Optimizing Cotton Production Layout from the Perspective of Arable Land Ecological Security: A Postprint

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Abstract

Utilizing agricultural production statistical data from 2000-2015, this study employs spatial autocorrelation, production contribution analysis, and the PSR model to examine changes in Xinjiang' s cotton production patterns and factors contributing to yield increases. Based on cultivated land ecological security evaluation results, the cotton planting reduction area for each county and city is calculated. The conclusions are as follows: Since 2000, the spatial pattern of cotton production has undergone significant changes, forming two main production areas on the northern and southern slopes of the Tianshan Mountains, with the "south increasing, north decreasing" trend intensifying. High-yield areas have expanded from points to surfaces on both sides of the Tianshan Mountains, forming multiple concentrated and contiguous high-yield centers. Cotton production exhibits spatial agglomeration effects, demonstrating continuous stability, with high-value clusters concentrated in the southern Xinjiang region. The increase in cotton production is mainly attributed to the continuous expansion of sown area. Cultivated land ecological security is at a critical or relatively unsafe state and shows a concentrated and contiguous distribution. The focus of cotton planting reduction in Xinjiang is concentrated in the southern Xinjiang region. In the adjustment of planting structure, issues such as water resource and land management system constraints, agricultural irrigation water efficiency, and alternative crop selection should be comprehensively considered to scientifically and orderly reduce cotton planting area.

Full Text

Preamble

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Abstract: Besides grain, cotton is the most important agricultural product and strategic supply in China, with the longest industrial chain and the highest industrial relevance. Cultivated land, as the most valuable farming resource, plays a crucial part in cotton production. Xinjiang is the largest cotton-producing area in China, which owns particular climate conditions and geographical advantages, such as temperature and light. However, with the unordered expansion of cotton acreage, the problems of scarcity of cultivated land and deterioration of ecological environment have become more and more prominent in recent years. This paper analyzed the spatial-temporal pattern, contribution factors, and evaluation of cultivated land ecological security about the cotton production in Xinjiang Province, by using agricultural production statistic data from 2000 to 2015. The methods of spatial auto-correlation, production contribution, and PSR model were implemented in this study and finally the theoretically reducing cotton sown area at county level was generated. The results indicated that the spatial pattern of cotton production has been significantly changed since 2000, the main cotton-production areas had been formed in northern and southern slopes of Tianshan, the trend of "increase in south and decrease in north" was significant, the high value zone of per unit yield was expanded to both sides of Tianshan, which formed the concentrated high-value center; the cotton production displayed certain spatial clustering effect; the high value clusters with continuous stability were mainly distributed in south Xinjiang; the factor of total sown areas, rather than the per unit yield and structural adjustment, had significant impact on cotton production contribution rate from 2000 to 2015. The evaluation result of cultivated land ecological security was less than 0.6, which meant a critical safety or less safety state. The proportion of type IV (the less safety type) and type V (unsafety type) was 84.21%, and the regions of these two types were concentrated distribution. The total theoretic reducing cotton sown area in Xinjiang was 101.176$\times10^{4}$ hm^2, and the regions of reducing sown area were mainly distributed in south Xinjiang, which accounted for more than 60% of the total area. Based on the analysis, the institutional restraint of water resources and land management, the efficiency of agricultural irrigation water and alternative crops plantation should be taken fully into account in order to improve cultivated land ecological security.

Keywords: cotton production; cultivated land ecological security; spatial autocorrelation; production contribution rate; PSR model; Xinjiang

1 Study Area

Xinjiang is located between 34°2 -48°10 N and 73°40 -96°18 E, covering an area of 166.49$\times10^{4}$ km^2, which accounts for approximately 1/6 of China's total

territory. It is characterized by a typical arid climate and abundant light and heat resources.

2 Methods

2.1 Spatial Autocorrelation Analysis

This study employed spatial autocorrelation analysis and the PSR model to evaluate cultivated land ecological security. Global Moran' s I was used to measure spatial autocorrelation, with values ranging from -1 to 1. Positive values indicate positive spatial correlation, negative values indicate negative correlation, and values close to -1/(n-1) suggest random distribution. The local spatial autocorrelation index was calculated to identify spatial clustering patterns.

2.2 Evaluation Indicator System

The evaluation system comprised multiple indicators with corresponding weights. The pressure sub-system (weight: 0.3670) included indicators such as cultivated land area per capita (X_1), fertilizer application intensity (X_2), pesticide application intensity (X_3), and agricultural film use intensity (X_4). The state sub-system (weight: 0.3542) included per unit yield (X_5), effective irrigation rate (X_6), soil organic matter content (X_7), soil pH value (X_8), and soil salinization rate (X_9). The response sub-system (weight: 0.2788) included agricultural water use efficiency (X_{13}), GDP per unit area (X_{14}), fertilizer utilization rate (X_{15}), and pesticide utilization rate (X_{16}).

2.3 Data Sources

The study utilized statistical data from 2000 to 2015, including the Xinjiang Statistical Yearbook, Xinjiang Rural Statistical Yearbook, and China Agricultural Yearbook. Remote sensing data from 2007 was used to extract cotton planting area information. Meteorological data from 14 stations covering 2001-2012 was employed for climate analysis.

3 Spatial Pattern Analysis

3.1 Temporal Changes

From 2000 to 2015, cotton production in Xinjiang showed significant spatial restructuring. The main production areas gradually formed on the northern and southern slopes of the Tianshan Mountains, with a clear trend of "increasing in the south while decreasing in the north." The high-yield zones expanded to both sides of the Tianshan range, forming concentrated high-value centers. The production exhibited notable spatial clustering effects, with high-value clusters demonstrating continuous stability primarily in southern Xinjiang.

3.2 Spatial Clustering Characteristics

The global Moran' s I values for cotton production from 2000 to 2015 were positive, indicating significant spatial clustering. In 2000, Moran' s I was 0.4867, with 56.11% of counties showing positive local autocorrelation. By 2015, this pattern intensified, with high-high clusters (hotspots) concentrated in southern Xinjiang and low-low clusters in northern regions. The LISA (Local Indicators of Spatial Association) analysis revealed five distinct spatial patterns: high-high, low-low, high-low, low-high, and non-significant clusters.

3.3 Production Contribution Factors

Analysis of production contribution rates showed that total sown area was the dominant factor affecting cotton production growth, accounting for approximately 69.74% of the total contribution. Per unit yield contributed about 23.23%, while structural adjustment contributed only 6.03%. This indicates that production increases relied primarily on area expansion rather than yield improvement or structural optimization.

4 Ecological Security Evaluation

4.1 PSR Model Assessment

The comprehensive evaluation index of cultivated land ecological security (F) was calculated using the PSR model. The results showed that the overall security level remained below 0.6 throughout the study period, indicating a state of critical safety or insecurity. The evaluation classified counties into five safety levels: safe (I, F$ 0.9), $relatively safe(II, 0.6\ F < 0.9)$, $critically safe(III, 0.5\ F < 0.6)$, $less safe(IV, 0.4$ $F<0.5)$, and unsafe (V, F<0.4).

4.2 Spatial Distribution of Safety Levels

In 2015, types IV and V combined accounted for 84.21% of all counties, concentrated in southern Xinjiang. Type V counties, representing the most unsafe conditions, comprised 69.74% of the total area, mainly distributed in regions with extensive cotton cultivation and severe ecological pressure. Type III counties accounted for 78.71% of the area in transitional zones, while safe and relatively safe counties (types I and II) were extremely rare.

4.3 Theoretical Reduction of Cotton Area

Based on ecological security thresholds, the total theoretical reduction of cotton sown area in Xinjiang was calculated to be 101.17$×10^{4}$ hm^2. The reduction should be primarily implemented in southern Xinjiang, accounting for over 60% of the total reduction area. The specific reduction amounts varied by county, ranging from 4.07 hm^2 to 47,604.79 hm^2, depending on local ecological conditions and current planting intensity.

5 Conclusions and Recommendations

(1) The spatial optimization of cotton production should prioritize ecological constraints. Water resource management institutions must be strengthened, and irrigation efficiency improved. Alternative crop planting should be promoted in ecologically fragile areas to reduce pressure on cultivated land.

(2) The government should implement differentiated policies based on local ecological carrying capacity. For counties with safety levels below 0.4, cotton planting should be significantly reduced or prohibited. For transitional zones (0.4-0.6), moderate reduction and technological improvements are recommended.

(3) Future cotton development should focus on improving per unit yield rather than expanding sown area. This includes promoting water-saving technologies, optimizing fertilization practices, and enhancing soil quality management. The spatial layout should concentrate production in ecologically suitable areas with high yield potential.

(4) Establishing a long-term monitoring system for cultivated land ecological security is essential. Regular assessment using the PSR model can guide dynamic adjustments to planting structure and ensure sustainable development of cotton production in Xinjiang.

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Note: Figure translations are in progress. See original paper for figures.