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Soybean Production and Spatial Agglomeration in China from 1949 to 2019

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Abstract: By mastering the spatial-temporal evolution of patterns of soybean production, a reference for optimizing a soybean production layout could be provided, ensuring food security. The variation coefficient method, and the comparative advantage and spatial autocorrelation models were used to analyze the spatial divergence regularities of soybean production, sown area and yield, spatial-temporal changes in the comparative advantages of soybean planting efficiency and soybean planting scale, and the spatial agglomeration characteristics in China from 1949 to 2019. The results indicate that (1) from 1949 to 2019, soybean production and yield changes in China remained constant with a fluctuating upwards trend, and soybean sown areas hardly changed, yet experienced a sharp fluctuation. (2) The Northeast China Plain (NECP) was the main soybean-producing area, and its main position was strengthened. In contrast, the main soybean production position of the Huang-Huai-Hai Plain (HHHP) has declined. The Northern arid and semi-arid region (NASR), the Sichuan Basin and surrounding areas (SBSR), the Middle-Lower Yangtze Plain (MLYP), and the Yunnan-Guizhou Plateau (YGP) became new soybean production growth poles. (3) The spatial distribution of soybean planting efficiency-related comparative advantages in China extended from northern China to the whole country, and the soybean planting scale-related comparative advantages proceeded through three stages: steady expansion, relative stability, contraction, and stabilization. (4) The spatial agglomeration of soybean planting efficiency-related comparative advantages has weakened, and the spatial agglomeration of the soybean planting scale-related comparative advantages exhibited a strengthening-weakening-strengthening-weakening process. Through our research analysis, we propose a policy resource to fully utilize the soybean planting efficiency-related comparative advantages in southern China (SC), promote grain-soybean rotation patterns in the HHHP and NECP, improve the soybean cultivation subsidy system, and build a soybean industry chain in the NECP.

Keywords: soybean; production pattern; spatial agglomeration; policy implications

1. Introduction

Soybean is an important crop in regard to global food security and sustainable development due to its dual properties as a protein food ingredient and oilseed [1]. Soybean, a native plant of China and one of its most important crops, has been known to man for over 5000 years [2]. China’s meat consumption and demand for soybean are rapidly increasing with a growing population, rising per capita income, and changing dietary preferences [3,4]. As the main soybean producer worldwide, China has transitioned from a net exporter of soybeans to a net importer since 1996, with soybean imports increasing from 1.11 Mt in 1996 to 100.33 Mt in 2020 [5]. China’s soybean imports account for 60.57% of the global soybean trade volume, making the country the world’s largest soybean importer and highly
dependent on imports from countries, such as Brazil, the United States, and Argentina [6,7]. At present, China’s soybean consumption heavily depends on international imports; however, the total population in China will peak by approximately 2030, and if the current soybean production and consumption trends persist, the soybean production and demand gap in China will continue to expand in the future [8]. In addition, soybean yields have been projected to decline by 7–19% in 2100 against the backdrop of global warming [9]. Therefore, China must urgently optimize its soybean planting area and increase soybean production to ensure its national food security.

Mastering the spatial-temporal change in soybean planting advantages and their geographical agglomeration patterns is fundamental to optimizing the spatial layout of soybean production and ensuring national food security [1,10]. In terms of soybean planting spatial changes [5,10], Sun et al. [11] studied the spatial-temporal patterns of the soybean sown area in China in response to soybean imports from 1980 to 2012, and the results demonstrate that the soybean sown area decreased in southeastern China while it increased in northwestern China. Regarding the soybean cultivation’s influencing factors, Liu et al. [12] analyzed the factors causing farmers to increase soybean production, and the study found that the age of farmers, farm income, land topography, and ease of sale positively influence the behavior of farmers. In addition, soybean imports were identified as another important factor influencing soybean cultivation [11,13–15]. In terms of timing the changes in soybean planting advantages, for political and economic reasons, soybean production in China has lost its competitiveness and has been declining since the early 2000s [15]. In terms of space optimization in soybean planting, land suitability [16], climate suitability [17], and climate production potential [18] have mainly been considered. Most areas of the Sanjiang Plain are suitable for soybean cultivation, except for areas with slopes of ≥30% [16]. Zhao et al. [17] determined that the areas of high climatic suitability for soybean planting are mainly located in the northeastern and northern-central regions and that the total area of high suitability covers 1.2988 × 10^8 ha. In addition, the effects of conservation tillage [19], wheat straw mulching [20], temperature [21], CO₂ [22], and drought [23,24] on soybean yields have been studied. Existing research plays a key role in optimizing the soybean production space and increasing soybean production. However, little research has studied the spatial-temporal changes in patterns of soybean production on a national scale and over a long time series; the spatial difference between the comparative advantages of soybean planting efficiency and soybean planting scale and their spatial agglomeration characteristics remains unclear.

Soybean trade exerts a negative impact on the resources and environments of both importing and exporting countries [25]. Land expansion for soybean production has increased since 2000 by 160% in Brazil and by 57% in Argentina [4], resulting in deforestation [26], greenhouse gas emissions [27], and ecological damage [28]. Across South America, 9% of the forestland lost was converted into soybean planting areas from 2000 to 2016 [4]. Simultaneously, the soybean cultivation space in China is constantly being replaced by land for the cultivation of crops, such as rice, corn, vegetables, and fruit, resulting in irrigation water usage increasing by 96.42% (3.05 km³), and the application of N fertilizer has increased by 256.65 thousand tons (almost 5 times) [15,25,29]. The optimization of the soybean planting space and enhancement of domestic soybean production to relieve pressure on resources and the environment in China and other soybean-exporting countries require immediate solutions.

With the frequent occurrence of global extreme weather hazards, the trade war between China and the United States, and outstanding structural contradictions in domestic food security, as a country with a large population, China’s food security must be firmly controlled at all times. The research of this paper consists of three parts: first, this paper analyzes the spatial-temporal evolution of patterns of soybean production from 1949 to 2019; second, this paper analyzes the spatial-temporal evolution of comparative advantages in soybean production and its spatial agglomeration characteristics; third, this paper provides relevant policy implications based on the research results. The objective of this paper is to
provide a means to optimize the layout of soybean production and alleviate the structural contradictions of food security in China.

The remainder of the paper is organized as follows. Section 2 introduces the data sources and methods used. Section 3 describes the spatial-temporal evolution of patterns of soybean production and the spatial-temporal evolution of the comparative advantages of soybean production and its spatial agglomeration characteristics. Section 4 presents a discussion of the results and limitations of this study. Finally, Section 5 provides the research conclusions and policy implications.

2. Data Sources and Methods

2.1. Data Sources

A total of 31 provinces of China were selected as the study area (excluding Hong Kong, Macao, and Taiwan). Statistical and raster data were used. Statistical data used include panel data on soybean and grain crop yields, sown area, and production in 31 provinces in China from 1949 to 2019. Data were drawn from the official website of the National Bureau of Statistics (https://data.stats.gov.cn/index.htm, accessed on 20 December 2020). As raster data, we used data on China’s cropland potential productivity (CPP) in 2010 from the Resource and Environment Science and Data Center, Chinese Academy of Sciences (https://www.resdc.cn/data.aspx?DATAID=261, accessed on 22 April 2022). The CPP data are based on China’s cultivated land distribution, soil, and DEM data from the Global Agro-Ecological Zones model, comprehensively considering light, temperature, water, CO2 concentration, pests and diseases, agroclimatic restrictions, soil, terrain, etc. Using 1949 as the starting point, and 10-year intervals, this paper analyzed the characteristics of the spatial-temporal patterns of soybean production and sown areas and the comparative advantages of the planting efficiency and planting scale in China over eight periods.

To measure the differences in patterns of soybean production on a regional scale, China was divided into nine agricultural zones (Figure 1): the Northeast China Plain (NECP, including Heilongjiang, Jilin, and Liaoning), the Northern arid and semi-arid region (NASR, including Inner Mongolia, Ningxia, Gansu, and Xinjiang), the Huang-Huai-Hai Plain (HHHP, including Beijing, Tianjin, Hebei, Shandong, and Henan), the Loess Plateau (LP, including Shanxi and Shaanxi), the Middle-Lower Yangtze Plain (MLYP, including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, and Hunan), the Sichuan Basin and surrounding regions (SBSR, including Chongqing and Sichuan), the Yunnan-Guizhou Plateau (YGP, including Yunnan, Guizhou, and Guangxi), Southern China (SC, including Fujian, Guangdong, and Hainan), and the Qinghai Tibet Plateau (QTP, including Qinghai and Tibet).

![Figure 1. Spatial distribution map of CPP in China.](image-url)
2.2. Methods

2.2.1. Coefficient of Variation Method

The coefficient of variation method can eliminate the influence of different units and average values on results and is widely used in the analysis of spatial differences within a geographical community [30]. The spatial variations in the soybean yield, production, and sown areas in China were analyzed by calculating the coefficient of variation over different periods. The established equations are given as follows:

\[ CV = \frac{\sigma}{\mu} \]  

(1)

where \( CV \) is the coefficient of variation, \( \sigma \) is the standard deviation, and \( \mu \) is the mean.

2.2.2. Comparative Advantage Model

The soybean yield level and planting area are the results of the interactions between the regional agricultural natural resource endowment, socioeconomic and local conditions, planting system, and market demand. The soybean yield and sown area were chosen as factors of the comparative advantages of soybean cultivation efficiency and scale, respectively, in each province. The established equations are given as follows:

\[ SAI_{ij} = \frac{s_{ij}}{s_i} / \frac{s_j}{s} \]  

(2)

\[ EAI_{ij} = \frac{t_{ij}}{t_i} / \frac{t_j}{t} \]  

(3)

where \( i \) and \( j \) denote province \( i \) and crop \( j \), respectively; \( s_{ij} \) and \( s_j \) denote the planting area of crop \( j \) in province \( i \) and China, respectively; \( s_i \) and \( s \) denote the planting area of all grain crops in province \( i \) and China, respectively; \( t_{ij} \) and \( t_j \) denote the yields of crop \( j \) in province \( i \) and China, respectively; \( t_i \) and \( t \) denote the yields of all grain crops in province \( i \) and China, respectively; and \( SAI_{ij} \) and \( EAI_{ij} \) denote the comparative advantages of the planting scale and efficiency, respectively, of crop \( j \) in province \( i \).

2.2.3. Spatial Autocorrelation Model

The spatial autocorrelation model usually includes global and local spatial autocorrelation aspects. Global spatial autocorrelation determines whether aggregation exists in the spatial distribution of the comparative advantages of soybean planting scales and the efficiency of various provinces. Local spatial autocorrelation determines the state of the spatial agglomeration or dispersion based on the similarities in values across provinces. The established equations are given as follows:

\[ Global \text{ Moran’s I} = \frac{n}{s^2} \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(x_j - \bar{x}) } \]  

(4)

\[ Local \text{ Moran’s I} = \frac{n(x_i - \bar{x}) \sum_{j=1}^{n} W_{ij}(x_j - \bar{x}) }{ \sum_{i=1}^{n} (x_i - \bar{x})^2 } \]  

(5)

where Global Moran’s I is the global spatial autocorrelation index; Local Moran’s I is the local spatial autocorrelation index; \( n \) is the number of provinces; \( x_i \) and \( x_j \) denote the attribute values of a certain element in provinces \( i \) and \( j \) (\( i \neq j \), respectively; and \( W_{ij} \) is the spatial weight matrix. The value range of the Global Moran’s I index is \([-1, 1]\). When the significance level is provided, if the Global Moran’s I index value is significantly
positive, this indicates a spatially significant clustering of regions with large (small) values of the comparative advantages of soybean planting efficiency or comparative advantages of the soybean planting scale. Conversely, if Global Moran’s I is significantly negative, this indicates significant spatial differences in the comparative advantages of soybean planting efficiency or soybean planting scale between a specific region and its neighbors. If Global Moran’s I = 0, no spatial correlation occurs.

2.2.4. Contribution Model

The interannual variation in soybean production is the result of the combined effect of the interannual variation in the soybean sown area and soybean yield. Therefore, the contribution model is used to determine the contribution of the soybean sown area and yield to production. The established equations are given as follows:

\[ A_c = \frac{(A_j - A_i) \cdot Y_i}{P_j - P_i} \]  \hspace{1cm} (6)

\[ Y_c = \frac{(Y_j - Y_i) \cdot A_i}{P_j - P_i} \]  \hspace{1cm} (7)

where \( A_c \) is the area contribution (%); \( Y_c \) is the yield contribution (%); \( A_i \) and \( A_j \) represent the soybean sown area in year \( i \) and \( j \) \((j > i)\), respectively; \( Y_i \) and \( Y_j \) represent the soybean yield in year \( i \) and \( j \), respectively; and \( P_i \) and \( P_j \) represent the soybean production in year \( i \) and \( j \), respectively.

3. Results

3.1. Spatial-Temporal Evolution of Production Pattern of Soybean

Changes in the soybean sown area, production, and yield over the past 71 years in China are shown in Figure 2. The soybean yield increased from 614 kg/ha in 1949 to 1937 kg/ha in 2019 at an average annual growth rate of 3.08%. The increase in soybean yield is attributed to improved cultivars, increased application of fertilizers, improved cultural practices, better pest/weed control, and the rapid adoption of technologies by producers [2]. China’s soybean production and yield changes remained consistent and exhibited a fluctuating upwards trend over the past 71 years. Soybean total production increased from 5.11 million tons (Mt) in 1949 to 18.08 Mt in 2019, at an average annual growth rate of 3.63%. The soybean sown area grew from 8.32 million hectares (Mha) in 1949 to 9.33 Mha in 2019, but the sown average annual growth rate reached only 0.17%, with dramatic fluctuations. Affected by high-quality and low-priced imported soybeans, the soybean sown area in China rapidly decreased from 9.48 Mha in 2001 to 6.83 Mha in 2015, reaching almost the lowest value in 71 years. To control the rapid decline in the soybean sown area, the Chinese government started pilot projects involving soybean target price subsidies in the NECP and Inner Mongolia in 2014; began to promote the corn–soybean rotation system in the NECP in 2016; and launched a soybean revitalization plan in the NECP, HHHP, and Southwest China in 2019. These policies have increased the willingness of soybean farmers to amplify the soybean sown area, facilitating an expansion in the area [31].

The coefficients of variation of soybean production, sown area, and yield in China from 1949 to 2019 are listed in Table 1. Among the coefficients of variation of the soybean sown area, production, and yield, the soybean sown area was the biggest in 1949, 2009, and 2019; the soybean yield was the biggest in 1959; and soybean production was the biggest in 1969, 1979, 1989 and 1999. This indicates that the spatial differences in the soybean yield, production and sown area in China from 1949 to 2019 experienced a process dominated by an area-yield-production-production-production-production-area-area pattern. The soybean yield rapidly increased amid improved soybean varieties, increased application of chemical fertilizers, and enhanced mechanization levels. Under the cumulated influence of the dual factors of soybean yield and sown area, the spatial differences in soybean
cultivation in China experienced a process dominated by production from 1969 to 1999, and the coefficient of variation of soybean production continued to boost. With what can be achieved with the existing level of scientific and technological development, the increase in soybean yield was limited, and the national level relatively remained constant. Under the influence of national soybean support policies, the sown area in the main soybean-producing region has increased rapidly, and the differences among the various provinces of China are significant [32]. Therefore, among the variation coefficients of the soybean sown area, production, and yield, the spatial difference in the soybean sown area was the greatest in 2009 and 2019.

![Figure 2. Changes in the soybean sown area, production, and yield in China from 1949 to 2019.](image)

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>1.46</td>
<td>1.46</td>
<td>1.46</td>
<td>1.51</td>
<td>1.58</td>
<td>1.73</td>
<td>2.20</td>
<td>2.39</td>
</tr>
<tr>
<td>Sown area</td>
<td>1.50</td>
<td>1.29</td>
<td>1.33</td>
<td>1.46</td>
<td>1.57</td>
<td>1.52</td>
<td>2.46</td>
<td>2.54</td>
</tr>
<tr>
<td>Yield</td>
<td>0.50</td>
<td>1.61</td>
<td>0.76</td>
<td>0.76</td>
<td>0.47</td>
<td>0.41</td>
<td>0.76</td>
<td>0.52</td>
</tr>
</tbody>
</table>

China’s soybean production increased by a net amount of 12.97 Mt from 1949 to 2019, with significant variation across the nine agricultural zones (Figure 3). Soybean production in the NASR, SBSR, and NECP showed rapid growth, with average annual growth rates of 33.54%, 8.23%, and 5.38%, respectively. Soybean production in the YGP and MLYP slowly increased to 0.8 and 2.6 Mt, respectively, and production remained stable. Soybean production in the SC began to nosedive after a gradual increase from 0.09 Mt in 1949 to 0.4 Mt in 1999, decreasing to 0.19 Mt in 2019. Soybean production for the LP, HHHP, and QTP fluctuated at approximately 0.5 Mt, 2 Mt, and 1000 t, respectively.
The soybean sown area in China slowly increased by 1.01 Mha from 1949 to 2019, with significant variation across the nine agricultural zones (Figure 4). The soybean sown area in the NASR, SBSR, NECP, and YGP exhibited positive growth, increasing by 1.13, 0.27, 2.52, and 0.22 Mha, respectively. The NECP remained the main soybean-producing area in China, and the soybean sown area significantly increased with the proportion of the soybean sown area to the total land area of China increasing from 26.28% to 50.45%. At the same time, the soybean sown area in the NASR rapidly expanded at an average annual growth rate of 10.83%. Moreover, the soybean sown area in the YGP underwent a slowly fluctuating upwards trend with an annual growth rate of 1.27%. On the contrary, the soybean sown area in the MLYP, SC, LP, and HHHP exhibited a downward trend, decreasing by 0.1, 0.08, 0.19, and 2.76 Mha, respectively. The soybean sown area of the HHHP dropped at a higher rate, with an average annual growth rate of −1.15%, and the proportion of soybean sown areas in China declined from 41.33% to 7.27%. This downturn can mainly be attributed to the lesser benefits, and more notably, to the extending return gaps than those of corn production [10].

**Figure 3.** Changes in soybean production in the nine agricultural zones of China from 1949 to 2019.

**Figure 4.** Cont.
Anhui achieved comparative advantages in soybean planting efficiency in 2009 (Figure 5g). Jiangsu, Zhejiang, Anhui, Fujian, Hubei, and Sichuan experienced a process from scratch, proportionately diminishing their advantages and gaps from 1949 to 1989. From 1979 to 1999, the comparative advantages of soybean planting efficiency in Henan, Jiangsu, Zhejiang, Fujian, Hubei, and Sichuan have gradually extended across China. All provinces in China, except Jilin, Beijing, Tianjin, Ningxia, Shanxi, Heilongjiang, and Anhui, achieved comparative advantages in soybean planting efficiency in 2009 (Figure 5g). Only five Chinese provinces, namely, Hebei, Guizhou, Guangxi, Jilin, and Anhui, did not achieve comparative advantages in soybean planting efficiency in 2019 (Figure 5h). The soybean yield in the SC and HHHP regions was high, reaching 2794.12 and 2566.37 kg/ha, respectively, reaching levels much higher than the national average of 1937.41 kg/ha.

Provinces with comparative advantages in soybean planting scales in China, from 1949 to 2019, were mainly located in the NECP, HHHP, and MLYP regions (Figure 6). The spatial evolution of the comparative advantages in soybean planting scales can be divided into three stages. From 1949 to 1989, comparative advantages in soybean planting scales in China exhibited the spatial characteristics of steady expansion, spreading from seven provinces in 1949 to nine provinces in 1989 (Figure 6a–e). Heilongjiang, Jilin, and Liaoning in the NECP and Henan in the HHHP have consistently maintained their comparative advantages. The proportion of the soybean sown area in the NECP grew from 26.28% to 39.24% with a net growth increase of 0.98 Mha. From 1989 to 1999, the spatial distribution of the comparative advantages in soybean planting scales in China remained relatively stable (Figure 6e,f). Provinces with comparative advantages in soybean planting scales in 1999 include the NECP, Inner Mongolia, Tianjin, Shanxi, Anhui, and Guangxi. From 1999 to 2019, comparative advantages in soybean planting scales in China contributed to a spatial contraction and stabilization (Figure 6f–h). Liaoning, Tianjin, Shanxi, Guangxi, and Jilin lost their comparative advantages in soybean planting scales. Only four provinces exhibited comparative advantages in soybean planting scales in 2019, i.e., Inner Mongolia, Heilongjiang, Anhui, and Zhejiang, and their spatial distribution tended to remain stable.
The spatial distribution of the comparative advantages in soybean planting scale saw a spatial agglomeration strengthening‐weakening‐strengthening‐weakening process.

Figure 5. Spatial distribution of the comparative advantages in soybean planting efficiency in China from 1949 to 2019.

Figure 6. Spatial distribution of comparative advantages in soybean planting scales in China from 1949 to 2019.
To explore the spatial pattern differentiation characteristics of the comparative advantage of soybean cultivation, we used Geoda software to calculate the Global Moran’s index. The first step was to create a weight file, the second step was to set the weight file, and the Rook spatial adjacency weight matrix with common boundaries was selected. The third step was to calculate the Global Moran’s I index of soybean planting efficiency and scale. The Global Moran’s I index and related indicators for the comparative advantages of soybean planting efficiency and scale over the eight periods are shown in Table 2. The Global Moran’s I index of soybean planting efficiency in 1949, 1959, 1989, 1999, and 2009 was higher than 0 and satisfies the requirements of the significance level test, indicating that the comparative advantages of soybean planting efficiency during these five periods revealed certain clustering characteristics in terms of spatial distribution. Similarly, the comparative advantages of soybean planting scales for these eight periods were spatially clustered. The Global Moran’s I index and Z values underwent an increase-decrease-increase-decrease process, and the comparative advantages of the soybean planting scale saw a spatial agglomeration strengthening-weakening-strengthening-weakening process.

Table 2. Change in the Global Moran’s I index of comparative advantages in soybean planting efficiency and scale in China from 1949 to 2019.

<table>
<thead>
<tr>
<th>Types</th>
<th>Year</th>
<th>Moran’s I</th>
<th>Z</th>
<th>p</th>
<th>Types</th>
<th>Year</th>
<th>Moran’s I</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparative advantages of</td>
<td>1949</td>
<td>0.4698</td>
<td>4.0965</td>
<td>0.0010***</td>
<td>Comparative advantages of</td>
<td>1949</td>
<td>0.3312</td>
<td>3.1188</td>
<td>0.0080***</td>
</tr>
<tr>
<td>soybean planting efficiency</td>
<td>1959</td>
<td>0.3988</td>
<td>3.5324</td>
<td>0.0020***</td>
<td>soybean planting scale</td>
<td>1959</td>
<td>0.4538</td>
<td>4.2601</td>
<td>0.0010***</td>
</tr>
<tr>
<td>1969</td>
<td>0.0506</td>
<td>0.9904</td>
<td>0.1420</td>
<td></td>
<td>1969</td>
<td>0.3660</td>
<td>3.4813</td>
<td>0.0030***</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>0.1498</td>
<td>1.4296</td>
<td>0.0770</td>
<td></td>
<td>1979</td>
<td>0.2153</td>
<td>2.6390</td>
<td>0.0180**</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>0.2017</td>
<td>1.9674</td>
<td>0.0350**</td>
<td></td>
<td>1989</td>
<td>0.3071</td>
<td>3.5760</td>
<td>0.0010***</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>0.1592</td>
<td>2.0447</td>
<td>0.0460**</td>
<td></td>
<td>1999</td>
<td>0.3484</td>
<td>4.0114</td>
<td>0.0010***</td>
<td></td>
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<tr>
<td>2009</td>
<td>0.2091</td>
<td>2.0315</td>
<td>0.0260**</td>
<td></td>
<td>2009</td>
<td>0.2987</td>
<td>3.8615</td>
<td>0.0030***</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>-0.1764</td>
<td>-0.2237</td>
<td>0.0990</td>
<td></td>
<td>2019</td>
<td>0.2153</td>
<td>2.6390</td>
<td>0.0180***</td>
<td></td>
</tr>
</tbody>
</table>

Note: ** and *** indicate that the Global Moran’s I index is significant at the 5% and 1% levels, respectively.

According to the spatial distribution map of the comparative advantages of soybean planting efficiency (Figure 7), the high–high spatial aggregation areas in 1949 occurred in the NECP, LP, NASR, and HHHP, i.e., Heilongjiang, Jilin, Liaoning, Inner Mongolia, Ningxia, Gansu, Shaanxi, Shanxi, and Hebei. The low–low spatial aggregation areas included Yunnan and Guizhou in the YGP and Hunan (Figure 7a). The spatial distribution of low–low aggregation areas in 1959 is consistent with that in 1949, while the high–high aggregation areas included the NECP and Inner Mongolia (Figure 7b). In 1989, Xinjiang was a high–high aggregation area, while low–low areas shifted from the YGP to the MLYP, including Yunnan, Hubei, and Hunan (Figure 7c). In 1999, the soybean planting efficiency cluster exhibited aggregation with high–high aggregation areas remaining in Xinjiang, low–low aggregation areas remaining in Hunan, and Beijing becoming a high–low aggregation area (Figure 7d). In 2009, Fujian was a high–high aggregation area, and Tibet was a low–high aggregation area (Figure 7e).

According to the spatial distribution map of the comparative advantages of the soybean planting scale (Figure 8), the spatial distribution of the comparative advantages of the soybean planting scale from 1949 to 1979 was relatively similar, with the high–high aggregation areas mainly occurring in Heilongjiang and Jilin; low–high aggregation areas remaining in Inner Mongolia; low–low aggregation areas, which were largely located in Xinjiang, Sichuan, Guizhou, and Hunan (Figure 8a–d). In 1989, the high–high aggregation areas included Heilongjiang, Jilin, and Inner Mongolia while Tibet became a high–low aggregation area and only Guizhou was a low–low aggregation area (Figure 8e). High–high aggregation areas in 1999 were the same as those in 1989, while the low–low aggregation areas included Xinjiang, Tibet, and Sichuan (Figure 8f). Aggregation areas in 2009 and 2019 remained consistent, with Heilongjiang and Jilin identified as high–high aggregation areas and Xinjiang was identified as a low–low aggregation area (Figure 8g,h), indicating that
the aggregation areas of the comparative advantages of soybean planting scales basically formed a highly stable state in recent years.

**Figure 7.** Local indicator of spatial association (LISA) aggregation map of the comparative advantages of soybean planting efficiency in China.

**Figure 8.** LISA aggregation map of the comparative advantages of soybean planting scale in China.
4. Discussion

The soybean yield is the main contributor to soybean production. From 1949 to 2019, soybean production in China was mainly affected by soybean yields; the contribution of the soybean yield was as high as 95.21%, and the contribution of the soybean sown area was only 4.79% (Table 3). However, there were differences in the dominant contributors to soybean production in different periods. In 1959–1979 and 1999–2009, the soybean sown area was the dominant contributor to soybean production; in 1949–1959, 1979–1999, and 2009–2019, the soybean yield was the dominant contributor to soybean production. According to USDA data, soybean yields in the United States and Brazil reached 3190 kg/ha and 3480 kg/ha, respectively, in 2019, however, China’s soybean yield was only 1937 kg/ha in 2019. In the future, China needs to further improve soybean breeding technology, the quality of soybean fields, and farmland infrastructure to boost soybean yields and continue to narrow the yield gap between China and major soybean-producing countries [12].

Table 3. Contributions of soybean sown area and yield to soybean production from 1949 to 2019.

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<tbody>
<tr>
<td>Area contribution (%)</td>
<td>25.71</td>
<td>122.65</td>
<td>636.69</td>
<td>31.18</td>
<td>−2.98</td>
<td>265.20</td>
<td>−0.39</td>
<td>4.79</td>
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<tr>
<td>Yield contribution (%)</td>
<td>74.29</td>
<td>−22.65</td>
<td>−536.69</td>
<td>68.82</td>
<td>102.98</td>
<td>−165.20</td>
<td>100.39</td>
<td>95.21</td>
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</table>

The patterns of soybean production are affected by multiple factors, such as natural resource endowments, economic development levels, soybean imports, and national policies. Soybean crops are highly adaptable to the natural environment, however natural conditions, such as climate, temperature, and soil conditions have a profound impact on the yield and quality of soybeans [33]. The NECP and HHHP present obvious comprehensive advantages in soybean production. The rapid development of the economy, the optimization of the dietary structure of urban and rural residents, and the increasing demand for meat, eggs, and milk have led to an acceleration in the consumption of feed grains, and such consumption has had a positive effect on soybean production [1]. Soybean yield in China is far lower than the levels in the United States and Brazil. Amid rising prices of agricultural production factors, domestic soybeans have no price advantage in the international market; the enthusiasm of farmers to plant soybean crops has dimmed; and the soybean planting area has been superseded by crops yielding more income, such as corn and rice [6]. In general, the soybean sown area in China is negatively related to soybean imports. In addition, national policies also affect patterns of soybean production. China has formulated a series of policies, including a soybean revitalization plan, however, it focuses on the NECP, HHHP, and southwestern China, resulting in an accumulation of soybean production space in these areas [34]. Therefore, the influencing factors of patterns of soybean production vary in different periods.

Grain imports have caused a deterioration of ecological environments, both for importing and exporting countries. To promote global sustainable development, grain importing countries can alleviate domestic grain shortages as well as exporting countries’ resourcing and environmental problems by optimizing the spatial distribution of domestic grain to increase production and reduce resource and environmental consumption. This paper only qualitatively analyzed the influencing factors of patterns of soybean production, and quantitative analysis should be conducted in the future. In addition, county-scale soybean production data should be obtained to conduct more refined research in the future.

5. Conclusions and Policy Implications

5.1. Conclusions

The soybean sown area has not varied considerably, however, spatial patterns of soybean planting underwent tremendous changes from 1949 to 2019. The NECP is the main soybean-producing area, and its main position has strengthened. The NASR, SBSR, MLYP,
and YGP regions have become new growth poles in terms of total soybean production, and soybean production in the HHHP region has decreased.

The spatial-temporal differentiation characteristics of the comparative advantages of soybean planting efficiency over the past 71 years can be divided into three stages: those concentrated in northern China from 1949 to 1979, those concentrated in the MLYP region from 1979 to 1999, and those spread across China from 1999 to 2019. The spatial-temporal differentiation characteristics of the comparative advantages in soybean planting scale over the past 71 years can also be divided into three stages: steady expansion from 1949 to 1989, relatively stable spatial distribution from 1989 to 1999, and spatial contraction and stabilization from 1999 to 2019.

The spatial distribution of the comparative advantages in soybean planting efficiency in 1949, 1959, 1989, 1999, and 2009 exhibited the characteristics of agglomeration. From 1949 to 2019, comparative advantages in soybean planting scales showed characteristics of spatial agglomeration, which involved a dynamic strengthening-decreasing-strengthening-decreasing change process. Currently, Heilongjiang and Jilin, in the NECP region, are high–high aggregation areas with comparative advantages in their soybean planting scales, and Xinjiang is a low–low aggregation area.

This paper illustrates the spatial-temporal evolution of the patterns of soybean production and the spatial-temporal evolution of the comparative advantages in soybean production and its spatial agglomeration characteristics. The results can guide China in formulating a food security strategy. Optimizing the spatial layout of soybean planting according to the comparative advantages of soybean planting efficiency; determining key areas for soybean planting subsidies based on the comparative advantage of the soybean planting scale; considering the spatial distribution of China’s soybean industry chain according to the agglomeration characteristics of the comparative advantage in soybean planting scale, thus, alleviating the national soybean shortage problem. This paper can also guide China in formulating grain security strategies in the context of the COVID-19 pandemic, major power games, and extreme climate disasters.

5.2. Policy Implications

The comparative advantages of soybean planting efficiency in SC and MLYP should be fully exploited. Li et al. [35] calculated the rate of cultivated land abandonment in mountainous counties in China from 2014 to 2015, which reached 14.32%, with abandonment rates reaching 34.03% in Jiangxi; 20–30% in Sichuan, Zhejiang, and Hunan; and 10–20% in Fujian, Guangdong, and Hainan. More than 30% of all plots have been abandoned in southwestern China since 1992 [36], 10.45% of all cropland in the Guizhou-Guangxi karst mountain area has been abandoned since 2001 [37], and 5.35% of all croplands have been abandoned in Sichuan Province [38]. Cropland abandonment totalled approximately 43.12 Mha and mainly occurred in the Northern China Plain and Sichuan Plain during the 1990–2010 period [39]. Zhang et al. [40] reported that counties with cropland abandonment from 1992 to 2017 were concentrated in SC. Provinces with high rates of cropland abandonment in China are high-value areas in terms of soybean yield and achieve comparative advantages in soybean planting efficiency. However, the current agricultural planting structure ignores the remarkable potential to achieve increased soybean production on abandoned cropland in SC and MLYP. Therefore, it is necessary to fully utilize the abandoned croplands in SC and MLYP to grow soybeans, obtain regional comparative advantages in soybean planting efficiency, expand the soybean sowing area, and develop the MLYP as a new growth pole for soybean production, centered in Anhui and Jiangsu; thereby increasing soybean production and self-sufficiency in China.

Grain–soybean rotation should be promoted in the HHHP and NECP. The HHHP was historically the main soybean-producing region in China. From 1949 to 1979, Shandong and Henan exhibited comparative advantages in soybean planting scales. However, with the increasing sown area for wheat and corn, the proportion of the soybean sown area in the HHHP region decreased from 41.33% to 7.27%, while soybean production fell from 34.99%
to 9.62% in China between 1949 and 2019. The HHHP has no longer exhibited comparative advantages in scale since 1999 but remains a high-value area in terms of soybean yield and exhibits comparative advantages in soybean planting efficiency, with water resources being the main restraint on food production in the region [41,42]. Within the context of fallow cropland, the sown area of water-consuming crops, such as wheat, should be trimmed down and replaced with soybean or corn–soybean rotation cultivation land, in accordance with local conditions [43–45], to gradually restore the main soybean production area, reduce groundwater consumption in the region and fully utilize the comparative advantages in soybean planting efficiency in the HHHP region. The black soil layer in the Northeast Plain has been skimmed for more than 71 years since reclamation [46], and the organic matter content has decreased by 4–7% below the levels at the beginning of reclamation. With the rapid expansion of rice cultivation [29], water scarcity has also alarmingly emerged, posing a serious threat to food security in China [47]. From 2009–2019, Heilongjiang and Liaoning in the NECP region exhibited comparative advantages in soybean planting efficiency. In the future, corn–soybean rotation in the NECP should be vigorously promoted to exploit the comparative efficiency of regional soybean cultivation and the role of soybean crops in nitrogen fixation. Simultaneously, the application of cropland quality improvement projects in the region should be encouraged to progressively improve soil fertility and increase the supply of high-quality soybean crops.

The soybean planting subsidy system should be reinforced. To become a World Trade Organization (WTO) member, China reduced tariffs on imported soybeans from 130% to 3% in 1995 [48]. Since domestic soybeans did not have a price advantage over foreign high-quality and inexpensive genetically modified soybeans, the domestic soybean market has been continuously occupied by imported soybeans [49]. To this end, the No. 1 Central Document of 2014 reported that a pilot project of soybean target price subsidies in the NECP and Inner Mongolia was launched. However, with the rise in the price of soybean production factors and the high cost of domestic soybean production, the actual profits of soybean planting lowered from 435.44 yuan in 2012 to 157.46 yuan in 2018. When considering labour and land costs, the net profit of soybean planting in 2018 reached –192.04 yuan. In addition, soybean production suffers negative impacts from extreme climate hazards and crop pests [50,51]. In 2019, the soybean planting area in Heilongjiang, Inner Mongolia, and Anhui accounted for 57.17% of the total area of China, and soybean production accounted for 61.01% of the total production in China. In addition, Heilongjiang and Inner Mongolia exhibited comparative advantages in soybean planting efficiency and scale. Therefore, it is necessary to focus on increasing subsidies for soybean planting in the region, increasing subsidies for agricultural insurance premiums, and increasing the amount of insurance compensation to enhance incomes; therefore, encouraging farmers to plant soybean crops and stabilize the planting area and production of the main soybean-producing region in China.

A complete soybean industry chain should be created in areas with comparative advantages in soybean planting scale abilities. From 1949 to 2019, the center of soybean production moved 335.89 km along the direction of 89.59° northeast, and the center of gravity of the soybean sown area moved 467.21 km along the direction of 77.41° northeast. At present, Heilongjiang and Jilin form a high–high cluster area with comparative advantages in the soybean planting scale, and it is necessary to fully utilize these advantages to implement major joint soybean research, accelerate the application of biotechnology to soybean breeding, and upgrade the breeding capacity of soybean seeds. Moderate-scale operation activities of soybean crops in the region should be accelerated with a focus on cultivating and supporting a number of soybean planting cooperatives, large producers, family farms, and other new business entities to promote large-scale operations. A soybean industry chain integrating soybean breeding, production, processing, and marketing should be established in the NECP region, Inner Mongolia, and Anhui to raise the market competitiveness of Chinese soybeans.
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References
10. Zhang, Z.; Lu, C. Clustering Analysis of Soybean Production to Understand its Spatiotemporal Dynamics in the North China Plain. Sustainability 2020, 12, 6178. [CrossRef]
12. Liu, S.; Zhang, P.Y.; Marley, B.; Liu, W. The factors affecting farmers’ soybean planting behavior in Heilongjiang Province, China. Agriculture 2019, 9, 188. [CrossRef]
17. Zhao, J.; Wang, C.; Shi, X.; Bo, X.; Li, S.; Shang, M.; Chen, F.; Chu, Q. Modeling climatically suitable areas for soybean and their shifts across China. Agric. Syst. 2021, 192, 103205. [CrossRef]


37. Han, Z.; Song, W. Spatiotemporal variations in cropland abandonment in the Guizhou–Guangxi karst mountain area, China. J. Clean Prod. 2019, 238, 117888. [CrossRef]


