New Quality Productivity in China's Grain Loss Reduction: Measurement and Evolutionary Dynamics Analysis

Pan Liu, Jia-Min Zhu, Dong Li, Yue Long

***Abstract*—To explore the development status of new quality productivity (NQP) in the field of grain loss reduction (FGLR) in China, we construct an indicator system with five dimensions: new quality labor (NQL), new quality labor object (NQLO), new quality labor material (NQLM), new quality production method (NQPM) and new quality development environment (NQDE). We Take 13 major grain production regions in China as the research object, and analyze their development level, regional differences and spatiotemporal evolution characteristics. Findings: (1) The overall trend is fluctuating, but the dimensional differentiation is significant. The growth rate of NQLM is the fastest, followed by NQLO and NQPM, the dimension of NQL fluctuates violently, and the growth of NQDE is slow. (2) The region forms a "strong south and weak north" pattern and the gap continues to widen. The overall level of the south has surpassed the north, and the internal differences in the north are particularly prominent. (3) The spatial and temporal evolution highlights structural contradictions. Provinces with high development levels are concentrated in the south, and the number of echelons in the north is small and there is a slight polarization, revealing the lack of regional coordination power.**

***Index Terms*—new quality productivity, grain loss reduction, regional differences**

Manuscript received April 23, 2025; revised July 5, 2025.

This study was supported in part by the Humanities and Social Sciences Planning Fund Project of the Ministry of Education of China under Grant 24YJA790034, Henan Agricultural University Social Sciences Prosperity Project Key Project under Grant NO.FRZS2024A02, China Postdoctoral Science Foundation General Project under Grant 2022M721039, Henan Province High-level Talent International Training Project under Grant GCC2025016, Henan Province Philosophy and Social Sciences Planning Annual Project under Grant 2024CJ1065, Henan Province Youth Talent Support Program under Grant 2025HYTP022, Henan Province Key R&D and Promotion Project (Soft. Science) under Grant 252400411188, Research on the Interest Coordination of Leading New Quality Productivity Formation by Supply Chain "Chain Leader" Enterprises under Government Subsidies under Grant 252400411188.

Pan Liu is an associate professor at College of Information and Management Science, Henan Agricultural University, Zhengzhou, 450046, China (e-mail: hnycliupan@163.com).

Jia-Min Zhu is a postgraduate student at College of Information and Management Science, Henan Agricultural University, Zhengzhou, 450046, China (corresponding author to provide phone: +86-199-0391-6760; e-mail: 19903916760@163.com).

Dong Li is a postgraduate student at College of Information and Management Science, Henan Agricultural University, Zhengzhou, 450046, China (e-mail: 17518816581@163.com).

Yue Long is a professor at School of Management Science and Engineering, Chongqing Technology and Business University, Chongqing, 400067, China (e-mail: ctbuec@126.com).

I. INTRODUCTION

IN July 2023, General Secretary Xi Jinping first proposed the concept of NQP during his research in Sichuan, Heilongjiang and other places, and emphasized the key role of technology innovation [1-3]. The Third Plenary Session of the 20th CPC Central Committee further elaborated that scientific and technological innovation is the core driving force for the development of NQP, especially in reforming agricultural production models and promoting grain saving and loss reduction [4]. As the core engine for the high-quality development of the grain industry, the development of NQP has important practical significance for ensuring national food security and promoting the strategy of building a strong agricultural country [5]. The importance of reducing food losses throughout the entire grain chain has been mentioned many times in important national documents. It is necessary to encourage food saving and loss reduction through technological innovations in green warehousing, breeding, processing, etc., and implement a series of incentive policies. Currently, although grain saving and loss reduction work has achieved certain results. However, the total loss of the three major staple foods still accounts for about 20.7% of their total output. It is estimated that the loss reduction potential of the three major staple foods will be between 20 million and 95 million tons in the next 10 years [6]. In view of this, it is urgent to empower food loss reduction with NQP. It is urgent to analyze the development status, regional differences and evolution trends of NQP in FGLR in main production areas and propose targeted countermeasures.

Relevant research mainly focuses on two aspects: the evaluation of the development level of NQP in the grain industry and the development of NQP in FGLR.

(1) Evaluation of the development level of NQP in the grain industry. At present, there is a lack of research on the evaluation of the development level of NQP in the grain industry, and related discussions are mostly focused on the development of NQP in agriculture [7-9]. Early studies focused on the connotation and role of NQP in agriculture, believing that it is the key to achieving agricultural and rural modernization and building agricultural power [10]. Kong and Xie [11] pointed out that high-quality new agricultural science talents are the primary factor in the development of NQP in agriculture, and the high-tech production materials brought about by innovation constitute its material basis, which has the characteristics of dynamism, timeliness, and sustainability. Jiang [12] further pointed out that NQP in

agriculture is mainly reflected in three aspects: science and technology, greening, and digitalization [13]. Jiang [12] and Luo [4] emphasized that the NQP of agriculture is driven by scientific and technological innovation, integrating new capital, big data, and new equipment, optimizing the combination of production factors, and forming an innovative, integrated, and green advanced productivity quality state. Recent studies have begun to focus on the measurement of the level of NQP of agriculture. For example, Qiao et al. [14] constructed an agricultural NQP indicator system based on NQL, NQLM, and NQLO, and tested its impact on agricultural carbon emissions. Zhu and Ye [15] found that the overall level of China's agricultural NQP is low, and there is a phenomenon of regional development polarization. Li et al. [16] pointed out that agricultural digitalization can significantly improve the level of China's grain NQP, especially in the main production areas.

(2) Research on NQP in FGLR. As an important part of the development of NQP in agriculture, food loss reduction is crucial to ensuring national food security [17]. Wang and Liu [18] proposed that the reconstruction of the agricultural science and technology innovation system and the modern agricultural industry system can improve agricultural productivity, resource utilization and sustainable development capabilities, and indirectly ensure food security. Zhou [19] also emphasized the importance of improving food production efficiency, resource utilization and sustainable development capabilities to ensure food security. When discussing the characteristics of the period of food security and the development of NQP in agriculture, Wu and Wu [20] particularly pointed out that in the new period, grain storage technology research and development and supervision should be strengthened to reduce food losses. Zhou and Gao [21] deeply analyzed the internal logic, realistic basis and key issues of food loss reduction in the whole chain from the perspective of NQP and proposed to use NQP as an engine to promote food loss reduction in the whole chain and achieve the long-term goal of food security.

In summary, the development of NQP has a significant effect on reducing grain losses throughout the entire grain chain. However, the current empirical research on the development level of NQP in FGLR is still insufficient, which limits its potential in promoting grain loss reduction. In view of this, this study aims to construct a measurement system for the development level of NQP in FGLR, evaluate the current status of the development of NQP in FGLR in China's main production areas, and reveal its dynamic evolution law, which has important theoretical and practical significance for promoting China's grain productivity to achieve a qualitative leap and achieve the diversified goals of reducing grain losses throughout the entire grain chain.

II. Theoretical Connotation and Index Construction

A. Connotation of NQP Theory in FGLR

Based on Marx's productivity theory [22-24] and General Secretary Xi Jinping's discussion on NQP, we analyze the theoretical composition of NQP in FGLR from five dimensions: NQL, NQLO, NQLM, NQPM, NQDE.

As the most active and decisive factor of NQP [25], NQL are the key to promoting the development of NQP in FGLR. The quantity and quality of talents with national food professional qualification certificates and high-level education backgrounds directly affect the development of this field. The efficiency of talent resource utilization, such as per capita GDP and per capita income of the primary industry, is also closely related to the level of NQP.

As the main carrier of NQP [26], the transformation and innovation of NQLO are crucial to food loss reduction [27]. The development of smart agriculture, biological breeding and food loss reduction related links, especially the number of agricultural intelligent equipment, artificial intelligence and Internet of Things companies, has become the key to technology research and development and application. The development of the biological breeding industry ensures a stable supply of high-quality grain sources [28], while the level of loss reduction technology and facilities in the harvesting, storage and transportation links determines the development of NQLO.

NQLM is the core of NQP in FGLR. The introduction and integrated innovation of cutting-edge technologies, as well as high-level R&D investment by governments, enterprises and universities, provide important support for scientific and technological innovation [29]. The number of agricultural green and utility model patents reflects the efficiency and ability of scientific and technological innovation, while changes in grain production reflect the practical effect of technological innovation in grain production and loss reduction.

The NQPM embodies the new development concept of "innovation, coordination, green, openness and sharing" [30], emphasizing resource conservation, environmental friendliness, data sharing and open cooperation [31]. Agricultural water uses and carbon emissions per unit of GDP measure the effectiveness of resource utilization and environmental protection. Digital production mode is a significant feature of NQP [32]. International competitiveness and cooperation level, such as the total amount of grain imports and exports and the number of foreign-invested agricultural projects, are important manifestations of NQPM. The intensity of fertilizer and pesticide use and the total amount of agricultural carbon emissions point to the realization of environmentally friendly production mode.

The NQDE, as an external driving force for the NQP in FGLR, is inseparable from government support, social attention and high-quality talent training environment. The government's support for scientific research projects in FGLR, as well as research and discussion and news reports on FGLR by scientific research institutes, universities, media, etc., are important supports for the NQDE. The government's educational expenditure on agricultural colleges and the support for the training of talents in the field of food are the basis for creating a good new quality talent environment.

B. Data Source and Index Construction

We evaluate the development of NQP in 13 main production areas in China from 2010 to 2021. According to the north-south division [33], the main production areas are divided into the south (Jiangsu, Anhui, Hubei, Hunan, Jiangxi, Sichuan) and the north (Henan, Shandong, Hebei, Inner Mongolia, Heilongjiang, Jilin, Liaoning).

The data are from the 2010-2021 "China Statistical Yearbook", "China Grain and Material Reserve Yearbook", "China Rural Statistical Yearbook" and the statistical yearbooks and information bulletins of various provinces, and the enterprise quantity data are manually collected through "Tianyancha". Missing data are supplemented by moving average method.

Based on a profound understanding of the NQP in FGLR, we integrate the research context of scholars such as Jiang [12], Wu [26] and Zhou [21], and construct a measurement system for the level of NQP in FGLR (see Table I).

III. Development Level of NQP in FGLR

A. Development Level of Main Production Areas

We conducted a quantitative assessment of the development level of NQP in FGLR in China's main production areas using the Entropy-TOPSIS method [34].

1) Overall Level of Development

According to the data in Table II, from 2010 to 2021, in the FGLR, the development level of NQP in China's main grain producing areas showed an overall fluctuating upward trend, with an average development level of 0.194.

The average annual development level of Jiangsu, Shandong, Hubei, Liaoning and Henan provinces exceeded the national average, accounting for 38.46% of the total production areas. There is a 2.8-fold gap between Inner Mongolia, which has the lowest development level, and Jiangsu, which has the highest level, highlighting the significant differences in the development of NQP in the FGLR among provinces.

The development levels of five provinces, Henan, Heilongjiang, Hubei, Jiangsu and Sichuan, showed a stable growth trend. However, seven provinces, including Anhui, Hebei, Jilin, Jiangxi, Liaoning, Inner Mongolia and Shandong, showed a fluctuating growth. In addition, although Hunan showed a fluctuating downward trend, its overall level ranked eighth, which shows that after discovering the situation of going downhill, Hunan was able to quickly adjust its strategy, use its inherent advantages, enhance its innovation capabilities, and thus promote the stable development of NQP.

In terms of annual growth rate, Inner Mongolia has the highest annual growth rate of NQDE in 2021, reaching 52%, while Hunan Province has the lowest growth rate in 2011, at -36.6%. Between 2017 and 2021, the annual growth rate of NQP showed an upward trend, reaching a peak of 16.8% in 2020, and falling to 6.6% in 2021.

2) Level of Regional Development

As shown in Fig. 1, from 2010 to 2021, the NQP in FGLR in both southern and northern China showed an upward trend, but the overall development level of the southern region was higher than that of the northern region, showing its leading position.

The southern region experienced a brief decline between 2010 and 2012, possibly due to economic, social or technological challenges. Through strategic adjustments and innovation enhancement, the development level of the southern region resumed growth.

The northern region continued to rise during the same period, probably due to increased technological innovation and industrial upgrading. Although there was a brief decline in 2016, it recovered quickly, showing the adaptability and execution of the northern region.

Between 2010 and 2015, the development level trends of the main production areas and the southern region were similar, probably due to exchanges and cooperation in technological innovation and industrial upgrading. Between 2015 and 2021, the trends of the main production areas converged with those of the northern region, probably reflecting that main production areas promoted the development of NQP after absorbing the experience and technology of the northern region.

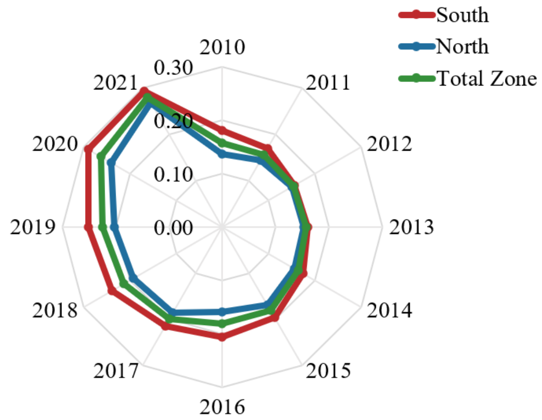

Fig. 1 Regional NQP development level in FGLR.

3) Development Level in Each Dimension

The following research results are obtained from Table III.

(1) NQL dimension. Jiangsu Province and Shandong Province perform well in cultivating and attracting NQL, while Hebei Province and Jiangxi Province are relatively lagging behind, showing that There is significant imbalance between regions, with the ratio of the maximum value to the minimum value being 2.5:1. During the inspection period, the overall growth showed fluctuating growth, with the highest growth rate being 95.37%.

(2) NQLO dimension. Hubei Province and Liaoning Province are leading, which may benefit from early industrial layout and policy support. Inner Mongolia and Jilin Province ranked lower, which may be related to the late start of new quality industries. There are obvious regional differences, with the ratio of the maximum and minimum values being 3:1. The annual growth rate fluctuates between -3.75% and 20.3%, reflecting the uneven development of new quality industries.

(3) NQLM dimension. Jiangsu Province ranks first, thanks to its economic strength and technological input and output. Jiangxi Province, Hebei Province and Inner Mongolia have lower development levels and huge regional differences, with a maximum to minimum ratio of 6.4:1. The annual growth rate fluctuates between -1.59% and 19.74%, showing the imbalance of input and output of NQLM.

(4) NQPM dimension. Jiangsu Province shows an absolute advantage, which may be related to its strong industrial foundation and innovation capabilities. Inner Mongolia and Jilin Province have greater development potential. The regional gap is relatively high, with a maximum-minimum ratio of 4.7:1. The annual growth rate is between -6.62% and 19.29%, and the growth rate is relatively slow.

(5) NQDE dimension. Jiangsu Province and Hunan Province are leading, which may be related to economic transformation and upgrading, infrastructure construction and policy advantages. Jilin Province, Hebei Province and Inner Mongolia are relatively backward, with the smallest regional gap, with a maximum-minimum ratio of 2.2:1. Although the overall growth is fluctuating, there are many negative growth phenomena, with the annual growth rate ranging from -8.23% to 12.36%, indicating that the improvement of the NQDE requires long-term efforts and continuous investment.

The results of the analysis show that the NQP in FGLR has generally increased in all dimensions, reflecting the attention and investment of main production areas. Jiangsu and Shandong provinces have performed well in multiple dimensions, thanks to their strong economic strength, scientific and technological innovation capabilities and policy support. In contrast, Inner Mongolia has lagged in development, this may be due to talent shortage, weak industrial foundation and scarce scientific and technological resources.

B. Analysis of Regional Differences

1) Overall Regional Differences

We used Dagum Gini coefficient method to analyze the regional differences in NQP in main production areas [35]. Table IV shows that the overall Gini coefficient has been fluctuating downward, from 0.186 in 2015 to 0.156 in 2018. Although it rebounded to 0.210 in 2020, the long-term trend is still downward, indicating that the NQP in main production areas is gradually optimizing in terms of grain loss reduction, tending to more efficient and balanced development.

The average value of the NQP Gini coefficient in the southern region is 0.173, higher than 0.158 in the north, indicating that the south is relatively better than the north in the development of NQP. During the sample period, the Gini coefficient in the north increased by 34.6%, while that in the south decreased by 27.3%, reflecting that the internal differences in the south are narrowing. Despite differences between the north and south, the overall trend is towards a more balanced direction.

2) Sources of Differences and Contribution Rates

Fig. 2 shows that the contribution rate of regional differences in NQP in FGLR is stable, the contribution rate of inter-regional differences has decreased, indicating that the differences in productivity development levels between regions have narrowed. The increase in the contribution rate of hypervariable density is symmetrical with the change in the difference contribution rate between regions, indicating an increase in the mutual influence between regions. This result is contrary to the research results of Zhu and Li [36], suggesting that intra-regional differences are the main factor in the overall differences in NQP.

To improve the development level of NQP and narrow regional differences, it is recommended to strengthen balanced development within regions, optimize the layout of NQP, and promote regional cooperation and exchanges.

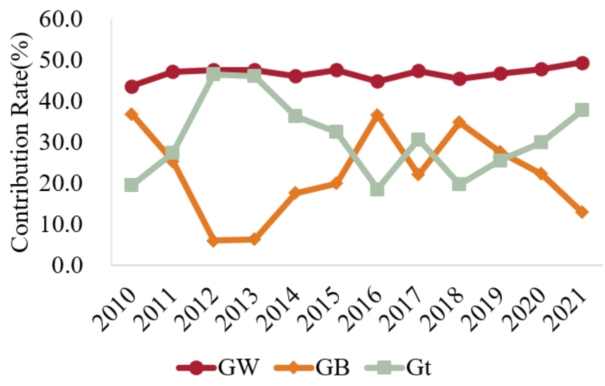

Fig. 2 Contribution rate of regional differences.

C. Dynamic Evolution Characteristics

1) Temporal Evolution

We used the kernel density estimation method to analyze the evolution characteristics of NQP in FGLR in China's main grain-producing areas and the north and south regions from 2010 to 2021. To ensure the observability and clarity of the graph, we selected the kernel density distribution in 2010, 2013, 2016, 2019 and 2021.

Main Grain Production Areas (Fig. 3). The overall nuclear density curve shifts to the right, indicating that the level of new quality productivity has steadily increased. A right tail appeared in 2021, indicating that the gap between regions is obvious. The height of the main peak "first decreases and then increases", and the width "first narrows, then widens, and then narrows again", indicating that the gap in development levels fluctuates.

Northern Region (Fig. 4). The main peak of the distribution curve shifts to the right, indicating that the level has improved. The height of the main peak decreases and the width widens, indicating that the gap within the region is gradually widening. There is a tailing phenomenon, indicating that the gap is obvious. The curve is unimodal, and the polarization phenomenon is slightly significant.

Southern Region (Fig. 5). The main peak shifts to the right as a whole, indicating that the level of new quality productivity has gradually increased; the peak height "first increases, then decreases, and then increases", and the peak width "first widens, then narrows", indicating that the development level fluctuates. There is a tailing phenomenon, indicating that the regional gap is obvious. The curve is unimodal, and there is no serious polarization.

2) Spatial Evolution

We used ArcGIS spatial analysis to conduct an in-depth spatial distribution pattern analysis of the development level of NQP in 13 main production areas in China. According to the research results and the research of Jiang [9], Zhu and Li [36], four echelon standards were set (first echelon>0.25, second echelon 0.2~0.25, third echelon 0.15~0.2, fourth echelon<0.15), and 2012 (Fig. 6), 2015 (Fig. 7), 2018 (Fig. 8) and 2021 (Fig. 9) were selected as research objects, revealing the spatial evolution of the development of NQP in China's main production areas.

The study found that the overall trend showed a development from a low level to a high level, and the number of provinces in the first echelon increased. Specifically, in 2012, 69.23% of the provinces were in the fourth echelon, indicating a low overall development level, and Jiangsu Province was the only province in the first echelon. In 2015, the number of provinces in the fourth echelon decreased, the second and third echelon increased, and Henan Province was added to the first echelon. In 2018, the second and third echelons remained the same, accounting for 61.54%, and Sichuan Province was added to the first echelon. In 2021, the fourth echelon disappeared, the second and third echelon remained stable, and the first echelon increased significantly to 53.85%. Anhui jumped from the third echelon to the first echelon, indicating an overall improvement in the level of NQP.

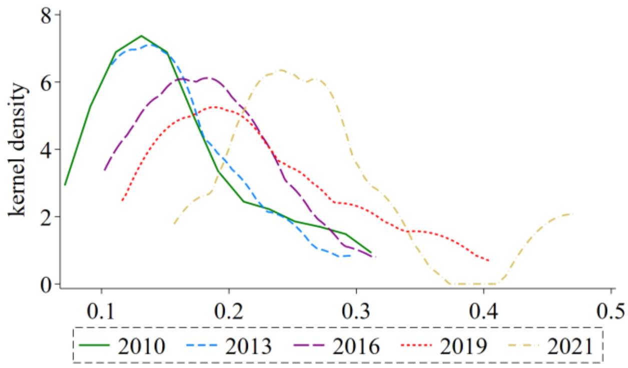

Fig. 3. Total regions.

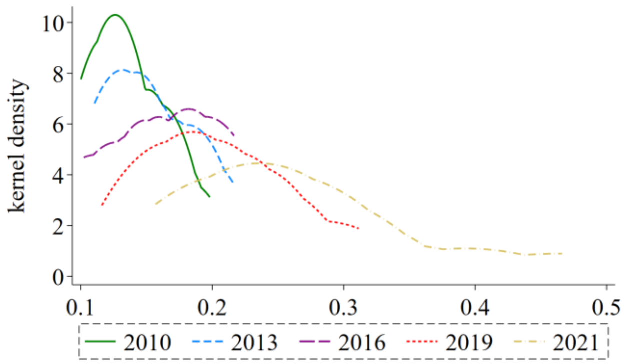

Fig. 4. Northern regions.

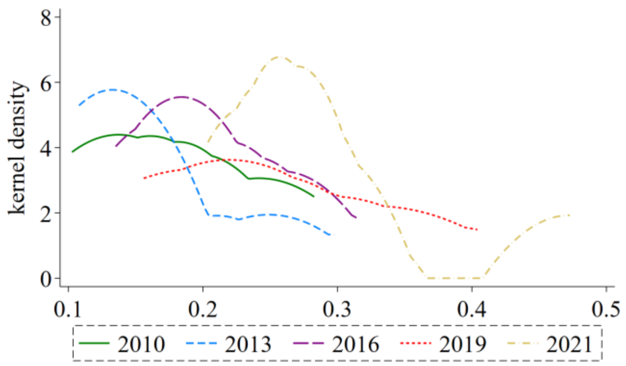

Fig. 5. Southern regions.

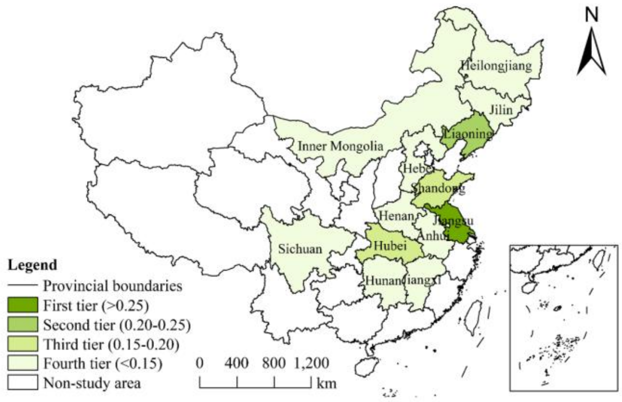

Fig. 6 Spatial distribution characteristics in 2012.

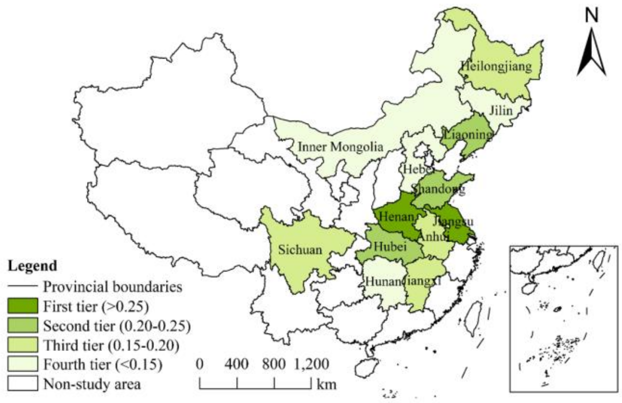

Fig. 7 Spatial distribution characteristics in 2015.

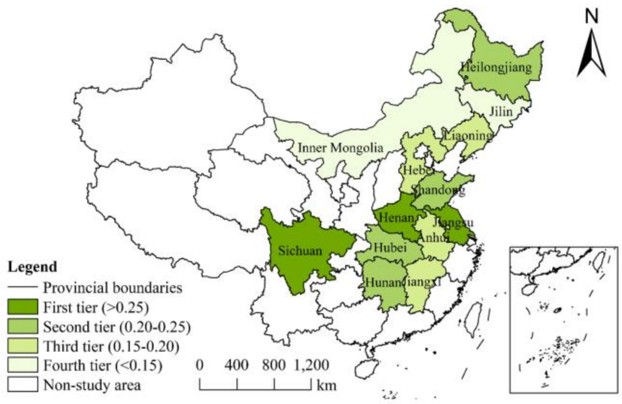

Fig. 8 Spatial distribution characteristics in 2018.

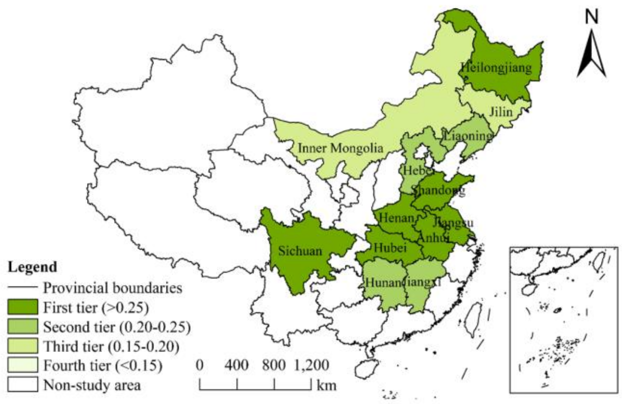

Fig. 9 Spatial distribution characteristics in 2021.

TABLE I
COMPREHENSIVE MEASUREMENT SYSTEM FOR THE DEVELOPMENT LEVEL OF NQP IN FGLR

Dimension	Primary Indicator	Secondary Indicator	Attribute
NQL	Quality structure	Average education level per capita in grain industry units	+
		Number of national vocational qualification certificates in grain industry	+
		Total amount of talent resources for new agricultural productivity	+
	Production efficiency	GDP per capita in the primary industry	+
		Per capita income level	+
NQLO	Smart agriculture	Number of agricultural intelligent equipment manufacturing companies	+
		Number of artificial intelligence companies	+
		Number of Internet of Things companies	+
	Bio-breeding industry	Number of biological breeding enterprises	+
		Revenue share of biological breeding industry	+
	Post-harvest grain loss reduction related industries	Level of agricultural mechanized harvesting	+
		Number of grain storage enterprises	+
		Total amount of post-harvest processing equipment	+
		Total amount of grain transportation hardware facilities	+
NQLM	Investment in scientific and technological innovation	Government agricultural RD investment	+
		Enterprise and institution agricultural RD project funding	+
		University agricultural RD project funding	+
	Output of scientific and technological innovation	Number of agricultural green invention patents	+
		Number of agricultural green utility model patents	+
		Change in grain production	+
NQPM	Eco-friendly production method	Total agricultural water use per unit of GDP	-
		Agricultural carbon emissions per unit of GDP	-
	Digital production method	Number of Internet broadband access ports	+
		Number of rural broadband access users	+
	Open cooperation	Total import and export of grain crops	+
		Total amount of foreign-invested agricultural projects	+
		Number of foreign-invested agricultural-related enterprises	+
	Environmentally friendly	Fertilizer application intensity	-
		Pesticide use intensity	-
		Agricultural phosphate fertilizer emission level	-
		Total agricultural carbon emissions	-
NQDE	Government-supported projects	Number of government-supported projects	+
		Number of national and provincial and ministerial policy support documents	+
	Social attention	Number of papers on grain	+
		Number of media articles	+
	Level of talent training environment	Percentage of total education expenditure	+
		Number of general colleges and universities	+
		Number of faculty and staff in colleges and universities	+

TABLE II
RESULTS OF THE MEASUREMENT OF THE DEVELOPMENT LEVEL OF NQP IN FGLR FROM 2010 TO 2021

Provinces	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean	Ranking
Anhui	0.129	0.135	0.120	0.108	0.138	0.176	0.241	0.179	0.191	0.156	0.221	0.251	0.170	9
Hebei	0.138	0.137	0.129	0.122	0.145	0.131	0.130	0.135	0.151	0.157	0.187	0.242	0.150	11
Henan	0.100	0.118	0.144	0.152	0.173	0.261	0.198	0.256	0.280	0.252	0.294	0.317	0.212	5
Heilongjiang	0.143	0.135	0.149	0.161	0.165	0.166	0.174	0.195	0.217	0.202	0.290	0.256	0.188	7
Hubei	0.187	0.196	0.193	0.200	0.211	0.214	0.219	0.241	0.247	0.257	0.278	0.289	0.228	3
Hunan	0.283	0.196	0.125	0.111	0.124	0.142	0.135	0.145	0.209	0.197	0.217	0.240	0.177	8
Jilin	0.100	0.103	0.114	0.112	0.109	0.104	0.102	0.133	0.133	0.183	0.134	0.157	0.124	12
Jiangsu	0.255	0.260	0.273	0.298	0.299	0.328	0.315	0.332	0.356	0.404	0.458	0.473	0.338	1
Jiangxi	0.130	0.121	0.119	0.134	0.142	0.155	0.172	0.205	0.181	0.165	0.194	0.204	0.160	10
Liaoning	0.198	0.215	0.220	0.217	0.211	0.222	0.217	0.224	0.184	0.200	0.215	0.243	0.214	4
Inner Mongolia	0.114	0.107	0.114	0.111	0.110	0.098	0.102	0.118	0.133	0.116	0.131	0.199	0.121	13
Shandong	0.161	0.191	0.182	0.195	0.175	0.200	0.192	0.237	0.249	0.311	0.427	0.466	0.249	2
Sichuan	0.103	0.113	0.108	0.112	0.132	0.161	0.153	0.181	0.251	0.321	0.368	0.302	0.192	6
All areas	0.157	0.156	0.153	0.156	0.164	0.181	0.181	0.199	0.214	0.225	0.263	0.280	0.194	—

TABLE III
RESULTS OF THE FIVE-DIMENSIONAL MEASUREMENT OF THE DEVELOPMENT LEVEL OF NQP IN FGLR FROM 2010 TO 2021

Province	NQL			NQLO			NQLM			NQPM			NQDE		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Anhui	0.366	0.139	0.607	0.162	0.056	0.31	0.12	0.045	0.287	0.155	0.112	0.187	0.145	0.12	0.185
Hebei	0.217	0.143	0.354	0.164	0.126	0.298	0.081	0.027	0.174	0.149	0.113	0.187	0.136	0.105	0.169
Henan	0.348	0.192	0.617	0.17	0.077	0.278	0.129	0.065	0.245	0.302	0.154	0.44	0.17	0.136	0.233
Heilongjiang	0.346	0.139	0.598	0.192	0.107	0.376	0.163	0.14	0.187	0.169	0.139	0.213	0.147	0.126	0.176
Hubei	0.305	0.204	0.371	0.262	0.227	0.308	0.152	0.054	0.304	0.148	0.087	0.254	0.226	0.207	0.252
Hunan	0.242	0.156	0.322	0.147	0.083	0.26	0.116	0.045	0.226	0.166	0.121	0.23	0.245	0.143	0.487
Jilin	0.338	0.139	0.509	0.087	0.041	0.223	0.101	0.075	0.126	0.116	0.091	0.168	0.137	0.103	0.166
Jiangsu	0.499	0.422	0.547	0.158	0.056	0.321	0.41	0.126	0.86	0.543	0.476	0.625	0.294	0.257	0.333
Jiangxi	0.198	0.134	0.289	0.173	0.118	0.255	0.064	0.026	0.109	0.159	0.114	0.236	0.174	0.142	0.235
Liaoning	0.299	0.186	0.455	0.24	0.181	0.268	0.103	0.048	0.177	0.214	0.183	0.285	0.159	0.145	0.219
Inner Mongolia	0.24	0.181	0.33	0.091	0.058	0.243	0.076	0.022	0.161	0.137	0.108	0.2	0.136	0.078	0.183
Shandong	0.475	0.335	0.62	0.2	0.076	0.473	0.247	0.094	0.492	0.303	0.226	0.562	0.197	0.172	0.27
Sichuan	0.252	0.166	0.325	0.206	0.059	0.473	0.139	0.055	0.274	0.167	0.118	0.247	0.177	0.147	0.228
All areas	0.317	0.134	0.62	0.173	0.041	0.473	0.146	0.022	0.86	0.21	0.087	0.625	0.18	0.078	0.487

TABLE IV
GINI COEFFICIENT AND DECOMPOSITION RESULTS OF NQP DEVELOPMENT LEVEL IN FGLR FROM 2010 TO 2021

Year	Overall Gini coefficient				Inter-regional differences	
	Overall	GW	GB	Gt	Northern region	Southern region
2010	0.192	0.084	0.071	0.037	0.133	0.205
2011	0.167	0.079	0.042	0.046	0.149	0.167
2012	0.163	0.077	0.010	0.076	0.128	0.187
2013	0.182	0.087	0.012	0.084	0.140	0.215
2014	0.160	0.074	0.028	0.058	0.122	0.178
2015	0.186	0.088	0.037	0.061	0.192	0.159
2016	0.175	0.079	0.064	0.033	0.153	0.163
2017	0.162	0.076	0.036	0.050	0.156	0.149
2018	0.156	0.071	0.054	0.031	0.156	0.127
2019	0.189	0.088	0.052	0.048	0.160	0.196
2020	0.210	0.100	0.047	0.063	0.223	0.176
2021	0.168	0.083	0.022	0.064	0.179	0.149
Mean	0.176	0.082	0.040	0.054	0.158	0.173

IV. Conclusions and Suggestions

A. Research Conclusion

This study constructs an index system of five dimensions of NQP in the FGLR (NQL, NQLO, NQLM, NQPM, NQDE), evaluates the development level of 13 provinces in China's main grain producing areas, and draws the following core conclusions:

(1) The overall development shows a fluctuating growth trend, with an average annual growth rate of 4.93% (the highest was 16.81% in 2020 and the lowest was -1.85% in 2012). There is a significant differentiation among the dimensions, with the fastest growth rate of NQLM, followed by NQLO and NQPM, the NQL dimension fluctuating violently, and the NQDE dimension growing slowly.

(2) Regional development presents an unbalanced pattern of "strong in the south and weak in the north". The overall level of the south exceeds that of the north, and the gap between the north and the south continues to widen. The intra-regional gap is the main reason for the uneven development of the main producing areas. Among them, the gap in the south has widened since 2012, but the level has surpassed, while the gap in the north continues to expand.

(3) The spatiotemporal evolution shows that regional differentiation has intensified. Provinces with high development levels (such as Jiangsu) are concentrated in the south, and there are fewer echelons in the north. Only in the north is there a slight polarization phenomenon, highlighting the lack of development momentum within the region.

B. Policy Recommendations

Based on the above conclusions, the following targeted policy recommendations are proposed:

(1) Targetedly strengthen capacity building in the north and promote regional coordination. In view of the continued widening of the North-South gap and the imbalance of internal development in the north, it is necessary to improve the infrastructure of warehousing and cold chain in the north through special fiscal transfer payments, and establish a "South-to-North Technology Transfer" mechanism to promote the transfer of intelligent loss reduction technology in the south to the north to avoid repeated investment.

(2) Focus on technology upgrading and fill the gap in NQPM. In view of the contradiction that the growth rate of NQLM is leading but the NQPM is lagging behind, the research and development subsidies for intelligent agricultural machinery and post-harvest loss reduction equipment should be increased, and technology promotion centers should be set up in the main production areas in the north to pilot the application of drying towers, low-loss harvesters and other equipment to accelerate technology transformation.

(3) Stabilize the supply of NQL and optimize the NQDE. In view of the sharp fluctuations in the dimension of NQL and the lack of support for the NQDE, a compound incentive of "basic salary, loss reduction benefit dividend" should be implemented for agricultural science and technology personnel to reduce the risk of talent loss. At the same time, the green credit process should be simplified, and income tax deductions should be given to enterprises that adopt loss reduction technology to stimulate market vitality.

(4) Build a differentiated dynamic monitoring system. Based on the differences in development motivations between the north and the south, the southern assessment focuses on the efficiency of technology upgrades (such as the coverage rate of smart devices), while the northern assessment tracks the progress of gap convergence (such as changes in the Gini coefficient); publish the productivity loss index of major production areas every quarter to drive accurate resource allocation.

C. Future Research

This study has certain limitations in terms of timeliness, as the data is only current up to 2021. Additionally, regarding the research sample, the analysis was confined to specific regions rather than encompassing national-level areas, which imposes constraints on the generalizability of the findings. In future research, we aim to delve deeper into this field and expand the scope of investigation to achieve more significant breakthroughs.

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