

Spatial pattern and its changes of grain production using GIS

Jianzhai WU¹, Chen SHEN¹, Jianhua ZHANG¹, Xiangyang ZHOU¹, Shuqing HAN¹ *

¹Agricultural Information Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China

*Corresponding author's Email:hanshuqing@caas.cn

Abstract. Aiming to provide the support for maintaining grain security in China, we discussed the spatial distribution of China's grain production and its changes in 1980-2013 using GIS spatial analysis method based on statistics data. The results show that regional differences of food production in China is obvious, and characterized as “up in south, low in north ”on the north-south direction and “low in center, high in both sides “on the east-west direction. From 1980 to 2013, the concentration degree of grain production improved, and the output significantly concentrated to the northern and central regions. The regions with the rapid increase in grain yield are almost located in the Midwest China, and the northern China has also made a significant increase.

1. Introduction

Food security in China has always been a concerning issue both in government management and academic research. Since the reform and opening up, China's agricultural production have experienced rapid development, and made remarkable achievements, which provided an effectively guarantee for national food security. In recent years, the major factors influencing grain supply and demand patterns from domestic and abroad have changed obviously (Heerink N, 2006),and China's grain supply and demand is facing a new environment. “ transporting grain output in south to north ”, which was a long standing issue, has replaced by " transporting grain produced in north to south " (Lu , 1997), and regional structural contradictions of food supply and demand including the regional unbalance gradually become serious (Yin, 2006). The regional pattern of food production has received more and more concerns in relevant study areas.

2. Data resources and methodology

In this paper, we take 31 provincial-level administrative units (provinces, municipalities or autonomous regions) as the basic spatial unit. Two administrative units changed in study period. Hainan, Chongqing were separated from Guangdong, Sichuan province and become independent provincial units. To ensure the accuracy and comparability of data, the relative data about grain production in Hainan and Chongqing was obtained according to the first three year's proportion to Guangdong, Sichuan respectively after separation from the former administrative .The basic data including food production, planting areas and so on, are from the "China Statistical Yearbook" ((National Bureau of Statistics of China, 1981, 2014).The index of concentration degree of grain production was used in the analysis of spatial pattern.



$$I = \frac{A-R}{M-R} \times 100\%$$

Where I is the concentration degree of grain production, A is the province's cumulative percentage of grain production, M is the cumulative percentage of food production under the assume of one province providing the total output, R is the cumulative percentage under the assume of each province having the same contribution degree to national grain production. The index may reflect the concentrated degree of grain production, and the higher index means greater concentrated tendency.

We also took C as proportion to national grain production, and divided 31 provinces into four types area, which are fast ($C \geq 150\%$), fast ($150\% > C \geq 80\%$), slow ($80\% > C \geq 50\%$), slow ($C < 50\%$). The index of concentration degree of grain production was used in the analysis of spatial pattern.

Where I is the concentration degree of grain production, A is the province's cumulative percentage of grain production, M is the cumulative percentage of food production under the assume of one province providing the total output, R is the cumulative percentage under the assume of each province having the same contribution degree to national grain production. The index may reflect the concentrated degree of grain production, and the higher index means greater concentrated tendency.

We also took C as proportion to national grain production, and divided 31 provinces into four types area, which are fast ($C \geq 150\%$), fast ($150\% > C \geq 80\%$), slow ($80\% > C \geq 50\%$), slow ($C < 50\%$). A subsection

3. Distribution and changes of grain output

3.1 Distribution of grain output

31 provinces are broadly divided into primary, secondary, tertiary, and quaternary groups using cluster analysis according to the proportion to country's total grain output (Figure 1). There are great regional differences of grain production spatial pattern in China, which are characterized as "up in south, low in north" on the north-south direction and "low in center, high in both sides" on the east-west direction. In 2013, the primary groups of China's grain production include Henan, Heilongjiang and Shandong Province, which are all located in the northern region. The quaternary groups are composed of Ningxia, Hainan, Tianjin, Shanghai, Beijing, Qinghai, Tibet, which are municipal or remote areas.

Most of the provinces with higher output are concentrated on flat areas with relatively abundant water areas, just like the Songnen Plain and JAC coastal plain. Henan Province has the highest grain output in 2013, reaching 5.46×10^8 , and the Tibet Autonomous Region is the lowest area with the output of 91.2×10^8 t. Grain output in northern China was 2.96×10^8 tons accounting for 54.32% of whole country production, and southern China were 2.50×10^8 tons and 45.76%. From the distribution in east-west direction, the central was the highest area with 2.67×10^8 tons output accounting for 48.92 percent, which is higher than eastern China or western China.

The spatial patterns of grain production are mainly determined by natural resource endowment and regional socio-economic development orientation. Relatively poor natural conditions and resource endowment of arable land in western China limit the process of agricultural production and promotion of agricultural science and technology, and lead to the lowest proportion of grain production.

Although the eastern region have the most advantageous conditions for grain production, but grain production is in a subordinate position in the social and economic development, and the rapid development of the second industries occupied a lot of arable land, which restricts food production. It is more obvious in the southeast coastal areas.

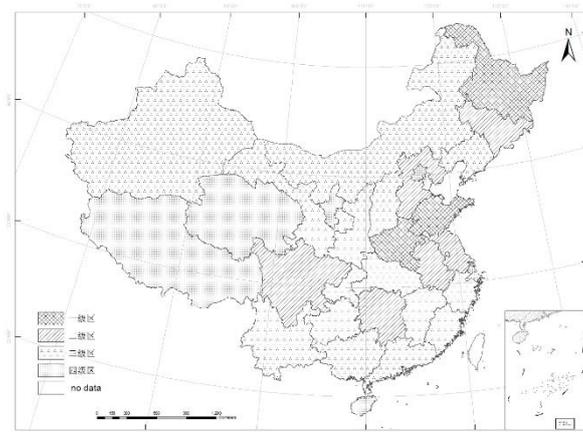


Figure1. Spatial pattern of grain output in China at 2013

3.2 Pattern changes of grain output

From 1980 to 2013, the spatial distribution of China's grain production has experienced obvious changes under the influence of a number of related factors. The concentration based on provincial units increased from 0.41 in 1980 to 0.45 in 2013. During the period, China's major areas of grain production increase is mainly located in the Northeast China, middle and Lower reaches of the Yellow River.

The increasing amount of Heilongjiang, Henan, Jilin, Shandong, Inner Mongolia, Anhui, Hebei was up to 1000×10^4 tons, Heilongjiang and Henan Provinces exceeded 3000×10^4 tons. The areas with production declining mainly distributed in the Southern China, especially in the southeast coastal area. The maximum reduce of grain production happened in Zhejiang Province, up to 6.65 million tons. Viewed from north-south direction, there are significant differences of grain production between Northern and Southern China, from 1980 to 2013. Due to the decline of rice output, the development of grain production in Southern China was more slowly, and the proportion to whole country has declined. The rapid increase of wheat and corn output in Northern China resulted in the improving of its proportion.

The first five provinces of production increasing are all located in northern regions, and the main decline areas are in south. during the period, grain production in Northern China increased by 1.67×10^8 tons reaching 2.96×10^8 tons, and the proportion increased by 14 percentage. Grain production in Northern China experienced a growing contribution to national food production, and the center of grain production moved towards north obviously.

As for east-west direction, grain production capacity of the eastern coastal province reduced gradually and western regions kept stable. Grain planting area moved to the central regions which are characterized by arable land resources and less non-farm employment opportunities, and the contribution to national food production is increasing. Hebei, Liaoning, Jiangsu and Shandong provinces located eastern region are major grain-producing provinces. Although grain production of eastern China increased from 1.33×10^8 tons in 1980 to 1.70×10^8 tons in 2013, the corresponding proportion reduced from 41.47 % to 31.20%. Eight provinces of central Region are major grain-producing provinces. Both the regional grain output and its proportion to whole country increased from 1980 to 2013. They are 1.19×10^8 ,37.15 percent in 1980 and 2.67×10^8 ,48.92 percent in 2013. In western region including 10 provinces, only one major grain-producing provinces(Sichuan). The grain output in the area changed from 0.69×10^8 tons in 1980 to 1.09×10^4 tons in 2013. The corresponding proportion decreased from 21.38% to 19.88%.

From 1980-2013, grain production increased in most areas of China, and the average annual growth rate was 1.79%, which means production capacity of arable land increased by 0.70 times during 30 years. Production annual growth in 13 provinces are higher than national average level. Average

annual growth in Inner Mongolia, Heilongjiang, Jilin, with an is over 4%. Especially in Inner Mongolia, it is, 5.8%, meaning its grain production increased more than four times. There are 18 provinces with lower average annual growth rate than national average level. The lowest growth rate of -2.05% happened in Zhejiang Province. Fujian, Guangdong, Shanghai, Beijing also experienced negative growth in grain production.

The average annual growth of grain production in northern China is 2.82%, and southern China is 0.89%. Viewed from east-west direction, only the central region's average annual growth of 2.73% is above the national average, eastern and western regions were 0.83% and 1.55%. During the study period, all the provinces with higher increase of grain production are all located in the northern region, especially concentrating in the northeast and the northwest plain areas.

In another side, 12 provinces of general growth areas or slower growth were located in the southern region, especially concentrating in the southeast coastal areas and the Yangtze River, and areas along the Yangtze River which were once an important grain production areas China.

4. Distribution and changes of grain yield

4.1 Distribution of grain yield

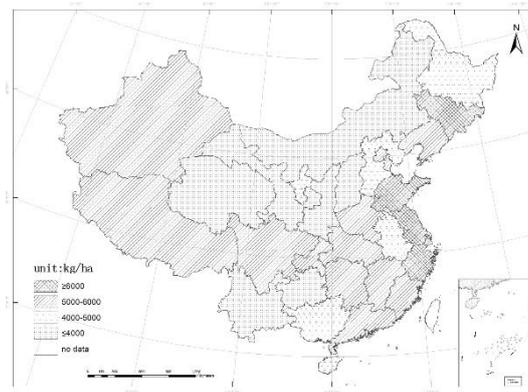


Figure2. Spatial pattern of grain yield in China at 2013

In 2013, China's highest grain yield was in Shanghai reaching 6608 kg/ha, and the lowest of 3,350 kg / ha was in Shanxi Province. Among 31 provinces, grain yield of Shanghai, Xinjiang, Jiangsu, Shandong, Zhejiang, Hunan, Liaoning, Jilin, Henan, Hubei, Tibet, Jiangxi, Fujian, Guangdong, Beijing, Tianjin, Chongqing was higher than the national average level. The remaining 13 provinces was lower.

The grain yield of 31 provinces was also divided into primary, secondary, tertiary, and quaternary groups using cluster analysis (Figure 1). The obvious differences of grain yield was easily founded among provinces. In 2013, the primary groups were composed of Shanghai, Jilin, Jiangsu, Shandong, Zhejiang, whose grain yields are all up to 6000 kg / ha. The quaternary groups included Inner Mongolia, Qinghai, Shaanxi, Guizhou, Yunnan, Gansu, Shanxi, in which the grain yields was lower than 4000kg/ha. The remaining 19 provinces made up the secondary and tertiary groups with the grain yield between 4000-5000 kg / ha.

Grain yield are significant differences among provinces in 2013. There are 4 provinces among top six higher yield located in eastern China and two are in middle region. The average grain yield in northern China was 4,890 kg / ha, and 4% lower than southern region of 5076 kg/ha. Viewed from east-west pattern, there was obvious decreasing from east to west. Eastern owed the highest grain yields of 5485 kg / ha, and significantly higher than the middle of 4992 kg / ha and Western of 4,306 kg / ha (Figure 2). There still obvious differences in same region. in the North China, Shandong Province, reached to 6120 kg / ha and nearly 30% higher than the yield of Hebei Province in 2013.

The spatial distribution of yield was consistent with that of precipitation and temperature, and the provinces with higher yield usually located in moist, warm areas.

The Middle and Lower Reaches of Yellow River, Yangtze River and Pearl River are more suitable for grain production due to the better natural endowment of water and land resources, of which grain yields are more than 5000 kg / ha. The three northeastern provinces with the high fertile soil and flat plain, were another important base to national grain production. Except Xinjiang and Tibet, most of the western region, especially in the Northwest were not suitable for food production because of their poor conditions of precipitation, temperature, etc. and they obtained the lower grain yields most between 3000-4500 kg / ha. Grain yields reached 6000 kg / ha or more in Xinjiang region, where mostly were agricultural oasis with the advantage in the application of science and technology, improving facilities level. Agriculture was the main industry in Tibet and the regional government paid more attention to the grain production most by improving grain yield under the circumstance of limited areas. From 2005, the regional government implemented the "improving grain yield action" and with the improving of fertilizer, machinery, utilities, labor, etc. and eventually lead to a gradual increase in grain yield in recent years.

4.2 Pattern changes of grain yield

There are 17 provinces whose yield increase exceeded 2000 kg/hm² from 1980 to 2013. The grain yield of Xinjiang, Jilin, Shandong, Henan province increased more than 3000kg/hm², and that of Xinjiang obtain the similar increase speed with North China. The grain yield of Qinghai, Shanxi, Yunnan, Guizhou region are relatively lower, with the growth of less than 1500 kg/hm². Guizhou was the minimal increase area and which increased by 980 kg/hm² during 30 years.

Viewed from the relative change speed, provinces were divided into four types of faster ($C \geq 150\%$), fast ($150\% > C \geq 80\%$), slow ($80\% > C \geq 50\%$), slower ($C < 50\%$) of (Figure 3). The results showed that there are 16 provincial which grain yields increased faster than the national average level, and those were the faster and fast level. Among them, there are 12 provinces achieved double the grain yield. Inner Mongolia, Xinjiang, Ningxia, Jilin were the faster increase areas which increased more than 1.5 times, and both Mongolia increased by 2.84 times which was the most increase provinces. There were 15 provinces which change speed was less than the national average along to the slow and slower increase areas. Yunnan, Sichuan, Liaoning, Guangdong, Fujian, Zhejiang, Guizhou were less than 50%, and the lowest one was Guizhou with 36.58%.

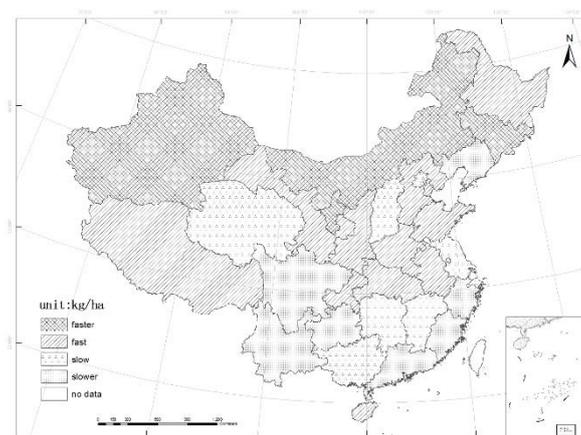


Figure3. Spatial pattern change of grain yield in China from 1980 to 2013

The rapid increase in grain yields are all located in the Midwest region, and among the 12 provinces with the double increase, 11 areas were in the north China, which showed that the supportive policies to major grain producing areas has achieved positive results. The provinces with lower increase speed are located in the eastern part of the South, especially in the eastern coastal areas. In addition, the

slower increase was showed in some important grain production areas due to the high grain yield itself, such as Liaoning Province of 46%.In Study period, grain yields in northern China increased by 1.2 times, while only 57%in Southern China. Central region obtained doubled increase and there were just over 70% in eastern and western regions.

5. Conclusions

The results showed that there are significant spatial differences of grain yield and output in China. Grain output in northern China is higher than that in southern China, and central region is higher than the east and west. the provinces with output increase is mainly distributed in the Northeast China and middle and Lower reaches of the Yellow River plain ,and the decrease areas mainly located in southern China, especially in the southeast coastal areas.

The basic distribution of grain yields in China is consistent with the spatial patterns of precipitation and temperature. During the study period, Grain yields in Midwest showed the highest increase. The distribution patterns and its changes of China's grain output and yields are reflected the natural endowments and characteristics of social and economic development in different areas. The better natural environments in coastal and higher labour efficiency promoted the yield change. The more emphasis on grain production in central region resulted in the rapid increase in production and yields. This variation will be further deepened due to the China's regional division-oriented policies to grain production in the future.

Acknowledgements

This work was supported by the Fundamental Research Funds of CAAS(Y2016ZK16, Y2016PT30).

References

- [1] Heerink N, Kuiper M, Shi X P 2006 *China and World Economy* China's new rural income support policy: impacts on grain production and rural income inequality vol 14 pp 58-69.
- [2] Yin P H,Fang X Q,Tian Q,Ma Y L 2006 *Journal of Geographical Sciences* The changing regional distribution of grain production in China in the 21st century vol 16 pp 396-404.
- [3] Lu Q, Lu M 1997 *Progress in Geography* Trends and basic causes of the regional pattern changes in China' s grain production since 1950s vol 16(1) pp 31~36.
- [4] National Bureau of Statistics of China 1981 *China Statistical Yearbook* (Beijing:China Statistics Press)
- [5] National Bureau of Statistics of China 2014 *China Statistical Yearbook* (Beijing:China Statistics Press)
- [6] Yang L, Yang G S, Yao S M 2012 *ECONOMIC GEOGRAPHY* A Study on the Spatial Heterogeneity of Grain Yield Per Hectare and Driving Factors Based on ESDA-GWR vol 32(6) pp 120-126.
- [7] Agnes R. Quisumbing 2013 *Global Food Security* Generating evidence on individuals' experience of food insecurity and vulnerability vol 2 pp 50-55.
- [8] Anderson K, Strutt A 2014 *Food Policy* Food security policy options for China: Lessons from other countries vol 49 pp 50-58.
- [9] FAO 1983 *Director General's Report* (Rome:World Food Security: a Reappraisal of the Concepts and Approaches)
- [10] FAO 1996 *World Food Summit* (Rome: Declaration on World Food Security and World Food Summit Plan of Action) pp 13-17
- [11] FAO 2014 *Food and Agriculture Organization of the United Nations* (Rome: FAO Statistics Division Working Paper Series--Selecting a Core Set of Indicators for Monitoring Global Food Security)
- [12] Yao C S; Teng Y; Huang L 2015 *Transactions of the Chinese Society of Agricultural Engineering* Evaluation index system construction and empirical analysis on food security in China vol 31(4) pp 1-10

- [13] Zhang Y, Zhang J Y, Yang Z F, Li J 2012 *Energy Policy* Analysis of the distribution and evolution of energy supply and demand centers of gravity in China vol 49 pp 695–706.
- [14] Maxwell D, Vaitla B, Coates J 2014 *Food Policy* How do indicators of household food insecurity measure up? An empirical comparison from Ethiopia vol 47 pp 107-116.