Chin. Geogra. Sci. 2020 Vol. 30 No. 3 pp. 493–504
https://doi.org/10.1007/s11769-020-1123-2

Springer Science Press
www.springerlink.com/content/1002-0063

Spatio-temporal Pattern and Driving Forces of Comprehensive Agricultural Productivity in Jilin Province, China

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Abstract: Improving comprehensive agricultural productivity is an important measure to realize agricultural modernization. Based on the data from Jilin Statistical Yearbook, this study analyzed the spatial and temporal characteristics of comprehensive agricultural productivity discrepancy in the main agricultural production areas of Jilin Province, China. The comprehensive agricultural productivity of 25 county-level administrative units were evaluated by a comprehensive index system based on five aspects which included 20 indicators from 2004 to 2017. The pattern of the discrepancy was analyzed by the spatial differentiation indices and spatial convergence theory. The results were as follows: 1) the overall comprehensive agricultural productivity was in a 'W-type' rising trend; 2) the discrepancy was in 'inverted W-type' trend; 3) the spatial distribution characteristics were mainly discrete plaque and 'inverted V-type'; 4) the formation of differences was forced by a combination of internal and external driving forces. Our study demonstrates the effectiveness of rising agricultural productivity and the level of economic and social developments in different counties in Jilin Province.

Keywords: spatio-temporal pattern; comprehensive agricultural productivity; spatial convergence/divergence; driving forces; Jilin Province, China

Citation: LIU Yunda, TONG Lianjun, 2020. Spatio-temporal Pattern and Driving Forces of Comprehensive Agricultural Productivity in Jilin Province, China. *Chinese Geographical Science*, 30(3): 493–504. https://doi.org/10.1007/s11769-020-1123-2

1 Introduction

Comprehensive agricultural productivity is the level of comprehensive agricultural output and competitiveness that can be stably achieved in a certain period (Block, 1994; Johnson, 1997; Kawamura, 2012). It is an important component of social productivity and a major indicator of the overall level of agricultural production and rural economic strength in a country or a region (Du, 2004). In the process of development of China's 'Three Rural Issues', studies on comprehensive agricultural productivity are closely related to strengthening the agricultural supply-side structural reform and optimizing the structure. Assessing the characteristics of comprehensive agricultural productivity is becoming an issue of focus and is of major concern to academics and governments (Carter et al., 2003; Li et al., 2015; Fuglie, 2018).

Many studies on comprehensive agricultural productivity have been carried out regarding the concept of connotation (Ye, 2005), index models (Pender et al., 2004; Sheng et al., 2019), development models (Charnes et al., 1981; Ruttan, 2002; Haimanot et al., 2017), element composition (Liang, 2005), and policy paths (Zhang and Zheng, 2015; Ren, 2015; Yang, 2016), from different fields of applied economics, systems science, agricultural resource utilization, and agricultural economic management. Additionally, different research

Received date: 2019-11-14; accepted date: 2020-03-06
Foundation item: Under the auspices of the National Natural Science Foundation of China (No. 41771138)
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methods have been explored, such as Agro-Ecological Zone methods (AEZ) (Chen et al., 2014; Seo, 2014), data envelopment analysis (DEA) (Chen and Xie, 2000; Wojcik et al., 2019), analytic hierarchy process (AHP) (Saaty, 2008; Jiang and Cui, 2011), systematic integrated prediction method (Chen and Yang, 2006), and Grey System and BP Neural Network (Su et al., 2006). The wide application of these research methods helped to analyze the comprehensive agricultural productivity from multiple perspectives. Current studies mostly use total factor productivity to measure the actual agricultural output (Kalirajan et al., 1996; Esposti, 2000; Dimelis and Dimopoulou, 2002; Chen et al., 2008). However, comprehensive agricultural productivity is not equivalent to actual agricultural output and the development level is a combined effect of economic, social, and ecological benefits. These studies ignored the long-term accumulation in formation and interaction of the various factors, so the level of the comprehensive agricultural productivity can not be impartially reflected due to differences over time and space.

The functional orientation and development direction of the main agricultural production areas in Jilin Province (China) are different from those in other restricted development zones. It has the characteristics of an area that has restrictions to development but is also an important commodity grain planting zone. It needs to fully implement the national plan for adding 50 billion kg of grain production capacity, but at the same time protect the cultivated land and control its development intensity. Therefore, it is of great practical significance to study the differences in comprehensive agricultural productivity over time and space in this region.

In the present study, differences in the comprehensive agricultural productivity over time and space in the main agricultural production areas of Jilin Province were measured based on the data from *Jilin Statistical Yearbook* (Statistic Bureau of Jilin, 2005–2018). Twenty-five county-level administrative units were evaluated by a comprehensive index system based on five aspects which included 20 indicators from 2004 to 2017. The pattern of the discrepancy was analyzed by the spatial differentiation indices and spatial convergence/divergence theory. Furthermore, driving forces of the formation of differences in comprehensive agricultural productivity were explored. The results will provide a scientific base for safeguarding national food security and for implementing the rural revitalization strategy to take the lead in realizing agricultural modernization.

2 Materials and Methods

2.1 Study area

In this study, a total of 25 research units were included based on the list of county-level administrative units in the main agricultural production areas of Jilin Province. Taking into account the changes in administrative divisions and the availability and comparability of data, Jiutai City, Shuangyang District of Changchun City, and Taobei District of Baicheng City, which withdrew from the city in 2014, are not included in this study (Fig. 1). The area of the study area is 102 309 km^2, accounting for 53.37% of the province. In 2017, the total population of the study area was 13.485 million, accounting for 51.55% of the province; the regional GDP was 533.215 billion yuan (RMB), accounting for 25.28% of the province; the area planted with grain was 428.37 ha, accounting for 91.13% of the total planting area; the total grain output was 34.23 million t, and the per capita grain output was 2430 kg (Statistic Bureau of Jilin, 2018). Due to differences in natural conditions in the main agricultural production areas of Jilin Province, the characteristics of agricultural resources are different. For example, the soil in the central plain is fertile and the agricultural concentration is relatively high; the annual precipitation in the western plain is relatively small, while sunshine time is longer; the central and eastern regions are mountainous areas with rich forest resources. Based on these different regional characteristics, this study divided the research area into the central (Nong’an County, Yushu City, Dehui City, Yongji County, Jiaohe City, Huadian City, Shulan City, Panshi City, Lishu County, Yitong County, Gongzhuling City, Shuangliao City, Dongfeng County, Dongliao County , Qianguo County, Changling County, Qian’an County, and Fuyu City), northwestern (Zhenyu County, Taonan City, and Da’an City), and southeastern (Tonghua County, Huinan County, Liuhe County, and Meihekou City) main agricultural production areas (Fig. 1).

2.2 Methods

2.2.1 Evaluation index system

The comprehensive evaluation index system was used to summarize the data into five aspects (the input capacity of agricultural resources, the output capacity of agricultural

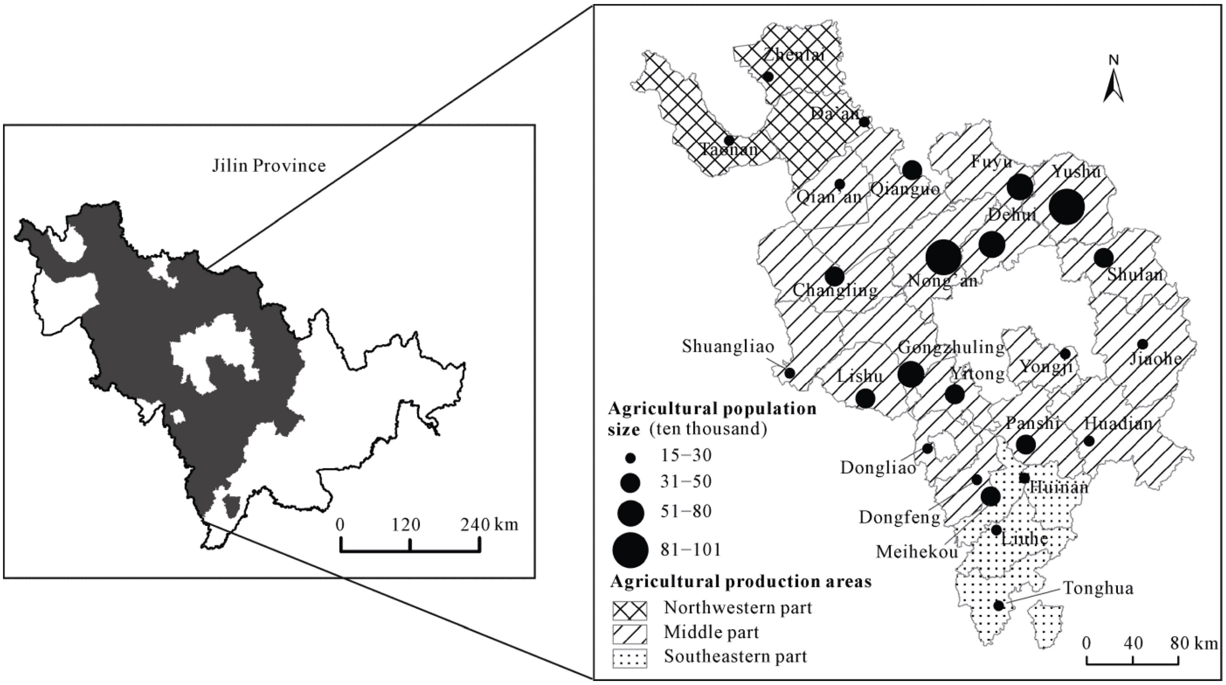

Fig. 1 Location of study area and units

products, the water conservancy capacity of farmland, the level of agricultural modernization, and the comprehensive supporting service capacity) following the scientific, systematic, typical, and completeness principles (Table 1). Among them, the input capacity of agricultural resources and the output capacity of agricultural products reflected the available resources, production conditions, and input and output levels of agricultural products, so static and beneficial indicators were mainly selected; the guarantee capacity of farmland water conservancy and the level of agricultural modernization reflected the level of protection, growth potential, and expansion capacity, so the dynamic and structural indicators were mainly selected; the comprehensive supporting service capacity reflected the resource allocation and the efficiency of agricultural science and technology, so the ratio indicators were selected. Ultimately, it was further subdivided into 20 indicators to support and map the development level of comprehensive agricultural productivity (Table 1).

Original data of all indicators were converted into dimensionless indices. Let X_{ijk} be the actual measured value of the index X_{ij} in the k_{th} year, and maxX_{ijk} and minX_{ijk} are the maximum and minimum values of the X_{ijk} index, respectively. Then, A_{ijk} is the value of X_{ijn} after the dimensionless conversion in the k_{th} year:

$$A_{ijk} = \begin{cases} X_{ijk} - \min X_{ijk} / \max X_{ijk} - \min X_{ijk} \\ \max X_{ijk} - X_{ijk} / \max X_{ijk} - \min X_{ijk} \end{cases}$$

The index values were calculated based on the data from *Jilin Statistical Yearbook* (Statistic Bureau of Jilin, 2005–2018).

2.2.2 Spatial differentiation indices

Because the basic principles and calculation ideas of various spatial differentiation indices are different, the expression of spatial differentiation trend, the evolution of the pattern, and the performance of the model are also different. Therefore, this study combined the traditional spatial differentiation indices, namely coefficient of variation (CV) (Williamson, 1965), Gini coefficient (G) (Cowell, 2009), and Theil index (T) (Theil, 1967). At the same time, to comprehensively reflect the degree of change in the overall differentiation of comprehensive agricultural productivity, the overall differentiation measure index (GDI) was integrated.

$$GDI = f(CV, G, T) \tag{1}$$

where CV is the value of coefficient of variation, G is the value of Gini coefficient, and T is the value of Theil index. This index can not only better reflect the information of the above three traditional spatial differentiation

Table 1 Comprehensive evaluation index system for the development level of comprehensive agricultural productivity

Aim	Aspect and weight	Indicator	Unit
Development level of comprehensive agricultural production capacity	Agricultural resource input capacity (0.25)	Area of sowing grain	ha
		Per capita cultivated area	ha/number of persons
		Mechanical density of farming and harvesting	Number of machines/ha
		Mechanical density of agricultural processing	Number of machines/ha
		Total power of agricultural machinery per unit area	kW/ha
	Agricultural product output capacity (0.30)	Total grain output	t
		Grain yield per unit area	t/ha
		Per capita food production	t/person
		Land productivity	Ten thousand yuan/ha
		Labor productivity	Ten thousand yuan/number of persons
		Farmers' per capita net income	Ten thousand yuan/number of persons
	Farmland water conservancy (0.15)	Effective irrigation rate of farmland	%
		Density of water-saving irrigation equipment	Number of machines/ha
		Drainage power machinery density	Number of machines/ha
	Agricultural modernization level (0.20)	Ratio of machinery to cultivated area	%
		Ratio of machinery to planted area	%
		Amount of fertilizer applied per unit area	t/ha
		Per capita electricity consumption of farmers	(kW·h)/ha
	Comprehensive supporting service capability (0.10)	Proportion of agricultural expenditures for agriculture	%
		Density of agricultural scientists	%

Note: index weight was calculated by entropy method

indices, but also achieves more stable results (Wang et al., 2013). The calculation methods used were from Jiang (2014).

2.2.3 Spatial convergence and divergence

To reflect the spatial and temporal pattern of differences in comprehensive agricultural productivity, the spatial theory of French philosopher Henry Lefebvre (Lefebvre and Enders, 1976; Martins, 1982) was referenced in this study, that is, 'if there is no space division, each city will be homogenized, but with the concept of space, there will be inhomogeneity. Space has political attributes that will create spatial differences between centralization and decentralization'. Drawing on this spatial theory with political attributes, we deducted the definition of spatial convergence/divergence degree in this study: the development level of the comprehensive agricultural productivity of the units in the research area is inevitably higher than, equal to, or lower than the average level, then the trend positively or negatively approaching to the average level is spatial convergence, and conversely spatial divergence. The spatial divergence analysis of the productivity differences of units was carried out for the two periods of 2004–2010 and 2010–2017.

2.2.4 Measurement of comprehensive agricultural productivity

The research period is divided into six time points (2004, 2007, 2010, 2013, 2015, and 2017). Using the year 2004 as the base year, the comprehensive scores of 25 units were calculated using the entropy method (Chen et al., 2009). The ranking was determined according to scores from high to low. The correlation coefficient between the comprehensive agricultural productivity and indicators of each unit in the six time points were analyzed using Kendall Rank Correlation Coefficient in SPSS 20.0. The spatial pattern of scores of the productivity of each unit in the six-time points was analyzed using ArcGis 10.2.

3 Results and Discussion

3.1 Spatio-temporal pattern of comprehensive agricultural productivity

Table 2 shows that from 2004 to 2017, the average value of comprehensive agricultural productivity evaluation of each unit was between 1.39 and 1.42, and the overall level was in a 'W-type' rising trend (Fig. 2).

The W-type trend indicates that comprehensive agricultural productivity of Jilin Province during the research period gradually increased and had high instability. In each year, the difference in scores between the units at the top and bottom of the rankings showed a trend of 'expanding first and then shrinking'. There were significant positive correlations between the comprehensive agricultural productivity and the area planted with grain, per capita cultivated land area, total grain output, per capita grain output, labor productivity, grain output per unit of cultivated land, and agricultural special expenditure (values of the correlation coefficients were 0.513, 0.360, 0.460, 0.440, 0.433, 0.280, and 0.300, respectively, and the confidence was between 0.01 and 0.05). This shows that the output capacity of agricultural products, the input capacity of agricultural resources, and the comprehensive supporting service capacity have a high contribution to comprehensive agricultural productivity, and that traditional agricultural production in the main agricultural production areas of Jilin Province is still a majority so further transformation and upgrades are required.

Table 2 Comprehensive score and ranking of comprehensive agricultural productivity development level of 25 units in the main producing areas of agricultural products in Jilin Province

City or County	2004		2007		2010		2013		2015		2017	
	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking	Score	Ranking
Nong'an	1.4417	9	1.3958	15	1.3579	18	1.4562	6	1.4107	14	1.4351	9
Yushu	1.4415	10	1.3978	14	1.4340	8	1.4179	11	1.4031	15	1.4739	4
Dehui	1.5397	1	1.5042	3	1.4515	4	1.4170	12	1.3879	16	1.4302	10
Yongji	1.3717	17	1.4169	13	1.3410	19	1.4121	14	1.5019	3	1.4071	13
Jiaohe	1.3662	18	1.3529	19	1.3193	22	1.3803	18	1.4231	11	1.3361	23
Huadian	1.3111	23	1.3495	20	1.3183	23	1.3937	17	1.4639	4	1.4001	16
Shulan	1.3935	15	1.4273	9	1.4093	13	1.4640	5	1.4164	12	1.4508	5
Panshi	1.3941	14	1.4236	10	1.3687	16	1.4083	16	1.3704	18	1.3892	19
Lishu	1.4709	5	1.5170	2	1.4388	6	1.4162	13	1.4455	7	1.3996	17
Yitong	1.3161	22	1.2701	25	1.2766	25	1.3145	24	1.2938	24	1.3534	22
Gongzhuling	1.4869	4	1.4829	5	1.4406	5	1.5153	2	1.4320	9	1.4836	3
Shuangliao	1.3381	20	1.4176	12	1.4027	14	1.3621	21	1.3670	19	1.3766	21
Dongfeng	1.4566	7	1.4606	6	1.4298	10	1.4423	10	1.4116	13	1.4419	6
Dongliao	1.2950	24	1.3183	23	1.3397	20	1.2856	25	1.2831	25	1.3338	24
Tonghua	1.3180	21	1.3379	21	1.4301	9	1.3615	22	1.3107	22	1.4009	14
Huinan	1.4353	11	1.3859	16	1.4188	11	1.4109	15	1.3862	17	1.3977	18
Liuhe	1.3416	19	1.3316	22	1.2800	24	1.3521	23	1.3019	23	1.2882	25
Meihekou	1.3890	16	1.3793	17	1.3615	17	1.3688	19	1.3379	21	1.4005	15
Qianguo	1.5338	2	1.5018	4	1.5885	1	1.5638	1	1.5221	2	1.5265	2
Changling	1.4476	8	1.4191	11	1.4378	7	1.4471	8	1.4342	8	1.4354	8
Qian'an	1.4003	12	1.3680	18	1.4111	12	1.4494	7	1.4520	5	1.3835	20
Fuyu	1.5045	3	1.4376	8	1.4726	3	1.4739	4	1.4248	10	1.4386	7
Zhenlai	1.3978	13	1.5433	1	1.4881	2	1.4946	3	1.5295	1	1.5403	1
Taonan	1.4570	6	1.4465	7	1.3834	15	1.4432	9	1.3605	20	1.4088	12
Da'an	1.2940	25	1.2987	24	1.3239	21	1.3680	20	1.4489	6	1.4187	11
Average score	1.4057		1.4074		1.3970		1.4168		1.4048		1.4140	

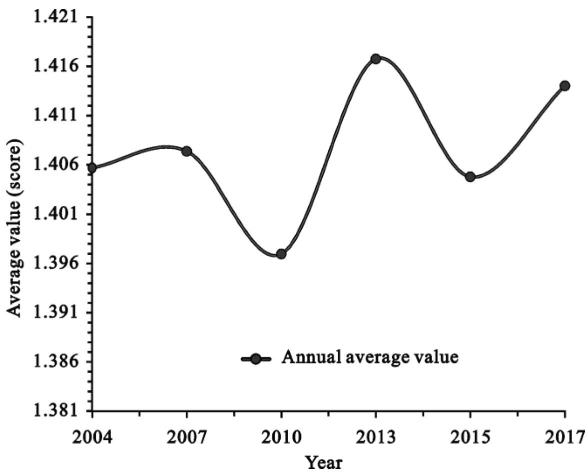

Fig. 2 Evaluation value of comprehensive agricultural productivity in the main producing areas of agricultural products in Jilin Province

From 2004 to 2017, the ranking of comprehensive agricultural productivity of each unit changed each year. The number of rising, falling, and constant annual rankings were counted (Fig. 3). The ratio of rise, fall, and constant rankings of the 18 units in the central producing areas was 1 : 1.2 : 0.3; the ratio of the three units in the northwest as 1 : 0.7 : 0.3; the ratio of the four units in the southeast was 1 : 2.2 : 0.8. This shows that the comprehensive agricultural productivity of the northwestern units was on the rise, the southeast struggled to rise, while the central area was relatively stable with few units fluctuating. The largest increase was the ranking of Da'an City in 2015 (up 14 places) and the largest decline was the ranking of Qian'an City in 2017 (down 15 places).

3.1.1 Evolution of comprehensive agricultural productivity discrepancy over time

Differences in comprehensive agricultural productivity among the units showed a fluctuating downward trend from 2004 to 2017, which was opposite to the overall evaluation trend value of the study area, showing an irregular 'inverted W-type' trend (Fig. 4). The difference among the units was the largest in 2010 (the peak-to-valley difference was 24.9%), and the difference was the smallest in 2017 (the peak-to-valley difference was 19.8%). According to the coefficient of variation, Gini coefficient, Theil index, and the overall difference measure index, patterns of comprehensive agricultural productivity discrepancy among units in the study area were divided into 'slowly increasing' and 'decreasing-increasing-decreasing' periods.

With the implementation of China's 'Revitalization Strategy for Old Industrial Bases in Northeast China', development priorities of this period were optimizing structure, improving efficiency, and reducing consumption. Although the proposed 'Jilin Province Main Functional Area Plan' clearly defined the development direction and strategic planning of the main agricultural production areas, there was a certain degree of delay and

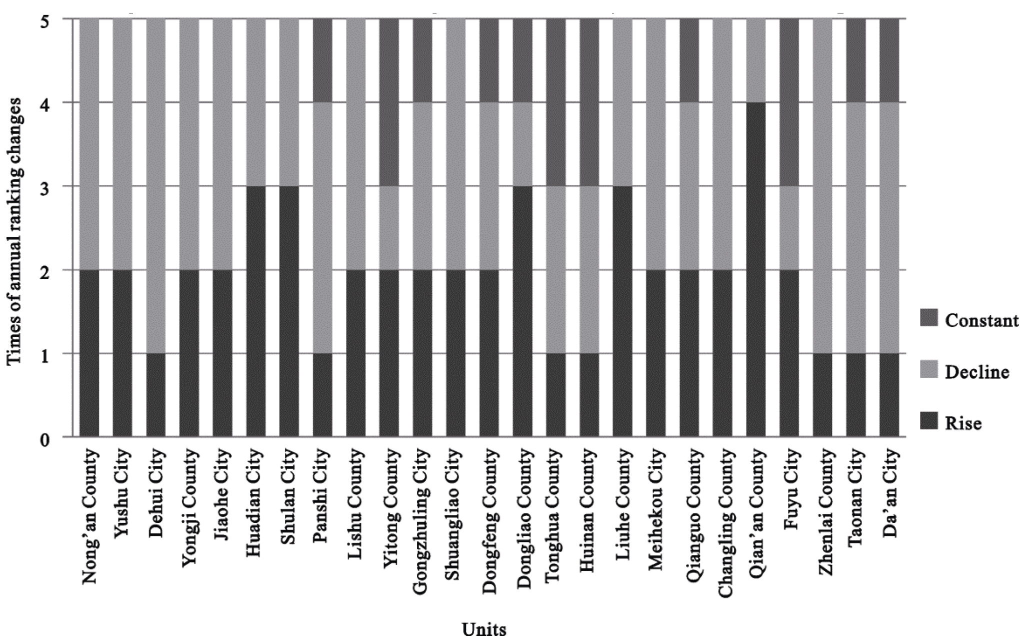

Fig. 3 Changes in annual ranking of agricultural comprehensive production capacity in each unit in Jilin Province

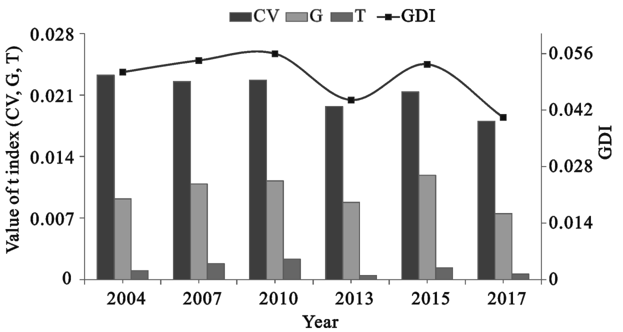

Fig. 4 Spatial differentiation indices of the comprehensive agricultural productivity from 2004 to 2017. CV is the value of coefficient of variation, G is the value of Gini coefficient, T is the value of Theil index, GDI is the overall differentiation measure index

lag in the emergence of policy effects and the adjustment of development direction. This may be related to the unique attributes of agriculture, that is, the combination of natural and economic reproduction and a relatively long production cycle. Therefore, the difference in comprehensive agricultural production capacity during this period was still slowly increasing.

With the implementation of the 'Overall Plan for Capacity Building of 50 Billion kg of Commercial Grain Production in Jilin Province', the productivity of 17 units has been improved to varying degrees, with Nong'an County, the main producing area in the central region, having the largest increase (7.24%). This promoted the rapid reduction of the overall difference from 2010 to 2013. From 2013 to 2015, agricultural disasters such as typhoons, drought, disease, pests, and rats frequently occurred with as much as 17.2% of the area affected. This led to a general decline in the productivity of the whole province, and an increase in the overall difference. The completion and commissioning of the irrigation district have enabled Da'an City, which is located in the northwest of the main producing area, to achieve a growth rate of 5.9%, showing that improving the water conservancy support capacity of farmland was still the key improving comprehensive agricultural productivity in western Jilin as well as the whole province. From 2015 to 2017, with the in-depth implementation of the 'Master Plan for Agricultural Modernization in Jilin Province' and the accelerated construction of the modern agricultural industrial system, production system, and management system, the productivity of nearly three-quarters of the province's units significantly increased. The rapid increase in productivity of the southeast and northwest of the main producing areas drove a rapid decline in overall differences. This showed that the productivity of the central part of the main producing areas still had large room for improvement and it was necessary to continuously enhance the support capacity for ensuring national food security. The southeast and northwest of the main producing areas need to continue the momentum of growth, further promote upgrading of the agricultural industry, and improve the level of agricultural modernization.

3.1.2 Evolution of comprehensive agricultural productivity discrepancy over space

During the research period, the spatial distribution characteristics of the differences in agricultural comprehensive production capacity in the main agricultural production areas of Jilin Province were mainly discrete plaque and 'inverted V-type' distribution.

The distribution of units with higher comprehensive agricultural productivity scores shifted from an agglomeration pattern in the central-northern part to a diffusion pattern in the central-eastern, central-southern, and northwest parts, while the distribution of the units with lower scores changed from agglomeration, to several blocks, to a discrete distribution (Fig. 5). Units with higher scores were mainly distributed in the central plains, while units with lower scores were distributed in the low-mountain hills in the central-east and plains in the northwest where wind and sand are frequent. Both had plaque-like distribution.

The distribution of units with higher scores was in an 'inverted V' pattern. In the west and east sides of the central plain, two lines were formed: northeast-southwest sideline (Yushu-Dehui-Nong'an-Gongzhuling-Lishu-Changling) and northwest-southeast sideline (Shulan-Jiaohe-Yongji-Huadian-Panshi-Huinan). The distribution of units on the west sideline remained 'inverted V' pattern, while the distribution of units on the east sideline fluctuated throughout the period.

From 2004 to 2010, the production capacity of the six units which were above average and continued to rise above the average level, was defined as the upper divergence form; contrarily, six units were in the form of lower divergence (Fig. 6a). The six units which were slightly above average and were increasingly average were defined as the upper convergent form; conversely,

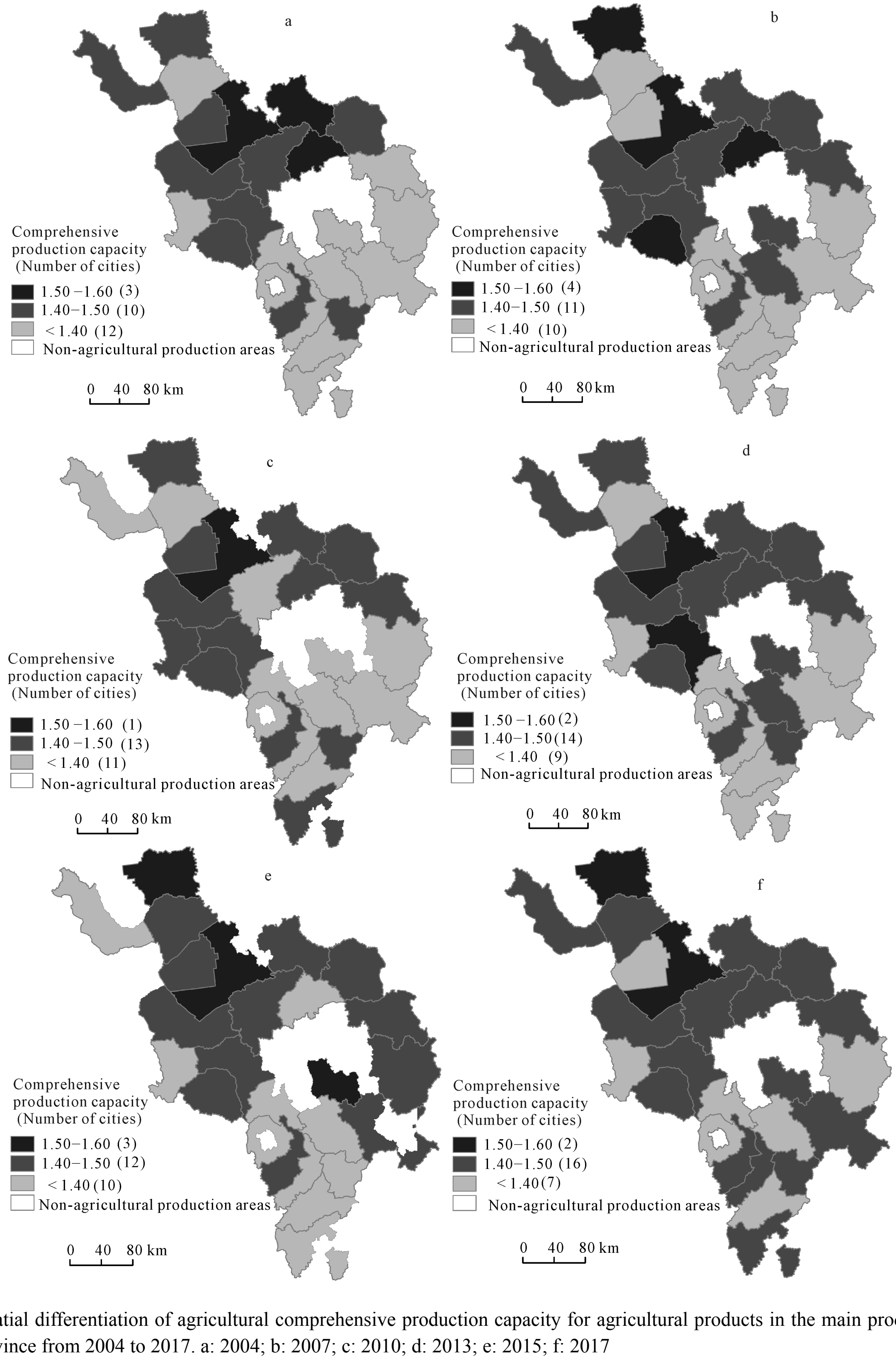

Fig. 5 Spatial differentiation of agricultural comprehensive production capacity for agricultural products in the main producing areas of Jilin Province from 2004 to 2017. a: 2004; b: 2007; c: 2010; d: 2013; e: 2015; f: 2017

seven units were in the lower convergent form. A total of 12 units were in the divergent form and 13 units were in the convergent form, resulting in an increase in overall differences. From 2010 to 2017, the units in the form of upper divergence were gradually reduced from 6 to 3, and the units in lower divergence were gradually reduced from 6 to 4 (Fig. 6b). Units in the upper convergence form gradually increased from 6 to 12, while units in the form of lower convergence were gradually reduced from 7 to 6. A total of 7 units were in the divergent form and 18 units were in the convergent form, resulting in a reduction of overall differences.

3.2 Driving forces for comprehensive agricultural productivity discrepancy

The comprehensive agricultural productivity discrepancy was the result of a combination of internal and external driving forces.

3.2.1 Internal driving force

The main internal driving force for the difference in comprehensive agricultural productivity experienced a shift from farmland water conservancy support capacity to comprehensive support service capacity, and then to the level of agricultural modernization (Fig. 7).

In 2004, the coefficient of variation of farmland water conservancy support capacity was 0.15, which was the highest amongst the factors, indicating that it was the main factor driving the formation of differences of comprehensive agricultural productivity. In the early stage of the revitalization strategy of the old industrial bases in Northeast China, the agricultural development of Jilin Province, especially in the western and eastern regions, was mostly driven by the government's investment in the capacity of farmland water conservancy. Therefore, the strength of farmland water conservancy support determined the level of productivity. The coefficient of variation for comprehensive supporting services ability in 2007 was 0.16. Together with the ability of farmland water conservancy, it became one of the main factors driving the formation of differences. At the same time, the concept of the main agricultural production areas was formally proposed, and policies for supporting agriculture and farmers were implemented, leading to the investment of more resources in integrated support services.

From 2010 to 2015, the key water-control project of Hada Mountain, the water diversion project from Nenjiang River to Baicheng City and the water diversion project from Songhua River to the cities in the middle of Jilin in the central area alleviated the influence of drought and flood disasters in the agricultural area to some extent. The capacity of farmland water conservancy and the ability of comprehensive supporting services were still important factors in driving differences

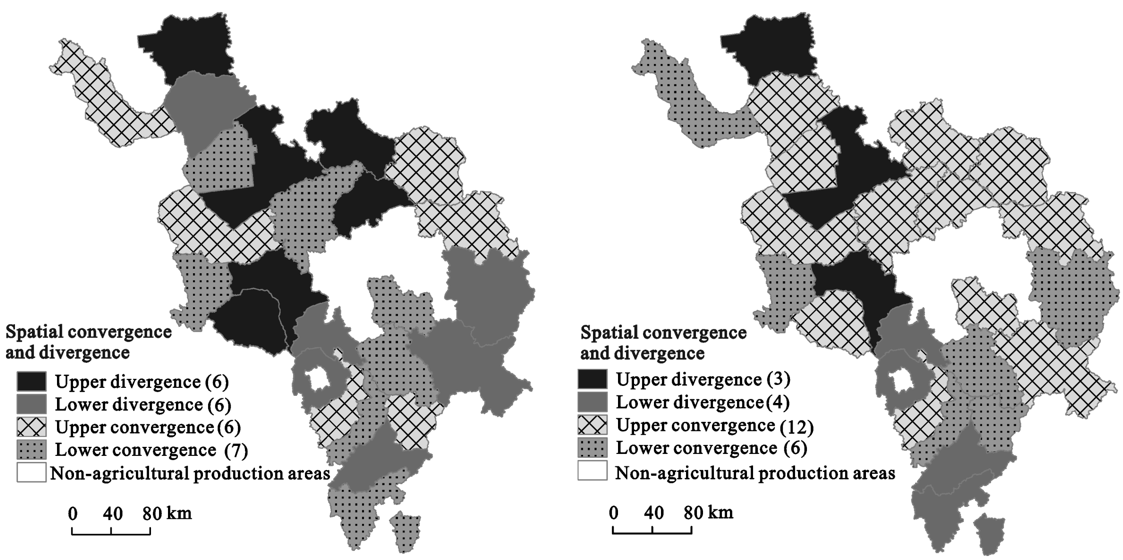

Fig. 6 Spatial convergence and divergence of comprehensive agricultural productivity in the main producing areas of agricultural products in Jilin Province from the year 2004 to 2017. a, 2004–2010; b, 2010–2017

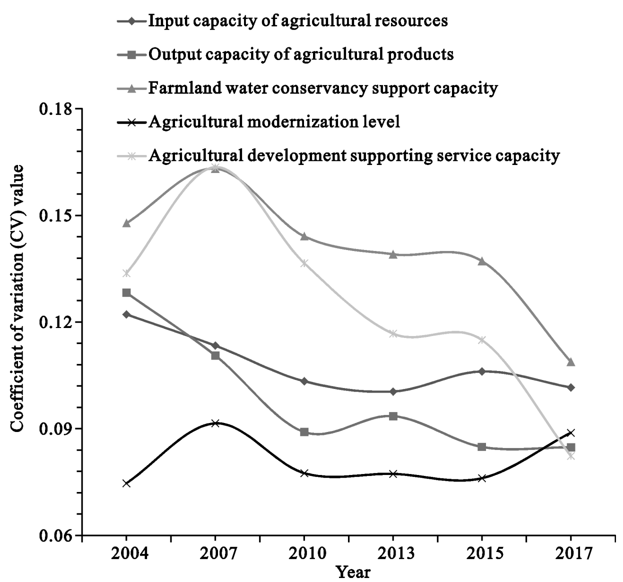

Fig. 7 Coefficient of variation value of internal driving force in agricultural comprehensive production capacity in Jilin Province from 2004 to 2017

in productivity during this period, however, their influence had weakened. At the same time, the influence of the input capacity of agricultural resources, the output capacity of agricultural products, and the level of agricultural modernization increased to varying degrees. From 2015 to 2017, with the formulation and implementation of the 'Master Plan for Agricultural Modernization in Jilin Province' and the 'Sustainable Agricultural Development Plan of Jilin Province', the level of agricultural modernization became the main factor driving the increase of differences. Meanwhile, it also became a key driver for the improvement of productivity and sustainable development in the main agricultural production regions.

3.2.2 External driving force

(1) Advantage of resource endowments

The main agricultural production areas in Jilin Province have unique resource traits, and each unit develops agricultural production according to local conditions. Three development zones with different characteristics have gradually formed: the central optimized development zone in the Songliao Plain with fertile soil; the central-eastern development zone with abundant forest resources and small cultivated land area; western protected development zone with a combination of fields, woodlands, grasslands and agro-pastoralism.

(2) Impact of development policy

During the research period, the guiding policies for development changed from 'Opinions of the Central Committee of the Communist Party of China and the State Council on Further Strengthening Rural Work to Improve Agricultural Comprehensive Productive Capacity' to 'Jilin Province's Main Functional Area Planning', from 'Jilin Province Agricultural Sustainable Development Plan' to 'Jilin Province to take the lead in realizing the overall plan for agricultural modernization', and then to 'Jilin Province Rural Revitalization Strategic Plan'. As an important commodity grain base in China, Jilin Province continuously supported various resources such as policies, capital, technology, and engineering tilted towards the main agricultural production areas. Advantageous resources continued to gather in areas with good basis and great potential, which further widened the differences of the agricultural productivity.

(3) Barrier of county boundaries

As the main body of economic interests, the county-level governments continued to enhance the boundary function for their interests. This made it difficult for counties to break through the rigid constraints of the administrative boundary to co-ordinate agricultural resources and upgrade the level of agricultural modernization, resulting in discontinuity and waste in the use of agricultural resources (Qiu et al., 2009). This barrier effect allowed the main agricultural production areas to take advantage of geographical locations, resources, and policies so that their comprehensive agricultural productivities rapidly improved. However, counties in the northwest and southeast main producing area were at a disadvantage.

(4) Adjustment of the market demand

Safeguarding national food security is one of the functions of the main agricultural production areas in Jilin Province. With the formation of large-scale market circulation, the market demand for modernization, standardization, and green and safe agricultural products promoted the development of agricultural resources, namely, the transformation to large-scale operation and specialized division of labor. The regulation of the market tended to benefit counties with larger scales of business, specialized division of labor, complete producing systems, and higher levels of the agricultural productivity.

(5) Response of the agricultural product processing industry

The agricultural product processing industry has become an important link in the agricultural industrial chain, and its degree of development has driven the development speed and quality of agricultural production. In this process, along with the demonstration and promotion of the development model of 'leading enterprises + professional cooperatives + characteristic bases', various agricultural resources are driven to flow to counties with higher levels of comprehensive agricultural productivity and promote their constant improvements. At the same time, the construction of professional organizations and the featured bases of agricultural products provide high quality primary products for the agricultural products processing industry, further enhancing the market influence of the leading enterprises.

4 Conclusions

This study analyzed the comprehensive agricultural productivity of 25 county-level administrative units by a comprehensive index system based on five aspects which included 20 indicators from 2004 to 2017. The pattern of the discrepancy was analyzed by the spatial differentiation indices and spatial convergence and divergence theory. Overall comprehensive agricultural productivity was in a 'W-type' rising trend, while the discrepancy was in 'inverted W-type' trend. Besides, the spatial distribution characteristics were mainly discrete plaque and 'inverted V-type'. The formation of differences was forced by a combination of internal and external driving forces. The spatial and temporal patterns of the differences in comprehensive agricultural productivity in the main agricultural production areas in Jilin Province objectively reflected the effectiveness of rising agricultural productivity and the level of economic and social developments in different counties. It also reflected the inadequacy of the plans to a certain extent. This study provides an effective scientific basis for further solving the 'three rural' problems and establishing and improving the agricultural industries with modernized production and management systems. However, due to limitations of data, quantitative models to reveal the driving mechanism of differences of agricultural comprehensive productivity, especially the mechanism of differences between counties, needs to be further explored.

Acknowledgement

We would like to express our sincere thanks to Xin Sun from University of Göttingen , Jiuchun Yang, Jing Li and Xiuli He from Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences for their help during the preparation of the manuscript.

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