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# Agricultural Green Development and Spatiotemporal Characteristics at the County Level in the Yellow River Basin

# --A Case Study of Ningxia Province

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**Abstract:** Drawing from the essence of sustainable agricultural practices, this study upholds the foundational principles of ecological and resourceful stewardship, prioritizing excellence in growth. An evaluative framework has been devised to gauge the eco-friendly progress of agriculture at the county level, encompassing three key areas: the preservation of resources, ecological sustainability, and the caliber of productivity. Utilizing a data set spanning a decade (2012-2021) and encompassing 25 counties within the Ningxia region, the research employed several analytical techniques: (1) applying the entropy approach to ascertain the degree of agricultural sustainability, (2) leveraging the kernel density estimation to examine the progression over time, (3) employing the Gini index to dissect regional disparities in sustainable development, and (4) categorizing the trajectory of eco-progression across the counties. The findings indicate an upward trend in the eco-progressiveness of Ningxia's counties, with a notable reduction in regional disparities and spatial inequalities. In conclusion, the study advocates for a strategic blend of holistic enhancement and targeted initiatives to steer Ningxia's agricultural sector towards a greener future.

**Keywords**. Agriculture, green development, entropy method, kernel density function, Gini coefficient, spatiotemporal characteristics

## 1. Introduction

As the 21st century has unfolded, the progression of industrial and urban growth has generated substantial economic prosperity for society and furthered societal advancement. However, this has also led to challenges for agricultural development, including the exhaustion of natural resources, environmental pollution, and significant

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disruptions to ecological systems. Darwin, in 1859, provided an analysis of sustainable progress through the lens of biological evolution[1]. It is imperative for humanity to focus on the quality of agricultural produce and the safeguarding of our ecological environment[2][3]. The Chinese government has not only pledged to reduce emissions but has also actively implemented these commitments. In late 2020, the Ningxia Hui Autonomous Region received approval to create a national demonstration zone for green agricultural development. The following year, a collaborative effort among seven Ningxia departments resulted in the formulation of the regional 14th Five-Year Plan for Agricultural Green Development (2021-2025), laying the groundwork for this national initiative. Utilizing data from 25 counties across Ningxia from 2012 to 2021, this study examines the spatial and temporal variations and traits of Ningxia's agricultural sustainability. By adopting a county-centric approach to investigation and research scope, the paper aims to contribute to the existing body of research on green agricultural development.

## 2. Literature Review

The year 1987 marked a significant milestone with the United States introducing the concept of sustainable development to the global stage. Scholars have since recognized the importance of an agricultural model that is not only efficient and technologically advanced but also environmentally conscious[4][5]. Proponents of green agriculture argue for the need to standardize agricultural products, produce eco-friendly food, and enhance ecological systems, thereby extending the principles of green practices across the entire agricultural sector[6][7][8]. This approach to agriculture is seen as complementary to broader national initiatives such as urban development, industrial growth, and the revitalization of rural areas[9], with an ongoing need to deepen and expand the concept's scope[10]. The 20th National Congress of the CPC has set ambitious targets for the sector, calling for an environmentally sustainable overhaul of agricultural practices[11]. This aligns with the nation's overarching strategy to prioritize resource conservation, environmental stewardship, and the pursuit of excellence in development.

When assessing the level of sustainability in agriculture, researchers have employed a variety of methodologies and focused on diverse subjects for their evaluations. For example, the concept of green GDP was highlighted by Alfsen Knut and colleagues in the context of the Green System of National Accounts in 1978[12]. Later, Osterburg's work in 2004 focused on the European Union's approach to green accounting[13]. Hall and Kerr introduced the innovative 'green index' in 2011, which included the development of an assessment framework for green development[14]. Spatial analysis has also been a key component in this field, with researchers estimating the sustainability levels of agriculture in China[15][16][17] and conducting measurements for regions such as Ningxia, Beijing, Hainan, and Tianjin[18][19][20][21]. Studies have also been conducted on particular areas critical to China's agricultural output[22], including the primary grain-producing regions, the Yellow River Basin[23], the Beijing-Tianjin-Hebei area, and the Bohai Rim[24][25].

Extending the scope of research, certain academics have delved into the specifics of agricultural sustainability at a more localized level, focusing on individual counties [26][27]. Upon surveying the existing literature, a common trend emerges: the majority of researchers have crafted comprehensive index systems aimed at gauging the degree of green development within the agricultural sector. In terms of quantification, techniques such as the non-radial, non-angular SBM (Solvency II Benchmark) model and the GML (Global Metadata Language) productivity index have been deployed to calculate the Agricultural Green Total Factor Productivity (AGTFP) [28]. Furthermore, the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analytical framework has been implemented to evaluate the sustainability of agricultural practices in the Tibet region [29].

Building upon the foundation laid by prior scholarly work, this study aligns with the nation's fundamental policies of conserving resources and protecting the environment, with a central focus on achieving development that is of high caliber. Utilizing the entropy weight approach, the research evaluates the sustainability of agricultural practices across 25 counties and districts in Ningxia, spanning a decade from 2012 to 2021. The analysis delves into the characteristics of how this green development has unfolded over time and across different regions, employing both longitudinal and cross-sectional comparative techniques to reveal the spatiotemporal patterns of evolution.

## 3. Construction of Evaluation Index System

The green development of agriculture is a highly complex economic concept, and a reasonable statistical measure of its development level can provide a data reference for clearly grasping the development status and clarifying its development shortcomings. In this paper, 25 counties (county-level cities and municipal districts) in Ningxia were taken as the evaluation objects, and the evaluation index system of agricultural green development level suitable for counties was constructed, and the level of agricultural green development in Ningxia was measured and its spatiotemporal evolution characteristics were explored.

### *3.1 Principles for Indicator Determination*

#### *3.1.1Principle of Data Availability*

The evaluation indicators of agricultural green development shall have the fundament of data availability. At present, most scholars have established an estimate index system for agricultural green development that includes resources, environment, ecology and supply based on policy documents such as the Assessment Measures for Agricultural Green Development Pilot Zones, but as far as the research on agricultural green development at the county level is concerned, some data are difficult to obtain completely. Therefore, in the process of constructing the indicator system, this paper should first consider the difficulty of data availability, and index selection with reliable data sources and easy to get.

#### *3.1.2 Scientific Principles*

Its core purpose is to make the evaluation indicators not only accurately and profoundly reflect the important characteristics of agricultural green development, but also scientifically reflect the intrinsic meaning of agricultural green development. In the process of collecting and sorting out specific indicators, comprehensive consideration and reasonable processing should be carried out in composite with specific indicators.

### *3.1.3 Principle of Representativeness*

There are differences in the factor endowment of agricultural development in Ningxia, particularly the characteristics of population distribution, natural environment and industrial structure. Therefore, when designing the indicator system, it is necessary to fully consider the characteristics of each region, and strive to ensure regional fairness and representatives of the evaluation system.

## *3.2 Indicator Selection*

As outlined in the “Assessment Measures for Agricultural Green Development Pilot Zones”, the multifaceted approach to green agriculture encompasses key dimensions such as resource management, environmental stewardship, ecological balance, and the provisioning of goods. It's important to note that the provision of sustainable agricultural products encompasses the overall quality of agricultural development, which in turn is closely related to the goals and objectives set forth. In line with this, the 14th Five-Year Plan for Agricultural Green Development in the Ningxia Hui Autonomous Region, covering the years 2021 to 2025, has outlined objectives to enhance the ecological environment of agriculture, elevate the quality, efficiency, and competitiveness of the sector, and to develop an institutional framework that prioritizes green ecology. This framework is in harmony with the country's foundational policies on conserving resources and protecting the environment, with a strong emphasis on achieving high-quality growth. Against this backdrop, the present study has integrated the dual concepts of environmental and ecological considerations, as well as supply and quality aspects, to delineate three primary indicators: conservation of resources, environmental sustainability, and the dual focus on quality and efficiency. The process of identifying subsequent, or secondary, indicators is an additional step in this methodology.

Systematically combing the relevant indicators in government documents and referring to the investigation results of the academic community, 11 representative secondary indicators were screened out through comprehensive data availability, through substitution, elimination and other operations, on the basis of ensuring the effectiveness and stability of the indicator system. (Table 1).

**Table 1.** Index system of agricultural green development level in Ningxia

| Target layer | Primary indicator | Secondary indicators | Unit of measure | Indicator explanation | Direction |
|---|---|---|---|---|---|
| Evaluation of the level of green development of | Resource conservation | Multiple cropping index of cultivated land | % | Crop sown area/cultivated area | - |
| | | Land productivity | 10,000 yuan/$hm^2$ | Gross agricultural output / area of agricultural arable land | + |
| | | Labor productivity | 10,000 yuan/person | Gross output value of agriculture, forestry, animal husbandry and fishery/employment in the primary | + |

| | | | | | |
|---|---|---|---|---|---|
| agriculture in Ningxia | | | | industry | |
| | Environmentally friendly | Fertilizer application intensity | t/hm$^2$ | Fertilizer application rate/crop sown area | - |
| | | Pesticide application intensity | t/hm$^2$ | Pesticide application rate/crop sown area | - |
| | | Strength of agricultural film | t/hm$^2$ | Agricultural plastic film use/crop sown area | - |
| | | Agricultural diesel usage | t | Statistical indicators | - |
| | | Proportion of nature reserves | % | Area of nature reserves/area of jurisdiction | + |
| | Efficient quality | Per capita disposable income of rural residents | yuan/person | Statistical indicators | + |
| | | Proportion of agricultural products with geographical indications | pcs/hm$^2$ | Number of GI products for agricultural products/cultivated area | + |
| | | The proportion of China's leading agricultural brands | pcs/hm$^2$ | Number of leading agricultural brands in China/cultivated area | + |

### *3.2.1 Resource Conservation*

The indicator in question measures the extent of resource utilization within agricultural production processes. The principle of green agricultural development mandates a paradigm where minimal resource inputs are employed to achieve higher output values. This approach not only enhances efficiency but also fosters an integrated system where agricultural practices are harmoniously aligned with the goals of resource conservation and environmental preservation.

### *3.2.2 Environmentally Friendly*

Traditional agriculture is characterized by 'high consumption, high contamination and high emission', and agricultural materials such as chemical fertilizers are the main sources of non-point source pollution, but there is a tremendous gap in the efficient utilization rate data at the county level. Therefore, the intensity of chemical fertilizer, pesticide and agricultural film was selected to estimate the source control of pollution. From the perspective of pollutant emission source control, the use of agricultural diesel was chose to evaluate the degree of pollutant emission in agricultural production. Finally, the establishment of nature reserves is the main way to protect ecosystems in China, and a nature reserve often includes a variety of ecosystems, which is of great significance to maintain biodiversity and ecological balance, so the proportion of nature reserves is used to evaluate the degree of ecosystem protection.

### *3.2.3 Efficient Quality*

Whether farmers adopt green production methods is closely relevant to the level of household economy, so the per capita disposable income of rural residents is selected to estimate the quality of economic output. Additionally, it is also essential to erect a green and low-carbon agricultural industrial chain to improve the quality, efficiency and competitiveness of agriculture.

### *3.3 Data Sources and Processing*

The foundational data necessary for these indicators have been sourced from a range of official publications, spanning from the China Statistical Yearbook for the years 2013 to 2022. Additionally, the Ningxia Hui Autonomous Region Statistical Yearbook has been utilized, along with the Statistical Communique on the National Economic and Social Development for prefecture-level cities, counties, and their respective districts. Ningxia Hui Autonomous Region Natural Resources Bulletin, China Green Food Network, Ningxia Sannong Information Service Desk, National Research Data and other statistical data and data.

### *3.4 Indicator Weights are Determined*

Using the entropy method to calculate the weight value of the estimate index[30]:

Step 1: Standardization of indicators for data standardization processing.

Positive indicators are those where higher values are considered better or more desirable. The goal of normalization in this case is to scale all values within the range of 0 to 1, where 1 represents the best possible score. The formula for normalizing positive indicators is:

$$x_{ij} = \frac{X_{ij} - X_j^{min}}{X_j^{max} - X_j^{min}} \tag{1}$$

Where: the term $x_{ij}$ denotes the adjusted or normalized measurement for indicator j within the i-th data set entry. In contrast, $X_{ij}$ represents the raw data value for the j-th indicator corresponding to the i-th entry. $X_j^{min}$ signifies the lowest recorded value for indicator j across the entire data set, while $X_j^{max}$ is the highest value observed for that same indicator. The variable i serves as a counter for the data set entries, generally extending from 1 up to n, which denotes the overall count of entries examined. Similarly, j acts as a counter for the indicators, customarily starting at 1 and going up to m, representing the total set of indicators being assessed.

Negative indicators are those where lower values are considered better or more desirable. The normal process for negative indicators is slightly different to invert the scale, making lower values correspond to higher normalized scores. The formula for normalizing positive indicators is:

$$x_{ij} = \frac{X_j^{max} - X_{ij}}{X_j^{max} - X_j^{min}} \tag{2}$$

This formula is similar to the one for positive indicators, but it reverses the logic because negative indicators are those where lower values are preferable. All symbols have the same meaning as in the positive indicator formula. The key difference is the order of subtraction in the numerator, which reverses the scale so that lower values of $X_{ij}$ correspond to higher normalized values. By using this formula, the lowest value of the indicator (which is the most desirable for a negative indicator) is scaled to 1, and the highest value is scaled to 0.

Using the method of standardized numerical translation to address the logarithmic issue encountered in the entropy method operation.

Step 2: Compute the weight of year j under indicator i

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} (i=1, 2, \ldots, m) \tag{3}$$

Step 3: Calculate entropy value of the j index ej

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{4}$$

k>0, ln is the natural logarithm, ej⩾0, the constant k is related to the number of samples m, assuming pij=1/m, then k=1/lnm, where the value of ej is between 0 and 1.

Step 4: Calculate the difference coefficient of the jth index.

The greater the GJ difference coefficient, the lager the effect of the index on the research object.

$$g_j = 1 - e_j \tag{5}$$

Step 5: Assign weights to metric and define weights aj

$$a_j = \frac{g_j}{\sum_{j=1}^{n} g_j} (j=1, 2,\ldots,n) \tag{6}$$

Step 6: The composite score was calculated using the weighted function method $z_j$

$$z_j = \sum_{j}^{n} a_j x_{ij} (i=1, 2,\ldots, n) \tag{7}$$

Among them, $Z_j$ is the evaluation comprehensive score, $X_{ij}$ is the standardized value on the i index, $A_j$ is the weight value of the ith index, and I is the total number of evaluation indicators. The weights of each indicator are shown in Table 2.

**Table 2.** Weights of evaluation indicators for agricultural green development from 2012 to 2021

| Primary indicator | weight | Secondary indicators | weight |
|---|---|---|---|
| Resource conservation | 0.14 | Multiple cropping index of cultivated land | 0.01 |
| | | Land productivity | 0.07 |
| | | labour productivity | 0.06 |
| Environmentally friendly | 0.34 | Fertilizer application intensity | 0.04 |
| | | Pesticide application intensity | 0.02 |
| | | Strength of agricultural film | 0.02 |
| | | Agricultural diesel usage | 0.01 |
| | | Proportion of nature reserves | 0.26 |
| Efficient quality | 0.51 | Per capita disposable income of rural residents | 0.10 |
| | | Proportion of agricultural products with geographical indications | 0.13 |
| | | The proportion of China's leading agricultural brands | 0.29 |

### *3.5 Calculation results*

Table 3 shows the comprehensive results of the calculation of the level of agricultural green development.

**Table 3.** Comprehensive score of agricultural green development in Ningxia prefecture-level cities from 2012 to 2021

| year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | Mean | growth | ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| total | 0.18 | 0.19 | 0.20 | 0.20 | 0.21 | 0.21 | 0.22 | 0.22 | 0.24 | 0.24 | 0.21 | 0.16 | |
| Yinchuan | 0.41 | 0.41 | 0.41 | 0.42 | 0.43 | 0.43 | 0.45 | 0.46 | 0.48 | 0.49 | 0.44 | 0.05 | 1 |
| Shizuishan | 0.14 | 0.12 | 0.14 | 0.14 | 0.15 | 0.15 | 0.16 | 0.15 | 0.17 | 0.17 | 0.15 | 0.08 | 5 |
| Wuzhong | 0.18 | 0.19 | 0.20 | 0.19 | 0.20 | 0.20 | 0.21 | 0.22 | 0.23 | 0.25 | 0.21 | 0.17 | 3 |
| Guyuan | 0.16 | 0.18 | 0.19 | 0.18 | 0.19 | 0.19 | 0.20 | 0.21 | 0.22 | 0.22 | 0.19 | 0.22 | 4 |
| Zhongwei | 0.17 | 0.20 | 0.20 | 0.20 | 0.21 | 0.21 | 0.22 | 0.23 | 0.24 | 0.25 | 0.21 | 0.35 | 2 |

As can be seen from Table 3, among the prefecture-level cities, the order of average annual growth rate is as follows, Zhongwei City> Guyuan City> Wuzhong City> Shizuishan City> Yinchuan City; among them, Shizuishan City and Yinchuan City have an average annual growth rate of more than 10%. The average annual growth rate of 9 counties (cities and districts) in Shapotou District, Dawukou District, Qingtongxia City, Tongxin County, Hongsibao District, Longde County, Jingyuan County, Huinong District and Yanchi County surpassed 10%; among them, the average annual growth rate of 6 counties (districts) is faster than the average, and the average annual growth rate of 6 counties (districts) is less than 5%.

From 2012 to 2021, the level of agricultural green development from high to low was Yinchuan City, Zhongwei City, Wuzhong City, Guyuan City and Shizuishan City. The level of agricultural green development in 12 counties (districts) was higher than the average of the entire area (0.2100). Among them, Yongning County, Yinchuan Municipal District and Helan County have a high level of agricultural green development, the means exceed 0.6, while Xiji County, Pengyang County, Huinong District, Tongxin County, Haiyuan County, Pingluo County, Dawukou District and Hongsibao District have a low level of agricultural green development, the means is below 0.2.

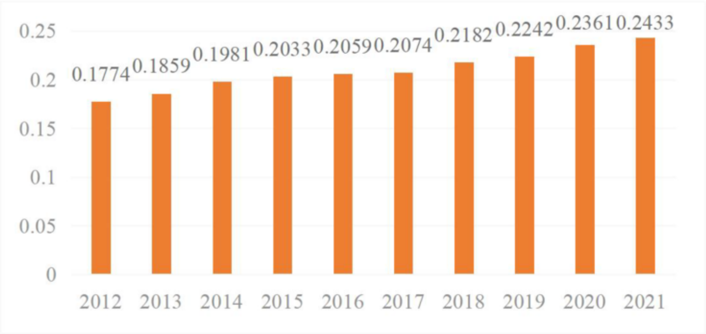


**Figure 1.** Comprehensive score of Ningxia's agricultural green development

Overall, the average level of agricultural green development in Ningxia increased from 0.1774 in 2012 to 0.2433 in 2021, with an average annual growth rate of 16% (Figure 1). It can be divided into three stages, two periods of high growth and development from 2012 to 2015 and 2018 to 2021, and a period of moderate development from 2015 to 2018.

## 4. Analysis of overall timing characteristics

### *4.1 Measurement tools*

Kernel density is a quantitative function used to estimate the unknown density, which has the advantages of strong robustness, and is a general tool for time series dynamic analysis. The specific formula is as follows:

$$f_s(x) = \frac{1}{ns}\sum_{i=1}^{n} k\left(\frac{x-x_i}{s}\right) \tag{8}$$

Among them, x is the mean value of agricultural green development level, fs(x) is the estimated kernel density, xi is the estimated sample, n is the total number of prefecture-level cities, s is the bandwidth, and k is the weighted kernel function, including Gaussian kernel and triangular kernel.

### *4.2 Analysis of results*

According to the comprehensive score of Ningxia's agricultural green development level, the kernel density estimation results of the temporal evolution characteristics of Ningxia's agricultural green development level were obtained by using Stata 15.0 software in 2012, 2016 and 2021.

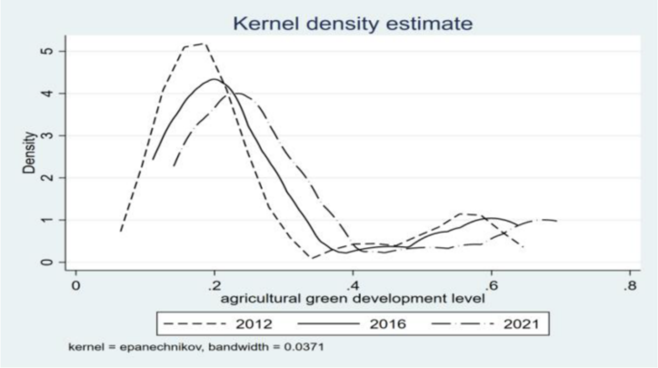


**Figure 2** Distribution of kernel density at the level of agricultural green development in Ningxia in 2012, 2016 and 2021

The kernel density curve from 2012 to 2021 showed a significant shift to the right, and the version amplitude of the second stage was greater than that of the first stage, indicating that the comprehensive level of agricultural green development in Ningxia continued to improve. From the perspective of shape, the three years showed a ‘three-peak-double-peak-double-peak’ evolution trend, indicating that the level of agricultural green development in Ningxia counties (cities and districts) from 2012 to 2021 showed a dynamic changing of multi-level differentiation at the beginning of the sample period and gradually weakening in the middle and late stages.

In 2016 and 2021, the right peak gradually showed a wide peak distribution, the capped kernel density gradually decreased, and the corresponding level score of the peak gradually increased, indicating that the number of higher-level counties (cities and districts) in Ningxia showed an increasing tendency, and the overall level of agricultural green development in the entire region was improving.

## 5. Analysis of the spatial characteristics of the level of agricultural green development in Ningxia

### *5.1 Analysis of overall spatial characteristics*

#### *5.1.1Measurement tools*

The Dagum Gini coefficient can not only show the existence of differences, but also decompose them to show their sources. The specific formula is as follows:

$$G = \frac{\sum_{j-1}^{k}\sum_{h-1}^{k}\sum_{i-1}^{n_h}\sum_{r-1}^{n_h}|y_{ji}-y_{hr}|}{2n^2\bar{y}} \tag{9}$$

$$G_{jj} = \frac{\sum_{i=1}^{n_j}\sum_{r=1}^{n_j}|y_{ji}-y_{jr}|}{2n_j^2\bar{y}_j} \tag{10}$$

$$G_{jh} = \frac{\sum_{i=1}^{n_j}\sum_{r-1}^{n_j}|y_{ji}-y_{hr}|}{n_j n_h(\bar{y}_j+\bar{y}_h)} \tag{11}$$

Among them, G is the overall Gini coefficient, k = 2 and n = 20 are the number of prefecture-level cities and counties (cities and districts), respectively. Yij(yhr) is the level of agricultural green development in county I(R) in J(H) region, and is the average level of agricultural green development in the whole region. Gjj and Gjh are the Gini coefficients within j region and between regions j and h, respectively. The results of Dagum's Gini coefficient, the contribution rate and differential decomposition are shown in the Appendix.

#### *5.1.2 Spatial difference analysis*

In this paper, the comprehensive score of Ningxia's agricultural green development level is divided into five categories, 0.00~0.20, 0.20~0.40, 0.40~0.60, 0.60~0.80 and 0.80~1.00, as shown in Table 4.

**Table 4.** Classification criteria for the evaluation of agricultural green development level

| Criteria for division | Evaluation grade of agricultural green development level |
|---|---|
| [0.00,0.20) | Low |
| (0.20,0.40] | Lower levels |

| | |
|---|---|
| (0.40,0.60] | Medium level |
| (0.60,0.80] | Higher level |
| (0.80,1.00] | Level |

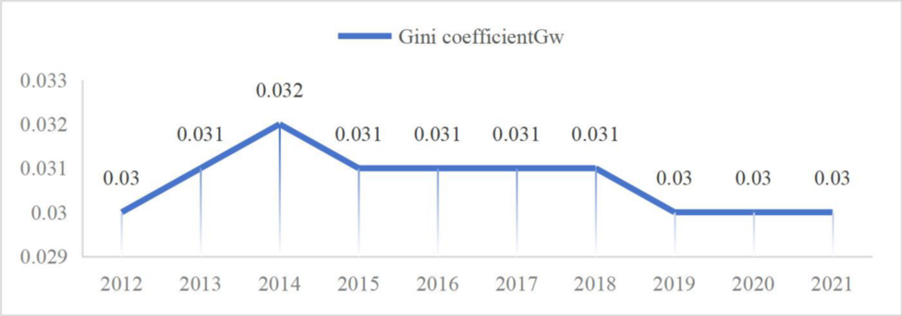


**Figure 3.** the level of agricultural green development in Ningxia from 2012-2021 year

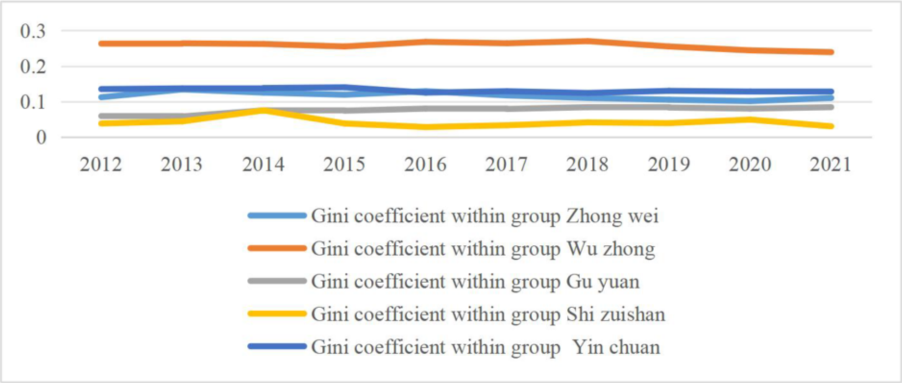


**Figure 4.** Differences in the level of agricultural green development in the whole region and at the local level

As shown in figure 3, the difference in the level of agricultural green development in the whole region are decreasing. Specifically, the Gini coefficient decreased from 0.297 in 2012 to 0.274 in 2021, a decrease of 7.74%. From the perspective of level, the Gini coefficient is more than 0.25, indicating that the overall level of agricultural green development in Ningxia is fairly various.

As shown in figure 4, from the perspective of the change trend at the prefecture-level city level, except for Guyuan City, the difference in the level of agricultural green development in the other four prefecture-level cities has decreased. Among them, from 2012 to 2021, on the one hand, the Gini coefficient decreased by 4.44% in Yinchuan City, 21.05% in Shizuishan City, 9.13% in Wuzhong City, and 1.79% in Zhongwei City, while on the other hand, the Gini coefficient in Guyuan City increased from 0.059 to 0.084, an increase of 42.37%, which illustrate the difference in the level of agricultural green development in the region has increased. From the perspective of the level of difference, Wuzhong City had the great difference in the level of agricultural green development, with an average Gini coefficient of 0.2584, while Shizuishan City had the minor difference, with an average Gini coefficient of 0.0415.

### *5.2 Spatial difference analysis in different dimensions*

From the perspective of resource conservation, there are high-level and medium-level counties (cities and districts), and by 2021, low-level areas still account for the enormous majority, such as Helan County, Yongning County and Qingtongxia City, indicating that the overall level of agricultural resource utilization is extremely unsatisfactory. Among them, the mean Gini coefficient is 0.228, which varies greatly amongst regions.

From the perspective of environmental friendliness, there are different degrees of improvement or deterioration in each county (city, district), but the change range is small, and the majority of them are still at a low level or a low level. The cause for this is that Yinchuan City is located in the economic center, Helan County and Yongning County have lot of nature reserve resources, and develop modern agriculture while suppressing traditional agriculture. Among them, the mean Gini coefficient of the environment-friendly dimension was 0.28, which varied greatly among regions.

### *5.3 Spatial evolution type analysis*

Referring to the classification method of Gai Mei et al. [10], the estimate types of agricultural green development level in Ningxia are shown in Table 5.

**Table 5.** Evolution types of agricultural green development level in Ningxia in 2012, 2016 and 2021

| Type of evolution | County (City, District) | Cities | partition |
|---|---|---|---|
| Higher—Higher—Higher | Yongning County | Yin chuan City | Yellow irrigation area in the north |
| Medium—Medium—High | Yinchuan Municipal District | Yin chuan City | Yellow irrigation area in the north |
| | Helan County | Ying chuan City | Yellow irrigation area in the north |
| Medium—Medium—Medium | Litong District | Wu zhong City | Yellow irrigation area in the north |
| | Dawukou District | Shizuishan City | Yellow irrigation area in the north |
| | Huinong District | Shizuishan City | Yellow irrigation area in the north |
| Low—Low—Low | Pingluo County | Shizuishan City | Yellow irrigation area in the north |
| | Red Temple Fort District | Wuzhong City | Central Arid Zone |
| | Peng yang County | Guyuan City | Southern Mountains |
| | Hai yuan County | Zhongwei City | Central Arid Zone |
| Low—Low—Low | Xi ji County | Guyuan City | Southern Mountains |
| | Tong xing County | Wuzhong City | Central Arid Zone |
| | Qing Tong xia County | Wuzhong City | Yellow irrigation area in the north |
| Low—Lower—Lower | Yuan zhou District | Guyuan City | Southern Mountains |
| | Jing yuan County | Guyuan City | Southern Mountains |
| | Sha bo tou District | Zhongwei City | Yellow irrigation area in the north |
| | Ling wu City | Yinchuan | Yellow irrigation area in the north |
| Lower—Lower—Lower | Yan chi County | Wuzhong City | Central Arid Zone |
| | Long de County | Guyuan City | Southern Mountains |
| | Zhong ning County | Zhongwei City | Yellow irrigation area in the north |

In terms of Table 5, spatial distribution, there is a lack of high-level areas for agricultural green development in Ningxia, and low-low-level counties (cities and districts) account for the majority, and the spatial pattern generally presents the agglomeration characteristics of higher in the Yellow River Basin and lower in the rest of the region, which is consistent with the distribution of agricultural and rural modernization development in Ningxia Hui Autonomous Region.

## 6. Conclusions

From 2012 to 2021, the agricultural green development level of prefecture-level cities in Ningxia ranked Yinchuan, Zhongwei, Wuzhong, Guyuan and Shizuishan in order from high to low, and the ranking of green development level of prefecture-level cities remained basically unchanged in the past 10 years. In terms of counties (cities and districts), the agricultural green development level of 12 counties (cities and districts) during the sample period was higher than the regional average (0.2100), among which Yongning County, Yinchuan City and Helan County had a higher agricultural green development level, with an average of above 0.6. The level of agricultural green development in Xiji County, Pengyang County, Huinong District, Tongxin County, Haiyuan County, Pingluo County, Dawukou District and Hongsi District was lower than 0.2, among which Hongsi District had the lowest level with an average of 0.11.

In the dimension of environmental friendliness, various counties (cities and districts) have improved or deteriorated to varying degrees, but the change is small, and most of them are still at a low level or low level. In terms of quality and efficiency, counties (cities and districts) have improved to different degrees during the sample period, but low-level areas still account for the majority. Among them, the average Gini coefficient of the quality efficiency dimension is 0.502, with great differences among different regions. In terms of resource conservation, there are no high-level, high-level or medium-level counties (cities and districts) during the sample period. Among them, the average Gini coefficient is 0.228, with large differences between regions.

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