69%, while other types all decreased. The percentage of counties transformed from growth, extensive, lagged, fading, and declining types to intensive type accounted for 19.12%, 5.58%, 2.96%, 0.94%, and 2.27% of the total counties, respectively (Table 3). In addition, 12.25% of the counties changed from intensive type during 1991–2000 to growth type during 2000–2010, respectively, and a small number of other counties showed coupling

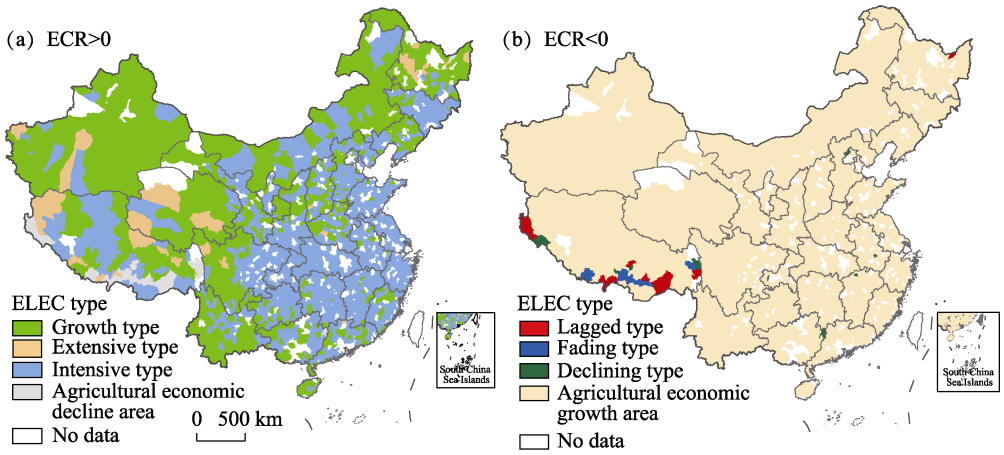


**Figure 6** ELEC spatio-temporal patterns at the county level in China for 1991–2010

type changes. Counties with changes from growth to intensive type were mainly distributed in Yunnan, Guizhou, Inner Mongolia, and the middle and lower reaches of the Yangtze River. Counties with changes from intensive to growth type were relatively scattered, mainly distributed in Tibet, Gansu-Xinjiang, and northeastern regions. Over the past two decades, the counties remaining as intensive type were mainly distributed in the popular economic development areas in China, such as the Huang-Huai-Hai Plain, Yangtze River Delta, Pearl River Delta, middle and lower reaches of the Yangtze River, Sichuan-Chongqing, and Loess Plateau.

**Table 3** The transfer matrix of the ELEC types at the county level in China for 1991–2010 (%)

| | 2000–2010 ($T_2$) | | | | | | $P_1$ | Decrease |
|---|---|---|---|---|---|---|---|---|
| | Growth | Extensive | Intensive | Lagged | Fading | Declining | | |
| 1991–2000 ($T_1$) | | | | | | | | |
| Growth | 13.59 | 0.64 | 19.12 | 0.25 | 0.40 | 0.64 | 34.63 | 21.05 |
| Extensive | 1.88 | 0.20 | 5.58 | 0.05 | 0.10 | 0.10 | 7.91 | 7.71 |
| Intensive | 12.15 | 3.01 | 31.23 | 0.44 | 0.54 | 1.04 | 48.42 | 17.19 |
| Lagged | 1.63 | 0.10 | 2.96 | 0.1 | 0.00 | 0.05 | 4.89 | 4.74 |
| Fading | 0.15 | 0.05 | 0.94 | 0.00 | 0.00 | 0.00 | 1.14 | 1.14 |
| Declining | 0.59 | 0.10 | 2.27 | 0.00 | 0.05 | 0.00 | 3.01 | 3.01 |
| $P_2$ | 29.99 | 4.10 | 62.10 | 0.89 | 1.09 | 1.83 | 100 | |
| Increase | 16.40 | 3.90 | 30.88 | 0.74 | 1.09 | 1.83 | | |

Note: The number in the transfer matrix indicates that the proportion of counties transformed from one coupling type to the other in the total counties belonging to the former type.

Under the combined action of internal and external driving forces, the ELEC types in each county have changed, generally showing positive trends. With improvements in agricultural science and technology, the support of agricultural policy, accelerated urbanization, and an increase in non-agricultural employment, the productivity of agricultural labor in most counties has increased, which has promoted the transfer of agricultural to non-agricultural labor. However, the transfer of agricultural labor is conducive to the rational allocation of agricultural resources, optimizing the structure of agricultural production, real-

izing the scale of land management, which has promoted agricultural economic growth. Furthermore, the development of the agricultural economy and increase in agricultural labor productivity will further promote the transfer of agricultural to non-agricultural labor.

For example, most counties in Inner Mongolia changed from the growth type from 1991–2000 to the intensive type in 2000–2010. Recently, agricultural technology innovations, popularization, and application combined with the support of related agricultural policies, the agricultural economy in Inner Mongolia has risen continuously. In the first period, the non-agricultural transfer of agricultural labor was unclear because of the poor development of agricultural modernization and the relatively few non-agricultural employment positions. Therefore, in this stage, the ELEC coupling mode is characterized as the growth type due to fast growth of agricultural economy compared to the relatively slow growth in the agricultural labor population. In the second period, the grassland dairy industry has developed and was increasingly popular, which promoted the modernization process of the agriculture and animal husbandry industries; the longer agricultural-industrial chain was beneficial to the transfer of agricultural labor. In addition, the rapid development of the real estate industry after 2000 sped up the development of the construction and service industries, which play an important role in absorbing the rural surplus labor force (Rong *et al*., 2014). This stage is characterized as intensive, with increases in agricultural economy and decreases in agricultural labor population.

## 5 ELEC coupling characteristics and implications for rural vitalization

According to the ELEC coupling types and spatial distribution characteristics, this study proposes several policy recommendations for rural vitalization through the optimized reconstruction of the rural population, industry, and economy as follows and in Table 4.

(1) Counties characterized as growth type are mainly distributed in western Sichuan, Qinghai-Tibet, Gansu-Xinjiang, most of the Inner Mongolia Autonomous Region, and northeast China. These regions are mostly located in northwest China, and the natural and geographical location conditions are relatively primitive. Recently, with improvements in agricultural technology and the support of agricultural policy, agricultural economic growth has been obvious, but heavily dependent on resources due to the slow transformation of the industrial structure (Guan and Xu, 2015). Furthermore, slower urbanization has maintained a low demand for agricultural to non-agricultural labor transfer. In addition, these regions are mostly the gathering place of minority nationalities, so the farmers have poor education and skills, which makes it more difficult for them to qualify for jobs with higher technical requirements. Therefore, although the agricultural economy has increased in such areas, the transfer of agricultural to non-agricultural labor is not notable. The rural vitalization of this type of region may be achieved through the following measures. First, the government needs to accelerate the transformation of industrial structure in these regions, provide a moderating hand to guide the scale management of the land, and actively cultivate new management entities. Second, it is necessary to strengthen the construction of rural professional talents, such as developing farmers' self-employment and employment professional skills training. Stimulating the rural endogenous development motivation is expected to promote the transfer of agricultural labor to non-agricultural industries.

(2) Counties characterized as the extensive type are mainly concentrated in western Si-

chuan, Qinghai-Tibet, Xinjiang, and Heilongjiang. There are few of these counties and they are generally located in the marginal areas of various provinces (autonomous regions); the physical environment and geographical location conditions are poor, with extreme poverty, and the orientation of industrial development is not clear, so the agricultural economic development is slower than that of the growth type counties. Rural vitalization in these regions may be achieved through the following measures. First, policy guidance and support and employment skills training for poor people should be strengthened. Second, it is important to determine regional functions and highlight the comparative advantages for future development. Additional measures include actively cultivating new-type rural industries, supporting and encouraging farmers to pursue a diversified economy, and promoting the combination of smallholder management with modern agriculture.

**Table 4** ELEC coupling characteristics and rural vitalization paths

| Type of economic development | Coupling type | Spatial distribution | Basic feature | Vitalization path |
|---|---|---|---|---|
| Agricultural economic growth area | Growth | Mainly distributed in western Sichuan, Qinghai-Tibet, Xinjiang, Gansu, most of Inner Mongolia, and northeast China | Physical and geographical location conditions are relatively poor; lacking substantial progress in industrial adjustment; heavily dependent on resources | Accelerating transformation of the industrial structure; moderately guiding land scale management; actively cultivating new management types; strengthening the construction of rural professional talent |
| | Extensive | Mainly distributed in western Sichuan, Qinghai-Tibet, Xinjiang, and some counties in Heilongjiang | Physical and geographical location conditions are relatively poor; deep poverty; unclear industrial development orientation | Strengthening policy guidance and support; determining regional functions and highlighting comparative advantages; cultivating new types of rural industries; encouraging diversified economy |
| | Intensive | Mainly distributed in the Huang-Huai-Hai Plain, Yangtze River Delta, Pearl River Delta, middle and lower reaches of the Yangtze River, parts of Sichuan and Chongqing and the Loess Plateau | Rapid economic development, high levels of urbanization and agricultural modernization; core areas for economic growth and high population density | Improving the quality of agricultural development; constructing special towns; promoting the integrated development of rural industries; strengthening grassroots governance and institutional innovation |
| Agricultural economic decline area | Lagged<br>Fading<br>Declining | Centrally distributed on the edge of the Tibet Autonomous Region | Poor physical and geographical location, infertile soil unfavorable for agricultural production; deep poverty; backward ideas, low labor quality and poor labor skills | Reinforcing infrastructure construction and capital investment; cultivating new agricultural management types; emphasizing rural education; attracting talent to return and restructure their hometowns |

(3) Counties characterized as the intensive type are mainly distributed in the Huang-Huai-Hai Plain, Yangtze River Delta, Pearl River Delta, middle and lower reaches of the Yangtze River, parts of Sichuan and Chongqing, and the Loess Plateau. These are the core areas of China's economic growth, with high population density, rapid socio-economic

development, high levels of urbanization and agricultural modernization, and tremendous changes in population and industrial structure, which create favorable conditions for agricultural economic growth and agricultural labor transfer (Ning *et al*., 2018). The rural vitalization in these regions may be achieved through the following measures. First, continuous favorable external conditions for urbanization and industrialization should be maintained while also improving the quality of agricultural development based on scientific and technological innovations. Second, constructing special towns in the areas with suitable conditions will be important because it also provides attention to inheriting and carrying forward the traditional culture of the country (Long *et al*., 2018). Third, it is necessary to stimulate the endogenous development in the countryside and promote the integration of rural primary, secondary, and tertiary industries. Additional attention should be given to the development of rural and environmental tourism, strengthening grassroots governance and institutional innovation, and providing typical development experiences and modes for other relatively primitive rural areas.

(4) Counties characterized as the lagged, fading, and declining types are relatively few. These counties are mainly concentrated on the edge of the Tibet Autonomous Region, a plateau area. Due to the harsh natural conditions, primitive peasant ideas, low quality of the labor force, and high poverty in this region has slowed the transfer of the surplus labor force in the countryside. The rural vitalization of this type of region may be achieved through the following measures. First, reinforcing the infrastructure construction and capital investment in poverty-stricken areas would reduce the incidence of poverty. Second, the government needs to actively cultivate new agricultural management types and conduct training on peasant employment skills to guide the agricultural to non-agricultural labor transfer. In addition, additional attentions should be given to rural education, attracting talents to return and restructure their hometowns (Long *et al*., 2016) and avoid problems such as land abandonment and rural decline (Fuglie, 2018).

## 6 Discussion and conclusions

### 6.1 Discussion

By selecting the statistical data in 1991, 2000 and 2010, this study explored the coupling relationships between agricultural labor changes and economic development and their spatio-temporal patterns to provide a reference for the development of rural economies and the coordination of man-land interrelations in China. Compared with previous studies, this study established a theoretical framework for the interaction between agricultural labor changes and economic development, and further defined and expounded on the connotation and extension of ELEC coupling types, which should enrich the theoretical research into rural transformation development. The transfer of agricultural labor can promote the harmonious development of man-land interrelations. However, due to the urban-rural dual household registration, land, education, and medical systems and other institutional obstacles (Tu and Long, 2017), more farmers choose the concurrent production mode (Zhang *et al*., 2018), which reduces agricultural labor productivity and hinders the process of agricultural modernization and transformation of the industrial structure. Mechanisms for protecting the rights and interests of farmers, stabilizing and improving the agricultural management system

in agreement with China's basic conditions, and promoting regional economic development and coordinating man-land interrelations will be an important topic for further research.

China has a vast territorial area, significant regional differences, and diverse types of socio-economic development. The impact of agricultural labor transfer on the development of the agricultural economy is also characterized by regional differences, which are influenced by many factors, including natural resources, geographic location, and socio-economic development level, as well as some subjective factors, such as farmers' personal preferences and value orientation. The coupling mode for different agricultural labor changes and economic development constitutes the type of ELEC combination in China's counties. We need to address the various coupling modes, objectively analyze their advantages and disadvantages, and plan for rural vitalization.

### 6.2 Conclusions

The study results provide several important conclusions:

(1) The agricultural labor population showed a decreasing trend and the agricultural labor change rates for 1991–2000, 2000–2010, and 1991–2010 decreased at 4.91%, 15.50%, and 19.65%, respectively. The change in the agricultural labor population evolved spatially following an east reduction and west increase pattern. The transfer of agricultural labor is conducive to alleviating the pressure on man-land interrelations, promoting land management, and transforming the agricultural industrial structure, raising the income level of farmers, and causing the rural economy to flourish.

(2) During 1991–2010, China's agricultural economy at the county level showed a continuous growth trend, with a total increase of 140.13%. During the periods of 1991–2000 and 2000–2010, the agricultural economic growth rate was 43.06% and 67.85%, respectively. In the former period, the agricultural economic growth rate in the eastern region was faster than that in central and western China. In the latter period, the agricultural economic growth rate in central and western regions was faster than that in eastern China. Regional differences were significant. With a developing socio-economy and accelerating industrialization and urbanization, the proportion of agricultural output value in the GDP gradually decreased, from 24.53% in 1991 to 10.1% in 2010.

(3) The ELEC coupling types are diverse and showed clear regional differences. The two major types, growth and intensive, were distributed in the northwestern and southeastern regions of China, respectively. Growth type counties decreased from 701 in 1991–2000 to 607 in 2000–2010. However, intensive type counties increased from 980 in 1991–2000 to 1257 in 2000–2010. Concurrently, the number of extensive type counties also decreased and were concentrated in some counties in Xinjiang, Tibet, and Qinghai. Areas characterized as lagged, fading, and declining types were also regions with high incidence of poverty in China, which need more attention and assistance.

(4) For 1991–2010, the ELEC types in various counties changed, showing healthy development trends. According to the coupling types and spatial distribution characteristics of agricultural labor changes and economic development, some countermeasures are proposed forward to promote rural vitalization. These suggestions include promoting new types of town construction, activating rural development factors, cultivating new management types, accelerating industrial restructuring, strengthening policy support, and attaching importance

to talents and education. Relying on these measures is expected to promote the integration and development of rural primary, secondary, and tertiary industries, and subsequently vitalize rural China.

## References

Chen M, Long H, Wang C *et al*., 2017. Review of and prospects for China's human and economic geography. *Journal of Geographical Sciences*, 27(12): 1556–1576.

Eberhardt M, Vollrath D, 2018. The effect of agricultural technology on the speed of development. *World Development*, 109: 483–496.

Emran S, Shilpi F, 2018. Agricultural productivity, hired labor, wages, and poverty: Evidence from Bangladesh. *World Development*, 109: 470–482.

Fan J, 2015. Draft of major function oriented zoning of China. *Acta Geographica Sinica*, 70(2): 186–201. (in Chinese)

Fuglie K, 2018. Is agricultural productivity slowing? *Global Food Security–Agriculture Policy Economics and Environment*, 17: 73–83.

Ge D, Long H, Zhang Y *et al*., 2018a. Analysis of the coupled relationship between grain yields and agricultural labor changes in China. *Journal of Geographical Sciences*, 28(1): 93–108.

Ge D, Long H, Zhang Y *et al*., 2018b. Farmland transition and its influences on grain production in China. *Land Use Policy*, 70: 94–105.

Guan W, Xu S, 2015. Spatial energy efficiency patterns and the coupling relationship with industrial structure: A study on Liaoning Province, China. *Journal of Geographical Sciences*, 25(3): 355–368.

Inwood S, 2017. Agriculture, health insurance, human capital and economic development at the rural-urban-interface. *Journal of Rural Studies*, 54: 1–14.

Kumwimba M, Meng F, Iseyemi O *et al.*, 2018. Removal of non-point source pollutants from domestic sewage and agricultural runoff by vegetated drainage ditches (VDDs): Design, mechanism, management strategies, and future directions. *Science of the Total Environment*, 639: 742–759.

Leng K, Bi Y, Jing L *et al*., 2018. Research on agricultural supply chain system with double chain architecture based on blockchain technology. *Future Generation Computer Systems–The International Journal of Science*, 86: 641–649.

Li G, Fang C, 2018. Spatial econometric analysis of urban and county-level economic growth convergence in China. *International Regional Science Review*, 41(4): 410–447.

Li S, Li X, 2017. Global understanding of farmland abandonment: A review and prospects. *Journal of Geographical Sciences*, 27(9): 1123–1150.

Li S, Sun Z, Tan M *et al*., 2016. Effects of rural-urban migration on vegetation greenness in fragile areas: A case study of Inner Mongolia in China. *Journal of Geographical Sciences*, 26(3): 313–324.

Li T, Long H, Zhang Y *et al*., 2017b. Analysis of the spatial mismatch of grain production and farmland resources in China based on the potential crop rotation system. *Land Use Policy*, 60: 26–36.

Li X, Yang Y, Liu Y, 2017a. Research progress in man-land relationship evolution and its resource-environment base in China. *Journal of Geographical Sciences*, 27(8): 899–924.

Li Y, Wang J, Liu Y *et al*., 2014. Problem regions and regional problems of socioeconomic development in China: A perspective from the coordinated development of industrialization, informatization, urbanization and agricultural modernization. *Journal of Geographical Sciences*, 24(6): 1115–1130.

Liu Y, Li Y, 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 Y, Li Y, 2017. Revitalize the world's countryside. *Nature*, 548(7667): 275–277.

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

Long H, 2014. Land consolidation: An indispensable way of spatial restructuring in rural China. *Journal of Geo-*

*graphical Sciences*, 24(2): 211–225.

Long H, Ge D, Zhang Y *et al*., 2018. Changing man-land interrelations in China's farming area under urbanization and its implications for food security. *Journal of Environmental Management*, 209: 440–451.

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

Long H, Qu Y, 2018. Land use transitions and land management: A mutual feedback perspective. *Land Use Policy*, 74: 111–120.

Long H, Tu S, Ge D *et al*., 2016. The allocation and management of critical resources in rural China under restructuring: Problems and prospects. *Journal of Rural Studies*, 47: 392–412.

Matos C, Bentes I, Pereira S *et al*., 2018. Which are the factors that may explain the differences in water and energy consumptions in urban and rural environments? *Science of The Total Environment*, 642: 421–435.

Mcarthur J, Mccord G, 2017. Fertilizing growth: Agricultural inputs and their effects in economic development. *Journal of Development Economics*, 127: 133–152.

Ning J, Liu J, Kuang W *et al*., 2018. Spatiotemporal patterns and characteristics of land-use change in China during 2010–2015. *Journal of Geographical Sciences*, 28(5): 547–562.

Rong H, Qiu D, Xie D *et al*., 2014. Assessing the real value of farmland in China. *Journal of Mountain Science*, 11(5): 1218–1230.

Sato T, 2013. Beyond water-intensive agriculture: Expansion of Prosopis juliflora and its growing economic use in Tamil Nadu, India. *Land Use Policy*, 35: 283–292.

Shao J, Huang Z, Deng H, 2018. Characteristics of nonpoint source pollution load from crop farming in the context of livelihood diversification. *Journal of Geographical Sciences*, 28(4): 459–476.

Tan M, 2014. The transition of farmland production functions in metropolitan areas in China. *Sustainability*, 6(7): 4028–4041.

Tu S, Long H, 2017. Rural restructuring in China: Theory, approaches and research prospect. *Journal of Geographical Sciences*, 27(10): 1169–1184.

Tu S, Long H, Zhang Y *et al*., 2018. Rural restructuring at village level under rapid urbanization in metropolitan suburbs of China and its implications for innovations in land use policy. *Habitat International*, 77: 143–152.

Yu Z, Xiao L, Chen X *et al*., 2018. Spatial restructuring and land consolidation of urban-rural settlement in mountainous areas based on ecological niche perspective. *Journal of Geographical Sciences*, 28(2): 131–151.

Zhang P, Zhang J, Chen M, 2017. Economic impacts of climate change on agriculture: The importance of additional climatic variables other than temperature and precipitation. *Journal of Environmental Economics and Management*, 83: 8–31.

Zhang Y, Long H, Ma L *et al*., 2018. Farmland function evolution in Huang-Huai-Hai Plain: Processes, patterns and mechanisms. *Journal of Geographical Sciences*, 28(6): 759–777.