Study on regional characteristics of soybean production in China from a temporal and spatial perspective

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Abstract. Being the country of origin of soybean, China was once the biggest producer of the world, and has become the largest importer by now. Various regions of China are seeing profound changes of soybean production. By analyzing the changes of soybean producing areas in China from 1978 to 2017, this article revealed the characteristics of soybean’s spatial variation in terms of the planting area and yield per unit area in the four decades in China and comprehensively explained the present situation and future potential growth of soybean production in China based on soybean growth characteristics and the resources in various regions. The results show that: (1) Since the Reform and Opening Up, the traditional main producing areas still maintain their principal part but show certain changes of geographical distribution; (2) The regional distribution of soybean production shows an overall trend of “concentrated over vast areas and dispersed in small areas”; (3) The planting areas of soybean are increasing steadily in Heilongjiang, Inner Mongolia, Jilin, He'nan and Anhui, while those are decreasing rapidly in Huang-Huai-Hai area and the southern area.

1. Introduction
Soybean’s home is in China, one of the most nutritious crops [1], which plays a primary part in the dietary structure of China. Soybean production in China has been constantly developing since the founding of new China. The planting area of soybean was 8.33 million hectares and the average yield per hectare was 600 kg in 1949, which have respectively grown to 9.35 million hectares by 12.2% and 1,935 kg by 222.5% by 2019. Soybean is now planted in all provinces, cities and autonomous regions except Qinghai of China, but is mainly produced in the eastern area, particularly the three provinces of northeast, the eastern area of Inner Mongolia and provinces in Huang-Huai-Hai area [2]. The planting area and yield per unit area of soybean in various areas of China have been exposed to constant changes after the implementation of the Reform and Opening Up [3].

In the 1980s, Sun Yuting et al. studied agroclimatic division in Heilongjiang Province to figure out the rational distribution of corn, soybean and wheat according to the climatic conditions favorable for
soybean growth [4]. In the 1990s, Zhu Wenying et al. researched on the ecotype and ecological division of soybean in Zhejiang Province, according to the climatic conditions and the cropping system of Zhejiang Province [5]. By the end of the 20th century, Tian Peizhan investigated the division of soybean varieties in Jilin Province in details [6]. In the early 2000s, Wei Jianjun et al. explored the ecological division and adaption law of soybean, and discussed the regional division and introduction work of soybean seed, combining the climatic conditions of Xinjiang [7]. In 2008, the Ministry of Agriculture and Rural Affairs (hereinafter referred to as the Ministry of Agriculture) released The Latest Eight-Year Layout Plan of Soybean in China, which planned for the regional distribution, main direction and development goal of soybean in the future China in details [8]. In 2012, Yang Ruping et al. made a detailed study on the yield per unit area and yield-related traits of soybean in various science and technology demonstration counties in different regions of China [9]. In 2016, Hu Xingguo et al. thoroughly researched on the growth period grouping of different soybean varieties and the soybean planting division in Inner Mongolia Autonomous Region [10]. In 2019, Xue Zhidan et al. studied the regional division of soybean planting in Heilongjiang Province based on the data from Heilongjiang weather stations [11].

By analyzing the changes of the soybean producing areas in China from 1978 to 2017, this article revealed the characteristics of soybean’s spatial variation in terms of the planting area and yield per unit area in the four decades in China and comprehensively explained the present situation and future potential growth of soybean production in China, according to soybean growth characteristics and the resources in various regions. It also provided national-level suggestions on optimization of the soybean production structure in different provinces in China as a reference for policy making and scientific research.

2. Assessment index and method

The overall situation of soybean production in China is the sum of and depends on soybean production in different regions; while the productive potential of soybean in all these areas affects the future trend of soybean production in turn [12]. By using the panel data of different provinces from 1978 to 2017 and decomposing various elements of soybean production, this article statically and dynamically analyzed the present situation and future trend of the status changes of soybean producing areas in China as well as the reasons for the changes.

To study the changes of regional characteristics of soybean yield in China, the soybean production index was applied as the measurement index [13]. The soybean production index refers to the proportion of soybean yield of a certain area in the overall soybean yield of China in a certain year, which is denoted by $I_{ij}$:

$$I_{ij} = \frac{Q_{ij}}{Q_i} = \frac{Q_{ij}}{Q_{ij} + Q_{-ij}}$$

Where $i=1, 2, ..., 36$ respectively indicates a certain year between 1978 and 2017, and $j$ represents different regions, including 29 regions, municipalities directly under the Central Government and autonomous regions such as Beijing, Shanghai, Tianjin and Guangzhou. Considering the two changes in administrative divisions, which takes place between 1978 and 2017, this article calculated the data of Hainan Province and Chongqing respectively in Guangdong Province and Sichuan Province thus to assure the consistency of sample data. Therefore, $Q_{ij}$ represents the soybean yield of Province $j$ in China in the year $i$, while $Q_{-ij}$ denotes the soybean yield of the whole China except Province $j$ in the year $i$. In order to accurately measure the present soybean production capacity and the variation trend in all regions, this article will carry out linear regression of the soybean production index $I_{ij}$ and the time variable $t$. The regression equation is as follows:

$$I_{ij} = C + \alpha t$$

Where $t=1$ means the year of 1978, $t=2$ indicates 1979 and so on, so $t=36$ refers to 2017. The constant $C$ refers to the status of soybean production in different provinces and regions in China. $I_{ij}$ shows different goodness of fit in different regions, which can be evaluated jointly by $R^2$, $R^2$ after
adjustment and value $P$. A higher value of $R^2$ and a lower value of $P$ suggest a higher fitting degree, meaning a steadier change of the soybean production index, and vice versa. Hence the trend of the soybean yield change in all provinces and regions of China can be analyzed through the regression coefficient $\alpha$ and value $P$.

To further study the factors contributing to the change of the status of soybean production in China, we regarded the soybean yield in a province or region as the product of the soybean planting area and the yield per unit area. Here and subsequently, $M_{ij}$ and $N_{ij}$ respectively stand for the planting area and the yield per unit area of soybean in Province $j$ of China in the year $i$, so $Q_{ij} = M_{ij} \times N_{ij}$. Through the regression below, we could further analyze the factors contributing to the changes of soybean production in different regions of China in terms of the planting area and the yield per unit area.

$$M_{ij} = C_1 + \alpha_1 t$$

$$N_{ij} = C_2 + \alpha_2 t$$

Where $t=1, 2, \ldots, 36$ has the same meaning as above, the constants $C_1$ and $C_2$ denote the planting area and the yield per unit area of soybean in different provinces and regions, and $\alpha_1, \alpha_2$ and value $P$ jointly indicate the changes of the planting area and the yield per unit area in all provinces and regions of China.

3. Results and analysis

3.1. Regional characteristics of production

Through the above analysis, we acquired the regression result of the changes of the soybean production index $I_{ij}$ in various provinces of China from 1978 to 2017. The significance level represented the significance of the regression results. We kept the regression results that were not significant, because they could reveal the changing rules to a certain extent, but the degree of explanation was not high. We would take this factor into account in the results (see Table 1). We had drawn Figure 1 with Tableau software based on the regression constant, coefficient and value $P$ (We had to leave out the Nansha Islands in the figure in order to display the results clearly, but we declare that the Nansha Islands constitute an indispensable part of China. The same applies to the figures below). From a static perspective, the status of soybean production in all provinces and regions of China could be concluded from the regression constant $C$. The regions with a higher value of $C$ included Shandong(16.09%), Heilongjiang(14.78%), Jilin(12.51%), Henan(12.12%), Liaoning(8.74%), Jiangsu(6.65%), Anhui(6.32%), Hubei(5.75%), Shanxi(2.83%), Shanxi(2.51%), Sichuan(1.4%), Zhejiang(1.2%), Jiangxi(1.16%) and Guizhou(1.05%). These provinces and regions, excluding uJiang, have been all major soybean producers in China with an average soybean production index above 5%, and played an important part in assuring the soybean supply of China. Regions with a lower soybean production index mainly included Hainan(0.01%), Inner Mongolia(0.01%), Xinjiang(0.01%), Xizang(0.03%), Tianjing(0.13%), Chongqing(0.14%), Shanghai(0.26%), Ningxia(0.29%), Gansu(0.40%), Yunnan(0.44%), Guangxi(4.7%), Beijing(0.55%), Fujian(0.56%), Guangdong(0.65%) and Hunan(0.86%). The index of these soybean producing areas was smaller than 1%, suggesting their low status in soybean production in China.
From a dynamic perspective, we could classify the changes of the status of soybean production in all provinces and regions from 1978 to 2017 into four groups according to the regression coefficient $\alpha$ and the value $P$. The first group was the 11 provinces or regions showing steady rise ($\alpha > 0$ and $P = 0.0000$), respectively Heilongjiang, Inner Mongolia, Sichuan, Hunan, Guangxi, Xinjiang, Chongqing, Jiangxi, Gansu, Guangdong and Fujian, which were arranged in a descending order based on the growth rate. All these regions saw a soybean production index rising ($\alpha > 0$) in a steady manner ($P = 0.0000$), including both the major soybean producing provinces such as Heilongjiang, Inner Mongolia and the non-major soybean producing areas such as Xinjiang, Tibet and Gansu. The second group refered to the 12 regions with a steady decline ($\alpha < 0$ and $P = 0.0000$), respectively Shandong, Liaoning, Jilin, Henan, Jiangsu, Hebei, Shanxi, Hubei, Beijing, Shanghai and Ningxia, which were arranged in a descending order based on the decline rate. This group consisted of both

Table 1. Regression results of the grain production index $I_i$ of all provinces in China from 1978 to 2017.

| Provinces    | Regression Equation | $R^2$   | Adjusted $R^2$ | P-values | Significant Levels |
|--------------|---------------------|---------|----------------|----------|--------------------|
| BeiJing      | $I_i=0.0055-0.00008t$ | 0.6288  | 0.6233         | 0.0000   | ***                |
| TianJin      | $I_i=0.0013+0.00003t$ | 0.0812  | 0.0675         | 0.0176   | **                 |
| HeBei        | $I_i=0.0575-0.00048t$ | 0.4049  | 0.3961         | 0.0000   | ***                |
| ShanXi       | $I_i=0.0283-0.00022t$ | 0.3669  | 0.3574         | 0.0000   | ***                |
| Inner Mongolia | $I_i=0.0001+0.00141t$ | 0.7412  | 0.7373         | 0.0000   | ***                |
| Liao Ning    | $I_i=0.0874-0.00141t$ | 0.7826  | 0.7793         | 0.0000   | ***                |
| Ji Lin       | $I_i=0.1251-0.00122t$ | 0.7803  | 0.7770         | 0.0000   | ***                |
| HeiLongjiang | $I_i=0.1478+0.00368t$ | 0.8675  | 0.8656         | 0.0000   | ***                |
| ShangHai     | $I_i=0.0026-0.00003t$ | 0.4005  | 0.3915         | 0.0000   | ***                |
| JiangSu      | $I_i=0.0065+0.00049t$ | 0.4570  | 0.4489         | 0.0000   | ***                |
| ZheJiang     | $I_i=0.0124+0.00002t$ | 0.0236  | 0.0090         | 0.2077   | -                  |
| AnHui        | $I_i=0.0632+0.00010t$ | 0.0125  | 0.0013         | 0.3611   | -                  |
| FuJian       | $I_i=0.0056+0.00007t$ | 0.2623  | 0.2513         | 0.0000   | ***                |
| JiangXi      | $I_i=0.0116+0.00008t$ | 0.2203  | 0.2087         | 0.0000   | ***                |
| ShanDong     | $I_i=0.1609-0.00208t$ | 0.8221  | 0.8194         | 0.0000   | ***                |
| HeNan        | $I_i=0.1212-0.00106t$ | 0.5437  | 0.5368         | 0.0000   | ***                |
| HuBei        | $I_i=0.0328-0.00017t$ | 0.1965  | 0.1846         | 0.0001   | ***                |
| HuNan        | $I_i=0.0086+0.00024t$ | 0.4490  | 0.4408         | 0.0000   | ***                |
| GuangDong    | $I_i=0.0065+0.00007t$ | 0.2340  | 0.2226         | 0.0000   | ***                |
| GuangXi      | $I_i=0.0047+0.00021t$ | 0.4440  | 0.4357         | 0.0000   | ***                |
| HaiNan       | $I_i=0.0001+0.00003t$ | 0.0804  | 0.0667         | 0.0182   | **                 |
| ChongQing    | $I_i=0.0014+0.00015t$ | 0.3154  | 0.3052         | 0.0000   | ***                |
| SiChuan      | $I_i=0.0140+0.00040t$ | 0.3756  | 0.3663         | 0.0000   | ***                |
| GuiZhou      | $I_i=0.0105+0.00001t$ | 0.0012  | 0.0003         | 0.7774   | -                  |
| YunNan       | $I_i=0.0044+0.00024t$ | 0.2902  | 0.2796         | 0.0000   | ***                |
| XiZang       | $I_i=0.0003+0.00001t$ | 0.0006  | 0.0001         | 0.8422   | -                  |
| ShanXi       | $I_i=0.0251-0.00008t$ | 0.0750  | 0.0591         | 0.0248   | **                 |
| GanSu        | $I_i=0.0040+0.00008t$ | 0.4969  | 0.4894         | 0.0000   | ***                |
| XinXia       | $I_i=0.0029-0.00002t$ | 0.2421  | 0.2307         | 0.0000   | ***                |
| XinJiang     | $I_i=0.0001+0.00019t$ | 0.7147  | 0.7105         | 0.0000   | ***                |

Note: There is no statistical analysis of soybean since no soybean is planted in Qinghai Province. *, **, ***, significant at $P<0.1$, $P<0.05$, and $P<0.01$, respectively. - indicates that the result is not significant.
major soybean producing areas such as Liaoning, Jilin, Henan and Shandong and major soybean selling areas such as Beijing and Shanghai, and also included both coastal areas and inland, which demonstrated that the soybean production capacity was declining in various regions of China. The third group was the province with a slight decrease ($\alpha < 0$ and $0 < P < 0.01$), and only Hubei falls into this group. Examining the long-term development trend, we could see that the soybean production index of Hubei has been declining ($\alpha < 0$), but its soybean production capacity only dropped in a weakly stable way ($0 < P < 0.01$). The fourth group comprised the provinces showing relative stability ($\alpha > 0$ or $\alpha < 0$ and $P > 0.01$), which included 5 regions, Shanxi, Tibet, Guizhou, Zhejiang, Hainan, Tianjin and Anhui. The soybean production index $I_{ij}$ in these regions showed insignificant correlation with the time variable ($P > 0.01$), suggesting a relatively stable status of soybean production [14].

![Figure 1. Dynamic changes of the soybean production index of various provinces, cities and autonomous regions of China since the founding of the People’s Republic of China.](image)

To sum up, the pattern of soybean production in various regions has been exposed to evident changes since the Reform and Opening up. The status of soybean production is rising in some regions, declining in some regions and remaining steady in some regions. With regard to the overall pattern of soybean production, the main force of soybean production is transferring from the center to the border, as the status of soybean production in the central and southern region is declining apparently, and the status of soybean production in the western and northeastern region is constantly strengthening [15]. The traditional regional division of soybean production, i.e. the classification of major producing provinces, major selling provinces and production-sale-balanced provinces, can no longer reflect the changes of the status of soybean production in all areas. Therefore, the current division needs to be further improved.

3.2. Regional characteristics of planting area

Through the above analysis, we could acquire the regression results of the changes of the soybean planting area $M_{ij}$ in various provinces of China from 1978 to 2017. The significance level represented
the significance of the regression results. We kept the regression results that were not significant, because they could reveal the changing rules to a certain extent, but the degree of explanation was not high. We would take this factor into account in the results (see Table 2). We had drawn Figure 2 with Tableau based on the regression constant, coefficient and value P. From a static perspective, the planting area of soybean in all provinces and regions of China could be concluded from the regression coefficient \( c_i \). The following provinces had a soybean planting area over 5,000 thousand hectares: Heilongjiang(1670.08), Henan(976.75), Shandong(697.58), Anhui(592.33), Jilin(590.09) and Liaoning(509.33), most of which also topped the list of the soybean production index. It demonstrated that the abundant planting area of soybean constituted a basic condition for assuring the soybean yield [16].

Table 2. regression results of the grain area index \( I_i \) of all provinces in China from 1978 to 2017.

| Provinces    | Regression Equation | \( R^2 \) | Adjusted \( R^2 \) | P-values | Significant Levels |
|--------------|---------------------|----------|---------------------|----------|-------------------|
| Beijing      | \( M_i=11.9016-0.1038t \) | 0.0777   | 0.0534              | 0.0816   | *                 |
| TianJin      | \( M_i=44.22967-0.74327t \) | 0.2590   | 0.2395              | 0.0008   | ***               |
| HeBei        | \( M_i=439.9396-6.8292t \) | 0.2996   | 0.2811              | 0.0003   | ***               |
| ShanXi       | \( M_i=201.568-0.18276t \) | 0.0121   | 0.0042              | 0.5783   | -                 |
| Inner Mongolia | \( M_i=109.0521+22.4178t \) | 0.8663   | 0.8628              | 0.0000   | ***               |
| Liao Ning    | \( M_i=509.3322-11.4404t \) | 0.9133   | 0.9110              | 0.0000   | ***               |
| Ji Lin       | \( M_i=590.0851-8.5265t \) | 0.5835   | 0.5725              | 0.0000   | ***               |
| HeiLongjiang | \( M_i=1670.078+51.0352t \) | 0.6209   | 0.6110              | 0.0000   | ***               |
| ShangHai     | \( M_i=3.9860+0.0172t \) | 0.0186   | 0.0175              | 0.5096   | -                 |
| JiangSu      | \( M_i=312.3179-3.1703t \) | 0.5192   | 0.5066              | 0.0000   | ***               |
| ZheJiang     | \( M_i=70.4054+0.4352t \) | 0.0492   | 0.0241              | 0.1691   | -                 |
| AnHui        | \( M_i=592.3349+3.8473t \) | 0.0791   | 0.0549              | 0.0787   | *                 |
| FuJian       | \( M_i=95.4850-1.0558t \) | 0.2166   | 0.1960              | 0.0025   | ***               |
| JiangXi      | \( M_i=149.9508-1.1396t \) | 0.3047   | 0.2864              | 0.0002   | ***               |
| ShanDong     | \( M_i=697.5766-14.9804t \) | 0.8463   | 0.8422              | 0.0000   | ***               |
| HeNan        | \( M_i=976.7489-16.9468t \) | 0.7797   | 0.7739              | 0.0000   | ***               |
| HuBei        | \( M_i=185.6669-0.6642t \) | 0.0652   | 0.0406              | 0.1000   | -                 |
| HuNan        | \( M_i=191.0083-1.7927t \) | 0.2060   | 0.1851              | 0.0033   | ***               |
| GuangDong    | \( M_i=152.6713-2.9739t \) | 0.9571   | 0.9559              | 0.0000   | ***               |
| GuangXi      | \( M_i=252.0456-3.1881t \) | 0.2890   | 0.2703              | 0.0003   | ***               |
| HaiNan       | \( M_i=11.9570-0.2399t \) | 0.6197   | 0.6061              | 0.0000   | ***               |
| ChongQing    | \( M_i=46.1979-1.2705t \) | 0.5325   | 0.5079              | 0.0002   | ***               |
| SiChuan      | \( M_i=139.7277+3.6020t \) | 0.5257   | 0.5132              | 0.0000   | ***               |
| GuiZhou      | \( M_i=106.5992+1.7265t \) | 0.5391   | 0.5270              | 0.0000   | ***               |
| YunNan       | \( M_i=35.3977+3.1655t \) | 0.8496   | 0.8457              | 0.0000   | ***               |
| XiZang       | \( M_i=2.7483-0.0447t \) | 0.0151   | 0.0119              | 0.5378   | -                 |
| ShanXi       | \( M_i=258.4254-1.3506t \) | 0.0903   | 0.0663              | 0.0596   | *                 |
| GanSu        | \( M_i=42.2552+1.2032t \) | 0.5120   | 0.4991              | 0.0000   | ***               |
| XinNia       | \( M_i=35.6503-0.5785t \) | 0.2519   | 0.2322              | 0.0010   | ***               |
| XinJiang     | \( M_i=11.5979+1.2597t \) | 0.3954   | 0.3795              | 0.0000   | ***               |

Note: There is no statistical analysis of soybean since no soybean is planted in Qinghai Province. *, **, ***: significant at \( P<0.1, P<0.05, \) and \( P<0.01, \) respectively. - indicates that the result is not significant.

From a dynamic perspective, we could classify the changes of the soybean planting area in all provinces and regions from 1978 to 2017 into five groups according to the regression coefficient \( c_i \) and the value P. The first group was the 8 regions showing steady rise (\( c_i > 0 \) and \( P < 0.005 \),
respectively Heilongjiang, Inner Mongolia, Sichuan, Yunnan, Guizhou, Chongqing, Xinjiang and Gansu, which were arranged in a descending order based on the growth rate. All these regions were located in the northeast and southeast of China, where the planting area of soybean was evidently increasing. The second group referred to the provinces of relevant stability ($\alpha_1 < 0$ or $\alpha_1 > 0$ and $P > 0.1$), and 4 regions fell into this category, respectively Zhejiang, Shanghai, Tibet and Shanxi. The correlation between the planting area and time variable was insignificant in these areas ($P > 0.1$), showing that the soybean planting area is relatively stable there. The third group consisted of the 14 regions exposed to a steady decrease ($\alpha_1 < 0$ and $P < 0.005$), respectively Henan, Shandong, Liaoning, Jilin, Hebei, Guangxi, Jiangsu, Guangdong, Hunan, Jiangxi, Fujian, Tianjin, Ningxia and Hainan, which were arranged in a descending order based on the decline rate. These regions had seen a steady decline of the soybean planting area ($\alpha_1 < 0$) in a stable way ($P < 0.005$). Among them, the decline of the top 3 is the traditional soybean production provinces in China. The fourth group included Beijing and Hubei as showing a certain decline ($\alpha_1 < 0$ and $0.005 < P < 0.1$), which showed a certain decline of soybean planting area. The fifth group included Shanxi and Anhui as showing a certain increase ($\alpha_1 > 0$ and $0.005 < P < 0.1$), which showed a certain increase of soybean planting area.

The overall soybean planting area of China is the sum of the planting areas of all provinces and regions, so the changes of the soybean planting area in any region directly affects the soybean planting area of the whole China [17]. According to the data of the soybean planting areas in different regions since 1949, soybean had been planted in all regions in China except Qinghai. Regions with an extremely large soybean planting area include Heilongjiang, Anhui, Henan, Jilin, Shandong and Liaoning, among which the soybean planting area of Heilongjiang had been rising steadily, the area in Anhui had been fluctuating upward and the areas of Jilin, Liaoning, Shandong and Henan had been constantly decreasing [18]. Regions with a relatively large soybean planting area included Inner Mongolia, Sichuan, Jiangsu, Shaanxi, Hubei, Shanxi, Hebei, Guizhou, Jiangxi, Hunan, Guangdong and Guangxi, among which the soybean planting areas in Inner Mongolia, Sichuan and Guizhou had been gradually increasing, the areas in Hebei, Jiangsu, Jiangxi, Guangdong, Guangxi and Hunan had been constantly dropping, the area in Hubei had been fluctuating downward and the area in Shanxi had been fluctuating both upward and downward. Regions with a smaller planting area include Fujian, Tianjin, Ningxia, Gansu, Hainan, Chongqing, Yunnan, Xinjiang, Zhejiang, Shanghai, Beijing and Tibet, among which the soybean planting areas in Xinjiang, Gansu, Chongqing and Yunnan had been growing though their original areas were small, the areas in Tianjin, Ningxia, Fujian and Hainan had been still reducing, the area in Beijing had been fluctuating downward, and the areas in Shanghai, Zhejiang and Tibet had been fluctuating both upward and downward.
3.3. Regional characteristics of yield per unit area

Through the analysis above we could see that the increase of soybean yield in China had been mainly driven by the constant growth of the per unit yield of soybean since 1949. Figure 3 reveals the changes of the yield per unit area of soybean in various regions. Regions with a lower per unit yield mainly included Chongqing, Guangdong, Guangxi and Hainan, where the yield per unit area had been increasing but was still low compared to other regions. Regions with a relatively higher per unit yield included Inner Mongolia, Liaoning, Gansu, Yunnan, Hunan, Jiangxi, Fujian and Ningxia, and the yield per unit area was steadily growing in all these regions except in Ningxia where the per unit yield remained stable. Regions with an extremely high per unit yield mainly included Heilongjiang, Jilin, Anhui, Shanghai, Beijing, Shanxi, Zhejiang, Tianjin, Guizhou, Tibet, Xinjiang, Hebei, Shandong, Shaanxi, Henan, Jiangsu, Hubei and Sichuan etc., among which the per unit yield of soybean in Heilongjiang, Jilin, Anhui, Shanghai and Tibet had been fluctuating upward, the per unit yield in Beijing, Tianjin, Shanxi, Zhejiang and Guizhou had been unstable and fluctuating and the per unit yield in other regions (Hebei, Shandong, Shaanxi, Henan, Jiangsu, Hubei, Sichuan and Xinjiang) had been growing steadily. To sum up, the yield per unit area of soybean had been rising in all regions regardless of the base number except in Ningxia, Beijing, Tianjin, Shanxi, Zhejiang and Guizhou where the per unit yield had been fluctuating in the seven decades.
The significance level for the regression results indicates how strong the relationship between the variables is. The significance levels are represented by P-values that are compared to predetermined thresholds (P<0.1, P<0.05, and P<0.01, respectively). A P-value less than the threshold indicates that the result is statistically significant at that level.

We would take this factor into account in the results (see Table 3). We had drawn Figure 3 with Tableau based on the regression constant, coefficient and value P. It could be seen that the static yield per unit area of soybean in China was 2,833.15kg/ha and the annual average increase was 68.48kg/ha. Also, the great fitting degree of the regression equation demonstrated the steady growth of the per unit yield of soybean in China since the Reform and Opening Up (P = 0 and α2 > 0). This was the same case with the per unit yield of soybean in various provinces and regions, despite their different growth rate (refer to α2). Based on the regression coefficient α2, the changes of the per unit yield of soybean in various provinces and regions in China from 1978 to 2017 could be divided into three groups. The first group referred to the 4 provinces, seeing a sharp rise of the per unit yield (α2 > 100), respectively Gansu, Jilin, Henan and Shandong, which were arranged in a
descending order based on the growth rate. These regions except Gansu were all major soybean producers in China and showed the highest growth rate of the per unit yield. The second group consisted of 8 provinces whose per unit yield was developing rapidly ($69 < \alpha_2 < 100$), respectively Inner Mongolia, Guizhou, Tianjin, Hebei, Liaoning, Heilongjiang, Hubei and Sichuan which were arranged in a descending order based on the growth rate. The per unit yield of soybean in these regions was rising faster than the average though it was not the fastest. The third group was the provinces with a lower growth rate ($0 < \alpha_2 < 69$), including 17 provinces, respectively Shanghai, Jiangxi, Jiangsu, Ningxia, Guangdong, Hunan, Guangxi, Anhui, Beijing, Qinghai, Fujian, Zhejiang, Xinjiang, Yunnan, Shaanxi, Shanxi and Tibet which were arranged in a descending order based on the growth rate. The yield per unit area in these regions was growing slower than the average level of China, and the yield in some certain regions was growing even more slowly compared to others [19].

4. Discussion
As an important indicator of regional market competitiveness in China, the soybean planting area is a comprehensive embodiment of natural resource endowment, cropping system, science and technology investment in agricultural production, market demand and policy support etc., and is directly influenced by the comparative benefits of soybean planting [20]. Compared with other food crops, the benefit of soybean planting is apparently higher than that of wheat and is basically equal to rice. The major competitor to soybean is corn. The comparative benefits between the two will directly affect the planting area of the two crops [21]. Upon the policy support of the soybean rejuvenation plan and agricultural supply-side structural reform, the government has reduced the area of grain corn in the “sickle zone” (a sickle-shaped zone in the map, involving large areas in various provinces and regions where the corn structure needs to be adjusted) non-advantaged producing areas, advocated developing high-quality edible soybean, increased soybean planting subsidies and provided “corn-soybean” crop rotation in recent years, in order to motivate farmers to plant soybean by improving the comparative benefits of soybean and appropriately reduce the corn planting area in the main soybean producing areas. Since the Reform and Opening Up, the soybean planting area in Heilongjiang, Inner Mongolia, Jilin, Henan and Anhui has been increasingly steadily [22], while the planting area in Huang-Huai-Hai area and the southern area such as Guangdong, Hubei, Jiangsu, Sichuan, Shandong, Shaanxi, Hebei and Fujian is declining rapidly. Jilin and Liaoning have a vast soybean planting area, which, however, is decreasing. By comparison, the soybean planting area in Heilongjiang and Inner Mongolia is large and increasing, because these regions enjoy abundant cultivated land resources, embrace resource superiority for soybean production and have a vast territory including wide fields with suitable eco-environment for soybean. In addition, the fertile land, favorable climate and high mechanization level in Heilongjiang and Inner Mongolia lay a solid foundation for the development of the soybean sector. Huang-Huai-Hai area sees evident advantages in the yield per unit area and quality, and the soybean here is mainly used for food and high-protein processing. Considering the expansion of future residents’ demand on protein food and animal husbandry’s demand on protein feed, the market advantage of high-protein soybean will be more prominent, which will lead to the increasingly evident regional advantages of Huang-Huai-Hai area, particularly Anhui Province.

The soybean rejuvenation plan had a good beginning in 2019. In the future, in addition to assuring grain supply to the large population with limited farmland, we shall give fully play to regional comparative advantages for the development of soybean production [23], implement the non-balanced development strategy that supports the top players and mainly rely on the development of the soybean industry in key superior areas, so as to improve China’s international competitiveness of the soybean industry and resist the impact of imported soybean on domestic soybean.
5. Conclusion

The overall trend of soybean production in China exerts a direct impact on the regional pattern. Since the Reform and Opening Up, the original regional pattern that considered northeast and Huang-Huai-Hai as the main producing areas of soybean in China had been exposed to changes, which was spreading from the traditional producing area to other producing areas. The traditional main producing areas still maintained their principal part but showed certain changes of geographical distribution, such as Heilongjiang, Jilin, Anhui, Henan, Shandong, Jiangsu and Liaoning. Among them, Liaoning and Shandong were exposed to the decline of soybean production; in Inner Mongolia, soybean production was playing an increasingly important role; Anhui still maintained a stable position as the main soybean producing area; despite the relatively slower development, Sichuan had been expanding its scale of soybean production in recent years; Henan’s role as the main soybean producing area was gradually replaced by Jilin Province; and Heilongjiang always ranked the first and showed evident growth in terms of both the absolute yield and development speed [24]. The regional distribution of soybean production showed an overall trend of “concentrated over vast areas and dispersed in small areas”. According to the analysis, the region of “three provinces in Northeast China” had always been the center of soybean production in China, and even witnessed the further concentration of soybean production. Huang-Huai-Hai area was also an important region of soybean production, but the production performance there was unstable or even declining. The soybean yield was increasing in all
main soybean producing areas except Liaoning and Shandong, which suggested the regional pattern of “concentrated in a few major producing provinces and dispersed in other regions”. With an evidently higher growth rate of soybean yield than other regions, Heilongjiang, Jilin, Anhui and Inner Mongolia were rapidly expanding their soybean production scale, where the concentrated production areas had been formed and constantly extended.

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