



# Indicators for Evaluating High-Quality Agricultural Development: Empirical Study from Yangtze River Economic Belt, China

Xufeng Cui<sup>1</sup> · Ting Cai<sup>1</sup> · Wei Deng<sup>1</sup> · Rui Zheng<sup>1</sup> · Yuehua Jiang<sup>1</sup> · Hongjie Bao<sup>2</sup>

Accepted: 26 July 2022 / Published online: 14 August 2022  
© The Author(s), under exclusive licence to Springer Nature B.V. 2022

## Abstract

Agriculture is the foundation of the national economy, and achieving high-quality agricultural development is an important support for strong economic development in the post-pandemic era. Based on the new development philosophy of the Chinese government, this study constructs an evaluation framework of “innovation-coordination-green-openness-sharing” for high-quality agricultural development, and quantitatively assesses the level of high-quality agricultural development in China’s Yangtze River Economic Belt with a systematic integration model, and explores the spatial evolution characteristics and obstacles of the level of high-quality agricultural development in Yangtze River Economic Belt. It reveals that the level of high-quality agricultural development in the Yangtze River Economic Belt shows a fluctuating upward trend in general, but there is variability among regions. The green dimension has the fastest development rate, followed by innovation and sharing. In terms of spatial characteristics, it gradually shows a pattern dominated by high levels and shows the characteristics of agglomeration, but the spatial correlation is not high. In terms of obstacle factors, openness and coordination are the main obstacle factors. Considering the different agricultural development models, it is suggested that international cooperation, new agricultural cooperation, and differentiated policies can be considered to promote high-quality agricultural development. This study provides a more complete evaluation framework for government policy-making authorities to measure the level of regional agricultural development and help regional agriculture achieve sustainable development at a higher quality level.

**Keywords** High-quality development · Innovation-coordination-green-openness-sharing · Agriculture · Spatial–temporal evolution · Obstacle diagnosis

---

✉ Xufeng Cui  
cxf@zuel.edu.cn

✉ Yuehua Jiang  
jyh@stu.zuel.edu.cn

Extended author information available on the last page of the article

## 1 Introduction

Agriculture is the foundation of the national economy, and its quality is closely related to the stable and sustainable development of agriculture. With the rapid development of the world economy, agricultural development has made remarkable achievements in the world. The agricultural structure has been optimized, the degree of sustainable development of agriculture has been deepened, and the transformation of agricultural economic development methods has been continuously promoted. However, there are many constraints and challenges in agricultural development, such as agricultural pollution (Li et al., 2021), lack of awareness of agricultural innovation (Rocha et al., 2019), and low agricultural productivity (Baležentis et al., 2021). Therefore, in order to ensure food security and achieve rapid economic development, we should pay attention not only to the output of agricultural, but also to the quality of agricultural development. Considering the goal of greening, quality and branding of agriculture, scholars put forward a variety of agricultural development philosophies, such as smart agriculture, sustainable agriculture, and low-carbon agriculture (Adesipo et al., 2020; Wang et al., 2022b; Zhao & Zhou, 2021).

The 2017 Central Rural work Conference of China proposed that “in order to implement the strategy of rural revitalization, we should firmly follow the path of promoting agriculture through quality and policy”,<sup>1</sup> and the Ministry of Agriculture and Rural Affairs of the PRC designated the year of 2018 as the “Year of Agricultural Quality”.<sup>2</sup> According to China’s official measurement, China’s total grain output has reached 1.339 billion tons in 2020, realizing the “seventeen consecutive years of bumper harvests” of China’s grain production and effectively ensuring China’s food security. Some scholars have pointed out that although the output of agricultural products has increased significantly in recent years, the main agricultural contradiction in China has changed from the pursuit of “quantitative agriculture” to the pursuit of “quality agriculture” (Kou, 2018; Xin & An, 2019). In this context, how to promote high-quality agricultural development has become a hot issue in academic research. Since the outbreak of COVID-19, high-quality agricultural development has become the support of China’s “domestic circulation” and an important engine of the “domestic and international dual circulation”, and its practical value has been further highlighted.

This study is expected to contribute to the literature in two aspects. On the one hand, previous scholars did not construct a systematic framework for organizing evaluation, especially the evaluation of agricultural green development level did not reflect the environmental constraints in the agricultural production process, see e.g. Liu et al. (2020), Adesipo et al. (2020), Li and Xu (2020). Therefore, this study has constructed a systematic analytical framework of “innovation-coordination-green-opening-sharing”, which is based on the Chinese government’s new development philosophy. On the other hand, the measurement of the development level, distribution and influencing factors of high-quality agriculture has been the focus of previous literature, but few scholars put forward differentiated management policies for the study area, see e.g. Zhang (2021), Xin and An (2019), Wang et al.

<sup>1</sup> *The Central Conference on Rural Work was held in Beijing*, published by Ministry of Agriculture and Rural Affairs of the People’s Republic of China, [http://www.moa.gov.cn/ztl/negzhy2017/zxd/201801/t20180103\\_6133744.htm](http://www.moa.gov.cn/ztl/negzhy2017/zxd/201801/t20180103_6133744.htm).

<sup>2</sup> *Notice of the Ministry of Agriculture on starting the Work of 2018 Agricultural Quality Year*, published by Ministry of Agriculture and Rural Affairs of the People’s Republic of China, [http://www.moa.gov.cn/nygb/2018/201803/201805/t20180528\\_6143195.htm](http://www.moa.gov.cn/nygb/2018/201803/201805/t20180528_6143195.htm).

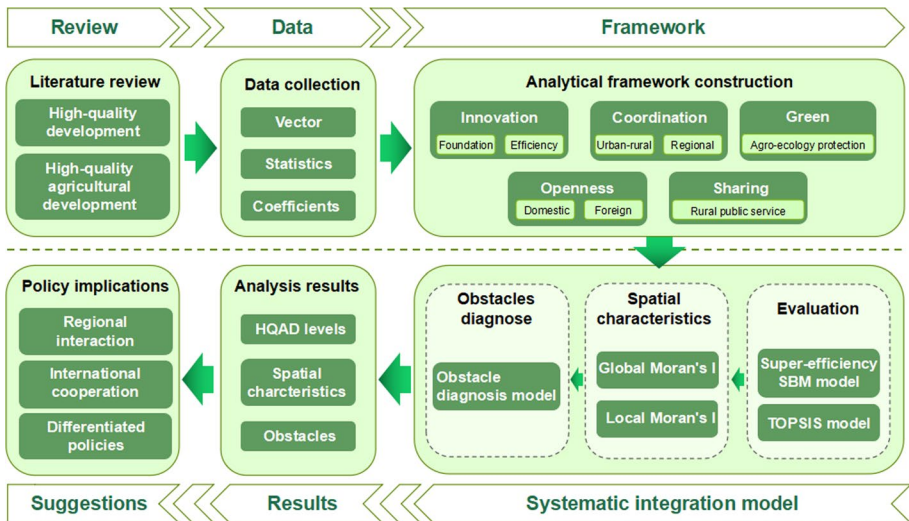


Fig. 1 The technology roadmap

(2022b). This study uses the mathematical model to evaluate the high-quality agricultural development from the aspects of spatio-temporal characteristics, obstacle factors and quadrant distribution, which can deepen the study of agricultural development and provide reference for agricultural management departments to make decisions.

To fill research gap, the primary purpose of this study is to build a systematic evaluation framework and an integrated model to reveal the high-quality agricultural development in the Yangtze River Economic Belt in recent 10 years. In order to better promote agricultural development in the study area, this study put forward differentiated management policies for agricultural development optimization according to the agricultural characteristics of each city. We believe that this study, while referring primarily to the Chinese experience, is a valuable voice in the discussion on the measurement and evaluation of high-quality agricultural development, which number is still inadequate.

The technology roadmap of the paper is shown in the Fig. 1, and the remainder of the paper is organized as follows. Section 2 locates our study within the literature on high-quality agricultural development. Section 3 describes the research methodology of this study, including the study area, methods and data. Section 4 investigates the evolution of agricultural quality development level, spatial distribution and spatial correlation over time in the Yangtze River Economic Belt, and put forward suggestions according to the agricultural development model. Section 5 presents the discussion. Section 6 presents the main conclusions and policy implications.

## 2 Literature Review

High-quality development (HQD) is the product of a certain stage of economic development in China, which means that the economy is not only pursuing speed and scale but quality and efficiency. It is not only applicable to the whole city economy, but also to agriculture, fishery and industry, etc. (Chen & Wang, 2021; Li & Liu, 2022; Wang & Li, 2021;

Wang et al., 2022a). Specifically, the definition of its philosophy is mainly divided into the following three types. Firstly, from the perspective of whether it can solve the main social contradictions in China, Jin (2018) believes that HQD is the state of economic development that can meet the growing economic and material needs of the people. Zhao (2017) believes that HQD is a sustained and healthy development, which is reflected in two aspects, on the one hand, to solve the problem of imbalance and inadequacy, and on the other hand, to solve the current social principle contradiction. Secondly, from the perspective of the new development philosophy, many scholars believe that HQD should implement the new development philosophy of “innovation, coordination, green, openness and sharing” as the main content, and realize the improvement of production efficiency, quality and sustainable development. Thirdly, from the perspective of multi-dimensional coordination (He, 2018; Shi & Zhang, 2018; Yang, 2018). Ren and Li (2018) believe that HQD is the development of rapid economic development, orderly integration of urban and rural areas, sustainable ecological improvement and improvement of people’s living standards.

Considering the rational allocation of agricultural production factors and the improvement of agricultural productivity, early scholars used total factor productivity (TFP) to measure agricultural quality (Baráth et al., 2020). As people pay more attention to the Sustainable Development Goals (SDGs), scholars realize that agricultural development is not only related to food security, but also to social stability and environmental protection. Some scholars have proposed sustainable agriculture, which is being defined as economically viable and profitable; socially encouraging as life quality of farmers is important and ecologically sound to preserve the natural environment and its resources sustaining the society, which focuses more on the environmental and safety issues (Streimikis & Baležentis, 2020; Wang et al., 2022b). High-quality agricultural development (HQAD) is the application of HQD in agriculture. Although only Chinese scholars put forward the concept of HQAD, sustainable agricultural development, and smart agriculture in the world can reflect the connotation of HQAD. Some scholars proposed that HQAD could be divided into four aspects: new driving force, efficient growth, industrial system integration, and sustainable development (Lu et al., 2022). Some scholars also think that the HQAD is the best mode of agricultural production with the goal of greening, quality and branding agriculture (Huang et al., 2020). Some scholars believe that the HQAD should reflect the new development philosophy, which is not only the requirement of HQD in the new era, but also the evaluation criterion of HQD (Liu et al., 2020).

Measuring the level of HQAD is conducive to analyzing the current situation and existing difficulties of agricultural development, and putting forward more targeted suggestions for promoting the healthy development of the agricultural economy and realizing the strategy of rural revitalization. By combing the literature on the level of HQAD (as shown in Table 1).

From the perspective of research direction, previous scholars have evaluated HQAD either based on existing economic theories to maximize agricultural economic value, or based on economic theories and sustainable development to maximize economic, social and ecological value. Previous scholars adopted total factor productivity (TFP) as an important indicator to reflect the growth rate and production efficiency of agricultural economy from the perspective of optimizing the allocation structure of economic factors of production, see e.g. Baráth et al (2020), Wang et al (2020) and Reza Anik et al. (2020). With the gradual and widespread application of the concept of sustainable development, scholars incorporated environmental resource constraints into the theory of traditional TFP, so as to obtain the green total factor productivity of agriculture (GTFP) and measure the quality of green agricultural development, such as Zhong et al. (2021), Xu et al. (2020)

**Table 1** Literature research on high quality development level of agriculture

Index system	Research method	Research scale	Literature source
Sustainable development of agriculture(economy, society, environment, ecology, and resources)	Entropy-TOPSIS model	Jiangsu Province, China (2016–2019)	Wang et al. (2022b)
Single factor productivity(SFP) and total factor productivity(TFP) of agriculture	Stochastic frontier production function	five Central Asian countries (1992–2017)	Wang et al. (2020)
Total factor productivity (TFP) of agriculture	Random parameter stochastic frontier models, propensity score matching (PSM), Difference in Difference (DID)	Slovenian (2006–2013)	Baráth et al. (2020)
Green development, supply efficiency, production scale and industrial diversification	Entropy weight method	31 provinces and cities in China (2017)	Xin and An (2019)
Agricultural resources, economic benefits, ecological environment, employees	Fuzzy hierarchy comprehensive evaluation	China	Zhang and Liu (2019)
Based on the new development philosophy, the index system with the development subject and development object as the criterion layer is constructed	Entropy weight method	30 provinces and cities in China (2017)	Qin (2020)
New development philosophy (innovation, coordination, green, openness and sharing)	Entropy weight method with time variable and exploratory spatial data analysis method	30 provinces and cities in China (2013–2017)	Li and Xu (2020)
Product quality, production efficiency, industrial benefits, operator's ability, international competitiveness, farmers' income and green development	Entropy method, kernel density, Pearson correlation analysis	30 provinces and cities in China (2016)	Huang et al. (2020)
New development philosophy (innovation, coordination, green, opening and sharing)	Entropy method, Moran index, Spatial econometric model	31 provinces and cities in China (2005–2017)	Liu et al. (2020)

and Fang et al. (2021). Some scholars have constructed a comprehensive framework for sustainable agricultural development based on economic, social and environmental dimensions, see e.g. Baležentis et al. (2021) and Du et al. (2020). Chinese scholars generally construct the HQAD evaluation framework from the five dimensions of "innovation, coordination, green, openness and sharing", and measure and analyze the level, spatial correlation and influencing factors of HQAD in China, see e.g. Liu et al (2020), Qin (2020) and Li and Xu (2020). Although most research framework can cover economy, society and ecology, it lacks systematicity. In particular, the evaluation of ecological protection level mostly adopts indicators such as green space area and pesticide and fertilizer usage, see e.g. Qin (2020), Li and Xu (2020), Huang et al (2020), which fails to reflect the input factors of agricultural production, resource utilization and environmental constraints.

From the perspective of research methods, the entropy weight method, fuzzy hierarchy comprehensive evaluation and other methods in previous literature are used to measure the high quality development level of agriculture, see e.g. Xin and An (2019), Zhang and Liu (2019), Qin (2020), Li and Xu (2020), Huang et al. (2020), Liu et al (2020). Based on the measurement results, few scholars use the spatial analysis method to analyze the characteristics of spatio-temporal evolution, see e.g. Li and Xu (2020), Liu et al. (2020), and use an econometric model to analyze the influencing factors of agricultural high-quality development level, see e.g. Lu et al. (2022), Liu et al. (2020), and finally put forward differentiated countermeasures and suggestions. On the whole, the spatial analysis and influencing factor analysis methods used in previous studies are rarely used, which makes it difficult for scholars to put forward correct and differentiated suggestions for promoting HQAD.

Although many scholars have carried out research on the HQAD, there are still some deficiencies. First, there is a deficiency in the systematic construction of the evaluation framework. Second, the research method is relatively inefficient, which leads to the depth of the research is not enough, and it is difficult to put forward targeted suggestions according to the characteristics of the study area. Therefore, this study constructs a systematic integrated model that incorporates a framework of "innovation-coordination-green-open-sharing" and mathematical methods. It can effectively assess HQAD systematically from processes of spatial and temporal characteristics, barrier factors, and quadrant distribution.

### 3 Methodology

#### 3.1 Study Area

The Yangtze River Economic Belt (YREB) includes 11 provinces and cities, including Shanghai, Jiangsu and Zhejiang, etc. It spans three economic regions in the east, middle and west of China (Fig. 2). The YREB has rich resource endowments, strong traffic conditions and important ecological status in China. It has strong comprehensive strength and great potential for development. The key to promoting the future development of the YREB lies in the overall grasp of the relationship between the elimination of old kinetic energy and the cultivation of new kinetic energy, self-development and coordinated development, economic development and environmental protection (*Outline of the Development Plan of the YREB in 2016*, [http://www.ndrc.gov.cn/fzgggz/dqjj/qygh/201610/t20161011\\_822279.htm](http://www.ndrc.gov.cn/fzgggz/dqjj/qygh/201610/t20161011_822279.htm)). The relationship among these three echoes with the philosophy of "innovation, coordination, green, openness and sharing" in the new development philosophy. Xiao et al. (2019) pointed out that although the YREB is abundant with agricultural resources

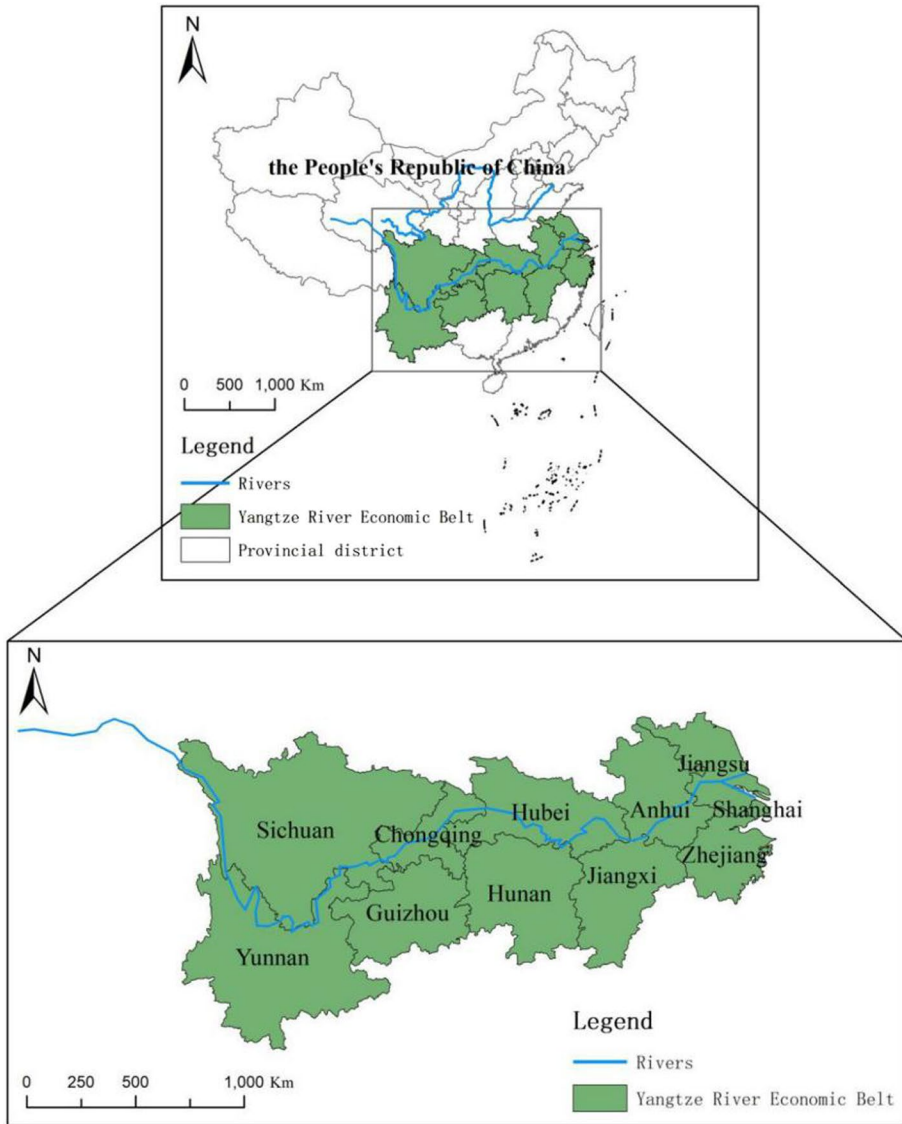


Fig. 2 Location of the Yangtze River Economic Belt. Data source: <http://bzdt.ch.mnr.gov.cn/>

and good quality of cultivated land, it faces difficulties such as lower food supply than the average level in China average level, reduction of agricultural land resources, aggravation of agricultural environmental pollution and so on. Therefore, in order to improve the utilization efficiency of agricultural resources in the YREB, consolidate the foundation of agricultural development, and help it to achieve HQD, this study measures the level of high-quality agricultural development, identify its temporal and spatial changes, spatial relations and obstacle factors, and put forward some suggestions to promote the high-quality agricultural development in YERB.

## 3.2 Methods

A systemic integration model named ESO is constructed for the evaluation and analysis of HQAD. It contains three modules: multidimensional evaluation model, spatial analysis model and obstacle diagnosis model. Among them, the multidimensional evaluation model undertakes the function of quantifying HQAD, the spatial analysis model tracks the spatial and temporal evolution of HQAD, obstacle diagnosis model identifies key obstacle for HQAD. These three modules achieve a systematic assessment of HQAD in three processes: quantification, analysis, and identification.

### 3.2.1 Multidimensional Evaluation Model

Based on the connotation of the new development philosophy and the relevant indicator frameworks, this study constructs the evaluation framework of the HQAD in the YREB, and then uses the unexpected output super-efficiency SBM model to calculate the agricultural green efficiency. Finally, the TOPSIS model and entropy method are used to calculate the comprehensive index of the level of HQAD.

**3.2.1.1 Multidimensional Evaluation Framework** The new development philosophy embodies the goal of China's HQD, so the process of promoting and realizing HQAD is the process of implementing the new development philosophy. Therefore, the evaluation of the development situation according to the new development philosophy is conducive to effectively identifying the problems in HQAD. The comprehensive evaluation framework of HQAD in the YREB is shown in Table 3.

#### (1) Agricultural Innovation

The level of innovation development refers to the level of transformation from innovation basis to innovation efficiency, which is mainly reflected in agricultural innovation basis and innovation efficiency (the indicators of agricultural innovation are shown in Table 3). Among them, the basis of agricultural innovation is the state of innovation subject and object, and the innovation level of agricultural subject is reflected by the educational level of agricultural laborers (Huang et al., 2020; Liu et al., 2020; Tambo & Wünscher, 2018; Zhang & Liu, 2019). The innovation level of agricultural objects is reflected by the degree of construction of the innovation platform (Huang et al., 2020; Zhang, 2021). Agricultural innovation efficiency refers to the benefits generated through agricultural production, operation and management, which is measured by the degree of agricultural scale (Liu et al., 2020; Qin, 2020), the degree of agricultural mechanization and grain per unit yield (Liu et al., 2020; Xin & An, 2019).

#### (2) Agricultural Coordination

Coordination is both a development goal and an indicator for evaluating the level of development, and China's development is in a state of in-coordination, which is mainly reflected in urban–rural coordination and regional coordination (the indicators of agricultural coordination are shown in Table 3). Therefore, in order to promote urban–rural coordination and agricultural regional coordinated development, this study selects urban–rural coordination



**Table 2** Evaluation frameworks of agricultural eco-efficiency

Index	Variable	Description of variable (unit)
Invest	Labor input	Agricultural employees (ten thousand people)
	Land input	Total sown area of crops (hm <sup>2</sup> )
	Mechanical input	Total power of agricultural machinery (KW)
	Irrigation input	Effective irrigation area (hm <sup>2</sup> )
	Agricultural film input	Use amount of agricultural film (t)
	Pesticide input	Pesticide dosage (t)
	Chemical fertilizer input	Chemical fertilizer usage (t)
	Fuel input	Usage of diesel oil (t)
Expected output	Output value	Agricultural output value (ten thousand CNY)
Unexpected output	Carbon emission output	Agricultural carbon emissions (t)

and regional coordination as the secondary index. Urban–rural coordination is a measure of the development gap between urban and rural areas, which is expressed by the ratio of urban–rural income level and consumption level (Xin & An, 2019). Regional coordination measures the speed of economic growth in the process of agricultural economic development, and uses the indication of agricultural economic growth rate (Liu et al., 2020).

### (3) Agricultural Green

Promoting green development and realizing the harmonious coexistence between man and nature is one of the main tasks of future development. Previous scholars generally used environmental pollution generated by agricultural production to express the green level of agriculture, such as chemical fertilizer, pesticide, diesel oil, the use of agricultural film, etc. (Li & Xu, 2020; Li et al., 2019; Liu et al., 2020). At present, more and more researchers pay attention to the indicative role of ecological efficiency in green development. Agricultural ecological efficiency refers to the degree of reducing agricultural resource investment and environmental pollution on the premise of ensuring agricultural output. This study uses agricultural ecological efficiency to express the green level of agricultural development, which not only reflects the input factors and resource utilization degree of agricultural production, but also reflects the environmental constraints in the process of agricultural production. On the basis of referring to the existing research (Hou & Yao, 2018; Wang & Zhang, 2018; Xu et al., 2019), the evaluation system of agricultural ecological efficiency is constructed, as shown in Table 2.

### (4) Agricultural Openness

Domestic openness and foreign openness are generally used to represent the opening level of a region (the indicators of agricultural openness are shown in Table 3). In this study, the average annual growth rate of agricultural added value in the past three years is used to express the openness of agriculture in China (Zhang, 2021), and the ratio of the total import and export of agricultural products to the gross output of the primary industry is used to express the openness of agriculture in foreign markets (Li & Xu, 2020; Liu et al., 2020; Zhang & Liu, 2019).

**Table 3** Evaluation framework of HQAD

Dimension index	Factor index	Basic index	Measurement method (unit)	Attribute
Innovation	Foundation of innovation	Education level of agricultural laborers (X11)	Proportion of junior high school and above population in rural population aged 6 and above (%)	+
		Innovation platform construction (X12)	Number of National Agricultural Science and Technology Parks (individual)	+
	Innovation efficiency	Agricultural mechanization degree (X13)	Total mechanical power/planting area (kw/hm <sup>2</sup> )	+
		Degree of agricultural scale (X14)	Planting area of crops/number of employees in primary industry (hm <sup>2</sup> /person)	+
Coordination	Urban–rural coordination	Grain per unit area (X15)	Total grain output/sown area (t/hm <sup>2</sup> )	+
		Income ratio between urban and rural residents (X21)	Net income of disposable income of urban households/rural residents (%)	–
	Regional coordination	Urban and rural consumption level (X22)	Consumption level of urban residents/consumption level of rural residents (%)	–
		Agro-ecology Protection level	Agricultural growth rate (X23)	Growth rate of agricultural output value (%)
Openness	Utilize the domestic market	Agricultural eco-efficiency (X31)	Seven input indicators and three output indicators*	+
		Domestic market activity (X41)	Average annual growth rate of agricultural added value in recent three years	+
Sharing	Utilize foreign markets	Agricultural external activity (X42)	Total import and export of agricultural products/GDP of primary industry (%)	+
	Rural public service level	Rural medical and health level (X51)	Average rural population per thousand village clinic staff (person)	+
		Rural social security level (X52)	Minimum social security expenditure per capita in rural areas (CNY/person)	+

(5) Agricultural Sharing

The ultimate goal of development is to ensure and improve people’s livelihood, increase the supply of public services in rural areas, improve the social security system, and finally, everyone does their best and everyone enjoys it (the indicators of agricultural sharing are shown in Table 3). In this study, the level of rural medical and health care and social security are used to indicate the level of agricultural sharing (Liu et al., 2020; Nie & Jian, 2020; Zhang & Liu, 2019).

**3.2.1.2 SBM Model of Over-Efficiency of Unexpected Output** This study adopts the super-efficiency SBM model of unexpected output proposed by Tone (2002). This model can not only incorporate the unexpected output into the model, but also combine the advantages of the super-efficiency model and SBM model to reduce the deviation caused by the loss of effective decision-making unit information.

The formula is as follows:

$$\begin{aligned}
 \min \beta &= \frac{\frac{1}{m} \sum_{i=1}^m (\bar{x}/x_{ik})}{\frac{1}{r_1+r_1} \left[ \sum_{s=1}^{r_1} \bar{y}^d/y_{sk}^d + \sum_{q=1}^{r_2} \bar{y}^u/y_{qk}^u \right]} \\
 \bar{x} &\geq \sum_{j=1, \neq k}^n x_{ij} \lambda_j; \bar{y}^d \leq \sum_{j=1, \neq k}^n y_{sk}^d \lambda_j \\
 \bar{y}^d &\geq \sum_{j=1, \neq k}^n y_{sk}^d \lambda_j; \bar{x} \geq x_k \\
 \bar{y}^d &\leq y_k^d; \bar{y}^u \geq y_k^u \\
 \lambda_j &\geq 0, \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \\
 s &= 1, 2, \dots, r_1; \quad q = 1, 2, \dots, r_2
 \end{aligned}
 \tag{1}$$

Among them,  $n$  representing the decision-making unit,  $m$  representing input,  $r_1$  expected output and  $r_2$  non-expected output,  $x, y^d, y^u$  representing input matrix, expected output matrix and non-expected output matrix,  $\beta$  is the agricultural eco-efficiency of a certain province/city.

**3.2.1.3 TOPSIS Model** TOPSIS model evaluates the advantages and disadvantages of each sample by approaching the degree of ideal solution (Stewart, 1992). This model can be used for the evaluation framework of HQAD level in YREB, but the traditional TOPSIS model is more subjective, while the entropy method is an objective multi-index comprehensive evaluation method, which determines the weight of the index according to the relative change degree of each index value (Chen, 2019). Therefore, this model combines the advantages of the entropy method and TOPSIS model, and is used to calculate the level of HQAD in the YREB. The specific steps are as follows:

- (1) Determine the target sequence

First of all, it needs to be standardized. The formula is as follows:

$$\begin{aligned} \text{Positive indicators : } Z_{ij} &= \frac{X_{ij} - \min X_j}{\max X_j - \min X_j}; \\ \text{Inverse indicators : } Z_{ij} &= \frac{\max X_j - X_{ij}}{\max X_j - \min X_j} \end{aligned} \tag{2}$$

Among them,  $Z_{ij}$  is the standardized value of the  $j$  year of the  $i$  index ( $i = 1, 2, 3, \dots, m; j = 1, 2, 3, \dots, n$ ),  $X_{ij}$  represents the original data of the index value of the  $j$  year of the  $i$  indicator,  $\min X_j$  and  $\max X_j$  represent the minimum and maximum values of item  $j$ .

After standardization, the matrix  $A$  is obtained.

$$A = \begin{bmatrix} Z_{11} & \dots & Z_{1n} \\ \dots & \dots & \dots \\ Z_{m1} & \dots & Z_{mn} \end{bmatrix} \tag{3}$$

(2) Calculate the weight of entropy method

First of all, the matrix  $A$  is normalized to get the matrix  $B_{ij}$ . The formula is as follows:

$$B_{ij} = \frac{Z_{ij}}{\sum_{j=1}^n Z_{ij}} \tag{4}$$

Then, the information entropy  $e_i$  is calculated as follows:

$$e_i = -\frac{1}{\ln n} \sum_{j=1}^n B_{ij} \times \ln B_{ij} \tag{5}$$

If  $B_{ij} = 0$ , then  $\lim B_{ij} \rightarrow 0, B_{ij} \times \ln B_{ij} = 0$

Finally, the weight  $w_i$  of the index is calculated as follows:

$$w_i = \frac{1 - e_i}{m - \sum_{i=0}^m e_i} \tag{6}$$

(3) Establish TOPSIS model

In order to make the evaluation results more objective, a standardized analysis matrix  $C$  is constructed according to the index weight  $w_i$ , and the formula is as follows:

$$C = \left| w_i \times Z_{ij} \right|_{m \times n} = \left| y_{ij} \right|_{m \times n} \tag{7}$$

(4) Determine the positive and negative ideal value

The positive ideal solution  $Y^+$  and the negative ideal solution  $Y^-$  represent the maximum and minimum values of the  $i$  index in the  $j$  year. The formula is as follows:

$$\begin{aligned}
 Y^+ &= \max\{y_{ij}\} \\
 Y^- &= \min\{y_{ij}\}
 \end{aligned}
 \tag{8}$$

(5) Calculate the distance

In this study, Euclidean distance is used to calculate the distance from the evaluation index of high agricultural quality level in YREB to the positive and negative ideal value. Among them,  $D^+$  is the distance between the  $i$  index and the positive ideal solution  $Y^+$ , and  $D^-$  is the distance between the  $i$  index and the negative ideal solution  $Y^-$ . The formula is as follows:

$$\begin{aligned}
 D^+ &= \sqrt{\sum_{i=1}^m (Y_i^+ - y_{iy})^2} \\
 D^- &= \sqrt{\sum_{i=1}^m (Y_i^- - y_{iy})^2}
 \end{aligned}
 \tag{9}$$

(6) Calculate the comprehensive evaluation index

$C_j$  is the comprehensive evaluation index for the  $j$  year of HQAD level in YREB. The formula is as follows:

$$C_j = \frac{D_j^-}{D_j^+ + D_j^-}
 \tag{10}$$

### 3.2.2 Spatial Analysis Model

Spatial autocorrelation indicates that some elements are spatially dependent on each other, which can measure the degree of agglomeration and correlation of spatial distribution of elements, including global spatial autocorrelation (Global Moran’s I, referred to as GMI) and local spatial autocorrelation (Local Moran’s I, referred to as LMI). Global spatial autocorrelation analysis can measure the spatial correlation degree of a certain attribute value in the whole study area, which can be realized by GMI index (Zheng et al., 2018). This study uses this model to analyze the degree of agglomeration and correlation of spatial distribution of the level of HQAD in the YREB.

The formula is as follows:

$$\begin{aligned}
 I &= \frac{C_{ij} \sum_{i=1}^n \sum_{j \neq i}^n W_{ij}}{S^2 \sum_{i=1}^n \sum_{j \neq i}^n W_{ij}} \\
 S^2 &= \frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^2
 \end{aligned}
 \tag{11}$$

$$C_{ij} = (X_i - \bar{X})(X_j - \bar{X})$$

Among them,  $I$  is the GMI index,  $X_i$  is the measured value of the level of HQAD in city  $i$ ,  $\bar{x}$  is the average value of the level of HQAD in YREB, and  $W_{ij}$  is the adjacent degree of location. If the two cities are adjacent in space, it will be marked as 1 and  $C_{ij}$  indicates the similarity of the measured value.

### 3.2.3 Obstacle Diagnosis Model

The five dimensions (innovation, coordination, green, openness and sharing) coordinated development of HQAD is an ideal state of development, but in the process of actual development, there will be conflicts in the system due to the lag development of a sub-dimension. In view of this, the obstacle degree diagnosis model (Chen et al., 2020) is used to quantify and identify obstacle factors that affect the HQAD of 11 provinces/cities in the YREB, so as to provide a basis for the formulation of HQAD policies.

The formula of obstacle diagnosis model is as follows:

$$O_{ij} = \frac{(1 - F_{ij}) \times W_{ij}}{\sum_{j=1}^{13} [(1 - F_{ij}) \times W_{ij}]} \quad (12)$$

Among them,  $O_{ij}$  represents the obstacle value of  $j$  indicators in the  $i$  city, the bigger the  $O_{ij}$ , the greater the resistance of the index to the realization of the system goal,  $F_{ij}$  represents the contribution degree of the factor, and  $W_{ij}$  represents the weight of the index.

### 3.3 Data

The panel data of 11 provinces/cities in YREB from 2010 to 2019 are selected to quantify and analyze the HQAD in the YREB in China. Among them, the education level of agricultural laborers comes from the *Statistical Yearbook of China's Population and Employment* (2011–2020) (<https://data.cnki.net/yearbook/Single/N2022040097>) published by the Department of Population and Employment Statistics, National Bureau People's Republic China. The number of national agricultural science and technology parks comes from the *Announcement of the rural department on the publicity of the construction of national agricultural science and technology parks* (2010–2019) ([https://www.gov.cn/zhengce/zhengceku/2020-12/27/content\\_5573792.htm](https://www.gov.cn/zhengce/zhengceku/2020-12/27/content_5573792.htm)).

The total power of machinery, sown area, effective irrigated area, total grain output, income ratio of urban and rural residents, the ratio of urban and rural consumption level, agricultural film pesticide, chemical fertilizer and diesel oil used, total agricultural output value, rural medical and health and social security level come from *China Rural Statistical Yearbook* (2011–2020) ([https://www.stats.gov.cn/tjsj/tjcbw/202201/t20220112\\_1826281.html](https://www.stats.gov.cn/tjsj/tjcbw/202201/t20220112_1826281.html)) published by the Department of Rural Socio-Economic Survey, National Bureau People's Republic China. The gross domestic product of the primary industry comes from the *China Statistical Yearbook* (2011–2020) (<https://www.stats.gov.cn/tjsj/nds/>) published by the National Bureau of Statistics of People's Republic of China.

The number of employees in the primary industry comes from the statistical yearbooks of 11 provinces/cities of the YREB (2011–2020), and the total import and export of agricultural products come from the *Statistical report of China's Agricultural products Import and Export* (2010–2019) (<https://wms.mofcom.gov.cn/article/ztxx/>

**Table 4** HQAD level in YREB from 2010 to 2019

Year	Innovation	Coordination	Green	Openness	Sharing
In 2010	5.26	3.35	1.95	1.72	4.04
Annual growth rate (%)	9.18	32.86	46.21	-3.99	9.71
In 2011	5.75	4.44	2.86	1.65	4.43
Annual growth rate (%)	3.52	0.70	12.13	13.36	3.98
In 2012	5.95	4.48	3.20	1.87	4.61
Annual growth rate (%)	3.36	6.61	23.36	-5.13	8.98
In 2013	6.15	4.77	3.95	1.77	5.02
Annual growth rate (%)	3.18	-13.92	4.06	-19.23	2.53
In 2014	6.34	4.11	4.11	1.43	5.15
Annual growth rate (%)	8.71	13.24	4.83	-3.02	0.57
In 2015	6.90	4.65	4.31	1.39	5.18
Annual growth rate (%)	5.03	0.09	20.28	0.35	2.00
In 2016	7.24	4.65	5.19	1.39	5.28
Annual growth rate (%)	1.39	-12.95	-1.33	9.25	1.02
In 2017	7.34	4.05	5.12	1.52	5.34
Annual growth rate (%)	4.43	14.95	19.67	-4.64	5.02
In 2018	7.67	4.66	6.12	1.45	5.61
Annual growth rate (%)	0.89	1.19	25.76	2.32	2.85
In 2019	7.74	4.71	7.70	1.49	5.77

[ncpmy/ncpydtj/200603/20060301783733.shtml](http://ncpmy/ncpydtj/200603/20060301783733.shtml)) published by the Ministry of Commerce of the people's Republic of China. In the statistical yearbook, the shortage of staff in village clinics per thousand rural population in Shanghai in 2019 was filled by the average of the previous three years.

The calculation method of agricultural carbon emissions is mature. Agricultural carbon emissions come from chemical fertilizers, pesticides, agricultural film, diesel oil, fossil fuels consumed by electricity and carbon loss caused by the destruction of soil layer during farming to ensure the normal growth of crops. This study refers to the calculation of carbon emission calculation coefficient put forward by Li et al. (2011), chemical fertilizer (0.8956 kg/kg), pesticide (4.9341 kg/kg), agricultural film (5.18 kg/kg), diesel oil (0.5927 kg/kg), farming (312.6 kg/hm<sup>2</sup>), irrigation (20.476 kg/hm<sup>2</sup>).

## 4 Results

### 4.1 Spatio-Temporal Evolution of HQAD in YREB

According to formula (1)–(10), the SBM model of over-efficiency of unexpected output and the TOPSIS model are used to calculate the HQD level of agriculture in the YREB, the results are shown in Table 4. Then according to the evaluation results, the temporal evolution and spatial distribution of HQAD in the YREB are analyzed.

#### 4.1.1 Time Evolution of HQAD in YREB

The level of HQAD in the YREB is fluctuating on the whole, with the lowest level in 2010, with a comprehensive score of 3.36 points, and the highest level in 2019, with a comprehensive score of 6.84 points, with an average annual growth rate of 8.23%. Thus, it can be seen that under the guidance of the national policy of strengthening agriculture and benefiting farmers, the level of HQAD in YREB has been greatly improved. However, the level of HQAD in YREB does not show a steady and continuous rise, but fluctuates. In 2014 and 2017, the growth rate of the total agricultural output value of the YREB decreased significantly, and other indicators fluctuated slightly, resulting in a slight decline in the comprehensive score of HQAD in the YREB. The growth rate of total agricultural output value in the YREB fell from 15.82% in 2013 to 4.30% in 2014, from 9.11% in 2016 to -0.01% in 2017. By consulting relevant policy documents and materials, it is found that China strengthened and implemented the quality and safety control of agricultural products in 2014 and 2017, and rectified the chaos in the industry. The state pays more and more attention to food safety protection, which can not only protect people's quality of daily life, but also promote the healthy and sustainable development of agriculture, but it will reduce the scale of agricultural industry in the short term of policy implementation. as a result, the gross agricultural output has not increased significantly in the past two years.

From the dynamic perspective of internal dimension, the order of growth is green > innovation > sharing > coordination > openness. Among them, the green dimension developed the fastest, rising by 5.75 points during the period, from 1.95 points in 2010 to 7.70 points in 2019. Although the dimensions of innovation, sharing and coordination fluctuated in a few years, they showed an obvious upward trend, and the rate of growth was next to that of innovation dimensions. For example, the level of agricultural innovation increased from 5.26 points in 2010 to 7.74 points in 2019, an increase of 2.47 points. The openness dimension has more frequent fluctuations during the period, but the level does not change much.

The radar map is used to visualize the evaluation results of HQAD in the provinces/cities of the YREB. The results are shown in Fig. 3, the level is increasing year by year, but there are some differences in the extent of the increase. The level of HQAD in Guizhou Province has the highest rising range. In 2010 and 2019, the level of HQAD in Guizhou Province is 0.20 and 0.66 respectively, with an average annual growth rate of 14.27%. China attaches great importance to agricultural development in the western region, actively promoting the local combination of regional characteristics to create characteristic agriculture, promoting the development of the whole industrial chain, and driving farmers out of poverty. The increase in the level of HQAD in Shanghai is the lowest, with an average annual growth rate of 3.71%. The agricultural development in Shanghai shows a situation of "medium level, small increase". This is due to the fact that some achievements have been made in agricultural standardized production and green development in Shanghai in recent years. however, the small space for industrial development, short industrial chain, low economic benefits and lack of agricultural talents have hindered the agricultural development in Shanghai, resulting in the lack of stamina for agricultural development in Shanghai.

#### 4.1.2 Spatial Distribution of HQAD in the YREB

In order to more intuitively show the spatial distribution of HQAD in YREB, the grade of HQAD in the YREB is divided into four levels to discuss its spatial distribution. Based on



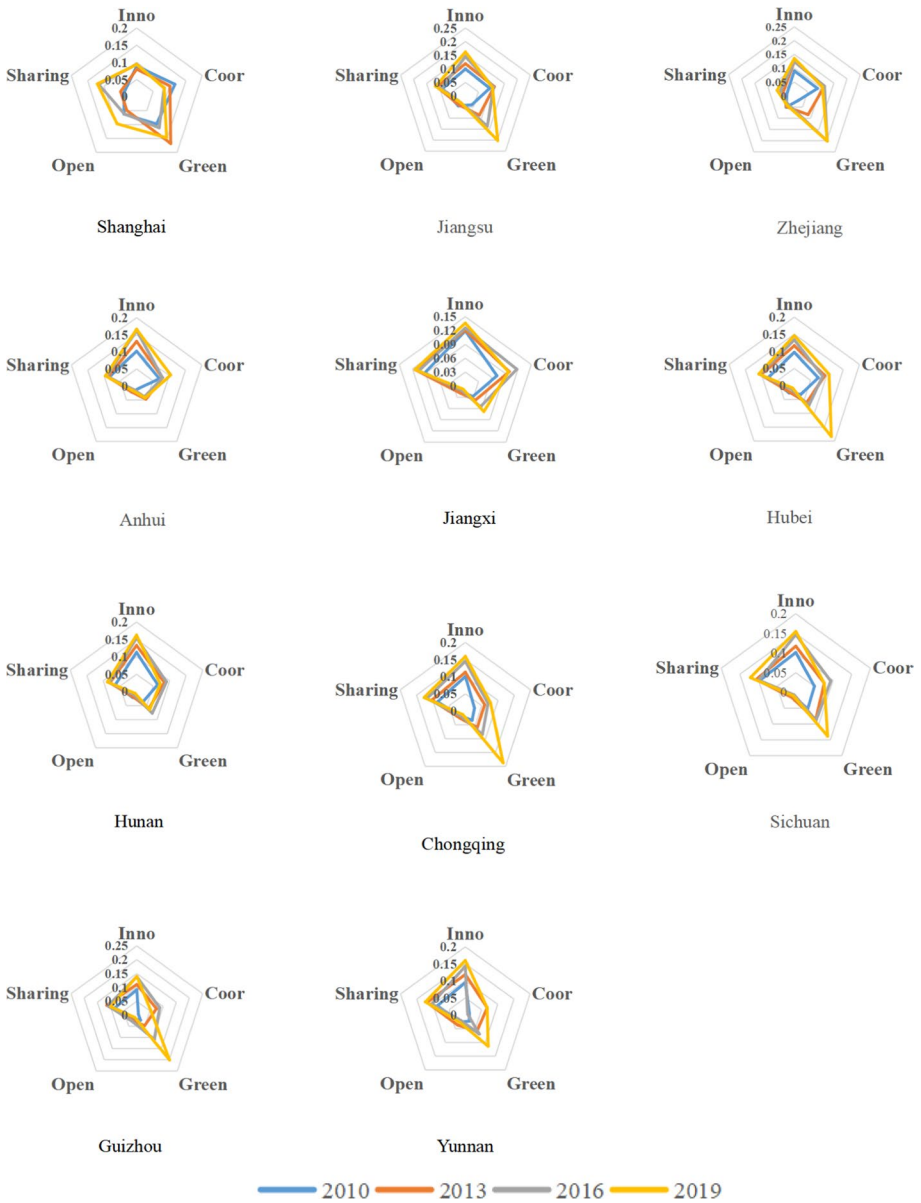
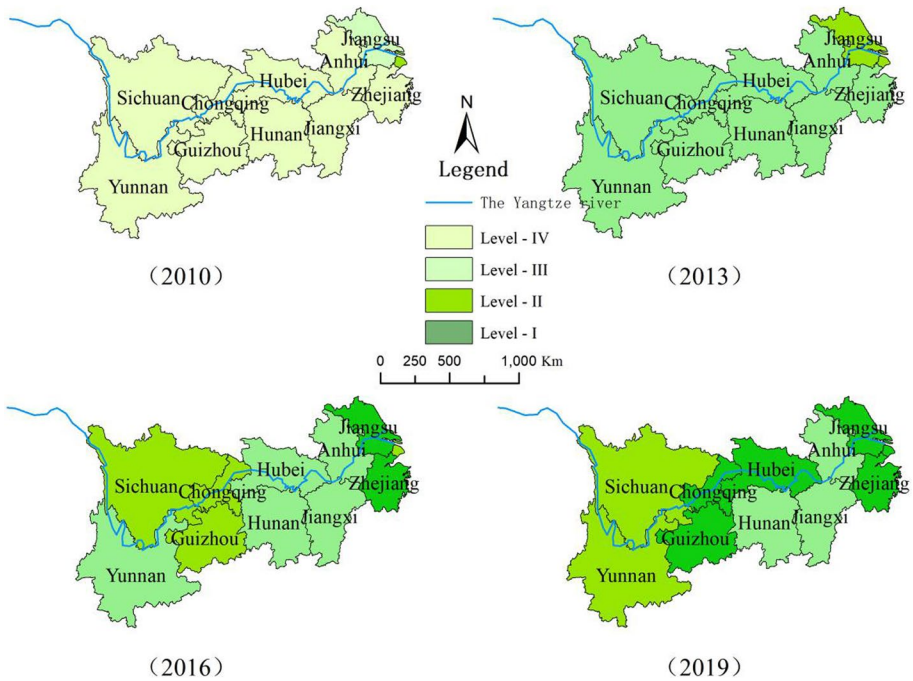


Fig. 3 Radar chart of HQAD in provinces/cities in YREB (2010, 2013, 2016, 2019)

the principle of TOPSIS model, in order to intuitively express the classification of comprehensive evaluation value, the level of HQAD in YREB is divided into four levels according to the method of equal interval, and four-time sections (2010, 2013, 2016, 2019) are selected for spatial visualization. The results are shown in Fig. 4.

In 2010, the HQAD in YREB is in the initial stage of development, the level of development was mainly Level-IV, and there were no Level-I and Level-II areas. There are only



**Fig. 4** Spatial distribution of HQAD in the YREB

two provinces/cities at Level-III, that is, Shanghai and Jiangsu, and there are more areas at the Level-IV, including 9 provinces such as Anhui, Hubei and Hunan etc.

In 2013, the HQAD in the YREB was at the middle level, mainly at Level-II and Level-III, although the HQAD in YREB has not yet reached Level-I of provinces (cities). However, the number of areas at Level-II and Level-III, has greatly increased, of which there are two provinces and cities at Level-II, including Shanghai and Jiangsu, and the other 9 cities are at Level-III. From 2010 to 2013, the level of HQAD has improved significantly, with 9 cities (Anhui, Hubei and Hunan, etc.) with a HQAD level at Level-IV being upgraded to Level-III, while the two provinces/cities at Level-III (Shanghai and Jiangsu) have been upgraded to Level-II.

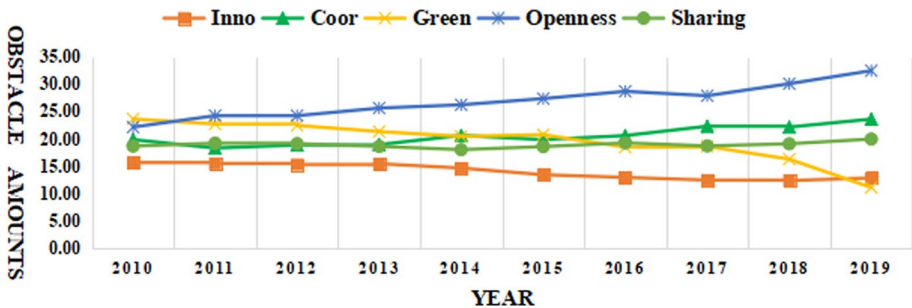
In 2016, the HQAD in the YREB Was still at the middle level, mainly at Level-II and Level-III. The number of areas at Level-I is 2 (Jiangsu and Zhejiang). The number of cities at Level-II is 3 (Sichuan, Chongqing, Guizhou). The other six cities belong to the Level-III.

In 2019, the HQAD in the YREB reached a higher level, mainly at Level-I and Level-II, and the number of areas at Level-I was 6, including Shanghai, Jiangsu, Zhejiang, Hubei, Chongqing and Guizhou. The number of areas at Level-II are 2 (Sichuan and Yunnan), while the other three cities are at Level-III. The level of HQAD improved significantly from 2016 to 2019. Hubei Province, which is at Level-III, raised its quality level to Level-I, and the level of HQAD in Chongqing and Guizhou raised its quality level from Level-II to Level-I.

Overall, from 2010 to 2019, the level of HQAD in YREB has continuously improved. With the exception of Shanghai, the level of HQAD has improved to a great extent, especially the level in Guizhou, Chongqing, Hubei and Zhejiang has been upgraded from Level-IV to Level-I.

**Table 5** Moran's I value of HQAD level in YREB from 2010 to 2019

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
GMI	0.272	0.220	0.307	0.377	0.387	0.363	0.090	0.233	0.287	-0.086
Z	2.158	1.914	2.592	2.586	2.628	2.484	1.066	1.758	1.959	0.104
P	0.018	0.029	0.013	0.016	0.014	0.020	0.147	0.057	0.039	0.405

**Fig. 5** Obstacles degree of HQAD in YREB (2010–2019)

## 4.2 Spatial Correlation Analysis of HQAD in YREB

Through the Spatio-temporal analysis of the HQAD in YREB above, it can be found that there may be a significant spatial relationship between the HQAD in the YREB. Therefore, the spatial autocorrelation analysis method was used to identify the spatial model of HQAD in China. According to formula (11), using GeoDa1.14 and Queen space weight matrix, the GMI values from 2010 to 2019 were calculated, and the significance test was carried out. The results are shown in Table 5.

As can be seen from Table 5, except for 2016, 2017 and 2019, the GMI of HQAD in the YREB was greater than 0 and passed the 5% significance test, indicating that there was a significant positive autocorrelation in HQAD of the provinces/cities of the YREB in these seven years, and the development of a province (city) will also be affected by the development of its neighboring provinces (cities). The spatial correlation degree in other years was low, indicating that the interactive relationship of HQAD among provinces/cities in these years was weak. By calculating the GMI of HQAD in YREB, it is found that the degree of interaction between the provinces/cities of the YREB is not high enough, so the agricultural development of the YREB needs to strengthen the driving role of high development areas, to speed up the establishment of strategic channels among provinces/cities and form a new pattern of complementary advantages, crisscross integration and regional coordinated development.

## 4.3 Diagnosis of Obstacles to HQAD in YREB

According to formula (12), the obstacle diagnosis model is used to calculate the obstacles of the subsystems of HQAD in the YREB, and the following characteristics can

be found (as shown in Fig. 5). From the perspective of the time-series change trend of the subsystem obstacle degree, the innovation and green subsystems show a downward trend, the openness subsystems show a continuous upward trend, and the coordination and sharing subsystems show a fluctuating upward trend. The obstacle degree of the innovation subsystem decreased from 15.67% in 2010 to 12.85% in 2019, with an average annual decline rate of about 2.18%. The obstacle degree of the green subsystem decreased from 23.63% in 2010 to 11.11% in 2019, with an average annual decline rate of about 8.05%. The obstacle degree of the open subsystem increased from 22.15% in 2010 to 32.46% in 2019, with an average annual growth rate of about 4.34%. The obstacle degree of the coordination subsystem increased from 19.86% in 2010 to 23.61% in 2019, with an average annual growth rate of about 1.94%; the obstacle degree of the shared subsystem increased from 18.68% in 2010 to 19.96% in 2019, with an average annual growth rate of about 0.74%.

From the perspective of the main obstacles, openness and coordination are the main obstacles to the HQAD in YREB, although in recent years, China has made certain achievements in promoting agricultural “going global”, international cooperation and agricultural trade, but there is still room for development. On the one hand, the advanced technology of developed countries should be further introduced, and the agricultural science and technology park, agricultural cooperation demonstration area, and agricultural openness and cooperation experimental area should be taken as the platform to improve the level of agricultural modernization in China. On the other hand, “Belt and Road Initiative” should strengthen national agricultural cooperation, actively participate in international consultations in the field of agriculture and the formulation and revision of various international agreements, conventions and standards on agriculture, so as to effectively safeguard the rights and interests of China and the vast number of developing countries. Besides, we should pay attention to the coordinated development in the HQAD. The report of the 19th CPC National Congress points out that “Socialism with Chinese characteristics has entered a new era, and the principal contradiction in our society has been transformed into a contradiction between the people’s growing needs for a better life and unbalanced and inadequate development”. China’s urban development has been at a relatively high level, while rural development is relatively lagging behind, so we should pay attention to urban–rural coordination and regional coordination, and implement the strategy of rural revitalization. Based on industries, resources and culture in rural, establish a two-way flow mechanism of urban and rural elements, activate rural vitality, and build a sustainable endogenous growth mechanism.

#### 4.4 Quadrant Analysis of HQAD in YREB

The four-quadrant analysis method, also known as the Boston matrix, divides the observed objects into four types according to the two most important attributes of the research object, and puts forward an optimization scheme for the type. Taking the economic scale of agricultural development as the Abscissa, the quality of agricultural development as the ordinate, and the mean value of the two as the focus value, a four-quadrant coordinate system is constructed (Fig. 6). Among them, the agricultural output value was used to express the scale of agricultural development, and the level of HQAD was used to express the quality of agricultural development.

Through Fig. 6, we can see that:

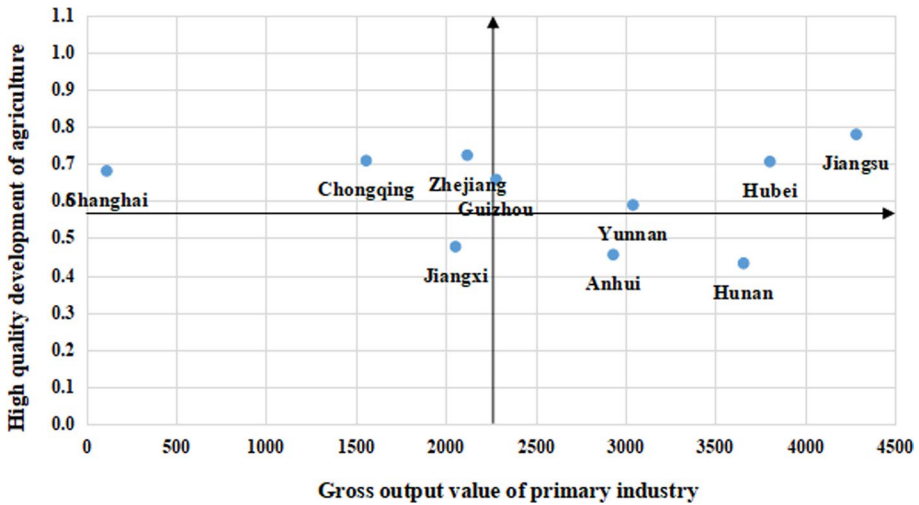


Fig. 6 Quadrant analysis of HQAD

- (1) The agricultural development of Jiangsu, Hubei, Yunnan and Guizhou provinces were “high-high”. It shows that these cities not only pay attention to the improvement of agricultural output value, but also to the connotative development of agriculture, but the regional linkage of agricultural development in YREB is too low, and the four provinces should play a leading role and optimize the structure of regional agricultural products, and form the overall development advantages of regional agriculture.
- (2) The agricultural development of Chongqing, Zhejiang and Shanghai were “low- high”, indicating that these cities pay attention to the connotative development of agriculture, but it is limited to topography, area and other factors, and the scale of agricultural development is lower than the average level. Therefore, it is suggested that these provinces/cities should pay attention to the realization of economies of scale, appropriately integrate cultivated land through land use transfer, guide large-scale operations of agricultural land according to local conditions, develop high value-added modern agriculture, and enhance the scale of agricultural output value.
- (3) The agricultural development of Hunan and Anhui were “high-low”, which indicates that the scale of agricultural development in these cities were higher than the average level, but the quality of agricultural development was not good. It is suggested that the city should pay attention to connotative development and pay attention to the improvement of agricultural quality.
- (4) The agricultural development of Jiangxi Province is “low-low”, which shows that the scale and quality of agricultural development in the province are lower than the average level. This province should actively develop urban modern agriculture and support the cities to increase the demand for agricultural products, so as to achieve the joint improvement of agricultural quality and scale.

## 5 Discussion

Agriculture is the foundation of the national economy and the social stability of the country. The development of things follows a dynamic process from quantitative change to qualitative change, and so does the development of agriculture in China. The HQAD is the inevitable stage from quantitative change to qualitative change (Huang et al., 2020). The HQAD not only refers to the high quality of economic benefits brought by agriculture, but also refers to the high quality of agriculture for environmental protection and social stability (Chen et al., 2020; Lu et al., 2022; Zhang & Liu, 2019). By constructing a systematic integrated model, this study evaluates HQAD in YREB from the aspects of temporal and spatial characteristics, obstacle factors, and quadrant distribution, which deepens the research on agricultural development and provides some decision-making references for agricultural management departments.

Using systematic indicators in the evaluation of HQAD can reveal the agricultural development situation in China. Although the existing research framework is related to the new development philosophy, which can answer a series of theoretical and practical questions about the purpose, motivation, mode and path of development, it lacks systematic embodiment, see e.g. Qin (2020), Liu et al. (2020) and Li and Xu (2020). Based on the perspective of new development philosophy, this study constructs a multidimensional evaluation model of HQAD from five aspects of “innovation, coordination, green, openness and sharing”. At the same time, this study uses agricultural ecological efficiency to indicate agricultural green development. Agricultural ecological efficiency is not only reflected in the input factors and resource utilization degree of agricultural production, but also reflects the environmental constraints in the process of agricultural production (Hou & Yao, 2018; Wang & Zhang, 2018; Xu et al., 2019).

This study adopts a systematic integrated model to quantify and analyze HQAD. Previous scholars use some methods to measure the level of agricultural high-quality development and its influencing factors (Li & Xu, 2020; Xin & An, 2019). This study uses the integrated model to measure the level of HQAD in the Yangtze River Economic Belt, and analyzes its temporal and spatial evolution characteristics, spatial correlation and main obstacles. The super-efficiency SBM model and TOPSIS model of unexpected output are used to measure the level of HQAD of 11 provinces and cities in YREB from 2010 to 2019. The spatial autocorrelation analysis method was used to identify the spatial distribution pattern. The obstacle diagnosis model was used to analyze the obstacle factors of HQAD in YREB. Finally, the four-quadrant analysis method was used to put forward the differential policy to promote the HQAD in YREB.

Our findings reveal that the level of HQAD in the YREB shows a fluctuating upward trend, and there are some differences among provinces (cities). The characteristics of the overall development level of agriculture in our study are similar to the results presented by Liu et al. (2020) and Xin and An (2019). The spatial distribution of HQAD in YREB showing the characteristics of spatial agglomeration, but the spatial correlation is not strong. The results of spatial distribution characteristics of HQAD are different from Huang et al. (2020). Considering the different research methods and regions, the results of spatial distribution characteristics might be a little different. This study finds that the main obstacle to the HQAD is openness and coordination, which is similar to the results of previous studies (Liu et al., 2020). The poor function of agricultural opening platform and the big gap between urban and rural areas have always been the difficulties in China’s agricultural development. This research provides considerable insights into the HQAD in China.

Scholars have proposed that the expansion of agricultural scale can improve the quality and safety level of agricultural products, and realize the quality tracking and efficient supervision of the whole chain (Chen & Fan, 2016). This study puts forward policy recommendations according to the perspective of coordinated development of agricultural development scale and agricultural development quality. Most of the existing studies give policy suggestions from the point of view of how to improve the quality of agricultural development, while ignoring the coupling relationship between quality and scale (Liu et al., 2020; Qin, 2020). Agricultural economic development needs to coordinate the relationship between scale and quality. If the two dimensions coordinate, they will promote each other, present a positive relationship, and promote the HQAD.

However, there is a limitation to this study. Considering the rationality of the study index system, scientific study methods and available study data, 11 provinces of YREB were selected in this study. The analysis of spatial correlation of HQAD in YREB shows that the GMI index of YREB is relatively low in some years, which may be due to the small number of study sub-areas. Although the spatial correlation degree can be affected by the number of study sub-areas, which mainly be affected by the relationship between a certain attribute of a geographical thing distributed in a region and the same attribute of all other things (Pawley & McArdle, 2021). In order to ensure the accuracy of the study, it is suggested that as many cities as possible should be selected as study objects in the future.

## 6 Conclusions

In this study, a systematic evaluation framework and an integrated model named ESO were used to evaluate the HQAD in YREB. Based on the Chinese government's new development philosophy, this study has constructed a systematic evaluation framework of "innovation-coordination-green-opening-sharing" and used multidimensional evaluation model, spatial analysis model and obstacle diagnosis model to reveal the development level, distribution and influencing factors of HQAD in YREB. Finally, differentiated management policies were put forward by using the four-quadrant analysis method. The main conclusions of the study are as follows.

- (1) Through the spatio-temporal evolution of HQAD in the YREB, our findings reveal that there is a growing trend of HQAD in the YREB, but there are still some problems in the process of agricultural development. The level of HQAD in the YREB shows a fluctuating upward trend, but there are some differences among provinces (cities); from the composition of HQAD, the growth speed of innovation dimension is the fastest, followed by sharing, coordination and green, and the speed of openness is the slowest. The spatial distribution of HQAD in YREB has gradually evolved from mainly at low level to mainly at high level, showing the characteristics of spatial agglomeration, but the spatial correlation is not strong. Agricultural managers should strengthen the benign interaction between regions and form a new pattern of complementary advantages, interlaced integration and coordinated development among regions.
- (2) In the past ten years, the main obstacle to the HQAD in YREB is openness, followed by coordination. Agricultural managers should strengthen cooperation and exchanges with foreign countries, expand agricultural opening up to the outside world actively, steadily and orderly, actively introduce international advanced agricultural science and technology, implement "Belt and Road Initiative" agricultural international coopera-

tion, build a new type of agricultural cooperative relationship, and improve the global governance system of agriculture. The government also should pay more attention to the coordination between urban and rural areas and the regional coordination of agriculture, establish a two-way flow mechanism of urban and rural elements based on rural industry, resources, culture and other elements, and activate rural vitality.

- (3) Based on the constraints and advantages of HQAD in the YREB, differentiated management policies are put forward for different regions. For “high-high” areas, it is suggested to give full play to the leading role of such areas to form a new pattern of complementary advantages; for “low-high” areas, it is suggested to realize appropriate agricultural scale and enhance agricultural scale effect; for “high-low” areas, it is suggested to pay attention to connotative development and pay attention to the improvement of the quality of agricultural development; for “low-low” areas, it is suggested to improve the scale of agricultural development ensuring the quality of agricultural development.

**Funding** This work was supported by the Fundamental Research Funds for the Central Universities, Zhongnan University of Economics and Law (CN) (Grant Number: 2722022BY014) and MOE (Ministry of Education of PRC) Project of Humanities and Social Sciences (Grant Number: 20YJC850001).

## Declarations

**Conflicts of Interest** The authors declare no conflict of interest.

## References

- Adesipo, A., Fadeyi, O., Kuca, K., Krejcar, O., Maresova, P., Selamat, A., & Adenola, M. (2020). Smart and climate-smart agricultural trends as core aspects of smart village functions. *Sensors*, *20*(21), 5977. <https://doi.org/10.3390/s20215977>
- Baležentis, T., Li, T., & Chen, X. (2021). Has agricultural labor restructuring improved agricultural labor productivity in China? A decomposition approach. *Socio-Economic Planning Sciences*, *76*, 100967. <https://doi.org/10.1016/j.seps.2020.100967>
- Baráth, L., Fertő, I., & Bojnec, Š. (2020). The effect of investment, LFA and agri-environmental subsidies on the components of total factor productivity: The case of Slovenian farms. *Journal of Agricultural Economics*, *71*(3), 853–876. <https://doi.org/10.1111/1477-9552.12374>
- Chen, M., & Wang, H. (2021). Import technology sophistication and high-quality economic development: Evidence from city-level data of China. *Economic Research-Ekonomska Istraživanja*, *35*(1), 1106–1141. <https://doi.org/10.1080/1331677X.2021.1956362>
- Chen, P. (2019). Effects of normalization on the entropy-based TOPSIS method. *Expert Systems with Applications*, *136*, 33–41. <https://doi.org/10.1016/j.eswa.2019.06.035>
- Chen, Y., & Fan, Y. (2016). Effects of scale agriculture on product quality and safety: A case study of Heilongjiang reclamation area. *Research of Agricultural Modernization*, *37*(6), 1076–1083. <https://doi.org/10.13872/j.1000-0275.2016.0115>
- Chen, Y., Zhu, M., Lu, J., Zhou, Q., & Ma, W. (2020). Evaluation of ecological city and analysis of obstacle factors under the background of high-quality development: Taking cities in the Yellow River Basin as examples. *Ecological Indicators*, *118*, 106771. <https://doi.org/10.1016/j.ecolind.2020.106771>
- Du, Y., Zhang, D., & Zou, Y. (2020). Sustainable supplier evaluation and selection of fresh agricultural products based on IFAHP-TODIM Model. *Mathematical Problems in Engineering*, *2020*, 1–15. <https://doi.org/10.1155/2020/4792679>



- Fang, L., Hu, R., Mao, H., & Chen, S. (2021). How crop insurance influences agricultural green total factor productivity: Evidence from Chinese farmers. *Journal of Cleaner Production*, 321, 128977. <https://doi.org/10.1016/j.jclepro.2021.128977>
- He, L. (2018). Vigorously promoting high-quality development and actively building a modern economic system. *Macroeconomic Management*, (7), 4–6. <https://doi.org/10.19709/j.cnki.11-3199/f.2018.07.003>
- Hou, M., & Yao, S. (2018). Spatial and temporal evolution and trend prediction of agricultural eco-efficiency in China from 1978–2016. *Acta Geographica Sinica*, 73(11), 2168–2183. <https://doi.org/10.11821/dlxb201811009>
- Huang, X., Cai, X., Chu, X., Ma, L., & Zuo, Z. (2020). Construction and evaluation of the evaluation index system for high-quality agricultural development in China. *Chinese Journal of Agricultural Resources and Regional Planning*, 41(4), 124–133. <https://doi.org/10.7621/cjarrp.1005-9121.20200415>
- Jin, P. (2018). Research on the economics of “high-quality development.” *China Industrial Economics*, (4), 5–18. <https://doi.org/10.19581/j.cnki.ciejournal.2018.04.001>
- Kou, J. (2018). Countermeasures and suggestions for promoting high-quality development of China’s agriculture in the new era. *Management of Agricultural Science and Technology*, 37(3), 1–4. <https://doi.org/10.16849/j.cnki.issn1001-8611.2018.03.001>
- Li, B., & Liu, Z. (2022). Measurement and evolution of high-quality development level of marine fishery in China. *Chinese Geographical Science*, 32(2), 251–267. <https://doi.org/10.1007/s11769-022-1263-7>
- Li, B., Zhang, J., & Li, H. (2011). Decomposition of spatial and temporal characteristics and influencing factors of agricultural carbon emissions in China. *China Population, Resources and Environment*, 21(8), 80–86. <https://doi.org/10.3969/j.issn.1002-2104.2011.08.013>
- Li, S., Gong, O., & Yang, S. (2019). Analysis of the agricultural economy and agricultural pollution using the decoupling index in Chengdu, China. *International Journal of Environmental Research and Public Health*, 16(21), 4233. <https://doi.org/10.3390/ijerph16214233>
- Li, X., & Xu, S. (2020). Research on the measurement of agricultural high quality development level and its spatial distribution characteristics based on the new development concept. *Journal of Jiangxi University of Finance and Economics*, (6), 78–94. <https://doi.org/10.13676/j.cnki.cn36-1224/f.2020.06.009>
- Li, Y., Fan, Z., Jiang, G., & Quan, Z. (2021). Addressing the differences in Farmers’ willingness and behavior regarding developing green agriculture—A case study in Xichuan County, China. *Land*, 10(3), 316. <https://doi.org/10.3390/land10030316>
- Liu, T., Li, J., & Huo, J. (2020). Spatial and temporal patterns and influencing factors of high-quality agricultural development in China. *Journal of Arid Land Resources and Environment*, 34(10), 1–8. <https://doi.org/10.13448/j.cnki.jalre.2020.261>
- Lu, X., Li, Z., Wang, H., Tang, Y., Hu, B., Gong, M., & Li, Y. (2022). Evaluating impact of farmland recessive morphology transition on high-quality agricultural development in China. *Land*, 11(3), 435. <https://doi.org/10.3390/land11030435>
- Nie, C., & Jian, X. (2020). Measurement of high quality development in China and the analysis of inter-provincial status comparison. *The Journal of Quantitative and Technical Economics*, 37(2), 26–47. <https://doi.org/10.13653/j.cnki.jqte.2020.02.002>
- Pawley, M. D. M., & McArdle, B. H. (2021). Inferences with spatial autocorrelation. *Austral Ecology*, 46(6), 942–949. <https://doi.org/10.1111/aec.13008>
- Qin, X. (2020). A study on the measurement and spatial differences of the level of high-quality development of Chinese agriculture—based on the perspective of the five development concepts. *Journal of Chinese Agricultural Mechanization*, 41(12), 189–195. <https://doi.org/10.13733/j.jcam.issn.2095-5553.2020.12.030>
- Ren, B., & Li, Y. (2018). The construction of China’s high-quality development judging system in the new era and its transformation path. *Journal of Shaanxi Normal University (philosophy and Social Sciences Edition)*, 47(3), 105–113. <https://doi.org/10.15983/j.cnki.sxss.2018.0421>
- Reza Anik, A., Rahman, S., & Sarker, J. R. (2020). Five decades of productivity and efficiency changes in world agriculture (1969–2013). *Agriculture*, 10(6), 200. <https://doi.org/10.3390/agriculture10060200>
- Rocha, A., Gonçalves, E., & Almeida, E. (2019). Agricultural technology adoption and land use: Evidence for Brazilian municipalities. *Journal of Land Use Science*, 14(4–6), 320–346. <https://doi.org/10.1080/1747423X.2019.1707312>
- Shi, B., & Zhang, B. (2018). New era, new dynamic energy, new economy—Analysis of the current high-quality development of China’s economy. *Shanghai Journal of Economics*, (5), 25–33. <https://doi.org/10.19626/j.cnki.cn31-1163/f.2018.05.003>
- Stewart, T. (1992). A critical survey on the status of multiple criteria decision making theory and practice. *Omega*, 20(5–6), 569–586. [https://doi.org/10.1016/0305-0483\(92\)90003-P](https://doi.org/10.1016/0305-0483(92)90003-P)

- Streimikis, J., & Baležentis, T. (2020). Agricultural sustainability assessment framework integrating sustainable development goals and interlinked priorities of environmental, climate and agriculture policies. *Sustainable Development*, 28(6), 1702–1712. <https://doi.org/10.1002/sd.2118>
- Tambo, J. A., & Wünscher, T. (2018). Building farmers' capacity for innovation generation: Insights from rural Ghana. *Renewable Agriculture and Food Systems*, 33(2), 116–130. <https://doi.org/10.1017/S1742170516000521>
- Tone, K. (2002). A slacks-based measure of super-efficiency in data envelopment analysis. *European Journal of Operational Research*, 143(1), 32–41. [https://doi.org/10.1016/S0377-2217\(01\)00324-1](https://doi.org/10.1016/S0377-2217(01)00324-1)
- Wang, B., & Zhang, W. (2018). Inter-provincial differences and influencing factors of agricultural eco-efficiency in China: A panel data analysis based on 31 provinces from 1996–2015. *Chinese Rural Economy*, (1), 46–62.
- Wang, G., Zhang, L., Sun, Y., Yang, Y., & Han, C. (2020). Evaluation on the allocative efficiency of agricultural factors in the five Central Asian countries. *Journal of Geographical Sciences*, 30(11), 1896–1908. <https://doi.org/10.1007/s11442-020-1817-5>
- Wang, H., & Li, B. (2021). Environmental regulations, capacity utilization, and high-quality development of manufacturing: An analysis based on Chinese provincial panel data. *Scientific Reports*, 11(1), 19566. <https://doi.org/10.1038/s41598-021-98787-y>
- Wang, S., Liu, J., & Qin, X. (2022a). Financing constraints, carbon emissions and high-quality urban development—Empirical evidence from 290 Cities in China. *International Journal of Environmental Research and Public Health*, 19(4), 2386. <https://doi.org/10.3390/ijerph19042386>
- Wang, Z., Huang, L., Yin, L., Wang, Z., & Zheng, D. (2022b). Evaluation of sustainable and analysis of influencing factors for agriculture sector: Evidence from Jiangsu Province, China. *Frontiers in Environmental Science*, 10, 836002. <https://doi.org/10.3389/fenvs.2022.836002>
- Xiao, Q., Zhou, Z., & Luo, Q. (2019). High-quality agricultural development in the Yangtze River Economic Belt in the new period: Problems and countermeasures. *Chinese Journal of Agricultural Resources and Regional Planning*, 40(12), 72–80. <https://doi.org/10.7621/cjarrp.1005-9121.20191210>
- Xin, L., & An, X. (2019). Construction and measurement analysis of evaluation system for high-quality development of agriculture in China. *Economic Review Journal*, (05), 109–118. <https://doi.org/10.16528/j.cnki.22-1054/f.201905109>
- Xu, X., Huang, X., Huang, J., Gao, X., & Chen, L. (2019). Spatial–temporal characteristics of agriculture green total factor productivity in China, 1998–2016: Based on more sophisticated calculations of carbon emissions. *International Journal of Environmental Research and Public Health*, 16(20), 3932. <https://doi.org/10.3390/ijerph16203932>
- Xu, X., Zhang, L., Chen, L., & Liu, C. (2020). The role of soil N2O emissions in agricultural green total factor productivity: An empirical study from China around 2006 when agricultural tax was abolished. *Agriculture*, 10(5), 150. <https://doi.org/10.3390/agriculture10050150>
- Yang, W. (2018). Implementing the spirit of the Central Economic Work Conference to promote high-quality development. *Macroeconomic Management*, (2), 13–17. <https://doi.org/10.19709/j.cnki.11-3199/f.2018.02.004>
- Zhang, C., & Liu, Q. (2019). Research on the evaluation and path of high quality development of agriculture in the context of rural revitalization strategy. *Economic Forum*, (4), 141–146. <https://doi.org/10.3969/j.issn.1003-3580.2019.04.021>
- Zhang, F. (2021). Evaluation study on high-quality integrated development of agriculture in Yangtze River Delta. *Journal of Arid Land Resources and Environment*, 42(1), 197–202. <https://doi.org/10.7621/cjarrp.1005-9121.20210123>
- Zhao, C. (2017). Promoting China's economy to achieve high-quality development. *Study Times*. <https://doi.org/10.38216/n.cnki.nxxsb.2017.000176>
- Zhao, D., & Zhou, H. (2021). Livelihoods, technological constraints, and low-carbon agricultural technology preferences of farmers: Analytical frameworks of technology adoption and farmer livelihoods. *International Journal of Environmental Research and Public Health*, 18(24), 13364. <https://doi.org/10.3390/ijerph182413364>
- Zheng, D., Hao, S., & Shun, C. (2018). Evaluation of agricultural ecological efficiency and its spatial–temporal differentiation based on DEA-ESDA. *Scientia Geographica Sinica*, 38(3), 419–427. <https://doi.org/10.13249/j.cnki.sgs.2018.03.012>
- Zhong, S., Li, Y., Li, J., & Yang, H. (2021). Measurement of total factor productivity of green agriculture in China: Analysis of the regional differences based on China. *PLoS ONE*, 16(9), e0257239. <https://doi.org/10.1371/journal.pone.0257239>

Springer Nature or its licensor holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.

## Authors and Affiliations

Xufeng Cui<sup>1</sup>  · Ting Cai<sup>1</sup> · Wei Deng<sup>1</sup> · Rui Zheng<sup>1</sup> · Yuehua Jiang<sup>1</sup> · Hongjie Bao<sup>2</sup>

Ting Cai  
caiting@stu.zuel.edu.cn

Wei Deng  
chanda@stu.zuel.edu.cn

Rui Zheng  
zrui@stu.zuel.edu.cn

Hongjie Bao  
hongjie@xbmu.edu.cn

<sup>1</sup> School of Business Administration, Zhongnan University of Economics and Law, Wuhan 430073, China

<sup>2</sup> School of Management, Northwest Minzu University, Lanzhou 730030, China