

Quantitative Study on Ecological Compensation for Cultivated Land in the Beijing-Tianjin Surrounding Area from a Food Security Perspective: Postprint

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Abstract

Based on ecosystem service values and from the perspective of food security, this study establishes a cultivated land ecological compensation model by calculating the grain cultivated land surplus-deficit quantity, grain-cultivated land overload index, and compensation coefficient. Through quantifying county-level cultivated land ecological compensation, it investigates the cultivated land ecological compensation issues in the Beijing-Tianjin surrounding region of Hebei Province. The research results indicate: 1) There exists a typical ‘spatial dislocation’ phenomenon between ‘ecological supply’ and ‘ecological consumption’ of cultivated land in the Beijing-Tianjin surrounding area, wherein ecological consumption of cultivated land is mainly concentrated in the southern region, while ecological supply is primarily concentrated in the western region. 2) In 2014, the ecosystem service value of cultivated land in the Beijing-Tianjin surrounding area was 4.4805×10^1 yuan, showing an overall state of self-insufficiency, with a total deficit of 7.834×10 yuan. 3) In the Beijing-Tianjin surrounding region, 17 counties and cities including Zhangbei County, Xinglong County, Yu County, Shangyi County, and Laiyuan County in Hebei Province showed surpluses, while all other counties and cities exhibited deficits. Among them, Luannan County required the highest cultivated land ecological compensation payment, amounting to 5.173×10 yuan, followed by Yutian County and Dongguang County at 4.864×10 yuan and 4.849×10 yuan, respectively. Although Zunhua City, Luanping County, and Quyang County could receive compensation, their cultivated land ecological conditions merely demonstrated a ‘tight balance’, which still requires extensive attention. 4) From the perspective of food security, the counties in urgent need of receiving cultivated land ecological compensation in the Beijing-Tianjin surrounding region in 2014 were Zhangbei County, Yu County, Shangyi County, Yangyuan County, Laiyuan County, and

Quyang County, while those required to pay cultivated land ecological compensation were Luannan County, Yutian County, Xian County, Wuqiao County, and Dingzhou City. Tang County, Laishui County, and Fengning Manchu Autonomous County neither required receiving nor paying cultivated land ecological compensation. Compared with previous studies, this research investigates the cultivated land compensation issues in Hebei Province's Beijing-Tianjin surrounding area from the perspective of ecological compensation. The research findings play an important role in promoting economic development, cultivated land ecological environment protection, and sustainable and efficient utilization of cultivated land resources in the Beijing-Tianjin surrounding region. Simultaneously, the application of this method can provide references for quantitative research on ecological compensation in similar regions, offer a basis for determining cultivated land protection indicators based on ecological value in other areas, and hold guiding significance for research on the value mechanism of cultivated land ecological compensation.

Full Text

Preamble

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Quantitative Study on Cultivated Land Ecological Compensation in the Beijing-Tianjin Environs from a Grain Security Perspective

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Abstract:

Based on ecosystem service value and from the perspective of grain security, this study establishes a cultivated land ecological compensation model by calculating grain-cultivated land balance, grain-cultivated land overload index, and compensation coefficients. The model quantifies county-level cultivated land ecological compensation to investigate compensation issues in Hebei Province's Beijing-Tianjin environs. Results indicate: (1) A typical "spatial dislocation" phenomenon exists between cultivated land "ecological supply" and "ecological consumption" in the Beijing-Tianjin environs, with ecological consumption concentrated primarily in the southern region and ecological supply concentrated mainly in the western region. (2) In 2014, the ecosystem service value of cultivated land in the Beijing-Tianjin environs was 4.4805×10^1 yuan, showing an overall inability to be self-sufficient with a total deficit of 7.834×10 yuan. (3) Among the region's counties and cities, 17 including Zhangbei, Xinglong, Yu,

Shangyi, and Laiyuan showed surpluses, while all others exhibited deficits. Luannan County required the highest ecological compensation payment at 5.173×10 yuan, followed by Yutian County (4.864×10 yuan) and Dongguang County (4.849×10 yuan). Although Zunhua, Luanping, and Quyang counties were eligible for compensation, their cultivated land ecological conditions remained in a “tight balance” requiring continued attention. (4) From a grain security perspective, counties urgently needing cultivated land ecological compensation in 2014 were Zhangbei, Yu, Shangyi, Yangyuan, Laiyuan, and Quyang, while counties needing to pay compensation were Luannan, Yutian, Xianxian, Wuqiao, and Dingzhou. Tangxian, Laishui, and Fengning Manchu Autonomous County neither required nor needed to pay compensation. Compared with previous research, this study approaches the cultivated land compensation issue in Hebei Province’ s Beijing-Tianjin environs through the lens of ecological compensation. The findings play an important role in promoting regional economic development, cultivated land ecological environmental protection, and sustainable, efficient utilization of cultivated land resources. Additionally, this methodology provides a reference for quantitative ecological compensation studies in similar regions, offers a basis for determining cultivated land protection indicators based on ecological value in other areas, and guides research on cultivated land ecological compensation value mechanisms.

Keywords: cultivated land; ecosystem service value; grain security; ecological supply; ecological consumption; ecological compensation; Beijing-Tianjin environs

Introduction

Food security concerns people’ s living standards, social stability, and national development. In recent years, the Chinese government has made tremendous efforts to achieve food security through grain direct subsidies and other measures, effectively alleviating food security issues. However, resulting economic pressures have become a new challenge. Consequently, research addressing food security has become a hotspot in sustainable cultivated land ecosystem studies. As is well known, grain-producing regions lose fair development opportunities due to their responsibility for grain production and cultivated land protection. Although grain products generate some income, this falls far short of the benefits derived from maintaining ecological environmental quality. To mobilize the initiative and enthusiasm of cultivated land protection stakeholders and resolve the contradiction between “food” and “development,” quantitative research on ecological compensation for cultivated land resources is imperative.

Current research by domestic and international scholars identifies the core of ecological compensation as clarifying its basis, which directly relates to the scientific validity and effectiveness of compensation and has become a key focus and challenge in ecological compensation work. Presently, some case studies

in China have determined compensation bases through ecosystem service value analysis in fields such as forests and water bodies, playing important roles in advancing ecological compensation theory. However, as the contradiction between “food” and “development” becomes increasingly prominent, research on cultivated land ecological value compensation is emerging as a new hotspot, though still in the exploratory stage.

The innovation of this study lies in using grain security as the basis for cultivated land ecological compensation. On the foundation of identifying compensation providers and recipients in the Beijing-Tianjin environs, we calculate compensation amounts based on ecosystem non-market service values and quantify the urgency of receiving or paying compensation. The research findings provide a basis for inter-regional cultivated land ecological economic compensation.

As an important grain supply and ecological security zone for Beijing and Tianjin, Hebei Province’s Beijing-Tianjin environs has made significant sacrifices in resource development and utilization, industrial production, and entertainment culture. Moreover, its grain supply and demand remains in a “tight balance” state. Therefore, selecting this region as the study area is typical, and the results help comprehensively grasp grain security issues in the Beijing-Tianjin environs, clarify economic relationships in cultivated land ecological compensation, and maintain regional economic development while achieving dynamic balance in cultivated land quantity and ecological environmental protection.

1.1 Study Area Status

This study selected 72 counties (cities) under the jurisdiction of six prefecture-level cities in Hebei Province bordering Beijing and Tianjin—Baoding, Cangzhou, Langfang, Tangshan, Chengde, and Zhangjiakou—as the research area, as shown in [Figure 1: see original paper]. The total land area of the study region is 1.33×10^5 km², with a total population of approximately 3.78×10^7 people. Annual precipitation ranges from 400–800 mm, and average annual temperature ranges from 0–12°C. The climate type is north temperate continental monsoon, characterized by dry and windy springs, hot and humid summers with abundant rainfall, large diurnal temperature variations in autumn, and cold, dry winters with little snowfall. Landform types are relatively complex, mainly including coastal beaches, plains, hills, and plateaus. Among land types in the study area, cultivated land and forest land are the most abundant, accounting for 30.48% and 28.00% of total land area respectively, while water area is the smallest at only 3.67% of total area. The region has unique location conditions and important geographical position. As an important grain supply and ecological buffer zone for Beijing and Tianjin’s food and ecological security, the Beijing-Tianjin environs bears heavy responsibilities for grain production, water conservation, sand blocking, and wind prevention.

1.2.1 Regional Cultivated Land Ecosystem Service Value Calculation

Drawing upon research progress from scholars such as Costanza et al. and Xie Gaodi et al., this paper conducts field investigations to calculate the ecosystem service value coefficient per unit area of cultivated land in Hebei Province's Beijing-Tianjin environs. In 2014, the economic value of a single ecosystem value equivalent in China was $567.45 \text{ yuan} \cdot \text{hm}^2$. Given that the average grain yield in the Beijing-Tianjin environs in 2014 was $5,536.32 \text{ kg} \cdot \text{hm}^2$ while the national average grain yield was $5,861.62 \text{ kg} \cdot \text{hm}^2$, the value of a single ecosystem equivalent in the Beijing-Tianjin environs was determined to be $535.96 \text{ yuan} \cdot \text{hm}^2$ after correcting the national single equivalent. The ecological service value coefficient per unit area of terrestrial ecosystems (unit equivalent \times equivalent) was then calculated, ultimately yielding the ecological service value coefficient per unit land area in the Beijing-Tianjin environs (VC,).

The formula for calculating ecosystem service value is:

$$Ae = \sum_{i=1}^n A_i \times V_i \quad (1)$$

where Ae represents the ecosystem service value of the i th land use type in the study area (yuan); A_i represents the area of the i th land use type in the Beijing-Tianjin environs (hm^2); and V_i represents the ecological service value coefficient per unit area of the i th land use type in the Beijing-Tianjin environs ($\text{yuan} \cdot \text{hm}^2$). This paper studies only cultivated land resources, meaning the land use type is cultivated land.

1.2.2 Ecological Footprint and Ecological Capacity Calculation

1) Ecological footprint calculation. The ecological footprint refers to the biologically productive land area required to maintain resource consumption for a specific population and assimilate waste under certain economic scale conditions. The ecological footprint calculation formula can be expressed as:

$$EF = N \times ef = N \times \sum_{i=1}^n \frac{c_i}{p_i} \times r_j \quad (2)$$

where EF is the total ecological footprint, N is population size, ef is per capita ecological footprint, i is the category of consumer goods, p_i is the world average productivity of the i th commodity, c_i is per capita consumption of the i th commodity, and r_j is the equivalence factor.

2) Ecological capacity calculation. Land yield factor is the ratio of regional average productivity to world average productivity of the same land type. The yield factors for land types adopt the average values used by Wackernagel et al. when calculating China's ecological footprint, with cultivated land being 1.8–

a value widely used in ecological footprint calculations at various regional scales. To coexist with other species and protect biodiversity, 12% of land should be reserved for biodiversity conservation, so this 12% biodiversity protection area should be deducted in ecological capacity calculations. The ecological capacity calculation formula is:

$$EC = N \times ec = N \times \sum_{j=1}^m a_j \times r_j \times y_j \quad (3)$$

where EC is regional ecological capacity, N is population size, ec is per capita ecological capacity, and a_j , r_j , and y_j are per capita biologically productive area, equivalence factor, and yield factor for the j th consumer goods type, respectively.

3) Ecological overload index calculation. The ecological overload index is calculated as:

$$EOI = \frac{EF - EC}{EC} \quad (4)$$

If $EOI = 0$, the studied region's ecological environment is in ecological balance; when $EOI > 0$, larger values indicate more severe ecological overload, and vice versa.

1.2.3 Regional Compensation Determination and Compensation Ratio Calculation

Drawing upon research by Zhou Xiaoping and Cao Ruifen et al., this study employs the grain supply-demand balance method to calculate regional grain-cultivated land balance. The specific process is as follows:

1) Regional grain-cultivated land demand calculation. Based on comprehensive consideration of regional total population, grain yield per unit area (grain output per unit sown area), grain self-sufficiency rate, and per capita grain consumption level, regional grain-cultivated land demand is calculated using formulas (5) and (6):

$$d_1 = \alpha \times c \quad (5)$$

$$D_1 = d_1 \times N = \frac{\alpha \times c \times N}{Y} \times S_1 \quad (6)$$

where d_1 represents per capita grain-cultivated land demand in the study area, α represents grain self-sufficiency rate, c represents per capita grain demand in the study region, S_1 represents total cultivated land area, Y represents total

grain output, N represents total population, and D_1 represents total regional grain-cultivated land demand.

2) Regional grain-cultivated land balance. Regional grain-cultivated land balance is the difference between grain-cultivated land demand (D_1) and supply (S_1), calculated as:

$$L_1 = S_1 - D_1 \quad (7)$$

where L_1 represents total grain-cultivated land balance in the region—the difference between cultivated land stock and total grain-cultivated land demand. $L_1 > 0$ indicates a grain-cultivated land surplus, while the opposite indicates a deficit.

3) Grain security overload index. This paper introduces the grain security overload index to measure the degree of cultivated land ecological utilization, referring to the percentage difference between cultivated land stock and total grain-cultivated land demand relative to cultivated land stock:

$$DI = \frac{L_1}{S_1} \quad (8)$$

where DI represents the regional grain-cultivated land overload index. If $DI = 0$, the region's grain-cultivated land is in balance, showing "tight grain security"; when $DI > 0$, larger values indicate greater grain-cultivated land surplus and higher grain security capacity; conversely, when $DI < 0$, smaller values indicate more severe grain-cultivated land gaps and higher food insecurity.

4) Compensation coefficient calculation model. With rapid contemporary socio-economic development, environmental protection awareness has gradually attracted attention. This deepening process can be simulated using an S-shaped Pearl growth curve to model payment capacity behavior, while the Engel coefficient model quantifies socio-economic levels and human living standards in the study area, as shown in formulas (9) and (10):

$$r = \frac{1}{1 + e^{-t}} \quad (9)$$

$$t = \frac{En - Ea}{Ea - Eb} \times \varphi \quad (10)$$

where r represents the social development stage coefficient related to willingness and ability to pay for cultivated land ecological protection (the compensation coefficient), with $r \in (0, 1)$; the numerator 1 represents the maximum value indicating maximum cultivated land ecological payment capacity; En is the comprehensive Engel coefficient; Ea is the urban Engel coefficient; Eb is the rural Engel coefficient; and φ is urbanization level.

5) Comprehensive calculation model. To comprehensively and accurately understand and calculate cultivated land grain security compensation amounts, we must not only clarify value compensation standards but also consider resource utilization and actual compensation capacity in compensation areas to establish a relationship function between ecological service value and ecological value compensation. This paper combines cultivated land ecological service value, grain security, and economic development level to calculate cultivated land grain security compensation amounts, as shown in formula (11):

$$A_{ec} = Ae \times \frac{S_1 - D_1}{S_1} \times r \quad (11)$$

where A_{ec} is the cultivated land grain security compensation amount to be paid (or received) in the study area (yuan \cdot year⁻¹); Ae is the cultivated land ecosystem service value in the study area (yuan \cdot year⁻¹); S_1 is total cultivated land area (hm²); D_1 is total regional grain-cultivated land demand (hm²); and r is the compensation coefficient. If A_{ec} is positive, the region needs to pay ecological compensation, with larger values indicating greater payment amounts; conversely, if A_{ec} is negative, the region should receive ecological compensation.

1.2.4 Regional Ecological Compensation Priority Calculation

Socio-economic development levels vary significantly among regions. Using regional economic development level (GDP) to quantify cultivated land ecological compensation degrees is the most convenient and intuitive method. The urgency of cultivated land ecological compensation for economically developed regions is lower than for less developed regions. Ecosystem service value comprises market value and non-market value components. Since the former has already returned to the region in monetary form through market mechanisms, this portion should be excluded when calculating Ecological Compensation Priority (ECPS), retaining only the non-market value portion. This paper determines a region's ecological compensation priority using the ratio of per-unit-area ecosystem service non-market value to per-unit-area GDP, expressed as:

$$SECP = \frac{VaIN}{GDPN} \quad (12)$$

where $SECP$ represents ecological compensation priority, $GDPN$ is regional GDP per unit area, and $VaIN$ is non-market value of ecosystem services per unit area. If a study area has a grain-cultivated land gap but small ecological compensation priority, it indicates food insecurity but minimal economic impact after paying ecological compensation, so it should pay cultivated land ecological compensation funds first. Conversely, if a region is relatively food secure and receiving ecological compensation would significantly improve its socio-economic development level, it should be prioritized for cultivated land ecological compensation.

1.3 Data Sources and Parameter Determination

Through interpretation of 2014 Landsat TM imagery for the Beijing-Tianjin environs, this study obtained research data. Using ENVI4.7 software platform, bands 5, 4, and 3 were combined. Through geometric correction and boundary clipping of the study area, ArcGIS10.0 was employed with supervised classification combined with visual interpretation to interpret cultivated land in the study region. Referencing the 2014 *Beijing-Tianjin Economic Statistical Yearbook* and Hebei Province land change survey data, interpretation accuracy was verified and adjusted to obtain the study area's cultivated land use database. Other relevant data came from the 2014 *Beijing-Tianjin Rural Statistical Yearbook*, *Beijing-Tianjin Economic Statistical Yearbook*, and *National Agricultural Product Cost-Benefit Data Compilation*.

Key parameters in this study were sourced as follows: For grain supply-demand balance calculations, based on FAO and Zhou Xiaoping et al.'s research, per capita grain consumption (c) was determined to be $400 \text{ kg} \cdot \text{person}^{-1}$. According to the 2008 *National Medium- and Long-Term Grain Security Planning Outline*, grain self-sufficiency rate (α) was set at 95%.

2.1 Ecosystem Service Value of Cultivated Land in the Beijing-Tianjin Environs

The total ecosystem service value of cultivated land in the Beijing-Tianjin environs in 2014 exhibited spatial differentiation, gradually decreasing from southeast to northwest. The total ecosystem service value of cultivated land in the Beijing-Tianjin environs was 4.4805×10^1 yuan, with the highest value in the central region at 1.9384×10^1 yuan (43.26% of the total), followed by the southern region at 1.4771×10^1 yuan (32.97%), and the smallest in the northern region at 1.0649×10^1 yuan (23.77%). Overall, the ecosystem service value of cultivated land showed an increasing trend from north to south, with values of 2.662×10 yuan in the northern region, 4.846×10 yuan in the central region, and 4.924×10 yuan in the southern region. This phenomenon directly resulted from the increasing trend of cultivated land quantity from north to south. At the municipal level, Cangzhou City had the highest value at 5.73×10 yuan, while Chengde and Langfang had the lowest at 1.933×10 yuan and 2.425×10 yuan respectively; other cities ranged from 3.5×10 to 5.5×10 yuan.

2.2 Ecological Overload Index of Cultivated Land in the Beijing-Tianjin Environs

The ecological overload index of cultivated land in Hebei Province's Beijing-Tianjin environs showed an overall deficit trend. Only Tangshan in the eastern region (0.07) and Langfang in the central region (0.05) showed surpluses, while all other counties and cities exhibited deficits. Except for Langfang, all cities in the central and southern regions showed deficits because these are economically developed areas in the Beijing-Tianjin environs, particularly Baoding City,

where rapid socio-economic development comes at the cost of consuming large amounts of high-quality cultivated land resources, with increasing population concentration making Baoding's cultivated land ecological capacity insufficient to support its ecological consumption. Cangzhou City in the central region had the largest overload index at -0.57 because, as a coastal city, some cultivated land suffers from salinization, resulting in the lowest crop yields among all cities in the province and consequently the largest cultivated land ecological overload index.

[Figure 2: see original paper] Ecological overload index of cultivated land in the area around Beijing and Tianjin

2.3 Ecological Compensation Priority of Cultivated Land in the Beijing-Tianjin Environs

A typical “spatial dislocation” phenomenon exists between “ecological supply” and “ecological consumption” in the Beijing-Tianjin environs. Cultivated land “ecological consumption” is mainly concentrated in the central and southern regions, while “ecological supply” is primarily concentrated in the northern region. According to the method for determining whether regions should receive or pay compensation, counties and cities receiving cultivated land ecological compensation in 2014 were mainly concentrated in Zhangjiakou, Tangshan, and Langfang cities, while 17 counties including Zhangbei, Xinglong, Yu, Shangyi, and Laiyuan were identified as paying compensation, primarily located in Baoding, Cangzhou, and Chengde regions, as shown in [Figure 3a: see original paper].

Ecological compensation priority for cultivated land in the Beijing-Tianjin environs gradually increased from southeast to northwest, as shown in [Figure 3b: see original paper]. The northwestern region showed higher priority, such as Kangbao, Zhangbei, and Shangyi counties in Zhangjiakou City, and Laiyuan County in Baoding City, which had larger cultivated land ecological compensation priorities. Zhangbei County had the highest priority (0.1680), followed by Laiyuan County (0.1487). These regions should receive cultivated land ecological compensation first because they have higher-quality cultivated land and greater food security, providing strong support for Beijing and Tianjin's development. Receiving cultivated land ecological compensation would accelerate their economic development. In contrast, the northeastern and central regions showed lower compensation priorities, such as Kuancheng Manchu Autonomous County, Laoting County, Dachang Hui Autonomous County, and Xinglong County, which should pay ecological compensation to other regions first. Kuancheng Manchu Autonomous County had the smallest priority (0.0145), followed by Laoting County (0.0199). These areas develop relatively slowly, have poor-quality and scarce cultivated land, show overall food insecurity, and experience minimal economic impact from ecological compensation, so they should pay ecological compensation funds first.

2.4 Analysis of Cultivated Land Ecological Compensation Amounts

From a compensation amount perspective, cultivated land ecological compensation in the Beijing-Tianjin environs in 2014 showed an overall inability to be self-sufficient, manifested as cultivated land ecological deficit with a total deficit of 7.834×10^8 yuan. The northwestern region had the highest total payment at 4.694×10^8 yuan, accounting for 59.91% of the study area's total. Cangzhou City had the highest payment at 1.811×10^8 yuan, followed by Baoding City at 1.541×10^8 yuan, and Chengde City also needed to pay 1.342×10^8 yuan. The northern region showed overall cultivated land ecological surplus, eligible to receive 6.97×10^8 yuan in cultivated land ecological compensation, with Zhangjiakou City receiving the most at 6.29×10^8 yuan, followed by Tangshan at 1.75×10^8 yuan and Langfang at 6.7×10^7 yuan. Although these regions are in surplus, their cultivated land ecological conditions remain in "tight balance." At the county level, Luannan County had the highest payment at 5.173×10^7 yuan, followed by Yutian County (4.864×10^7 yuan) and Dongguang County (4.849×10^7 yuan). Tang County had the smallest payment at 4.914×10^7 yuan, with the maximum value being 105 times the minimum, showing a huge disparity. Zhangbei County received the largest compensation amount at 6.540×10^7 yuan, followed by Xinglong County (5.944×10^7 yuan) and Yu County (8.2×10^6 yuan). Counties with "tight balance" cultivated land ecological conditions were Zunhua, Luanping, and Quyang, as shown in [Figure 4: see original paper].

[Figure 4: see original paper] Quantification of ecological compensation of counties (cities) in the area around Beijing and Tianjin

2.5 Cultivated Land Ecological Compensation Amount from a Grain Security Perspective

Based on calculation results, ARCGIS10.0 natural breakpoint method was used to classify ecological compensation priority into four levels: 0.1681-0.0750, 0.0749-0.0484, 0.0483-0.0315, and 0.0314-0.0145, with larger values indicating higher compensation priority. Analysis of the above cultivated land ecological compensation amounts ([Figure 4: see original paper]) shows that counties with the largest grain-cultivated land gaps were 19 counties including Luannan, Yutian, Dongguang, and Cangzhou, all with compensation amounts above 3.400×10^7 yuan. Among these, Luannan, Yutian, Xianxian, Wuqiao, and Dingzhou had smaller ecological compensation priorities, showing food insecurity and less per capita cultivated land resources. These counties provide ecological services to other regions at the cost of grain and ecological security, belonging to "ecological consumption zones." Payment of ecological compensation would have minimal economic impact, so they should prioritize ecological payments. Counties with grain-cultivated land surpluses were 17 counties including Zhangbei, Xinglong, Yu, and Shangyi. Among these, Zhangbei, Yu, Shangyi, Yangyuan, Laiyuan, and Quyang had the largest

ecological compensation priorities, showing food security. Rapid advancement of urbanization and industrialization has made these counties “ecological supply zones,” and receiving compensation would significantly impact their economic development, so they should receive ecological compensation first. Tangxian, Laishui, and Fengning Manchu Autonomous County all had small grain-cultivated land gaps and small ecological compensation priorities, but can basically meet their own requirements and do not urgently need ecological compensation.

3 Conclusions and Discussion

Using prefecture-level and municipal administrative regions as research units, this paper introduced a cultivated land ecological compensation quantification model to explore the cultivated land ecological conditions of 72 counties (cities) in Hebei Province’ s Beijing-Tianjin environs and quantify compensation intensity. Research results show: (1) In 2014, the total ecosystem service value of cultivated land in the Beijing-Tianjin environs was 4.4805×10^1 yuan, with overall value distribution characteristics of low values in the north and high values in the central and southern regions, consistent with the trend of increasing cultivated land quantity from north to south. (2) The ecological overload index of cultivated land in the Beijing-Tianjin environs showed an overall deficit trend. Small areas in Zhangjiakou, Tangshan, and Langfang in the northern region showed surpluses, while all other counties (cities) showed deficits. (3) A typical “spatial dislocation” phenomenon exists between “ecological supply” and “ecological consumption” of cultivated land in the Beijing-Tianjin environs, with “ecological consumption” mainly concentrated in central and southern regions while “ecological supply” is primarily in the northern region. Seventeen counties including Zhangbei, Xinglong, Yu, Shangyi, and Laiyuan should receive cultivated land ecological compensation, while all other counties and cities should pay compensation. (4) In 2014, the ecosystem service value of cultivated land in the Beijing-Tianjin environs showed an overall inability to be self-sufficient, with a total deficit of 7.834×10 yuan. Luannan County required the highest cultivated land ecological compensation payment, followed by Yutian and Dongguang counties. Zhangbei County received the largest compensation amount. Although Zunhua, Luanping, and Quyang counties could receive compensation, their cultivated land ecological conditions remained in “tight balance” requiring continued attention. (5) From a grain security perspective, counties urgently needing cultivated land ecological compensation in the Beijing-Tianjin environs were Zhangbei, Yu, Shangyi, Yangyuan, Laiyuan, and Quyang, while counties needing to pay compensation were Luannan, Yutian, Xianxian, Wuqiao, and Dingzhou. Tangxian, Laishui, and Fengning Manchu Autonomous County could basically guarantee grain security and be self-sufficient, neither requiring nor paying cultivated land ecological compensation.

Previous research has focused more on compensation priority—the question of “who compensates whom first” —with less research on ecological compensation

quantification. This study explores cultivated land ecological compensation issues in Hebei Province's Beijing-Tianjin environs from a grain security perspective combined with ecological compensation priority, quantifying inter-county (city) cultivated land ecological compensation amounts and priorities, and clarifying economic relationships in cultivated land ecological compensation among counties in the Beijing-Tianjin environs. This plays an important role in promoting economic development, cultivated land ecological environmental protection, and sustainable, efficient utilization of cultivated land resources in the Beijing-Tianjin environs. However, this study only conducted quantitative analysis of spatial distribution patterns of cultivated land ecological compensation in the Beijing-Tianjin environs for 2014, without deeply analyzing the causes of these spatial distribution patterns or conducting comprehensive spatiotemporal dynamic analysis combined with temporal variation patterns. Future research could explore appropriate methods for further in-depth analysis of spatiotemporal variation characteristics and driving forces of cultivated land ecological compensation in the Beijing-Tianjin environs, as well as measures and suggestions for improving cultivated land ecological environmental quality.

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