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Evaluation of Integrated Production Capacity of Well-facilitated Farmland in Jiangsu Province

Qian ZHUANG *

School of International Pharmaceutical Business, China Pharmaceutical University, Nanjing 211198, China

Abstract The fundamental task of well-facilitated farmland construction is to continuously lift the integrated production capacity. External project construction for well-facilitated farmland can not completely solve existing problems in improvement of intrinsic quality of farmland. Based on research findings of integrated production capacity of farmland, starting from basic elements such as water, soil, seed, fertilizer, and pesticide, this paper introduced factors influencing the integrated production capacity of well-facilitated farmland, including natural quality of farmland, supporting infrastructure, agricultural technology level and management level, and labor quality. Besides, it establish an evaluation system for integrated production capacity of well-facilitated farmland in Jiangsu Province by Analytic Hierarchy Process (AHP), and made an empirical study using indicator data of 2010 – 2014. Results indicated that the general index of integrated production capacity of farmland in Jiangsu Province in 2010 – 2014 was ascending, reflecting improvement of integrated production capacity of farmland. With the aid of radar map, it further found that the coupling between water, soil, seed, fertilizer, and pesticide and other elements play a crucial role in lifting the integrated production capacity of farmland. Finally, based on existing problems in construction of well-facilitated farmland in Jiangsu Province, it came up with some pertinent recommendations from the perspective of coordinated development of all elements.

Key words Well-facilitated farmland, Integrated production capacity, Analytical hierarchy process (AHP)

1 Introduction

Farmland is an essential material base of agricultural production. Long time of scientific research observation indicates that farmland with high fertility has contribution rate up to 60% – 70% to the grain yield, while farmland with low fertility has only 40% contribution rate to the grain yield[1 – 3]. At present, China's agricultural modernization is excessively dependent on chemical fertilizer, pesticide and antibiotic due to influence of industrial pollution; farmland pollution is increasingly deteriorating; farmland quality is not optimistic; all of these are threatening quality and safety of agricultural products[4 – 7]. Traditional farmland capital construction mainly solves external project conditions, but this could not completely solve existing problems in improvement of farmland quality. On June 13, 2014, *Rules of Well-facilitated Farmland Construction* was issued by General Administration of Quality Supervision, Inspection and Quarantine and Standardization Administration and formally implemented on June 25, 2014. According to this standard, the well-facilitated farmland is farmland divided into permanent capital farmland with level land, concentrated, well facilities, fertile soil, excellent ecology, and high anti-disaster ability. Well-facilitated farmland is quintessence of farmland. Developing well-facilitated farmland plays a great role in increasing farmland area, improving farmland quality, and ensuring balance in requisition and compensation. Well-facilitated farmland construction focuses on intrinsic quality construction. It is an essential means for increasing grain yield, farmers' income, and promoting stable development of agriculture. Jiangsu Province is a large province of grain production, and its land resources are mainly plain with excellent natural properties, deep soil layer and high and medium fertility, suitable for farming. At present, the farmland protection area of Jiangsu Province reached 69 million mu, accounting for more than 80% of agricultural land. However, the per capita farmland is less than 0.9 mu, far lower than the average national level. Land load rate and output rate are high, but the reserve resources are insufficient, thus the demand for well-facilitated farmland construction is urgent in Jiangsu Province. In 2014, Jiangsu Province drafted the *Plan for Well-facilitated Farmland Construction in Jiangsu Province* (2014 – 2020), which set forth construction criteria for well irrigating facilities, level and fertile farmland, smooth field roads, and well established farmland forest network. In this paper, we focus on providing theoretical guidance on well-facilitated farmland construction in Jiangsu Province from the perspective of continuously lifting the integrated production capacity.

2 Establishing the evaluation indicator system for integrated production capacity of well-facilitated farmland in Jiangsu Province based on AHP

2.1 Development characteristics of modern agriculture in Jiangsu Province

(i) The human-land conflict is violent. The per capita farmland in Jiangsu Province is less than 0.9 mu, much lower than the average national level. In addition to high land load rate and insufficient reserve land, Jiangsu Province is a typical province with restrictive agricultural resources. (ii) Agricultural ecological and environmental pollution is deteriorating. Modern

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* Corresponding author. E-mail: zhuangcpu@163.com

agricultural development of Jiangsu Province excessively relies on chemical fertilizer, pesticide, and antibiotic, which leads to serious soil pollution[8-11]. In addition to water loss and soil erosion and nutrient loss, agricultural ecological environment is deteriorating, and the quality and safety of agricultural products are difficult to guarantee[12]. (iii) Labor cost is relatively high. The economy of Jiangsu Province is relatively developed, the labor cost is high. It is difficult to increase grain yield merely through expanding the area. Besides, rural funds, labor, and land have serious problem of loss, price of agricultural input products is constantly rising, and labor cost for agricultural production is also increasing. (iv) Allocation of agriculture-related funds is not even. In Jiangsu Province, about 60% financial funds for agriculture are used for control of rivers, while only 40% are used for agricultural production. (v) It is difficult to guarantee high and stable yield of rice. Jiangsu Province is a large province of rice production, rice breeding technology and planting mechanization remain in the leading position in China, but there are still many problems in rice infrastructure construction and management[13, 14]. In recent years, with increasing global warming, plant disease and insect pests and natural disasters occur frequently, and the stress resistance of rice is generally low[15].

Table 1 Evaluation indicator levels and indicator calculation formula for integrated production capacity of well-facilitated farmland in Jiangsu Province

Target level	System level	No.	Indicator level	Calculation formula
High efficient farming, high quality breeding, and safe output	Agricultural soil resource and farming level	1	Soil fertility composite index	Soil organic matter content ÷ dry soil weight × 100%
		2	Multiple crop index	Total sown area of crop in the whole year ÷ total area of farmland × 100%
		3	Land reclamation rate	Reclamation area of waste land ÷ total area of waste land × 100%
		4	Land output rate	Total grain yield in the whole year ÷ total sown area of grain crops × 100%
		5	Water loss and soil erosion control rate	Water loss and soil erosion control area ÷ total area of water loss and soil erosion × 100%
	Agricultural water resource and irrigation level	6	Water quality composite index	Obtained from consulting experts
		7	Water conservancy facility completeness rate	Total number of complete water conservancy facilities ÷ total number of water conservancy facilities × 100%
		8	Effective irrigation rate	Area of effective irrigation ÷ total farmland area × 100%
		9	Irrigation water use coefficient	Canal system use coefficient × field water use coefficient
		10	Water-saving irrigation rate	Area of water-saving irrigation ÷ effective irrigation area × 100%
	Agricultural seed resource and sowing level	11	Seed quality	Including seed purity, germination rate, germination energy, seed moisture content, seed viability, and seed health
		12	Fine seed coverage rate	Fine seed sown area ÷ total sown area × 100%
		13	Fine seed and method matching	Obtained from consulting experts
	Agricultural fertilizer resource and application level	14	Intensity of fertilizer application	Fertilizer application (net) ÷ total sown area, expressed in kg/hm^2
		15	Fertilizer use rate	(Nutrient absorbed by crops in fertilizer application zone-nutrient absorbed by crops in nutritional deficiency zone) ÷ (fertilizer application amount × nutrients in fertilizer) × 100%
		16	New fertilizer use rate	New fertilizer application in unit area ÷ ordinary fertilizer application in unit area × 100%
	Pesticide use and plant disease and insect pest prevention and control level	17	Intensity of chemical pesticide application	Chemical pesticide application ÷ total sown area, expressed in kg/hm^2
		18	Safe and high efficient pesticide use rate	Safe and high efficient pesticide use in unit area ÷ ordinary pesticide use in unit area ×100%
		19	Coverage rate of professional unified prevention and control	Available in public platform
	Others	20	Light energy use ratio	$E = \frac{500 \times y \times H}{\sum Q \times 666.7 \times 10^4} \times 100\%$
		21	Air pollution index	Available in public platform
		22	Integrated mechanization rate of farming, planting, and harvesting	(Mechanized cultivation rate + mechanized transplanting rate + mechanized harvesting rate) / 3

2.2 Establishing the evaluation indicator system based on AHP Based on grading results of agricultural land, we selected indicators suitable for evaluating integrated production capacity of well-facilitated farmland in Jiangsu Province. Based on AHP, we established the evaluation indicator system. The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology[16]. In this paper, we tried to establish three hierarchies. The first hierarchy is target level, with high efficient farming, high quality breeding, and safe output as targets; the second hierarchy is system level, including agricultural soil resource and farming level, agricultural water resource and irrigation level, agricultural seed resource and sowing level, agricultural fertilizer resource and application level, pesticide use and plant disease and insect pest prevention and control level, and other 6 subsystems; the third hierarchy is indicator level, involving various contents of indicators (in this study, we set 22 indicators), as listed in Table 1.

To ensure scientific and reasonable judgment matrix of different levels, we invited 10 experts of soil research, soil environmental protection, land use plan, and modern agricultural development from research institutions, colleges and universities, and government sectors, asked them to evaluate the relative importance of each indicator, conducted weighted sum of judgment of every expert, so as to obtain final judgment matrix of each level, and calculate each indicator weight through the judgment matrix. Finally, we carried out CR consistency test using the ratio of consistency index CI to random consistency index RI; when CR < 0.1, it is deemed that judgment matrix has consistent satisfaction. The judgment matrix for evaluation indicator system for integrated production capacity of well-facilitated farmland in Jiangsu Province is shown in Table 2.

Table 2 Judgment matrix for evaluation indicator system for integrated production capacity of well-facilitated farmland in Jiangsu Province

G	A_1	A_2	A_3	A_4	A_5	A_6
A_1	1/3	1	1/2	3	3	1
A_2	2	3	2	1	1/2	1/2
A_3	1/2	1/2	3	2	1	1/3
A_4	1	1/2	1	2	2	1/3
A_5	2	2	1	1/2	2	1
A_6	3	2	1/2	1/3	1/3	2

Through calculation, the maximum characteristic value of judgment matrix $\lambda_{max} = 6.321$, and the corresponding characteristic vector is $(0.307, 0.214, 0.098, 0.154, 0.142, 0.085)^T$. Namely, the system level of the evaluation indicator system for integrated production capacity of well-facilitated farmland in Jiangsu Province: the weight is 0.307, 0.214, 0.098, 0.154, 0.142, and 0.085 respectively for agricultural soil resource and farming level, agricultural water resource and irrigation level, agricultural seed resource and sowing level, agricultural fertilizer resource and application level, pesticide use and plant disease and insect pest prevention and control level. According to the maximum characteristic value, we further calculated the consistency index CI = 0.0642. From the table, RI = 1.24, finally, we calculated the random consistency index CR = 0.0518 < 0.1, indicating that judgment matrix result is effective.

Similarly, we can calculate the weight of each indicator level, as listed in Table 3.

Table 3 Evaluation indicator system for integrated production capacity of well-facilitated farmland in Jiangsu Province

Target level	System level	Weight//%	No.	Indicator level	Weight//%
High efficient, high quality, and safe	Agricultural soil resource and farming level	30.7	1	Soil fertility composite index	39.1
			2	Multiple crop index	19.5
			3	Land reclamation rate	13.8
			4	Land output rate	17.6
			5	Water loss and soil erosion control rate	10.0
	Agricultural water resource and irrigation level	21.4	6	Water quality composite index	25.6
			7	Water conservancy facility completeness rate	21.8
			8	Effective irrigation rate	24.1
			9	Irrigation water use coefficient	17.9
			10	Water-saving irrigation rate	10.6
	Agricultural seed resource and sowing level	9.8	11	Seed quality	30.0
			12	Fine seed coverage rate	30.0
			13	Fine seed and method matching	40.0
	Agricultural fertilizer resource and application level	15.4	14	Intensity of fertilizer application	40.0
			15	Fertilizer utilization rate	30.0
			16	New fertilizer use rate	30.0
	Pesticide use and plant disease and insect pest prevention and control level	14.2	17	Intensity of chemical pesticide application	30.0
			18	Safe and high efficient pesticide use rate	40.0
			19	Coverage rate of professional unified prevention and control	30.0
	Others	8.5	20	Light energy use ratio	30.0
			21	Air pollution index	30.0
			22	Integrated mechanization rate of farming, planting, and harvesting	40.0

3 Empirical analysis

3.1 Data source Data were collected from *Statistical Yearbook of Jiangsu Province* (2010 – 2014), *Statistical Communiqué of Jiangsu Province on National Economic and Social Development* (2010 – 2014), related data of Statistics Bureau of Jiangsu Province, Jiangsu Agriculture Website, and website of Jiangsu Provincial People's Government.

3.2 Evaluation model The integrated production capacity of well-facilitated farmland is comprehensive manifestation of all indicators. Every indicator reflects the situation from different aspects, therefore, we established a multi-target weighted evaluation quantitative model:

$$P = \sum_{i=1}^{n} \left(\sum_{j=1}^{n} a_j r_j \right) w_i$$

where W_i is the weight of the i-th system, r_j is the weight of the j-th indicator, a_j is the standardized indicator value of the j-th indicator, and P is general index of integrated production capacity of well-facilitated farmland.

3.3 Target value In the determination of expected values, we mainly referred to *Rules of Well-facilitated Farmland Construction and Plan for Well-facilitated Farmland Construction in Jiangsu Province* (*2014 – 2020*), and considered expected values of similar indicator provisions in the evaluation indicator system for agricultural sustainable development, circular agriculture, and agricultural modernization, and established the target value for integrated production capacity of well-facilitated farmland in Jiangsu Province.

3.4 Evaluation of integrated production capacity of farmland in Jiangsu Province According to the evaluation model, we calculated 6 subsystems of integrated production capacity of farmland in Jiangsu Province, as listed in Table 4.

Table 4 Actual value and target value of system level for integrated production capacity of farmland in Jiangsu Province (2010 – 2014) (%)

Year	2010	2011	2012	2013	2014	Target Value
Agricultural soil resource and farming level	77.7	84.6	82.6	87.6	85.3	100
Agricultural water resource and irrigation level	67.7	72.6	65.2	66.7	69.2	100
Agricultural seed resource and sowing level	73.5	85.8	83.4	84.9	82.7	100
Agricultural fertilizer resource and application level	40.5	50.6	47.3	51.6	60.2	100
Pesticide use and plant disease and insect pest prevention and control level	45.1	52.3	59.8	67.3	68.7	100
Others	79.8	88.2	87.5	84.1	88.7	100

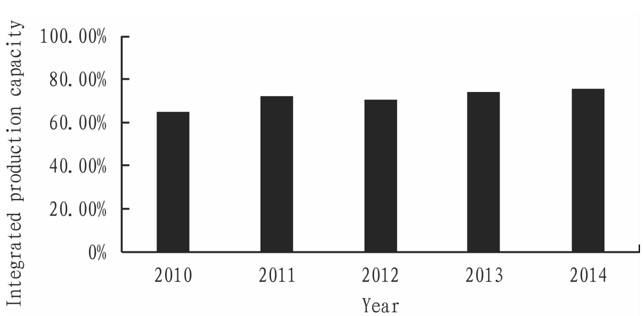

Fig. 1 Variation trend of general index of integrated production capacity of farmland in Jiangsu Province (2010 – 2014)

From Fig. 1, the general index of integrated production capacity of farmland in Jiangsu Province in 2010 – 2014 was ascending, reflecting improvement of integrated production capacity of farmland. The year 2011 was the initial year of the Twelfth Five-Year Plan period, the modern agriculture developing plan of Jiangsu Province clearly took improving production capacity of agricultural products, lifting quality and safety of agricultural products, and strengthening protection of agricultural ecological environment as major tasks, and took modern seed industry system construction project, agricultural product quality and safety traceable project, agricultural natural disaster reduction and prevention project, and low carbon circular agriculture project as major project construction. To further analyze the gap between actual value and target value of the index of the system level, and find out the short plate restricting integrated production capacity of farmland in Jiangsu Province, we plotted the radar map, as shown in Fig. 2.

In general, the integrated production capacity of farmland in Jiangsu Province is mainly restricted by agricultural fertilizer resource and application level and pesticide use and plant disease and inset pest prevention and control level. Therefore, the general index of integrated production capacity of farmland in 2012 slightly dropped. In 2013 – 2014, agricultural fertilizer resource and application level and pesticide use and plant disease and inset pest prevention and control level slightly rose, agricultural soil resource and farming level and agricultural water resource and irrigation level improved, and agricultural seed resource and sowing level and other factors remained stable and excellent development trend. All 6 subsystems of the integrated production capacity of farmland in Jiangsu Province took on an increasing balance trend. Such benign balance state promotes the general index of integrated production capacity of farmland in Jiangsu Province to rise, indicating that coordinated development of soil, water, seed, fertilizer, pesticide, and other elements play a key role in lifting the integrated production capacity of farmland. All 6 subsystems of the integrated production capacity of farmland are complementary with each other. A single subsystem can not exert a big impact, and it needs overall force of all subsystems to realize considerable effect.

4 Conclusions and recommendations

4.1 Conclusions The fundamental task of well-facilitated farmland construction in Jiangsu Province is to continuously lift the integrated production capacity, which is a fundamental force for sustainable agricultural development. In recent years, there is an inevitable connection between the improvement of integrated production capacity of farmland and the well-facilitated farmland construction in Jiangsu Province. However, the construction achievements of external projects must be converted into coordination advantages of all elements, to ultimately promote sustainable improvement of integrated production capacity of farmland. The solution to various problems, such as heavy metal pollution of soil, imperfect farmland water conversancy facilities, no supporting fine seeds and methods, and excessive application of chemical fertilizer and pesticide in modern agricultural development of Jiangsu Province, can not totally depend on external projects of well-facilitated farmland construction. Therefore, Jiangsu Provincial Government should set foot on the overall situation and promote the sustainable improvement of integrated production capacity of well-facilitated farmland from the perspective of coordinating development of all elements.

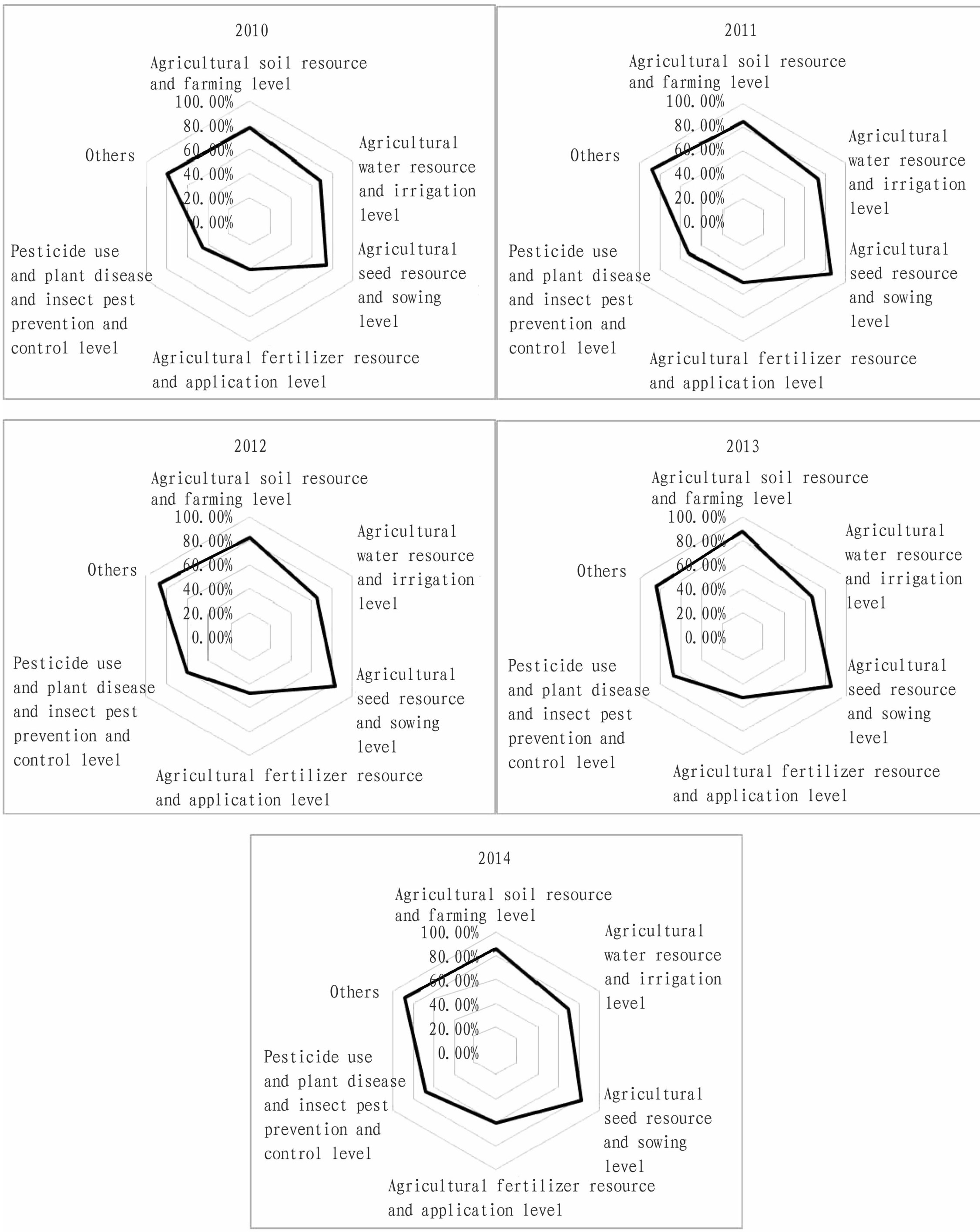

Fig. 2 Radar map for evaluation indicator system of integrated production capacity of farmland in Jiangsu Province (2010 – 2014)

4.2 Recommendations (i) It is recommended to carry out monitoring of polluted farmland soil and quality test of agricultural products, strengthen safe use and management of polluted farmland soil, and take agronomic measures, planting structure adjustment, soil pollution control and rehabilitation measures, to ensure safety of farmland soil. (ii) It is recommended to seize the opportunity of the state attaching great importance to the farmland and water conservancy construction, and consolidate resources, strengthen field water saving infrastructure construction, to establish a new agricultural pattern integrating water storage, conservation, collection, and saving. (iii) It is recommended to improve quality of farmers, cultivate new generation of young farmers, propagate through television lectures or advertisements, make farmers realize importance of fine seeds and fine methods, include the application of fine seeds and fine methods into the evaluation condition, and encourage farmers to apply fine seeds and fine methods. (iv) All levels of financial departments should increase support for production and application of organic fertilizers, and encourage agricultural technology extension organizations to contract farmland, to realize high output with little chemical input and make farmers really feel benefits of scientific fertilizer application. (v) In the aspect of plant disease and insect pest prevention and control, it is recommenced that the provincial party committee takes plant disease and insect pest prevention and control as a major task and organizes to make assessment; the provincial finance should annually allocate certain funds for supporting unified prevention and control of plant diseases and insect pests, and it is recommended to make clear construction requirements and implement the personnel license system and build service brands. (vi) It is recommended to actively extend new technologies of agricultural mechanization and new tools and machines, promote integration of agricultural machinery and agronomy, realize whole process mechanization of rice and wheat production as soon as possible, focus on developing high efficient facility agriculture, and improve overall mechanization level of agricultural production.

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which corresponds with China's national situation, and is the best way regulating shortage and surplus of urban and rural labor forces.

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