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Coupling Relationship between Agricultural Labor and Agricultural Production Against the Background of Rural Shrinkage: A Case Study of Songnen Plain, China

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Abstract: Based on panel data from 1995, 2005, and 2015 in the Songnen Plain in Heilongjiang Province, this paper used quantitative and spatial analysis methods to reveal the spatiotemporal evolution characteristics and coupling relationship between agricultural labor and agricultural production at the county level against the background of rural shrinkage. The results showed the following: (1) From 1995 to 2015, the agricultural labor population in Songnen Plain increased first and then decreased. The transfer of agricultural labor in the northern and eastern areas was clear, and the agricultural labor population in the central and western areas showed an increasing trend. (2) From 1995 to 2015, the agricultural production showed a growth trend, from the characteristics of "high in the southwest and low in the northeast" to "high in the central areas and low around", with clear regional differences. (3) The coupling relationship between agricultural labor and agricultural production was diverse, showing a trend of positive development from extensive, lagged, and declining types to growth or intensive types. In some areas, the transfer of agricultural labor brought about an increase in the per capita cultivated land and an intensive transformation of production, but problems such as hollow villages, the abandonment of cultivated land and food insecurity often occurred. In addition, the increase in the agricultural labor population promoted the growth of grain yield and agricultural output value, but the decrease in per capita cultivated land might lead to a decrease in the per capita income. Finally, based on the coupling types and spatial distribution characteristics of agricultural labor and agricultural production, some policy suggestions are proposed for rural revitalization.

Keywords: agricultural labor; agricultural production; elasticity coefficient; coupling relationship; Songnen Plain of China

1. Introduction

In recent decades, urban–rural shrinkage has been occurring worldwide, which is a new phenomenon. There are abundant international research results on urban shrinkage, but little attention has been paid to rural shrinkage [1]. In fact, since the 1950s, with the rapid development of urbanization and industrialization, there have been different rural development processes and problems in various countries around the world. However, these various countries have all experienced rural shrinkage stages, such as declining agricultural status, a sustained outflow of the young and middle-aged population, rural economic recession, and a widening gap between urban and rural areas [2]. After the establishment of the WTO and the Doha negotiations, Argentina, Brazil, and other countries joined the global agricultural supply system, which intensified the competition of

international agricultural products and agricultural overcapacity. Under the intense, lasting, and comprehensive impact of economic globalization, a new round of global rural shrinkage has been triggered. The attempt to gain access to better-cultivated land may cause excessive deforestation and threaten the natural environment, which may have also been one of the main reasons for the Amazon fire in 2019. Nowadays, the phenomenon of farmers' differentiation, agricultural weakening, and rural hollowing is very common, and rural shrinkage has become a global focus [3]. Different countries and regions have dissimilar rural economic structures and development levels and different types of rural shrinkage. The impact of globalization on agricultural production and individuals or groups engaged in agricultural production activities has become an important field of international agricultural geography and rural geography research [4].

Agriculture has always been regarded as the core of rural development and the most powerful and lasting symbol of rurality, and agriculture has an important influence on rural, social, and cultural organizations. After nearly half a century of experiencing the profound impact of industrialization, urbanization, and globalization, agriculture in developed countries has changed from a core position to a marginal position. For example, by 2000, less than 20% of the rural population depended on agriculture for survival in the United States, Canada, Britain, and France [5]. The main mode of development in the European countryside has emerged from the leading role of agricultural production to the integration of the functions of agricultural production, cultural function, and social function [6]. Market liberalization and multifunctional development encourage farmers to master more entrepreneurial skills and foster entrepreneurship [7,8]. Agricultural labor is an important economic factor in agricultural production [9,10]. There are many classical theories about the transfer of agricultural labor, such as the Lewis model [11] and Ranis–Fei model [12] under the classical dual economic theory, which analyzed the transformation process from a traditional agricultural production department to a modern production department and revealed the necessary conditions and transfer effects of the transfer of agricultural labor [13]. In addition, there are Todaro's population mobility model [14,15] and Jorgenson's labor mobility model [16], which revised the hypothesis of the Lewis model and explained the problem of agricultural labor transfer in developing countries to a certain extent. Labor transfer is essentially a profit-seeking process of agricultural surplus labor based on the law of diminishing marginal returns. The impact of labor transfer on agricultural production is reflected in two ways: Agricultural production efficiency and available capital. On the one hand, labor transfer liberates farmers from agricultural production and promotes the concentration of agricultural land, which is an important measure to promote economic growth, transform agricultural production modes, and realize agricultural transformation and upgrading [17–20]. Labor transfer also helps farmers to accept more advanced ideas and education, improves the quality of labor, promotes the extension of agricultural technology and increases the farmers' income, and the multiplier effect will further promote the development of the agricultural economy [9]. On the other hand, some scholars believe that the loss of labor can be resolved to a certain extent by purchasing chemical fertilizer from non-agricultural income, employing short-term workers or using machinery. After the income risk and financial constraints are effectively improved, families tend to move to a more specialized mode of agricultural production, which is conducive to agricultural development [21]. In addition, some scholars note that the loss of labor will reduce the available labor resources in rural areas, affect the productivity and mode of production of the left-behind labor, lead to the degradation or extensive use of agricultural land, and make it difficult to adopt innovative agricultural technologies and methods. Thus, agricultural production will fall into a vicious circle trap [22,23], which is not conducive to the sustainable development of agricultural production. From the relationship between labor transfer and rural economic growth, according to human capital theory, labor migration from areas with lower wages to areas with higher wages will promote the optimal allocation of social resources, help improve the income situation of migrants and increase the economic growth rate of the whole country [24]. However, because the labor productivity of migrants is usually relatively high, labor mobility will lead to an absence of the main body of rural development and expand the income gap between

developed and undeveloped areas [13], which is not conducive to the sustainable development of rural areas. From the perspective of the economic mechanism, migration, especially when young people are the main population, can reduce the demand for local services, lead to the reduction of local services facilities and further economic recession, and aggravate the process of rural shrinkage [25], which is not conducive to the sustainable development of rural areas and agriculture. It is evident that rural shrinkage is not only the inevitable product of industrial structure changes but also the inevitable portrayal of the urban–rural competition between the population and economy in the era of globalization [26].

Since China's reform and opening up, with the rapid development of industrialization and urbanization, agricultural labor has been shifting to non-agricultural industries. Especially since the 1990s, the grain yield has maintained a fluctuating upward trend, increasing from 435 million tons in 1991 to 546 million tons in 2010. During the same period, agricultural labor has also changed dramatically, and the agricultural labor population has rapidly decreased from 350 million people to 277 million people, with the proportion of the non-agricultural employment of agricultural labor and the non-agricultural income of farmers rising [27,28]. However, while a non-agricultural transfer of agricultural labor has occurred, non-agricultural construction, agricultural restructuring, ecological conversion, and other factors have led to a large reduction in cultivated land area, with a net annual decrease of 826,300 ha from 1996 to 2006 [29]. As a populous and agricultural country, China's dramatic reduction in the cultivated land area will threaten the sustainable food security of one-fifth of the world's population [30]. From the late 1970s, Chinese scholars began to pay attention to the transfer of agricultural labor, agricultural production, and their relationship. The research contents mainly included the quantity and scale estimation of agricultural labor [31–34], the influencing factors [35,36], the effect [18,37], and the methods [38,39] of agricultural labor transfer, etc. On this basis, scholars further revealed the spatiotemporal variation [40–42], the comprehensive effect [31,43], and the socioeconomic driving force [44–47] of agricultural production based on the indicators of grain yield, cultivated land area, and agricultural output value. In recent years, based on the study of rural hollowing, scholars have further explored the relationship between agricultural labor transfer and agricultural production, including the impact of agricultural labor transfer on grain yield, cultivated land area, and agricultural economic development [48–50], food security [51], the transformation of agricultural production modes [52], and the time-series change characteristics of agricultural land conversion against agricultural labor transfer, etc. [53]

From the existing research regarding the relationship between agricultural labor and agricultural production, few studies reflect the coupling relationship between agricultural labor and agricultural production comprehensively. Most of China's domestic research is carried out at provincial and municipal levels or in the eastern coastal areas, the Yangtze River Delta and western mountainous areas, while there is less research on the main grain-producing areas in northeastern China. Northeastern China is an important commodity grain base and the "stabilizer" to ensure national food security in China. Northeastern China is also the most obvious area impacted by global agricultural overcapacity and grain import. The rural development of northeastern China is facing many important factors, such as international trade competition, economic globalization, rapid urbanization, industrial restructuring, etc. Songnen Plain in Northeastern China is one of the first national modern agricultural demonstration bases, which plays an important role in ensuring national food security. Based on panel data from 1995, 2005, and 2015 in Songnen Plain in Heilongjiang Province, this paper revealed the spatiotemporal evolution characteristics and coupling relationship between agricultural labor and agricultural production (grain yield, cultivated land area, and agricultural output value) at the county level. This work can be used to enrich the research results of agricultural geography and rural geography in the new period, provide a reference for the differentiated policy formulation of the rural revitalization strategy, and identify a suitable revitalization path.

The remainder of this paper has four parts: Section 2 introduces materials and methods, Section 3 includes an analysis of the results, Section 4 presents a discussion, and Section 5 states the final conclusions.

2. Materials and Methods

2.1. Study Area

Songnen Plain is an important region of the three major plains in northeastern China, spanning Jilin Province, Heilongjiang Province, and the Inner Mongolia Autonomous Region. This study chose Songnen Plain in Heilongjiang Province (hereafter referred to as Songnen Plain) as the study area. Songnen Plain starts from Nenjiang City in the north and extends south to Wuchang City. The western boundary is the administrative boundary between Heilongjiang Province and the Inner Mongolia Autonomous Region. The eastern boundary is Xiaoxing'an Mountains and Zhang Guangcai Mountains. The total area of the study area is 158,800 km^2, accounting for 2% of the total land area of China. There are 36 county units (including counties, cities and municipal districts) in the study area (Figure 1). The terrain here is relatively flat, and it is one of the only three black soil plains in the world. From 1995 to 2005, the rural population of Songnen Plain increased from 15.55 million to 16.30 million and dropped to 15.87 million in 2015. The agricultural labor population increased from 3.24 million to 4.72 million and then dropped to 4.40 million in 2015. In recent years, the phenomenon of rural contraction caused by the decrease of population the has become relatively obvious, which has a certain impact on the sustainable development of agriculture and rural areas.

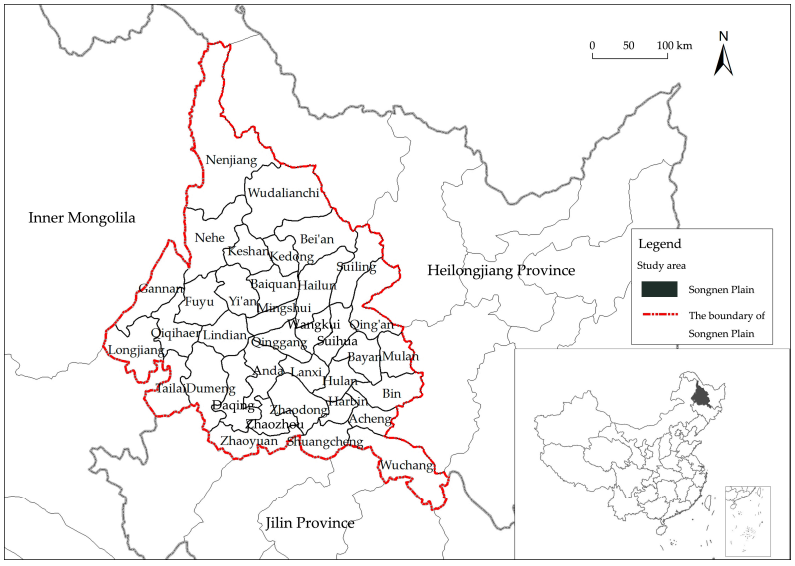

Figure 1. Description of the study area.

2.2. Data Sources

The statistical data of agricultural labor, grain yield, cultivated land area, and the agricultural output value of the counties in Songnen Plain in 1995, 2005, and 2015 were taken from the "Heilongjiang Statistical Yearbook". In the process of data analysis, some missing values were interpolated, and the basic data of 36 county units were finally obtained. The internal administrative divisions of the study area changed in 20 years. Considering the availability of data and the comprehensiveness of analysis, this paper calculates the statistical data of each region in the corresponding year based on the administrative division of 1996.

Agricultural labor in this paper refers to all the labor personnel who actually participate in agricultural production activities and obtain physical or monetary income in the rural population.

Although part-time employment in agricultural labor is relatively common, due to the influence of the urban–rural dual structure in China, the agricultural labor population in the statistical yearbook is based on the location of household registration, so the statistical data of agricultural labor population may have some limitations. Limited by weather conditions, the planting system of Songnen Plain is one crop per year, and its main crops are rice, maize, soybean, and wheat. Because of the different planting structures, the farming activities are different, and the working time (generally from early April to late September) and intensity of labor are also different [54,55]. The grain yield mainly includes the crop yield of rice, maize, soybean, and wheat. In order to eliminate the impact of climate change on grain yield, the yield data of the research nodes were averaged. In addition, taking into account the impact of inflation, the data of agricultural output value were converted to 1995 equivalent values.

2.3. Methods

Elasticity in economics refers to the sensitivity of change, which is used to measure the dependence of the growth rate of one economic variable on that of another variable. It is measured by an elasticity coefficient, i.e., the ratio between the relative growth rates of two interrelated indicators in a given period of time. The greater the absolute value of the elasticity coefficient, the higher the sensitivity between them. This paper uses the elasticity analysis method, and the elasticity coefficient is constructed with reference to Liu Yansui and other authors' research results [48–50]. The coupling relationships between agricultural labor and the cultivated land area, grain yield, and agricultural output value, respectively, were revealed through the index of the grain–labor elasticity coefficient, the cultivated land–labor elasticity coefficient, and the output–labor elasticity coefficient.

2.3.1. The Grain–Labor Elasticity Coefficient (GLEC)

The grain–labor elasticity coefficient can be defined as the ratio of the change rate of grain yield to the change rate of the agricultural labor population in a certain period of time. The calculation formula is as follows:

$$GLEC_{ij} = \frac{GCR_{ij}}{LCR_{ij}} = \frac{(G_{ij} - G_{i0})/G_{i0}}{(L_{ij} - L_{i0})/L_{i0}} \quad (1)$$

where $GLEC_{ij}$ represents the grain–labor elasticity coefficient in year j of region i, and GCR_{ij} (%) and LCR_{ij} (%) represent the rates of change for the total grain yield and agricultural labor population in year j of region i, respectively. Similarly, G_{ij} (t) and L_{ij} (person) are, respectively, the total grain yield and agricultural labor population in year j of region i, while G_{i0} (t) and L_{i0} (person) are the total grain yield and agricultural labor population of region i in the base year, respectively. By analyzing the changes in $GLEC_{ij}$, the coupling types of agricultural labor and grain yield are divided into six types, namely the growth type, extensive type, intensive type, fading type, lagged type and declining type (Table 1), and the characteristics of these types are summarized and refined.

Table 1. Classification and characteristics of the grain–labor elasticity coefficient (GLEC).

Type	GCR_{ij} [1]	LCR_{ij} [2]	$GLEC_{ij}$ [3]	GLEC Characteristics
Growth	$GCR_{ij} > 0$	$LCR_{ij} > 0$	$GLEC_{ij} > 1$	The grain yield increases faster than the agricultural labor population.
Extensive	$GCR_{ij} > 0$	$LCR_{ij} > 0$	$0 < GLEC_{ij} < 1$	The grain yield increases slower than the agricultural labor population.
Intensive	$GCR_{ij} > 0$	$LCR_{ij} < 0$	$GLEC_{ij} < 0$	The grain yield increases, but the agricultural labor population decreases.
Fading	$GCR_{ij} < 0$	$LCR_{ij} < 0$	$GLEC_{ij} > 1$	The grain yield decreases faster than the agricultural labor population.
Lagged	$GCR_{ij} < 0$	$LCR_{ij} > 0$	$GLEC_{ij} < 0$	The grain yield decreases, but the agricultural labor population increases.
Declining	$GCR_{ij} < 0$	$LCR_{ij} < 0$	$0 < GLEC_{ij} < 1$	The grain yield decreases slower than the agricultural labor population.

[1] GCR: grain yield change rate; [2] LCR: agricultural labor population change rate; [3] GLEC: grain–labor elasticity coefficient.

2.3.2. The Cultivated Land–Labor Elasticity Coefficient (CLEC)

The cultivated land–labor elasticity coefficient can be defined as the ratio of the change rate of cultivated land area to the change rate of the agricultural labor population in a certain period of time. The calculation formula is as follows:

$$CLEC_{ij} = \frac{CCR_{ij}}{LCR_{ij}} = \frac{(C_{ij} - C_{i0})/C_{i0}}{(L_{ij} - L_{i0})/L_{i0}} \quad (2)$$

where $CLEC_{ij}$ represents the cultivated land–labor elasticity coefficient in year j of region i, and CCR_{ij} (%) and LCR_{ij} (%) represent the rates of change for the cultivated land area and agricultural labor population in year j of region i, respectively. Similarly, C_{ij} (ha) and L_{ij} (person) are the cultivated land area and agricultural labor population in year j of region i, while C_{i0} (ha) and L_{i0} (person) are the cultivated land area and agricultural labor population of region i in the base year, respectively. By analyzing the changes in $CLEC_{ij}$ and the per capita cultivated land area of agricultural labor (hereafter referred to as the per capita cultivated land), the coupling types of agricultural labor and cultivated land area are divided into two types, namely the growth type and recession type (Table 2), and the characteristics of these types are summarized and refined.

Table 2. Classification and characteristics of the cultivated land–labor elasticity coefficient (CLEC).

Type	CCR_{ij} [1]	LCR_{ij} [2]	$CLEC_{ij}$ [3]	CLEC Characteristics
I Growth	$CCR_{ij} > 0$	$LCR_{ij} < 0$	$CLEC_{ij} < 0$	The agricultural labor population decreases, the cultivated land area and per capita cultivated land increases.
II Growth	$CCR_{ij} > 0$	$LCR_{ij} > 0$	$CLEC_{ij} > 1$	The agricultural labor population increases slower than the cultivated land area, and per capita cultivated land increases.
III Recession	$CCR_{ij} > 0$	$LCR_{ij} > 0$	$0 < CLEC_{ij} < 1$	The agricultural labor population increases faster than the cultivated land area, and per capita cultivated land decreases.
IV Recession	$CCR_{ij} < 0$	$LCR_{ij} > 0$	$CLEC_{ij} < 0$	The agricultural labor population increases, the cultivated land area decreases and per capita cultivated land decreases.
V Recession	$CCR_{ij} < 0$	$LCR_{ij} < 0$	$CLEC_{ij} > 1$	The agricultural labor population decreases slower than the cultivated land area, and per capita cultivated land decreases.
VI Growth	$CCR_{ij} < 0$	$LCR_{ij} < 0$	$0 < CLEC_{ij} < 1$	The agricultural labor population decreases faster than the cultivated land area, and per capita cultivated land increases.

[1] CCR: cultivated land area change rate; [2] LCR: agricultural labor population change rate; [3] CLEC: cultivated land–labor elasticity coefficient.

2.3.3. The Output–Labor Elasticity Coefficient (OLEC)

The output–labor elasticity coefficient can be defined as the ratio of the change rate of agricultural output value and the change rate of the agricultural labor population in a certain period of time. The calculation formula is as follows:

$$OLEC_{ij} = \frac{OCR_{ij}}{LCR_{ij}} = \frac{(O_{ij} - O_{i0})/O_{i0}}{(L_{ij} - L_{i0})/L_{i0}} \quad (3)$$

where $OLEC_{ij}$ represents the output–labor elasticity coefficient in year j of region i, and OCR_{ij} (%) and LCR_{ij} (%) represent the rates of change for the agricultural output value and agricultural labor population in year of j region i, respectively. Similarly, O_{ij} (yuan) and L_{ij} (person) are the agricultural output value and agricultural labor population in year j of region i, respectively, while O_{i0} (yuan) and L_{i0} (person) are the amount of agricultural output value and agricultural labor population of region i in the base year, respectively. By analyzing the changes in $OLEC_{ij}$, this paper classifies the coupling types of agricultural labor and agricultural output value into six types, namely the growth type, extensive type, intensive type, fading type, lagged type and declining type (Table 3), and summarizes and refines the coupling relationship characteristics between these types.

Table 3. Classification and characteristics of the output–labor elasticity coefficient (OLEC).

Type	OCR_{ij} [1]	LCR_{ij} [2]	$OLEC_{ij}$ [3]	OLEC Characteristics
Growth	$OCR_{ij} > 0$	$LCR_{ij} > 0$	$OLEC_{ij} > 1$	The agricultural output value increases faster than the agricultural labor population.
Extensive	$OCR_{ij} > 0$	$LCR_{ij} > 0$	$0 < OLEC_{ij} < 1$	The agricultural output value increases slower than the agricultural labor population.
Intensive	$OCR_{ij} > 0$	$LCR_{ij} < 0$	$OLEC_{ij} < 0$	The agricultural output value increases, but the agricultural labor population decreases.
Fading	$OCR_{ij} < 0$	$LCR_{ij} < 0$	$OLEC_{ij} > 1$	The agricultural output value decreases faster than the agricultural labor population.
Lagged	$OCR_{ij} < 0$	$LCR_{ij} > 0$	$OLEC_{ij} < 0$	The agricultural output value decreases, but the agricultural labor population increases.
Declining	$OCR_{ij} < 0$	$LCR_{ij} < 0$	$0 < OLEC_{ij} < 1$	The agricultural output value decreases slower than the agricultural labor population.

[1] OCR: agricultural output value change rate; [2] LCR: agricultural labor population change rate; [3] OLEC: output–labor elasticity coefficient.

3. Results

3.1. The Spatiotemporal Changes in Agricultural Labor

From 1995 to 2005, the agricultural labor population in Songnen Plain increased rapidly, and 92% of the counties increased, with a total increase of 46% (Figure 2). The main reason was that the economic development of the region was still dominated by agricultural production, and good production conditions could enable laborers to obtain considerable income. At the same time, the adjustment of industrial structure in these areas was slow, and the employment capacity of the secondary and tertiary industries was weak. The increase in the agricultural labor population more than doubled, which was mainly distributed in the central and western parts of Songnen Plain. Only three counties, accounting for 8% of the total agricultural labor population, were in decline, and were distributed in the southeastern section of Songnen Plain.

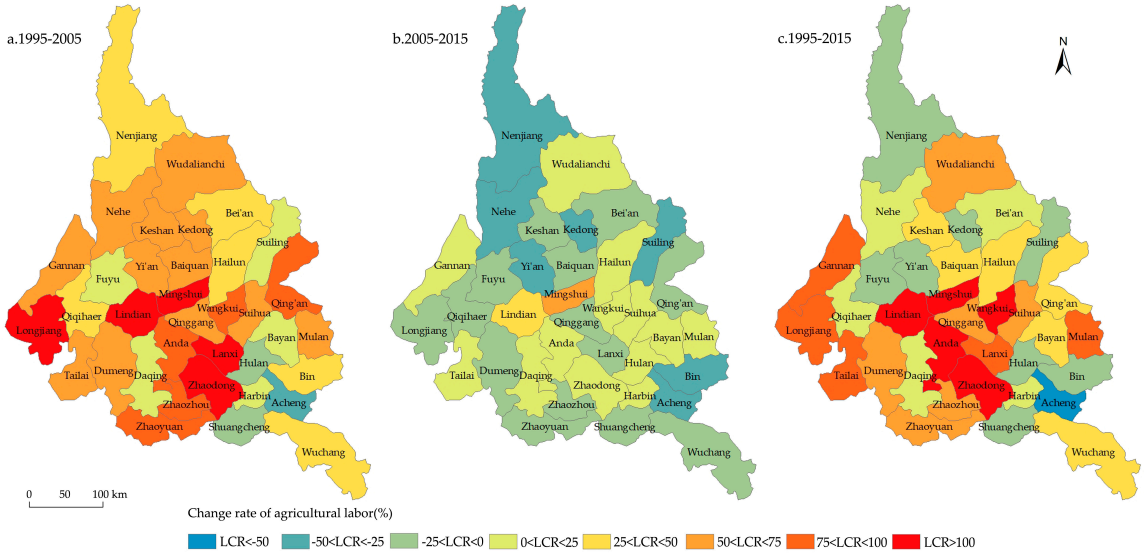

Figure 2. Spatiotemporal patterns of agricultural labor change at the county level in Songnen Plain for 1995–2015.

From 2005 to 2015, with the development of urbanization and the improvement of agricultural modernization, the agricultural surplus labor gradually shifted. In total, 58% of the counties showed a net decrease in the agricultural labor population, and the total agricultural labor population in Songnen

Plain decreased by 7%. From Figure 2, it is evident that the counties with a rapid decline of the agricultural labor population were mainly distributed in the northern, western, and southeastern areas of Songnen Plain. In most areas, the agricultural labor population varied from -25% to 25%, which was relatively concentrated. The areas where the agricultural labor population was still increasing rapidly were mainly located in the central of Songnen Plain, including Lindian and Mingshui, with growth rates of 51% and 40%, respectively.

From 1995 to 2015, the total agricultural labor population in Songnen plain increased by 36%, reflecting its role as an important commodity grain base in China to attract the working population. The transfer of agricultural labor in the northern and southeastern areas of Songnen Pain was clear. Agricultural mechanization, industrialization, and urbanization are the main driving forces of the non-agricultural transfer of agricultural labor. In most other areas, especially in the central and western areas, the growth of the agricultural labor population was clear, mainly because of the slow adjustment of industrial structure, the low degree of agricultural modernization, and the need for a large agricultural labor population.

3.2. The Spatiotemporal Changes in Agricultural Production

3.2.1. Grain Yield

From 1995 to 2005, the grain yield increased by 3%, mainly in the south (Figure 3). The growth rate of Qiqihar was the highest, while that of northwestern areas was lower or decreased slightly. From 2005 to 2015, the total grain yield of counties increased rapidly, increasing by 134%. The grain yield of counties in Songnen Plain increased, with the counties in the central and western areas increasing rapidly, while the growth rate in the northern and southeastern areas was relatively slow. From 1995 to 2015, in general, the grain yield of all counties increased, especially in the southwest, which became the main contributor to the increase in grain yield. The growth rate of grain yield gradually decreased from the southwest to the northeast.

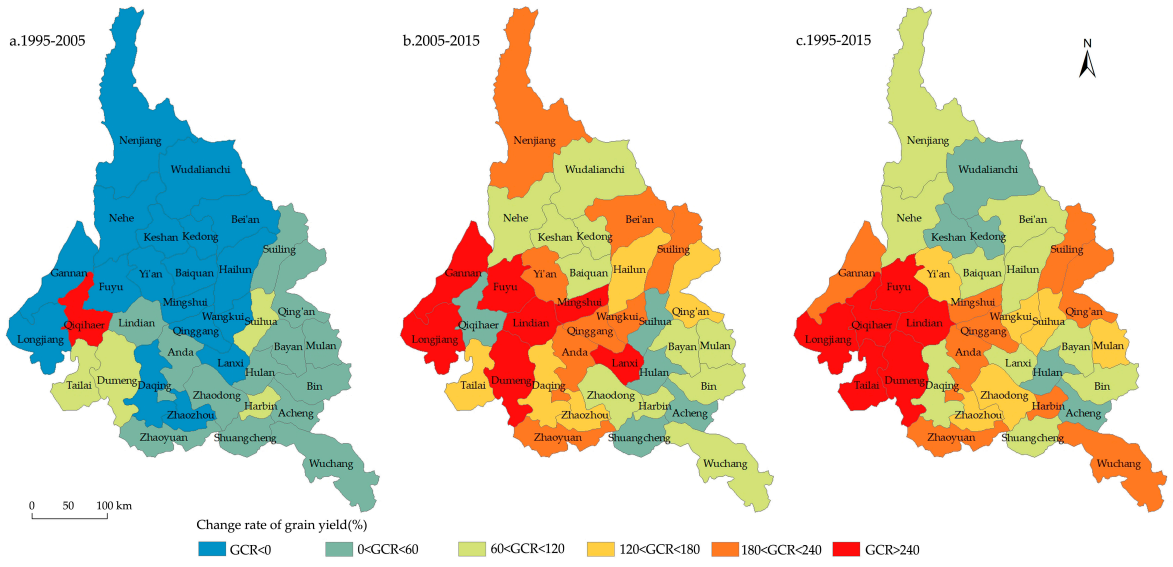

Figure 3. Spatiotemporal patterns of grain yield at the county level in Songnen Plain for 1995–2015.

3.2.2. Cultivated Land Area

From 1995 to 2005, the cultivated land area of 78% of the counties increased, which led to an increase of 9% of the total cultivated land area in Songnen Plain (Figure 4). From the spatial pattern perspective, the decrease in the cultivated land area was mainly located in the northern area. From 2005 to 2015, the cultivated land area of Bei'an and Wudalianchi in the north increased by 93% and 104%, respectively, while the cultivated land area in most areas changed slightly. The cultivated land area of Acheng, Daqing, Gannan, and Zhaoyuan had a significant decreasing trend. From 1995 to 2015, the cultivated land area in 33 counties increhased by 30%. With the development of reserve cultivated land resources, the cultivated land area in most areas increased by varying degrees. However, in recent years, the cultivated land area in some areas has decreased to a certain extent due to the expansion of construction land.

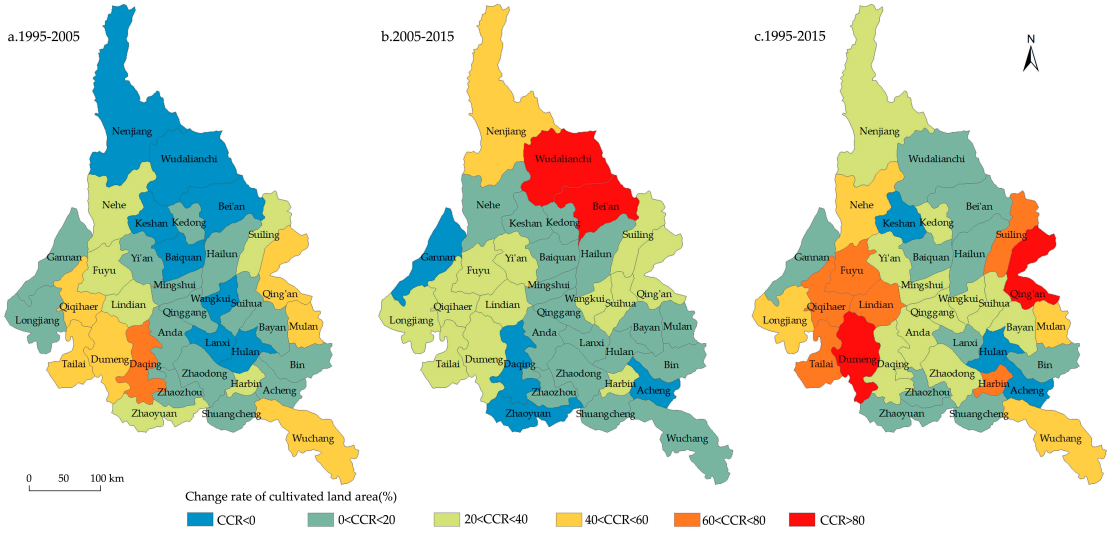

Figure 4. Spatiotemporal patterns of cultivated land area at the county level in Songnen Plain for 1995–2015.

3.2.3. Agricultural Output Value

From 1995 to 2005, the total agricultural output value of Songnen Plain increased by 50%, and only six counties decreased, accounting for 17% of the total area (Figure 5). These counties were Bei'an, Hailun, Lanxi, Mingshui, Qinggang, and Wudalianchi. Among these counties, the agricultural output value of Lanxi decreased the most, accounting for 37%. From 2005 to 2015, except Harbin and Nehe, the agricultural output value of other regions increased to a different extent, with a total increase of 124%. The counties with a higher growth rate were mainly distributed in the central and northern areas of Songnen Plain. From 1995 to 2015, the total agricultural output value of Songnen Plain increased by more than 100%. Generally, the agricultural output value of 36 counties increased by varying degrees. Higher growth rate areas were distributed in the southern of Songnen Plain, and the agglomeration phenomenon was more obvious.

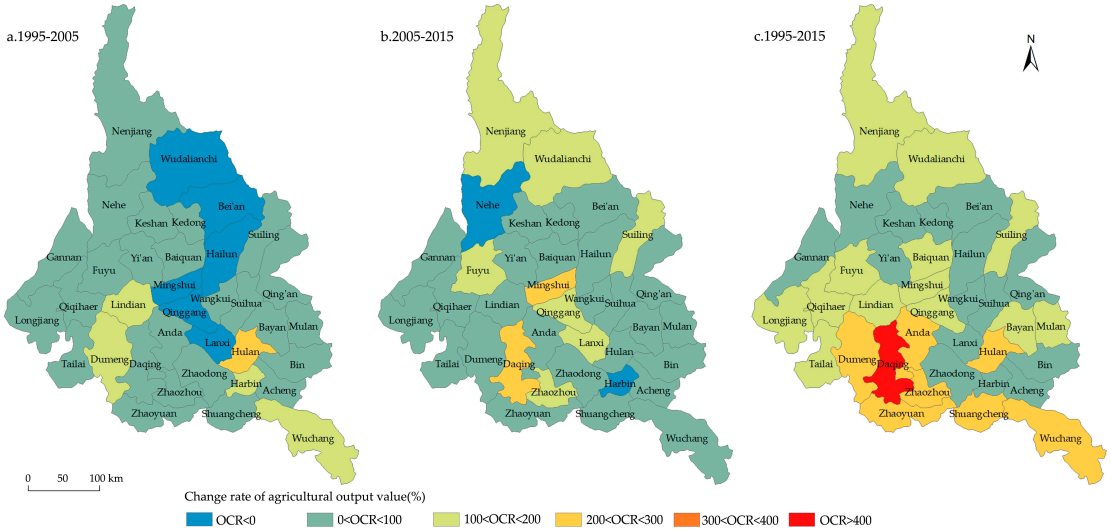

Figure 5. Spatiotemporal patterns of agricultural output value at the county level in Songnen Plain for 1995–2015.

3.3. Coupling Relationship Between Agricultural Labor and Agricultural Production

3.3.1. GLEC Coupling Characteristics

GLEC Spatiotemporal Patterns

Using Formula (1) and Table 1, the changes in the grain–labor elasticity coefficient in Songnen Plain from 1995 to 2015 were obtained (Table 4). According to the change in grain yield and agricultural labor population, the coupling types and coupling characteristics of grain–labor in Songnen Plain in different periods were further analyzed (Table 5, Figure 6).

Table 4. The statistics of GLEC in Songnen Plain.

GLEC [1]	Average	Standard Deviation	Minimum	Maximum
1995–2005	1	2	−1	13
2005–2015	16	131	−214	744
1995–2015	9	40	−33	239

[1] GLEC: grain–labor elasticity coefficient.

Table 5. Changes in the GLEC in Songnen Plain for 1995–2015.

GCR [1]	Type	LCR [2]	GLEC [3]	1995–2005	2005–2015	1995–2015
GCR > 0	Growth	LCR > 0	GLEC > 1	6 (17%)	11 (31%)	30 (83%)
	Extensive	LCR > 0	0 < GLEC < 1	11 (31%)	0	2 (6%)
	Intensive	LCR < 0	GLEC < 0	1 (3%)	25 (69%)	4 (11%)
GCR < 0	Fading	LCR < 0	GLEC > 1	0	0	0
	Lagged	LCR > 0	GLEC < 0	18 (50%)	0	0
	Declining	LCR < 0	0 < GLEC < 1	0	0	0

[1] GCR: grain yield change rate; [2] LCR: agricultural labor population change rate; [3] GLEC: grain–labor elasticity coefficient.

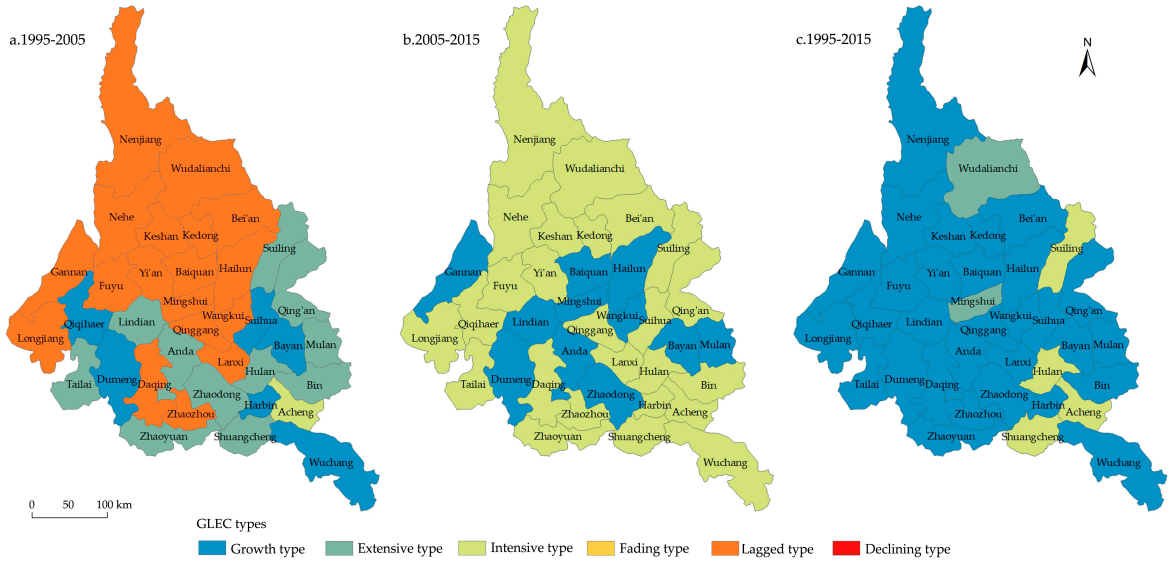

Figure 6. Spatiotemporal patterns of the GLEC at the county level in Songnen Plain for 1995–2015.

From 1995 to 2005, according to the characteristics and classification of the grain–labor elasticity coefficient, the proportions of the "same increase" in the agricultural labor population and grain yield in counties were 47%, and the proportion of the reverse change was 52%. According to Figure 6, (1) the counties with an increasing grain yield could be divided into three types. The six counties with a grain yield increasing faster than the increase in the agricultural labor population belonged to the growth type. They were scattered in the southern area of Songnen Plain. There were 11 counties whose growth rate of grain yield was slower than that of the agricultural labor population, which belonged to the extensive type and were mainly distributed in the periphery of growth-type counties and the eastern edge of Songnen Plain. Acheng was the only one county with increasing grain yield and decreasing agricultural labor population, i.e., it belonged to the intensive type, and is located in the southeastern area of Songnen Plain. (2) There were 18 counties with decreasing grain yield and increasing agricultural labor population, i.e., it belonged to the lagged type, which were mainly distributed in the central and northern areas of Songnen Plain except Daqing and Zhaozhou in the south.

From 2005 to 2015, with the development of the economy and society and the progress of agricultural technology, the grain yield of each county in Songnen Plain continued to grow. Simultaneously, 31% of the counties also experienced an increased agricultural labor population, while 69% of the counties decreased. According to Figure 6, (1) there were 11 counties whose growth rate of grain yield was faster than that of the agricultural labor population, i.e., growth-type counties, which were mainly distributed in the central area of Songnen Plain. The marginal areas included Dumeng, Gannan, and Mulan. (2) There were 25 counties in which the grain yield increased while the agricultural labor population decreased, i.e., intensive-type counties, which were concentrated in the northwestern and southeast areas of Songnen Plain.

Generally, from 1995–2015, the grain yield in Songnen Plain showed a growth trend, of which the growth type accounted for 83%, the extensive type accounted for 6%, and the intensive type accounted for 11%. Each county had a trend towards growth and intensive development. (1) The growth rate of grain yield was faster than that of the agricultural labor population, that is, there were 30 growth-type counties, which were concentrated in most areas of Songnen Plain. (2) The growth rate of grain yield was slower than that of the agricultural labor population, that is, there were two extensive counties: Mingshui and Wudalianchi. (3) There were four counties in which the grain yield increased while the agricultural labor population decreased, i.e., intensive-type counties, comprising Suiling in the northeast, Acheng, Hulan, and Shuangcheng in the southeast.

The Transformation Characteristics of the Coupling Types

From Figure 6, it is evident that the coupling types of grain–labor in the counties of Songnen Plain have changed. The transfer matrix from 1995–2005 to 2005–2015 is shown in Table 6. Here, P1 represents the proportion of different types in 1995–2005 and P2 represents the proportion of different types in 2005–2015 (the same below). Generally, from 1995–2005 to 2005–2015, the growth-type counties increased by 25%, intensive-type counties increased by 67%, and extensive-type and lagged-type counties decreased. Coupling types from the extensive type and lagged type to growth type accounted for 11% and 14% of the counties, respectively. Coupling types from growth type, extensive type, and lagged type to intensive type accounted for 11%, 19%, and 36%, respectively. From Table 6, it is evident that all the types that were extensive and lagged from 1995 to 2005 changed into growth or intensive types. From 1995 to 2015, Bayan and Dumeng experienced the growth type of coupling, while Acheng experienced the intensive type of coupling.

Table 6. The transfer matrix of the GLEC types at the county level in Songnen Plain for 1995–2015 (%).

1995–2005 (T1)	2005–2015 (T2)				P1	Decrease
	Growth	Extensive	Intensive	Lagged		
Growth	6	0	11	0	17	11
Extensive	11	0	19	0	31	31
Intensive	0	0	3	0	3	0
Lagged	14	0	36	0	50	50
P2	31	0	69	0	100	
Increase	25	0	67	0		

3.3.2. CLEC Coupling Characteristics

CLEC Spatiotemporal Patterns

Using Formula (2) and Table 2, the changes in the cultivated land–labor elasticity coefficient in Songnen Plain from 1995 to 2015 were obtained (Table 7). According to the changes in cultivated land and agricultural labor, the coupling types and coupling characteristics of cultivated land–labor in Songnen Plain in different periods were further analyzed (Table 8, Figure 7).

Table 7. The statistics of CLEC in Songnen Plain.

CLEC [1]	Average	Standard Deviation	Minimum	Maximum
1995–2005	1	4	−15	17
2005–2015	1	7	−12	37
1995–2015	−1	6	−30	6

[1] CLEC: cultivated land–labor elasticity coefficient.

Table 8. Changes in the CLEC in Songnen Plain for 1995–2015.

CCR [1]	Type	LCR [2]	CLEC [3]	1995–2005	2005–2015	1995–2015
CCR > 0	I Growth	LCR < 0	CLEC < 0	2 (6%)	19 (53%)	7 (19%)
	II Growth	LCR > 0	CLEC > 1	6 (17%)	9 (25%)	8 (22%)
	III Declining	LCR > 0	0 < CLEC < 1	20 (56%)	4 (11%)	18 (50%)
CCR < 0	IV Declining	LCR > 0	CLEC < 0	7 (19%)	2 (6%)	1 (3%)
	V Declining	LCR < 0	CLEC > 1	0	1 (3%)	0
	VI Growth	LCR < 0	0 < CLEC < 1	1 (3%)	1 (3%)	2 (6%)

[1] CCR: cultivated land area change rate; [2] LCR: agricultural labor population change rate; [3] CLEC: cultivated land–labor elasticity coefficient.

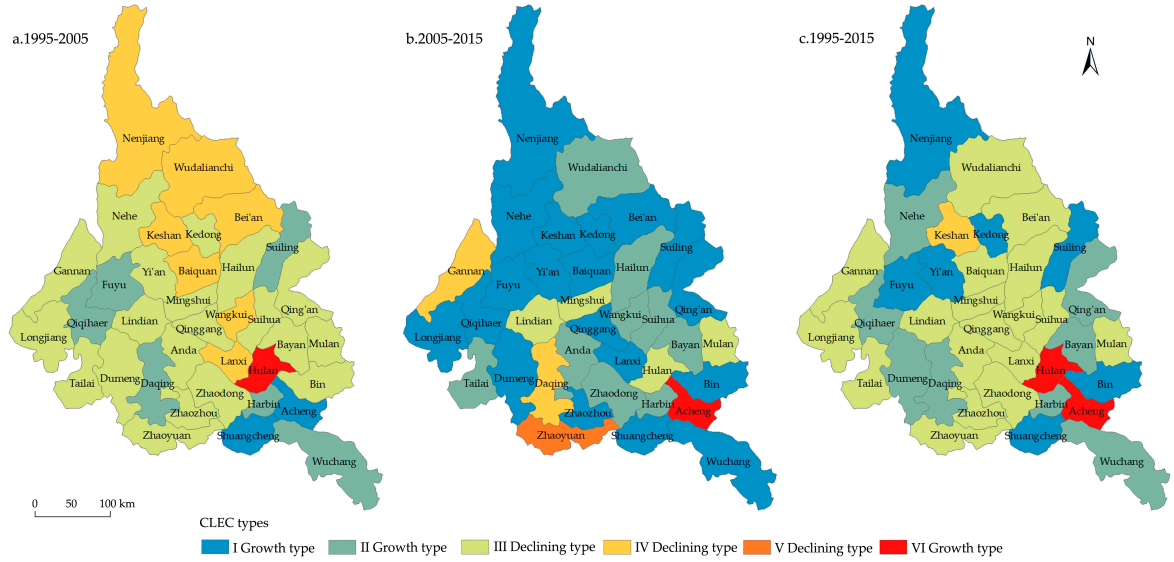

Figure 7. Spatiotemporal patterns of the CLEC at the county level in Songnen Plain for 1995–2015.

From 1995 to 2005, according to the characteristics and classification of the CLEC, 24% of the coupling types were growth type, 75% were declining type, and the overall development of the region needed to be improved. According to Figure 7, (1) the counties with an increasing cultivated land area could be divided into three types. There were two counties with decreasing the agricultural labor population, which belonged to the growth type: Acheng and Shuangcheng. There were six counties with an increase in cultivated land area faster than that in the agricultural labor population, which belonged to the growth type and were scattered in Songnen Plain. There were 20 counties with an increase in cultivated land area slower than that in agricultural labor population. These counties belonged to the declining type and were concentrated in most areas of Songnen Plain. (2) The counties with a decreasing cultivated land area could be divided into two types. There were seven counties with an increase in the agricultural labor population, which belonged to the declining type. One county experienced a decrease in cultivated land area slower than that in the agricultural labor population and belonged to the growth type, which is called Hulan.

From 2005 to 2015, 81% of the coupling types were growth type and 20% were declining type, which showed a positive development trend of the region as a whole. According to Figure 7, (1) the counties with an increase in the cultivated land area could be divided into three types. While the cultivated land area increased, the agricultural labor population decreased in 19 counties, which were growth-type counties. They were concentrated in the northern area of Songnen Plain and scattered in the southern area. Eight counties whose cultivated land area increased faster than the increase in agricultural labor population were growth-type counties. There were four counties whose increase in cultivated land area was slower than the increase in the agricultural labor population. These counties belonged to the declining type, comprising Hulan, Lindian, Mingshui, and Mulan. (2) The counties with a decrease in cultivated land area could be divided into three types. There were two counties with an increasing agricultural labor population, which belonged to the declining type: Daqing and Gannan. Zhaoyuan was the county whose cultivated land area decreased faster than agricultural labor population, and it belonged to the declining type. Acheng was the county whose cultivated land area decreased slower than the agricultural labor population, and it belonged to the growth type.

Generally, from 1995 to 2015, 92% of the total number of counties experienced growth in their cultivated land area, but the declining-type counties still accounted for most of the Songnen Plain. (1) The counties with an increasing cultivated land area were divided into three types. There were seven counties with a decrease in the agricultural labor population, which belonged to the growth type. These counties were scattered in Songnen Plain. There were eight counties with an increase in

cultivated land area that was faster than that in the agricultural labor population, which belonged to the growth type. These counties were scattered in the western and eastern areas of Songnen Plain. There were 18 counties whose increase in cultivated land area was slower than the increase in the agricultural labor population. These counties belonged to the declining type. With the exception of Mulan in the east, these counties were concentrated in the central and western areas of Songnen Plain. (2) The counties with the decreasing cultivated land area were divided into two types. Keshan was the county with an increase in the agricultural labor population and belonged to the declining type. There were two counties whose decrease in cultivated land area was slower than that in the agricultural labor population, which belonged to the growth type: Acheng and Hulan.

The Transformation Characteristics of the Coupling Types

From Figure 7, it is evident that the elasticity types of the cultivated land–labor of Songnen Plain changed, the elasticity types could be divided into six types, and the transfer matrix was constructed as shown in Table 9. Generally, from 1995–2005 to 2005–2015, the number of growth-type counties increased by 61%. Most of the counties changed from the declining type to the growth type, showing a positive trend of development. However, some counties need further improvement, such as Gannan, Lindian, Mingshui, Mulan, and Zhaoyuan, which were still declining-type counties from 1995–2005 to 2005–2015, and Daqing and Hulan, which shifted from the growth type to the declining type. From Table 9, it is clear that the ways of transforming the growth type into the declining type were different. Daqing's change was due to the reduction of cultivated land and the increasing agricultural labor population, and Hulan's change was due to the increase in the agricultural labor population, which was greater than the cultivated land area. However, they both experienced a reduction in the per capita cultivated land. From 1995 to 2015, although the coupling types changed, the growing areas were Acheng, Fuyu, Harbin, Qiqihar, Shuangcheng, Suiling, and Wuchang.

Table 9. The transfer matrix of the CLEC types at the county level in Songnen Plain for 1995–2015 (%).

1995–2005 (T1)	2005–2015 (T2)						P1	Decrease
	I	II	III	IV	V	VI		
I	3	0	0	0	0	3	6	3
II	11	3	0	3	0	0	17	14
III	25	17	8	3	3	0	56	47
IV	14	6	0	0	0	0	19	19
V	0	0	0	0	0	0	0	0
VI	0	0	3	0	0	0	3	3
P2	53	25	11	6	3	3	100	
Increase	50	22	3	6	3	3		

3.3.3. OLEC Coupling Characteristics

OLEC Spatiotemporal Patterns

Based on Formula (3) and Table 3, the changes in the output–labor elasticity coefficient in Songnen Plain from 1995 to 2015 were obtained (Table 10). According to the changes in agricultural output value and agricultural labor population, the coupling types and coupling characteristics of output–labor in Songnen Plain in different periods were further analyzed (Table 11, Figure 8).

Table 10. The statistics of OLEC in Songnen Plain.

OLEC [1]	Average	Standard Deviation	Minimum	Maximum
1995–2005	−4	32	−194	32
2005–2015	4	20	−22	83
1995–2015	−4	30	−151	72

[1] OLEC: output–labor elasticity coefficient.

Table 11. Changes in the OLEC in Songnen Plain for 1995–2015.

OCR [1]	Type	LCR [2]	OLEC [3]	1995–2005	2005–2015	1995–2015
OCR > 0	Growth	LCR > 0	OLEC > 1	9 (25%)	12 (33%)	20 (56%)
	Extensive	LCR > 0	0 < OLEC < 1	18 (50%)	2 (6%)	7 (19%)
	Intensive	LCR < 0	OLEC < 0	3 (8%)	19 (53%)	9 (25%)
OCR < 0	Fading	LCR < 0	OLEC > 1	0	0	0
	Lagged	LCR > 0	OLEC < 0	6 (17%)	1 (3%)	0
	Declining	LCR < 0	0 < OLEC < 1	0	2 (6%)	0

[1] OCR: agricultural output value change rate; [2] LCR: agricultural labor population change rate; [3] OLEC: output–labor elasticity coefficient.

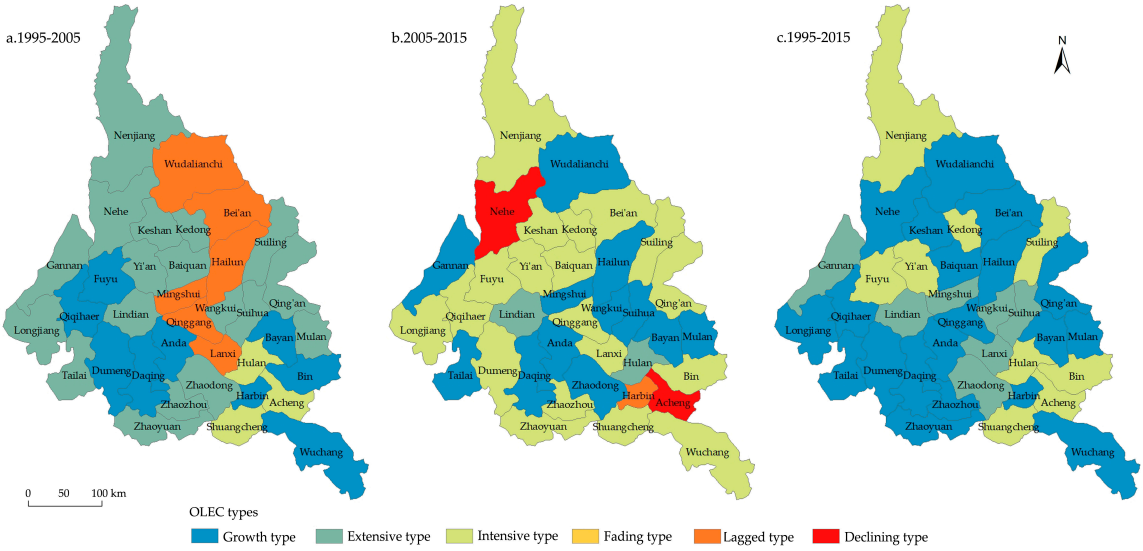

Figure 8. Spatiotemporal patterns of the OLEC at the county level in Songnen Plain for 1995–2015.

From 1995 to 2005, according to the characteristics and classification of the output–labor elasticity coefficient, the proportions of the "same increase" in agricultural labor population and agricultural output value in counties was 75%, and the proportion of the reverse change was 25%. According to Figure 8, (1) the counties with an increase in agricultural output value were divided into three types. There were nine counties whose agricultural output value increased faster than the agricultural labor population, i.e., growth-type counties, which were mainly distributed in the southern area of Songnen Plain. There were 18 counties whose agricultural output value increased slower than the agricultural labor population, i.e., extensive-type counties, which were mainly distributed in the northern, eastern, and southern areas of Songnen Plain. There were three counties whose agricultural labor population was decreasing, which belonged to the intensive type, located in the southeastern area of Songnen Plain, and these were Acheng, Hulan, and Shuangcheng. (2) In the counties with decreasing agricultural output value, six counties increased their agricultural labor population and belonged to the lagged type.

From 2005 to 2015, with the development of the economy and society and the progress of agricultural technology, the agricultural output value in most counties of Songnen Plain continued to grow. The overall development of the region was benign. According to Figure 8, (1) the counties with an increase in agricultural output value were divided into three types. There were 12 counties whose agricultural output value increased faster than the agricultural labor population, i.e., growth-type counties, mainly distributed in the central area of Songnen Plain. The marginal areas included Gannan, Tailai, and Wudalianchi. Hulan and Lindian were the counties whose agricultural output value increased slower than the agricultural labor population and belonged to the extensive type. There were 19 counties whose agricultural labor population was decreasing, i.e., intensive-type counties, concentrated in the northern and southern edges of Songnen Plain. (2) The counties with a decrease in agricultural output value were divided into two types. Harbin belonged to the lagged type with an increasing agricultural labor population. Acheng and Nehe belonged to declining type with a decrease in agricultural output value slower than that in the agricultural labor population.

Generally, from 1995 to 2015, the agricultural output value in Songnen Plain showed a growth trend, of which the growth type accounted for 56%, the extensive type accounted for 19%, and the intensive type accounted for 25%. (1) There were 20 counties whose agricultural output value increased faster than the agricultural labor population, i.e., growth-type counties, widely distributed in Songnen Plain. (2) There were seven counties whose agricultural output value increased slower than the agricultural labor population, i.e., extensive-type counties, mainly distributed in the central area of Songnen Plain. (3) There were nine counties whose agricultural output value increased, and the agricultural labor population decreased, i.e., intensive-type counties, comprising Nenjiang in the north, Fuyu, Kedong, Suiling, and Yi'an in the central and Acheng, Bin, Hulan, and Shuangcheng in the southeast.

The Transformation Characteristics of the Coupling Types

From Figure 8, it is evident that the types of the output–labor elasticity coefficient changed (Table 12). Generally, from 1995–2005 to 2005–2015, growth counties and intensive counties showed a net increase of 25% and 50%, respectively, while the extensive and lagged counties decreased. The counties whose coupling type changed from extensive type and lagged type to growth type accounted for 17% and 8% of counties, respectively. The counties whose coupling type changed from growth type, extensive type, and lagged type to intensive type accounted for 14%, 28%, and 8% of counties, respectively. Several counties are worth noting: Hulan changed from intensive type to extensive type, which indicated that the agricultural labor population was increasing rapidly. Acheng changed from intensive type to declining type, and Harbin changed from growth type to lagged type, indicating that the agriculture output value had changed from increasing to decreasing. However, the agricultural labor population in Acheng continued to decrease while that in Harbin continued to increase. Nehe changed from extensive type to declining type, which showed that both the agricultural labor population and the agricultural output value had decreased, and the development of agriculture was in urgent need of transformation.

Table 12. The transfer matrix of the OLEC types at the county level in Songnen Plain for 1995–2015 (%).

1995–2005 (T1)	2005–2015 (T2)					P1	Decrease
	Growth	Extensive	Intensive	Lagged	Declining		
Growth	8	0	14	3	0	25	17
Extensive	17	3	28	0	3	50	47
Intensive	0	3	3	0	3	8	6
Lagged	8	0	8	0	0	17	17
Declining	0	0	0	0	0	0	0
P2	33	6	53	3	6	100	
Increase	25	3	50	3	6		

4. Discussion

4.1. Comparison of the Results of Agricultural Labor Transfer and Agricultural Production

4.1.1. On the Transfer of Agricultural Labor

The results showed that agricultural labor in Songnen Plain began to transfer slowly. International experience showed that the decline in the proportion of the agricultural labor population is an important feature of economic and social modernization. From Table 13, it is evident that the proportion of agricultural labor population in China, Brazil, Russia, and South Korea was relatively high. Among them, the proportion of agricultural labor population in China and Brazil was more than 35%, showing a trend of first increasing and then decreasing. The proportion of the agricultural labor population in France, Germany, Great Britain, Italy, and the United States of America was relatively stable and always less than 10%. In 2015, the proportion of agricultural labor population was 36% in China, which was slightly lower than the 44% in Brazil, but much higher than developed countries such as France, Great Britain and the United States of America, indicating that China still had great potential for the transfer of agricultural labor.

Table 13. Agricultural labor population in countries as a proportion of the rural population in 1995, 2005 and 2015 (%).

Region	1995	2005	2015
China	38	40	36
Northeastern China	29	39	42
Songnen Plain	33	36	34
Brazil	37	52	44
France	7	6	5
Germany	5	4	5
Great Britain	4	3	3
Italy	7	5	4
Russia	18	18	13
South Korea	24	20	14
United States of America	6	3	4

Source: The Food and Agriculture Organization (FAO), www.fao.org; Statistical Yearbook of Provinces and Municipalities.

In 2004, China reached the first turning point referred to by Lewis, with the phenomenon of labor shortage and wage increase [56]. However, the amount and proportion of the agricultural labor population in northeastern China increased steadily, which was in contrast to the overall trend of the change in the whole country and was consistent with most previous research results [48–50]. From 1995 to 2015, the proportion of the agricultural labor population in northeastern China increased from 29% to 42%. The proportion of the agricultural labor population in China and Songnen Plain experienced a process of first increasing and then decreasing. However, the proportion of the agricultural labor population in China changed from 38% to 36% and decreased by 2%, while in Songnen Plain, it changed from 33% to 34% and increased by 1%. Compared with the whole country, the transfer of agricultural labor in Songnen Plain was lagging behind and facing the great pressure of transfer.

In Table 14, we can compare the agricultural labor population and rural labor population in China and the Songnen Plain. Rural labor included not only agricultural labor, but also industrial labor, construction labor, and other non-agricultural labor. The agricultural labor population in China decreased from 1995 to 2015, while the agricultural labor population in Songnen Plain increased first and then decreased. From 1995 to 2005, the agricultural labor population in China decreased by 7%, while in Songnen Plain, it increased by 46%. This result shows that, while the national agricultural labor transferred, the Songnen Plain still attracted a large number of people engaged in agriculture because of its good agricultural development situation and low degree of modernization. From 2005 to

2015, although the agricultural labor population in Songnen Plain was decreasing, the rate was 20% slower than that of the whole country, and the rural labor population had hardly changed. At this stage, agricultural labor in Songnen Plain began to shift, which lagged behind the whole country. Due to the narrow transfer space in northeastern China, the absorptive capacity of agricultural surplus labor was far lower than the national level, which led to the Songnen Plain facing greater transfer pressure, and the transfer of agricultural labor was still at a lower level from farmers to migrant workers [57].

Table 14. Agricultural labor population and rural labor population in China and Songnen Plain.

Year	China			Songnen Plain		
	Agricultural Labor Population (Million)	Rural Labor Population (Million)	Proportion (%)	Agricultural Labor Population (Million)	Rural Labor Population (Million)	Proportion (%)
1995	323.35	450.42	72	3.24	3.98	81
2005	299.76	503.87	59	4.83	6.57	72
2015	219.19	370.41	59	4.40	6.78	65

4.1.2. On the Coupling Relationship Between Agricultural Labor and Agricultural Production

The "Hu Huanyong Line" is an important dividing line in depicting the change patterns of agricultural labor population and grain yield, and cultivated land area, respectively [48–50]. Ge Dazhuan noted that in the pastoral areas and the agro-pastoral ecotones to the west of this line, the coupling relationship between agricultural labor and grain yield was mainly in the same direction. The eastern area was the core area of grain yield in China, where the agricultural labor population was decreasing while the grain yield was increasing. In the rapid agricultural transition zone along the southeastern coast, both of these aspects decreased. Through the study of Songnen Plain in northeastern China, it was found that the agricultural labor population and grain yield in some counties increased significantly, indicating that the role of agricultural labor transfer in promoting grain yield had not been fully demonstrated in the main grain-producing areas. Liu Yansui found that the Songnen Plain had become one of the main cultivated land-increasing areas because of the development of reserve cultivated land resources. The coupling relationship between agricultural labor and cultivated land in 2000–2005 was mainly the declining type, but we found that although the whole Songnen Plain was still the declining type in 1995–2015, its main coupling type had changed into the growth type in 2005–2015. Whether it will continue to show a positive development trend in the future remains an object of further observation and research.

In terms of agricultural output value, the growth rate of the agricultural economy in the central and western areas of China was higher than that in the eastern areas from 2000 to 2010. With the development of the economy and society, the proportion of agricultural output value to GDP gradually decreased from 25% in 1991 to 10% in 2010. Heilongjiang belongs to the economic growth zone, and the coupling type of OLEC mainly belongs to the growth type and extensive type [50]. For Songnen Plain, there were more extensive counties in 1995–2005. However, with the support of national policies and the improvement of the level of agricultural modernization, the agricultural output value in the counties increased significantly from 2005 to 2015, and the growth-type and intensive-type counties accounted for 88%. The agricultural output value was developing well and still played an important role in the regional gross domestic product.

In summary, it is found that when the Songnen Plain is taken as the study unit, the conclusions are different from those of the whole country, northeastern China, and Heilongjiang Province. This difference reflects the particularity of Songnen Plain as an important commodity grain base in the development stage of the country. To some extent, the results of this study can represent the development characteristics of other similar main grain-producing areas. The conclusions of the study are helpful to the promulgation and implementation of targeted policies.

4.2. Comparison of Analytical Methods for the Relationship Between Agricultural Labor Transfer and Agricultural Production

Scholars have explored the relationship between the transfer of agricultural labor and agricultural production by various methods, laying a foundation for future research (Table 15). Most scholars tend to use the method of building economic models, including the production function model [51,58], general equilibrium model [59], and spatial econometric model [60,61]. In addition, the common methods include the field survey method [62,63] and the elasticity coefficient method [48–50]. As shown in Table 15, although no method is perfect, a variety of methods can verify and complement each other to obtain the best analysis results.

Table 15. Comparison of common methods.

Methods	Characteristics	Study Case
Build economic models	It can quantify the influence of each explanatory variable on the explained variable, but the selection of variables in this method is subjective, some models have certain assumptions, and it can only explore the degree of influence in one direction.	[51,58–61]
Field survey method	The data of this kind of method are closer to reality, and the research scale is small and pertinent, but this method weakens the analysis of spatiotemporal evolution.	[62,63]
Elasticity coefficient method	This method is easy to calculate, which is helpful for dividing regional types and stages of development, but it cannot quantify the extent of impact.	[48–50]

In contrast, constructing the elasticity coefficient of agricultural labor and agricultural production is an important way to explore the coupling relationship between them. Scholars use the elasticity coefficient to analyze China's counties, Jiangsu Province, and other regions [64], but the analysis angle and region are relatively unique. The change in the coupling relationship between the transfer of agricultural labor and grain yield, cultivated land area, and agricultural output value, respectively, has not been taken into account in different regions, especially in the main grain-producing areas. Therefore, the study of the coupling relationship between agricultural labor and agricultural production in Songnen Plain can help us to better judge the development stage of agricultural labor transfer in the region, facilitate the comparison with the national development level, and propose targeted policy recommendations. In addition, this study can provide a reference for relevant research and is a useful supplement to the existing research on the relationship between the transfer of agricultural labor and agricultural production.

4.3. Policy Suggestions on Rural Development in Songnen Plain

Against the background of rural shrinkage, the Chinese government issued a series of strategies for the revitalization of northeastern China and rural areas in recent years, paying further attention to the issue of agricultural labor and agricultural production. According to the research results, this paper proposed corresponding countermeasures and suggestions for different types of coupling.

From the perspective of the cultivated land–labor coupling types, (1) for the declining-type counties, in which the per capita cultivated land gradually decreases, the ecological conservation zones should be strictly delimited to avoid reclaiming cultivated land blindly, which will destroy the ecological environment. In addition, we should coordinate the relationship between cultivated land and agricultural labor scientifically, accelerate the transfer of agricultural labor, coordinate urban and rural land allocation, and improve the intensity and efficiency of construction land. (2) For the growth-type counties, in which the per capita cultivated land gradually increases, we should form specialized production areas based on resource advantages, develop family farms and agricultural

professional cooperatives vigorously, and foster new professional farmers with an entrepreneurial spirit. We should make use of the location advantages of neighboring economically developed regions, strengthen division and cooperation with neighboring areas, and strive to achieve the sustainable development of rural areas and agriculture.

From the perspective of the grain–labor and output–labor coupling types, (1) for the growth-type counties, in which the agricultural labor population, the grain yield, and agricultural output value increase, the resource dependence in this part of the region is usually clear [50], which is not conducive to realizing the large-scale management of agricultural production in the long run. Furthermore, the production efficiency is difficult to improve, and the process of urbanization and industrialization will further lag behind. This type of county should accelerate the transformation of its industrial structure, promote agricultural modernization and mechanized production actively, improve the level of the large-scale management of land, and promote the non-agricultural transfer of agricultural labor. (2) For the extensive-type counties, in which the agricultural labor population increases faster than the grain yield and agricultural output value, we should adjust the planting structure in time and make the function orientation clear according to the market changes. Furthermore, we should encourage farmers to start their own businesses and cultivate new rural formats. Regions with resource advantages can develop multi-functional agriculture, such as leisure agriculture and sightseeing agriculture, which not only helps to increase farmers' income, but also helps to promote the sustainable development of rural areas. (3) For the intensive-type counties, in which the agricultural labor population decreases while the grain yield and agricultural output value increase, this part of the region exhibits rapid economic growth, high urbanization, and an agricultural modernization level. This region belongs to the core area of economic growth in the surrounding areas. Rapid economic development and technological progress increase the surplus rural labor, which in turn promotes the transfer of agricultural labor. The increase in grain yield shows that the transfer of agricultural labor plays a "positive" role in promoting grain yield [48]. While improving the quality of agricultural development and promoting the integration of the rural "three industries", we should focus on reasonable policy guidance and develop characteristic towns to avoid the negative impact on food security (such as hollow villages and land waste), which is caused by the weakening of the positive effect of the transfer of agricultural labor and the excessive transfer of agricultural labor. (4) For the fading, lagged, and declining types in which the grain yield and agricultural output value decrease, the quality of labor is low, and the labor skills are poor in this part of the region. We should strengthen our assistance, as well as consolidate and improve the basic rural management system, and cultivate new business entities actively. Moreover, we should attach importance to the development of agricultural education, improve the quality of farmers, and attract talents to return to rural areas.

The regional differences in Songnen Plain are significant, and the types of social and economic development are diverse. On the one hand, there are regional differences in the impact of the transfer of agricultural labor on rural development. In addition to the dependency relationship between agricultural labor and agricultural production, there are also social problems such as the aging of agricultural labor (about 85% of laborers are over 50 years old) and the severe tendency of feminization [55]. How to protect farmers' rights and formulate reasonable rural development policies is the direction of future research. In addition, there is an alternative relationship between agricultural labor and machinery. The relationship between agricultural mechanization and agricultural production is also the direction of investigation in the future. On the other hand, the transfer of agricultural labor is affected not only by objective factors such as geographical location, natural resources, and social economy, but also by subjective factors such as farmers' personal preferences and value orientation. Therefore, this constitutes the type combinations of agricultural labor and agricultural production in the counties of Songnen Plain. We should analyze the characteristics of various types of coupling modes objectively and seek the path of rural revitalization and sustainable development.

5. Conclusions

From 1995 to 2015, the agricultural labor population in Songnen Plain increased first and then decreased, and the level of agricultural production of each county was quite different. The transfer of agricultural labor in counties in the northern and eastern areas was clear. Agricultural modernization, industrialization, and urbanization were the main driving forces of the non-agricultural transfer of agricultural labor. The growth trend of agricultural labor in the central and western areas was clear, mainly because of the rapid growth of cultivated land area, satisfactory agriculture income, slow adjustment of industrial structure, and the weak employment capacity of secondary and tertiary industries. The main driving force for regional development was still agriculture. The level of agricultural production in Songnen Plain showed a growth trend, with characteristics from the initial "high in the southwest and low in the northeast" changing to "high in central areas and low around".

The elasticity coefficient analysis method can effectively analyze the coupling relationship between agricultural labor and agricultural production, reflecting the process of regional agricultural transformation and development. The coupling types of counties in Songnen Plain are varied, and the regional differences are obvious, showing a benign growth trend as a whole. The coupling types of agricultural labor and agricultural production in most counties changed from "lagged type", "extensive type", and "declining type" to "growth type" and "intensive type". The growth and intensive-type counties have the characteristics of agglomeration distribution, which coincide with the regions with good socio-economic development. The transfer of agricultural labor in some areas has brought about an increase in per capita cultivated land and an intensive transformation of production types. However, problems such as hollow villages, the abandonment of cultivated land, and food insecurity should be avoided. Simultaneously, the increase in the agricultural labor population in some areas has promoted the growth of grain yield and agricultural output value, but problems such as the decrease in per capita cultivated land and per capita income should be avoided. Therefore, it is necessary to formulate differentiated rural revitalization strategies according to local conditions.

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