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Quality Evaluation and Spatiotemporal Characteristics Analysis of Agricultural Development in Zhejiang Province

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Abstract. This paper establishes a comprehensive and scientifically rigorous evaluation index system specifically designed for high-quality agricultural development. Utilizing methods such as the entropy weight method, comprehensive evaluation index method, and Dagum Gini coefficient, it provides an in-depth analysis of the level and spatiotemporal dynamics of agricultural development in Zhejiang Province. The results indicate that Zhejiang Province has consistently demonstrated an improvement in the overall quality of its agricultural development, evident from a substantial increase in the agricultural development index, particularly after 2018. This upward trend is primarily driven by significant advancements in agricultural production efficiency, coupled with the rapid integration and expansion of mechanization and technology. Additionally, the study highlights notable regional disparities and burgeoning trends in agricultural development within Zhejiang. Specifically, the northern region maintains its leading position, while the eastern region is progressively gaining prominence. To facilitate comprehensive and high-quality agricultural development across Zhejiang Province, the paper suggests strategies including fostering coordinated regional development, optimizing resource allocation, and refining the structure of the agricultural industry.

AMS subject classifications: 94A17, 68M20

Key words: Zhejiang Provinces, Agricultural development, Spatiotemporal characteristics, Regional differences.

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1 Introduction

The report of the 20th National Congress of the Communist Party of China underscores high-quality development as the foremost objective in building a modern socialist country. With China's rapid economic expansion, people's purchasing power and consumption patterns are continuously evolving, necessitating a heightened standard for agricultural development and product supply. Agriculture, as the cornerstone of the national economy, plays an increasingly pivotal role in achieving high-quality development in this new phase of development. Nevertheless, disparities in natural, economic, social, and technological conditions lead to uneven levels of agricultural development across regions and time periods in China. The 2024 government work report emphasizes the pressing need to enhance regional coordinated development, with Zhejiang Province facing particularly heightened expectations for its agricultural high-quality development. Characterized by uneven regional development, Zhejiang Province comprises 11 cities and several key urban agglomerations, occupying a strategic position. The 11 prefecture-level cities are: Hangzhou (HZ), Ningbo (NB), Wenzhou (WZ), Zhoushan (ZS), Taizhou (TZ), Lishui (LS), Jinhua (JH), Quzhou (QZ), Huzhou (HuZ), Jiaxing (JX) and Shaoxing (SX). In the context of the economic new normal, examining the level of high-quality agricultural development in Zhejiang, its temporal and spatial variations, and exploring feasible solutions hold immense theoretical and practical significance. This analysis not only aids Zhejiang's agricultural high-quality development but also serves as a valuable reference for other regions.

Currently, the approaches to establishing an evaluation index system for high-quality agricultural development mainly encompass three aspects. Firstly, based on economic growth theory, the level of development is assessed through total factor productivity and agricultural green total factor productivity. Secondly, in line with the new development paradigm, a multidimensional evaluation system incorporating macroeconomic growth indicators is constructed for comprehensive analysis. Thirdly, combining the essence and attributes of high-quality agricultural development, a system encompassing indicators such as product quality, economic benefits, scientific and technological innovation, industrial structure, green development, and social benefits is established.

On this basis, scholars have skillfully employed various analytical tools such as the PROMETHEE method, cluster analysis, and principal component analysis, while closely integrating advanced techniques such as spatial statistics and standard deviation ellipse analysis, to conduct in-depth exploration and research on the spatial evolution trajectory and regional influencing factors of high-quality agricultural development. It is particularly noteworthy that Zhejiang Province still holds tremendous potential for improvement in agricultural development and resource utilization, which warrants further exploration and exploitation.

This paper focuses on Zhejiang Province as the research subject, drawing upon the research conducted by Liu et al. [1] and Xin & An [2], to establish a systematic and scientifically rigorous evaluation index system tailored for high-quality agricultural development. It employs a combination of the entropy weight method, the comprehensive evaluation index method, and the Dagum Gini coefficient to conduct a thorough examination of the agricultural development level and its spatial-temporal characteristics within Zhejiang Province [3]. The objective of this analysis is to furnish both theoretical foundation and practical insights for fostering high-quality and coordinated agricultural development across various regions within Zhejiang Province [4].

2 Research methods and data sources

2.1 Data sources

From 2013 to 2022, the research scope of this paper encompasses 11 prefecture-level cities in Zhejiang Province [5]. In conducting this study, relevant data were sourced from various publications including the Statistical Yearbook of Zhejiang Province, the Statistical Yearbook of China's Rural Areas, the Statistical Yearbook of China's Tertiary Industry, as well as the Statistical Yearbook of Municipalities and the Statistical Bulletin of National Economic and Social Development. During the data collection process, it was observed that data for certain years or specific indicators were missing. To address this issue, the linear interpolation method was employed to supplement these missing data points [6].

2.2 Research methods

This paper utilizes two methods to evaluate the level of high-quality agricultural development in Zhejiang Province: the entropy weight method [7], and the Dagum Gini coefficient decomposition method [8].

2.2.1 Entropy weight method

Step 1: Standardization of positive indicators

Given the potential disparities in dimensions and magnitudes among the indicators within the evaluation framework, which could compromise the accuracy of the assessment outcomes, it is imperative to standardize the raw data initially. The objective of standardization is to transform indicators characterized by varying dimensions and magnitudes into dimensionless and directly comparable values. In the formula, X_{ij} denotes the raw data corresponding to the j-th indicator for the i-th province/municipality/ autonomous region. Meanwhile, Y_{ij} represents the standardized value of this indicator. Furthermore, $\max X_{ij}$ and $\min X_{ij}$ signify the maximum and minimum values, respectively, of the j-th indicator across all i-th provinces, where $i=1,...,m, j=1,...,n$. For positive/negative indicators, the standardization calculation formulas are

$$\text{For positive indicators:} Y_{ij}=\frac{X_{ij}-\min X_{ij}}{\max X_{ij}-\min X_{ij}}+0.001, \tag{2.1}$$

$$\text{For negative indicator: } Y_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}} + 0.001. \tag{2.2}$$

To avoid situations where the logarithm becomes meaningless when calculating entropy (such as when the logarithmic value is 0 or negative), we adopt a non-negative shift processing method for the standardized data, which involves adding a small positive number, such as 0.001, to each data point.

Step 2: Calculate the proportion P_{ij} of the j-th indicator Y_{ij} for the i-th province as follows:

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}}. \tag{2.3}$$

Step 3: Calculate the entropy value E_j of the j-th indicator, where

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} P_{ij} \ln P_{ij}. \tag{2.4}$$

Given the proper application of formulas (2.1) to (2.4), it is guaranteed that the entropy value E_j will fall within the range of $0 \leq E_j \leq 1$.

Step 4: Calculate the coefficient of variation for the j-th indicator.

$$G_j = 1 - E_j \tag{2.5}$$

Step 5: Calculate the weight W_j of each attribute.

$$W_j = \frac{G_j}{\sum_{j=1}^{n} G_j} \tag{2.6}$$

Step 6: Employ the multi-objective linear weighted function approach to assign weights to all evaluation indicators. The linear weighted summation method then yields a comprehensive score

$$V_i = \sum_{j=1}^{n} (W_j Y_{ij}). \tag{2.7}$$

2.2.2 Dagum Gini coefficient and decomposition method

The Dagum Gini coefficient serves as an additional metric for evaluating regional disparities in high-quality agricultural development. A higher coefficient indicates more severe regional inequalities in high-quality agricultural development. It is defined by the following equation:

$$Z = \frac{\sum_{j=1}^{k} \sum_{h=1}^{k} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{hr}|}{2n^2 R} \tag{2.8}$$

In this equation:

- k represents the total number of divided regions.
- n is the number of prefecture-level cities in the region.
- j and h denote different divided regions.
- n_j and n_h signify the number of prefecture-level cities in regions j and h, respectively.
- y_{ji} and y_{hr} represent the high-quality agricultural development values of city i in region j and city r in rRegion h, respectively.
- R represents the average value of high-quality agricultural development in all prefecture-level cities.
- Z is the overall Dagum Gini coefficient.

The variables k,n,n_j,n_h, etc., are the key components in defining the Dagum Gini coefficient, and they are crucial for measuring regional disparities.

The Gini coefficient of region j can be calculated by

$$Z_j = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_j} |y_{ji} - y_{jr}|}{2n_j^2 R_j}. \tag{2.9}$$

The total disparity in high-quality agricultural development among regions is

$$Z_w = \sum_{j=1}^{k} Z_j P_j S_j, \tag{2.10}$$

Where, P_j signifies the fractional representation of the number of cities located within region j, whereas S_j denotes the share of high-quality agricultural development value relative to the overall value in region j.

When quantifying the inequality in high-quality agricultural development among regions, three indicators are utilized: the Gini coefficient between regions G_{jh}, the contribution of relative inter-regional influence to the overall Gini coefficient Z_{nb}, and the contribution of excess variation density to high-quality agricultural development Z_t. The formulas are as the following:

$$G_{jh} = \frac{\sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |y_{ji} - y_{jr}|}{n_j n_h (R_j + R_h)}, \tag{2.11}$$

$$Z_{nb} = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} (P_j S_h + P_h S_j) D_{jh}, \tag{2.12}$$

$$Z_t = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh}(P_j S_h + P_h S_j)(1 - D_{jh}), \tag{2.13}$$

where D_{jh} represents the relative impact of high-quality agricultural development of regions j and h. In this article, we divide Zhejiang Province into four regions for discussion, so k in Equations (2.12) and (2.13) equals 4. In addition, to avoid double counting and self comparison, the loop ends at $j-1$.

2.3 Index system construction

High-quality development is a comprehensive and in-depth concept that emphasizes not only economic growth but also the coordinated development of social, cultural, ecological, and other aspects [9]. This development model emphasizes the fulfillment of people's aspirations for a better life while being powered by innovation. It strives for coordinated, green, open, and shared development. Once the economy reaches a certain level of scale, high-quality development shifts its focus to optimizing the economic structure, ensuring harmonious coexistence between the economy and ecology, and facilitating the transition between old and new driving forces. In the realm of agriculture, high-quality development transcends mere expansion of economic aggregates and scales; it also underscores the importance of green, shared, innovative, coordinated, and open agricultural development.

When constructing the water level evaluation index system of high quality agricultural development, this paper refers to the previous research results and follows the principles of scientific irgor, systematization, independence and accessibility [10]. The agricultural high-quality development system presented in this paper comprises six first-level indicators, encompassing 18 fundamental indicators (see Table 1 for details).

Agricultural Productivity (AP) encompasses various factors such as agricultural production efficiency (APE), seeding yield rates (SYR), and labor production efficiency (LPE). These metrics collectively mirror the comprehensive agricultural production capability and the efficiency of grain harvesting, serving as the cornerstone for the advancement of high-quality agriculture.

Agricultural Green Development (AGD) emphasizes enhancing resource utilization efficiency while minimizing environmental impact. This includes indicators such as the unit application rates of fertilizers (UF), pesticides (UP), and agricultural films (UAF) [11].

Agricultural Mechanization and Technology Application (AMTA) serves as an indicator of the integration of agricultural science and technology and the mechanization level within agricultural development. This is measured through factors such as per capita mechanical power (PCMP) and agricultural mechanization level (AML).

Agricultural Economic Output (AEO) offers insights into the economic returns of agricultural endeavors through indicators like total grain production (TGP), the economic effect of agricultural products (EEAP), and the total agricultural output value

(TAOV). This information serves as a vital foundation for policymakers to formulate effective strategies.

Rural Residents' Economy and Living Standards (RELS) provide a gauge of the advancement of agricultural modernization and the commitment to people-centered development. This is evaluated using metrics like rural residents' per capita disposable income (RPCDI), the rural Engel coefficient (REC), and rural residents' per capita consumption (RPCC).

Urban and Rural Coordinated Development (URCD) reflects the progress towards regional coordination and the reduction of the urban-rural divide. This is assessed through indices such as the industrial structure index (ISI), urban and rural income coordination level (URICL), urban and rural consumption coordination level (URCCL) and industrial coordination index (ICI) [12].

Table 1: Evaluation index system for agricultural development

Criterion	**Index**	**Calculation Method**	**Dominance**	**Weight**
AP (54.25)	APE	AAFHF/TAFHF	+	22.69
	SYR	TAFHF/Sown Area	+	16.69
	LPE	TAFHF/RE	+	14.87
AGD (1.2)	UF	FU/Sown Area	-	0.22
	UP	PU/Sown Area	-	0.75
	UAF	AFU /Sown Area	-	0.23
AMTA (17.17)	PCMP	TPAM/TRP	+	4.00
	AML	TPAM/Cultivated Area	+	13.17
AEO (18.64)	TGP	Statistical Yearbook	+	3.00
	EEAP	TAOV/TGSA	+	10.65
	TAOV	Statistical Yearbook	+	4.99
RELS (5.55)	RPCDI	Statistical Yearbook	+	3.86
	REC	Food Expenditure/RPCC	-	0.89
	RPCC	Statistical Yearbook	-	0.80
URCD (3.19)	ISI	1-(TAOV/TAFHF)	+	0.28
	URICL	UPCDI /RPCDI	-	1.51
	URCCL	SYR/RPCC	-	1.17
	ICI	OVSTI/OVPI	-	0.23

These indicators collectively form an evaluation system tailored for the high-quality development of agriculture in Zhejiang Province. This system aids in comprehensively assessing and guiding the direction of agricultural development, ensuring that agricultural advancements are both efficient and sustainable. Furthermore, it fosters the holistic progression of the social economy. The weights of each basic indicator are derived from Equation (2.6), and the weights of each criterion layer are obtained by summing them up.

To enhance simplicity and clarity in Table 1, here are the abbreviations paired with concise English explanations: Agriculture, Forestry, Animal Husbandry, and Fishery (AFHF), Added Value of AFHF (AAFHF), Total Output Value of AFHF (TAFHF), Rural Employees (RE), Fertilizer Usage (FU), Pesticide Usage (PU), Agricultural Film Utilization (AFU), Total Power of Agricultural Machinery (TPAM), Total Rural Population (TRP), Total Grain Sown Area (TGSA), Urban Residents' Per Capita Disposable Income (UPCDI), Output Value of the Secondary and Tertiary Industries (OVSTI), and Output Value of Primary Industry (OVPI).

3 Result analysis

3.1 Province-wide evaluation and analysis

The entropy method was employed to assess the high-quality agricultural development index of Zhejiang Province spanning from 2013 to 2022. Figure 1 illustrates that the overall evaluation of high-quality agricultural development in Zhejiang Province exhibits an upward trajectory. Notably, 2019 marked a pivotal year, preceding which the agricultural development level index experienced fluctuations, characterized by declines and subsequent increases. Between 2013 and 2019, the index rose notably from 0.3247 to 0.4939, with an average annual growth rate of 2.42%. From 2020 to 2022, the index increased modestly, from 0.4381 to 0.5024. These findings not only highlight the dynamic changes in high-quality agricultural development within Zhejiang Province but also reflect the unique developmental features and emerging trends at different stages.

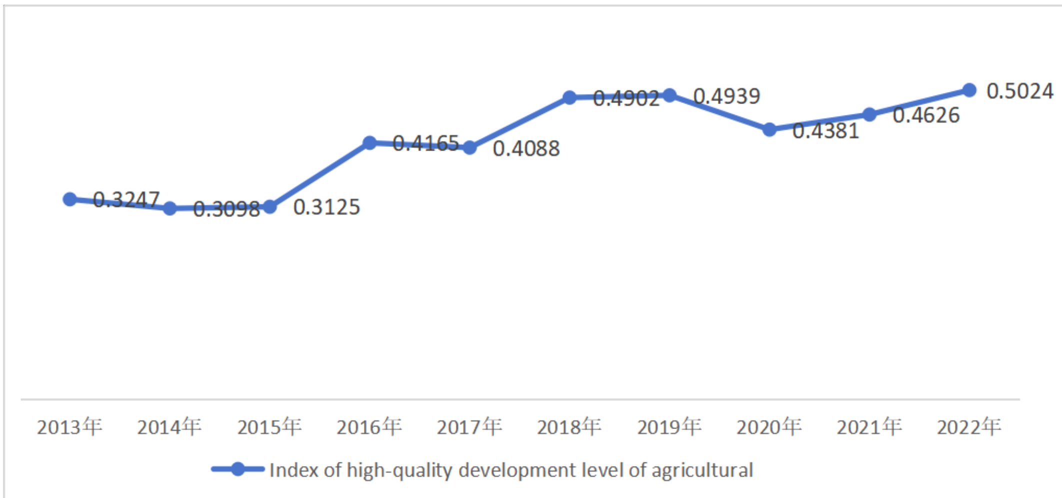

Figure 1: The high-quality agricultural development index of Zhejiang Province spanning from 2013 to 2022.

3.2 Temporal and spatial characteristics of high-quality agricultural development in Zhejiang Province

3.2.1 Time change

The measurement results of high-quality agricultural development in Zhejiang Province from 2013 to 2022 can be calculated using formula (2.4), as shown in Table 2.

From Table 2, it can be seen that from 2013 to 2022, the agricultural development level of most cities in Zhejiang Province has improved. In 2013, the majority of cities in the province had agricultural development quality indices below 0.22, with only Zhoushan and Jiaxing exceeding 0.15. By 2022, there was a general increase in the indices across all cities, with seven cities surpassing 0.15 and three exceeding 0.2. The provincial average for the agricultural development quality index reached 0.177 in 2022. Despite an overall upward trend, development remains uneven. In both 2013 and 2022, seven municipalities fell below the provincial average. Notably, Zhoushan City had the highest agricultural development quality index in 2022, which was 3.21 times that of Quzhou City, highlighting disparities in high-quality agricultural development across the province. In terms of average annual growth rate, Zhoushan led with 1.47%, indicating strong agricultural development momentum, whereas Quzhou's growth rate of only 0.22% reflected relatively weaker development momentum.

These data series not only reveal the disparities among various regions within Zhejiang Province and the relatively lagging conditions of some cities, but also highlight Zhejiang's unwavering pursuit of high-quality agricultural development goals. They clearly demonstrate the diverse achievements made by different regions and cities in terms of agricultural modernization progress, sustainable development levels, and production efficiency. At the same time, they point out their respective strengths and the areas that urgently need enhancement and improvement [13].

The horizontal development trends of the six core indicators within the high-quality agricultural development system in Zhejiang Province can be determined using formula (2.6), as illustrated in Table 3.

From Table 3, it is evident that between 2013 and 2022, the development level indices of the various subsystems within the high-quality agricultural development system in Zhejiang Province exhibited diverse trends. Notably, subsystems including agricultural production efficiency, agricultural economic output, agricultural mechanization, and technology application consistently demonstrated high development indicators. This underscores substantial advancements and enhancements in crucial aspects of agricultural development.

However, the development index for other subsystems, including the coordinated development of urban and rural areas, the economy and living standards of rural residents, and the green development of agriculture, has been relatively lower. This suggests that these areas still require further attention and resources to achieve a more balanced and comprehensive agricultural development.

In terms of development trends, all subsystems have shown some degree of growth

Table 2: Measurement results of high quality agricultural development in Zhejiang Province

City	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HZ	0.102	0.102	0.108	0.111	0.111	0.114	0.115	0.118	0.104	0.128
NB	0.131	0.139	0.143	0.149	0.149	0.152	0.157	0.164	0.169	0.175
WZ	0.077	0.092	0.096	0.099	0.107	0.110	0.110	0.119	0.124	0.128
ZS	0.211	0.228	0.233	0.243	0.242	0.581	0.342	0.343	0.356	0.359
TZ	0.109	0.114	0.121	0.128	0.396	0.175	0.394	0.207	0.217	0.227
LS	0.086	0.091	0.091	0.097	0.098	0.103	0.107	0.109	0.116	0.119
JH	0.106	0.109	0.113	0.116	0.115	0.117	0.121	0.122	0.133	0.136
QZ	0.090	0.094	0.101	0.359	0.010	0.102	0.104	0.107	0.108	0.112
HuZ	0.139	0.128	0.129	0.150	0.152	0.156	0.160	0.167	0.177	0.180
JX	0.174	0.173	0.179	0.184	0.186	0.186	0.183	0.192	0.192	0.202
SX	0.142	0.152	0.151	0.153	0.155	0.166	0.166	0.174	0.189	0.185
Total	0.325	0.310	0.313	0.417	0.409	0.490	0.494	0.438	0.463	0.502
Average	0.124	0.129	0.133	0.163	0.165	0.178	0.178	0.166	0.171	0.177

over the study period. Specifically, the index for agricultural mechanization and technology application has exhibited the most notable increase, steadily rising from 0.224 in 2013 to 0.2997 in 2022. This underscores the importance of technological advancements and mechanization in driving agricultural progress in Zhejiang.

On the other hand, the agricultural production efficiency index has experienced fluctuations, with an initial increase followed by a decrease. Despite this, it has still managed to rise from 0.4301 in 2013 to 0.4649 in 2022. The agricultural economic output index, on the other hand, peaked at 0.3416 in 2017 but has since declined, showing significant volatility.

In contrast, the indices for green agricultural development and the economic living standards of rural residents have demonstrated steady year-on-year growth. These indices have risen from 0.0009 and 0.1237 in 2013 to 0.014 and 0.0464 in 2022, respectively. This indicates a gradual improvement in these areas, although the overall levels are still relatively low compared to other subsystems.

Lastly, the urban-rural coordinated development index has shown a slight downward trend, declining from 0.0561 in 2013 to 0.0451 in 2022. However, it is worth noting that the decline has been minimal, suggesting that efforts to promote coordinated development between urban and rural areas have had some degree of success, albeit with room for further improvement. Overall, the analysis provides valuable insights into the strengths and weaknesses of Zhejiang's agricultural high-quality development system and highlights areas for future focus and improvement.

As shown in Figure 2, the overall quality of agricultural development in Zhejiang Province has demonstrated a steadily improving trend over the past decade, with a notable increase observed in particular in 2018.

Table 3: Horizontal trends of each subsystem of Zhejiang's high-quality agricultural development system

Year	AP	AGD	AMTA	AEO	RELS	URCD
2013	0.4301	0.0009	0.2240	0.1652	0.1237	0.0561
2014	0.4941	0.0029	0.2310	0.0846	0.0675	0.0308
2015	0.4991	0.0006	0.2280	0.0696	0.0514	0.0593
2016	0.5706	0.0004	0.1259	0.1137	0.0279	0.0613
2017	0.3160	0.0591	0.1104	0.3416	0.0237	0.0462
2018	0.2474	0.0020	0.2447	0.2741	0.0192	0.0239
2019	0.6427	0.0197	0.2001	0.0996	0.0145	0.0235
2020	0.4786	0.0163	0.2838	0.1534	0.0418	0.0260
2021	0.4806	0.0196	0.2872	0.1693	0.0195	0.0239
2022	0.4649	0.0140	0.2997	0.1604	0.0464	0.0451

The upward trend in high-quality agricultural development in Zhejiang Province is primarily attributed to substantial enhancements in agricultural production efficiency, which holds a significant weight in the comprehensive evaluation system. This highlights the crucial role played by technological innovation, refined agricultural management practices, and optimized resource allocation in driving agricultural progress within the province. Notably, the rapid advancement in agricultural mechanization and technology application has been particularly prominent. These advancements have directly contributed to increased production efficiency and have helped to reduce labor costs, thereby enhancing the overall competitiveness and sustainability of Zhejiang's agricultural sector. As these trends continue, it is expected that the high-quality agricultural development in Zhejiang Province will further accelerate, leading to even greater advancements in the future.

However, fluctuations in the agricultural economic output index can be attributed to various factors, including market volatility, price shifts, and policy adjustments. These dynamics collectively influence the stability of agricultural production. Additionally, the slight decline in the Rural-Urban Development Index indicates an imbalance in development between urban and rural areas. This disparity may stem from unequal resource allocation, infrastructure provisions, and access to public services. Addressing these issues is crucial to fostering more equitable and inclusive growth across Zhejiang Province. Despite this, the economic conditions and living standards of rural residents have achieved steady growth, thanks to policy support, the expansion of the agricultural industry chain, and the increase in employment opportunities for rural labor in the non-agricultural sector [14].

3.2.2 Spatial change

The study on the spatial distribution and development of high-quality agricultural practices in Zhejiang Province aims to explore the geographical distribution characteristics of

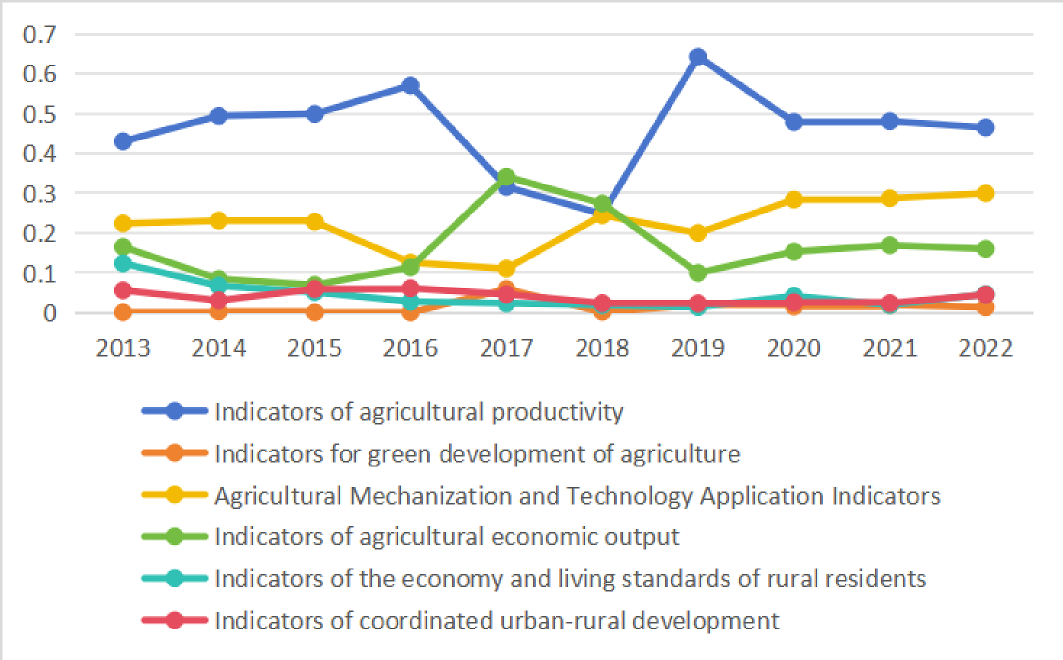

Figure 2: Horizontal trends of each subsystem of Zhejiang's high-quality agricultural development system from 2013 to 2022

these advanced agricultural practices within Zhejiang Province, as well as their changing trends and influencing factors over different time periods. This is of great significance for formulating agricultural policies, optimizing agricultural resource allocation, and promoting sustainable agricultural development.

As illustrated in Figure 3, a comparative analysis spanning the years 2013 to 2022 reveals several prominent trends in the spatial distribution and evolution of high-quality agricultural practices in Zhejiang Province. Initially, in 2013, high-value areas for high-quality agricultural development were predominantly concentrated in the northern part of the province, with middle and low-value areas predominantly located in the south. However, by 2022, although the northern region remained the primary location for high-value areas, the eastern region also exhibited a notable increase in agricultural development levels.

Regarding regional differences, at the two critical time points of 2013 and 2022, the agricultural development levels in the northern and eastern regions of Zhejiang Province significantly outpaced those in the southern and western regions, highlighting a pronounced gap between the north and south. This regional disparity is further reflected in the observed spatial pattern: areas with better development trends have consistently maintained their leading positions, while regions with initially lower baseline levels have lagged behind. This phenomenon indicates that hotspots and coldspots for high-quality agricultural development have formed a relatively independent and distinctly characterized spatial distribution pattern, specifically manifested as a "clustered" or "blocky" distribution, fully demonstrating the significance of spatial differentiation [15].

Despite these spatial differences, the overall level of high-quality agricultural development in various regions of Zhejiang Province has shown a steady upward trend. In particular, the northern and eastern regions have not only maintained their leading positions but have also demonstrated a tendency to further expand their advantages. This spatial expansion trend is evident, particularly towards the eastern and southern regions of the province [16].

In summary, the northern region of Zhejiang Province remains at the forefront of high-quality agricultural development, while the influence of the eastern region is gradually increasing. Collectively, Zhejiang Province's high-quality agricultural development is expanding towards the eastern and southern regions, with each region consistently enhancing its development level. This trend signifies a positive momentum in agricultural development, indicating that efforts to promote and enhance agricultural practices in the province are yielding fruitful results.

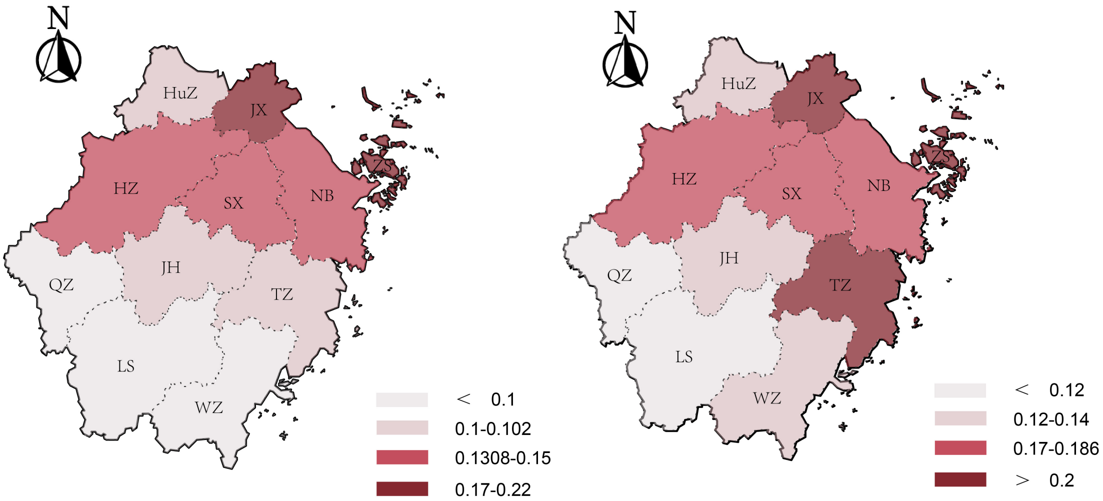

Figure 3: Spatial pattern changes of agricultural quality level in Zhejiang Province in 2013 and 2022.

3.3 Regional disparities

In order to deeply study the regional differences of agricultural development in Zhejiang Province, the province is divided into four main regions: East Zhejiang, West Zhejiang, South Zhejiang and North Zhejiang. Specifically, the eastern Zhejiang region includes Ningbo, Wenzhou and Zhoushan; The southern Zhejiang region consists of two cities: Taizhou and Lishui. The western Zhejiang region covers Jinhua and Quzhou. The northern Zhejiang region includes Hangzhou, Jiaxing, Huzhou and Shaoxing. This paper makes a detailed difference analysis from the four regions and the 11 prefecture-level cities they contain, as detailed in Table 4.

Table 4: Gini coefficient of regional agricultural high quality level index in Zhejiang Province

Region	2013	2022	Gini coefficient change
East Zhejiang	0.213	0.233	0.020
West Zhejiang	0.041	0.049	0.008
South Zhejiang	0.058	0.155	0.097
North Zhejiang	0.098	0.082	-0.016
Inter-regional	0.078	0.095	0.017

Based on the data from 2013, Eastern Zhejiang exhibited the highest Gini coefficient for high-quality agricultural development, reaching 0.213, indicating the greatest degree of variation within the region. In contrast, Northern Zhejiang had a Gini coefficient of 0.098, while Southern and Western Zhejiang demonstrated lower coefficients of 0.058 and 0.041, respectively. This suggests that, although the differences among the four regions of Zhejiang Province are relatively modest, the disparities within each individual region are more pronounced. By 2022, Eastern Zhejiang continued to show the largest intra-regional variation, with the Gini coefficient increasing to 0.233. Southern and Northern Zhejiang followed with Gini coefficients of 0.155 and 0.082, respectively. Western Zhejiang maintained the lowest Gini coefficient at 0.049.

From 2013 to 2022, it is evident that the intra-regional disparities in the level of high-quality agricultural development within eastern Zhejiang have persisted and even shown a tendency to widen. Meanwhile, apart from the northern Zhejiang region, the internal differences among the other three regions have also increased marginally. However, despite these intraregional variations, the Gini coefficient among the four regions remained relatively stable and low over this decade. This suggests that, despite some intraregional disparities, the overall agricultural development between these regions did not exhibit significant differences. In other words, while there are variations within regions, the overall agricultural landscape across these four regions remains relatively balanced in terms of development.

The regional contribution rates and overall trends in high-quality agricultural development in Zhejiang Province from 2013 to 2022 can be calculated using formulas (2.11), (2.12), and (2.13), as shown in Table 5 and Figure 4.

G_{jh}, as an indicator measuring the contribution rate of a specific regional difference, reflects the degree of differentiation in agricultural development among different regions within Zhejiang Province. From the data, the value of G_{jh} exhibits significant volatility between 2013 and 2022. Specifically, in 2013, G_{jh} was 33.396%. Over the subsequent

Table 5: The contribution and evolution trend of regional differences in high-quality agricultural development in Zhejiang Province

Year	G_{jh} (%)	Z_{nb}(%)	Z_t(%)
2013	33.396	20.621	45.983
2014	19.393	15.761	64.846
2015	25.150	21.543	53.307
2016	27.140	17.810	55.050
2017	27.732	16.753	55.515
2018	14.343	20.503	65.154
2019	26.531	17.725	55.745
2020	27.951	20.179	51.870
2021	30.901	20.630	48.469
2022	30.334	20.065	49.601

years, it underwent a process of initial decline, followed by an increase, and then another decline. Notably, in 2014, G_{jh} dropped sharply to 19.393%, which may be related to agricultural policy adjustments or changes in the market environment at that time. However, from 2015 onwards, G_{jh} gradually recovered and remained relatively stable in 2016 and 2017. Despite a decline again in 2018, G_{jh} showed an upward trend in the following years. This volatility indicates that agricultural development in different regions of Zhejiang Province is not static but is influenced by a combination of factors.

Compared to G_{jh}, the Z_{nb} indicator may represent another regional balance or contribution rate related to agricultural development. From the data, the value of Z_{nb} remains relatively stable between 2013 and 2022, with a small fluctuation range. Specifically, the value of Z_{nb} hovers around 20%, with the highest values appearing in 2013 and 2021, at 20.621% and 20.630% respectively, and the lowest value in 2018, at 20.503%. This relative stability suggests that when promoting agricultural development, Zhejiang Province may have focused on balance and coordination among different regions, thereby ensuring the stability and sustainability of overall agricultural development.

Z_t, as an indicator measuring the overall contribution rate of regional differences in high-quality agricultural development in Zhejiang Province, is crucial for understanding the agricultural development status of the entire province. From the data, the value of Z_t exhibits a trend of initial increase, followed by a decrease, and then stabilization between 2013 and 2022. Particularly between 2014 and 2018, the value of Z_t underwent significant fluctuations, rising from 64.846% in 2014 to a peak of 65.154% in 2018, and then gradually declining. This trend indicates that the regional differences in high-quality agricultural development in Zhejiang Province expanded and then stabilized.

A comprehensive analysis of the trends in the G_{jh}, Z_{nb}, and Z_t indicators leads to the following conclusions: In the process of promoting high-quality agricultural development, Zhejiang Province indeed exhibits differences among different regions, and these

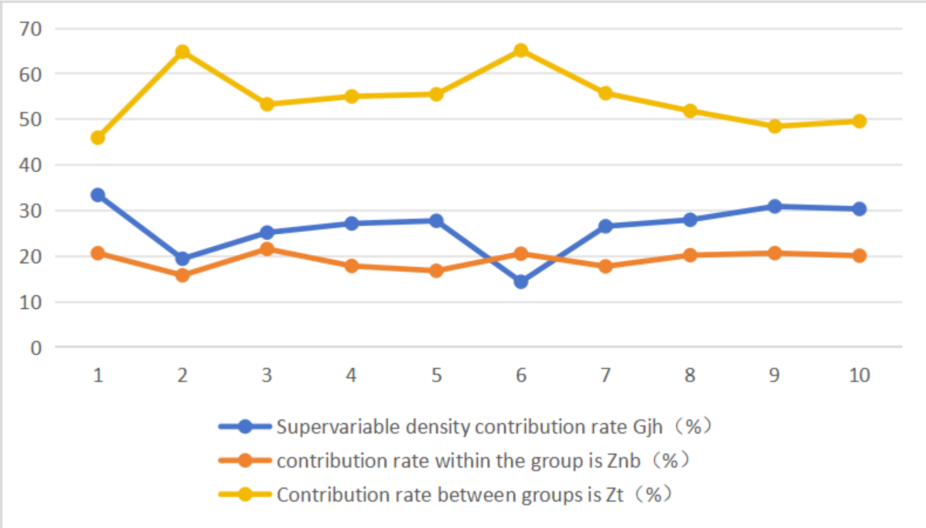

Figure 4: Spatial pattern changes in agricultural high quality level in Zhejiang Province from 2013 to 2022

differences have shown an expanding trend in recent years. However, this expansion is not disorderly but is influenced to a certain extent by policy regulation and market mechanisms. At the same time, Zhejiang Province has also paid attention to balance and coordination among different regions, thereby ensuring the stability and sustainability of overall agricultural development.

3.4 Evaluation on the high quality development dimension of agriculture in Zhejiang Province

Using the formulas (2.7) and (2.11) to calculate, we can obtain the specific values of six key indicators for high-quality agricultural development in Zhejiang Province and sorted the results accordingly, as shown in Table 6. It was observed that in terms of improving farmers' livelihoods (RELS), the performance of the four regions was relatively close, with insignificant differences. However, for the other five indicators, significant differences were observed among different regions.

Table 6: High-quality agricultural development level in four regions from 2013 to 2022

Dimension	East	West	South	North
AP	0.36309 (3)	0.43226 (2)	0.47742 (1)	0.35295 (4)
AGD	0.11252 (1)	0.00642 (4)	0.00745 (3)	0.05150 (2)
AMTA	0.17793 (2)	0.15195 (3)	0.27563 (1)	0.08208 (4)
AEO	0.19363 (3)	0.31961 (1)	0.09262 (4)	0.20874 (2)
RELS	0.04709 (4)	0.07238 (2)	0.06142 (3)	0.08264 (1)
URCD	0.04249 (4)	0.06175 (2)	0.05848 (3)	0.10722 (1)

Table 6 presents comprehensive data on six pivotal indicators of high-quality agricultural development across four regions of Zhejiang Province: East, West, South, and North, covering a ten-year period from 2013 to 2022.

In terms of Agricultural Production Performance (AP), the West region stands out with a score of 0.47742, highlighting its high efficiency and quality in agricultural production. The East region follows closely with a score of 0.36309, ranking third. Although the South and North regions have lower scores, they also demonstrate their continuous efforts in agricultural production.

Agricultural Green Development (AGD) is a crucial indicator for measuring agricultural sustainability. The East region excels in this indicator with a score of 0.11252, significantly higher than other regions. This indicates that the East region has achieved remarkable results in promoting agricultural green development and protecting the ecological environment. The South, West, and North regions have relatively lower scores in this indicator, but there is still room for improvement.

Regarding Agricultural Mechanization Technology Application (AMTA), the South region leads with a score of 0.27563, demonstrating its high level of agricultural mechanization. The East region ranks second with a score of 0.17793. The West and North regions have lower scores in this indicator, suggesting that they need to strengthen their application of agricultural mechanization technology.

Agricultural Economic Structure Optimization (AEO) is an important indicator for measuring the rationality of the agricultural economic structure. The West region scores the highest in this indicator with 0.31961, indicating that its agricultural economic structure is relatively reasonable. The South region scores the lowest with 0.09262, suggesting that its agricultural economic structure needs further optimization.

In the Rural Environmental Comprehensive Improvement Level (RELS) indicator, the North region performs best with a score of 0.08264. This indicates that the North region has achieved significant results in rural environmental remediation. The other three regions have relatively lower scores in this indicator but are actively working to improve their rural environments.

Urban-Rural Coordinated Development (URCD) is a key indicator for measuring the balance of urban and rural development. The North region scores the highest in this indicator with 0.10722, showing that its urban and rural development is relatively balanced. The other three regions have lower scores in this indicator, indicating that they need to intensify their efforts to promote urban-rural coordinated development.

In summary, each region of Zhejiang Province demonstrates varying strengths and weaknesses across the six key indicators of high-quality agricultural development. To further advance agricultural development of high quality, the province needs to adopt differentiated strategies tailored to the unique characteristics and needs of each region. This includes increasing investment in agricultural scientific research, optimizing the agricultural structure, elevating the level of agricultural mechanization, fostering green development practices, enhancing the economic and living standards of rural residents, and bolstering the coordinated development between urban and rural areas.

4 Discussion and Conclusions

The study evaluated agricultural high-quality development in Zhejiang Province using specific indexes. It found significant spatial changes and regional gaps in agricultural development. These discoveries indicate a need for tailored regional strategies and enhanced collaboration to reduce disparities and boost overall agricultural productivity.

The overall development of high-quality agriculture in Zhejiang Province showed an upward trend, especially after 2018, the agricultural development level index increased significantly, which was mainly due to the significant improvement of agricultural production efficiency, among which technological innovation, agricultural management improvement and resource allocation optimization played a key role in improving the comprehensive agricultural production capacity and grain harvest efficiency. The rapid growth of agricultural mechanization and the application of technology has further promoted the improvement of production efficiency while reducing labor costs. Despite the volatility of the agricultural economic output index, the overall growth trend is clear, reaching a peak in 2017, which may be closely related to market dynamics, price movements and policy adjustments. The steady growth of the agricultural green development index reflects the improvement of resource utilization efficiency and the reduction of environmental impact. In addition, the economic conditions and living standards of rural residents have also achieved continuous improvement, thanks to policy support, the expansion of the agricultural industry chain, and the increase in employment opportunities for rural labor in the non-agricultural sector. Although the urban-rural coordinated development index fluctuated slightly, the overall gap between urban and rural areas was narrowed, and the coordination of urban and rural income and consumption levels was improved, which showed that Zhejiang Province had made positive progress in all fields in the process of promoting high-quality agricultural development.

The spatial distribution of high-quality agricultural development in Zhejiang Province has exhibited notable regional variations and a rising trend from 2013 to 2022. The northern region has emerged as a hub for high-value agricultural areas, while the eastern region has also witnessed significant growth, indicating a gradual surge in agricultural development. Despite some differences between the north and south, the overall agricultural development level in all regions is steadily improving, with the northern and eastern regions not only maintaining their leading positions but also expanding their advantages.

Furthermore, the spatial expansion of high-quality agricultural development is evident, particularly in the eastern and southern regions. However, there are significant disparities in agricultural development among different regions within Zhejiang Province, with the eastern region experiencing the largest differences, while the northern, southern, and western regions show relatively smaller disparities. From 2013 to 2022, the internal differences in the eastern region continued to widen, while those in other regions increased slightly, but the inter-regional differences remained relatively low.

These regional differences have a significant impact on the level of agricultural development. To foster balanced development, Zhejiang Province should promote a regional coordination mechanism, integrate resources, and leverage the latecomer advantage of the southern region to achieve comprehensive and high-quality agricultural development.

5 Suggestions

5.1 Promoting regional coordinated development

Zhejiang Province is confronted with notable issues of regional imbalance and inadequacy when it comes to high-quality agricultural development [17]. Specifically, economically developed regions within the province exhibit a higher level of agricultural sophistication and productivity. To address this disparity, it is imperative for the southern, western, and northern parts of Zhejiang to foster closer collaboration and draw inspiration from the proven strategies employed by more advanced agricultural areas. By doing so, these regions can compensate for their own shortcomings in agricultural development.

To facilitate this process, it is recommended to deepen the existing regional coordination mechanisms. This could involve establishing a coordinated development corridor centered around provincial capitals and major regional hubs. Leveraging the economic prowess of northern and eastern Zhejiang, resources could be more effectively shared among regions. Moreover, efforts should be made to dismantle the barriers that hinder the free flow of agricultural factors, such as capital, technology, and labor. By implementing cross-regional cooperation frameworks, a concerted push towards agricultural development can be achieved.

Such collaborative endeavors are crucial in bridging the development divide between different parts of Zhejiang. They not only contribute to a more equitable distribution of agricultural resources but also pave the way for achieving high-quality and balanced agricultural development across the province [18].

5.2 Optimize resource allocation

To optimize agricultural production efficiency, the strategic allocation of resources is paramount, with a strong emphasis on regional characteristics. Each agricultural zone, whether it's the expansive plains, rugged hills, or coastal areas, has its unique set of challenges and opportunities. Tailored machinery configurations are essential for enhancing adaptability and efficiency in these diverse landscapes. For instance, in plains, large-scale machinery can be used to cover vast areas efficiently, while in hills and coastal areas, more nimble and specialized equipment is needed to navigate terrain and ecological challenges. This approach ensures that resources are used effectively and that agricultural operations are tailored to the specific needs of each region. Furthermore, technological innovation and agricultural mechanization play a crucial role in boosting production efficiency. Precision agriculture technologies, such as satellite positioning and remote sensing, provide farmers with real-time data on crop health, soil conditions, and weather patterns. This information enables farmers to make informed decisions about planting, fertilization, and irrigation schedules, thereby optimizing resource use and minimizing waste. To harness the full potential of these technologies, it is essential to strengthen agricultural education and training programs. By ensuring that practitioners have modern machinery skills, they can operate and maintain sophisticated equipment effectively. Additionally, an agricultural market information platform provides farmers with crucial data on market trends, prices, and demand, enabling them to make informed decisions that maximize profits and minimize risks. In conclusion, by integrating tailored machinery configurations, precision agriculture technologies, robust agricultural education, and an information platform, we can significantly enhance agricultural production efficiency and sustainability.

5.3 Optimize agricultural industrial structure

To optimize the agricultural industry structure, it is imperative to adjust and refine the sector in accordance with market demand and regional resource endowments. This involves cultivating high-value agricultural products with distinct local characteristics to enhance the economic viability of agriculture. Leveraging the geographical and climatic diversity of Zhejiang Province presents an opportunity to develop signature agricultural products, notably Longjing tea, Jinhua ham, and Shaoxing yellow wine. Establishing a robust quality and safety supervision system for agricultural products is crucial to guarantee product integrity and safety, thereby bolstering consumer trust.

Furthermore, fostering the deep processing of agricultural products is essential to extend the agricultural value chain and augment the added value of these commodities. This can be achieved by transforming primary agricultural products into convenience foods and health supplements, among others. Such initiatives not only promote diversification within the agricultural industry but also contribute to its overall competitiveness and sustainability.

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Conflicts of Interest

The authors declare no conflict of interest.

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