Establishment and Application of Assessment Indicator System of Agricultural Catastrophe Vulnerability

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Abstract To give play to the role of agricultural catastrophe risk fund in spreading agricultural catastrophe risk, we select natural conditions, economic conditions, social conditions, as the external vulnerability assessment indicators; select commodity rate of agricultural products, substitutability of agricultural products, the extent of agricultural products being related to the national economy and the people's livelihood, as the internal vulnerability assessment indicators. We assign weight to indicators using Analytic Hierarchy Process, and establish assessment indicator system of agricultural catastrophe vulnerability, to analyze the compensation for losses of different agricultural products arising from agricultural catastrophe in different regions. And we take the case of rice in Sichuan Province, to demonstrate the role this indicator system.

Key words Agricultural catastrophe risk fund, Assessment indicator system of agricultural catastrophe vulnerability, Analytic Hierarchy Process

China is a natural disaster-prone country and the natural disasters cause huge casualties. Especially in recent years, the frequency of occurrence of natural disasters has shown an upward trend, causing serious economic losses to agricultural production. According to the data from the Ministry of Civil Affairs of China, the direct economic losses arising from disasters amounted to 204.21 billion yuan, and 252.81 billion yuan in 2006; in 2007, all types of natural disasters in China inflicted impact to varying degrees on a total of about 400 million people, and the direct economic losses arising from disasters amounted to 236.3 billion yuan; in 2008, the "1 · 25" snow disaster in southern region caused huge economic losses as high as 151.65 billion yuan. On September 4, 2008, the press conference held by the State Council Information Office announced that "5 · 12" Wenchuan earthquake caused direct economic losses up to 845.14 billion yuan. In 2010, 5 provinces in Southwest China like Yunnan Province, suffered a severe drought, and this drought caused agricultural economic losses over 10 billion yuan in Yunnan Province. Mounting incidence of catastrophe and resulting losses, make China attach unprecedented importance to the establishment of a sound agricultural catastrophe risk management system. Since 2004, the Central Committee's Document No. 1 has mentioned catastrophe risk insurance system many times, and in 2010, proposed to improve agricultural reinsurance system, and establish catastrophe risk spreading mechanism supported by finance.

Based on the above-mentioned current situation, to support the establishment and operation of agricultural catastrophe risk fund, we conduct exploratory research and establish assessment indicator system of agricultural catastrophe vulnerability, and take the case of rice in Sichuan Province to demonstrate the application of this indicator system, aiming at providing recommendations at operational level for establishment and operation of agricultural catastrophe risk fund, giving full play to the role of government in the agricultural catastrophe risk management, and helping improve the operation efficiency of agricultural catastrophe risk fund, thereby promoting agricultural development and ensuring farmers' income.

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1 Overview of literatures

As to the definition of catastrophe risk, the international research holds that whether an event is defined as catastrophic event is be measured from four angles. First, it is measured from the perspective of all mankind. Richard and Posner define catastrophe as "the event causing serious loss of cost, and may even threatening human survival". Second, it is measured from the perspective of a country or region. For example, Munich Reinsurance Company believes that if after the occurence of natural disaster, the areas affected can not rely on their own strength to help themselves, but must rely on regional or international assistance, this natural disaster is defined as a serious natural catastrophe. Third, it is measured from the perspective of the entire insurance industry. For example, the Property Claim Services (PCS) under the U. S. Federal Insurance Services Office (ISO), is to define catastrophic event based on the perspective of the entire industry, which defines catastrophe as "the event causing direct property insurance losses in excess of $ 25 million and affecting a wide range of insurers and the insured, in accordance with the price level in 1998". Fourth, it is measured from the perspective of single insurance company. Many individual insurance companies also set an internal standard to determine whether an event is catastrophic event, and even if it is not a catastrophic event for the entire industry[1-2]. In China, Deng Quguo defines agricultural catastrophe as the event with small probability within a period of time (usually one year), causing losses at a time greater than expected, and cumulative losses surpassing the bearing capacity of the main body (peasant household, agricultural insurance company or government)[3]. Yu Boyang points out that the catastrophic characteristics of the agricultural risk are very obvious: the probability of agriculture being vulnerable to catastrophe is great, and there are great agricultural losses due to the impact of catastrophe, but the testability of agriculture being affected by catastrophe is poor[4].

According to Xiao Yuhong's research of agricultural catastrophe risk management pattern in developed countries, the major agricultural catastrophe risk management patterns include the government-led participatory pattern adopted by the United States and Canada, the government-backed insurance company pattern adopted by Japan, the government-funded commercial insurance pattern adopted by Germany, France and Spain[5]. Xie Shiqing draws a conclusion that the government-backed agricultural catastrophe risk management pattern overseas, through mature catastrophe risk system and rich catastrophe management experience, is of positive significance to China's establishment and operation of agricultural catastrophe risk fund[6].

2 Agricultural catastrophe risk management system

Once the agricultural catastrophe occurs, the compensation pressure on insurance company is huge, whose reserve fund and capital in cash is likely to be devoured all, which will seriously affect the financial security and sustainable management of the insurance company. Consequently, there is a need to adopt appropriate pattern and establish catastrophe risk fund, accumulating catastrophe risk fund in normal times and releasing the fund when agricultural catastrophe occurs. Only by doing this can we speed up the process of compensation, and ensure the safety of the operation of agricultural insurance company.

As to establishment of agricultural catastrophe risk fund in China, we can adopt the multi-financing model, but there are many obstacles to raising a variety of funds. There are contradictions regarding the proportion of bearing agricultural compensation for catastrophic losses between governments at all levels, between the government and the insurance company. Therefore, we try to establish the agricultural catastrophe risk management system (Fig. 1), to resolve contradictions between the main body in establishment of agricultural catastrophe risk fund. Agricultural catastrophe risk management system is a systematic project, which needs the joint participation of the government, insurance companies, peasant households and other parties. Through mutual coordination and unity, all parties can maintain effective long-term development.

3 Establishment of assessment indicator system of agricultural catastrophe vulnerability

Vulnerability refers to the possibility of individuals or families facing some risk, and the possibility of suffering wealth loss or the quality of life declining under a recognized level due to risk. Vulnerability includes sensitivity, exposure, adaptive capacity, and other elements[7]. From the perspective of the government, we introduce the concept of vulnerability into agricultural catastrophe, and advance the indicator assessment system based on agricultural catastrophe vulnerability, to compare the sensitivity and resilience of different agricultural products in different regions to agricultural catastrophe. The composite evaluation scores are derived, for the establishment and operation of agricultural catastrophe risk fund.

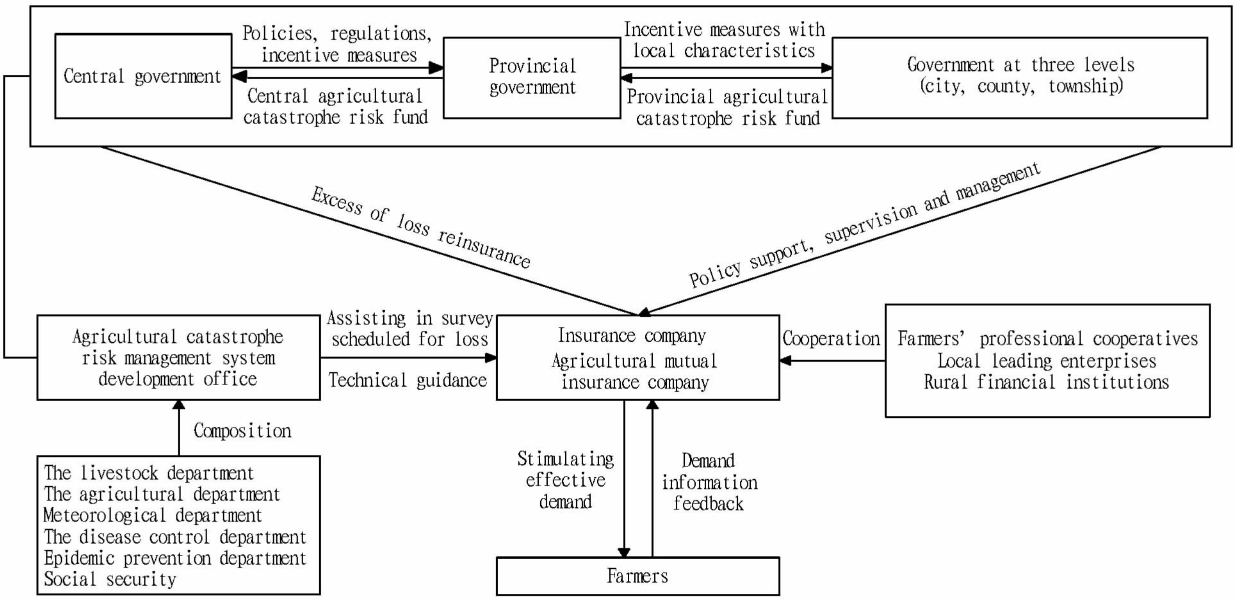

Fig. 1 Agricultural catastrophe risk management system

3.1 Design of assessment indicator system of agricultural catastrophe vulnerability

3.1.1 Design process of assessment indicator system of agricultural catastrophe vulnerability. Before the designing of assessment indicator system of agricultural catastrophe vulnerability, the most important task is to determine the assessment process. Based on the characteristics of the agricultural catastrophe risk, we introduce the idea of project management, and adopt the process reported in Fig. 2, to assess agricultural catastrophe vulnerability in various regions.

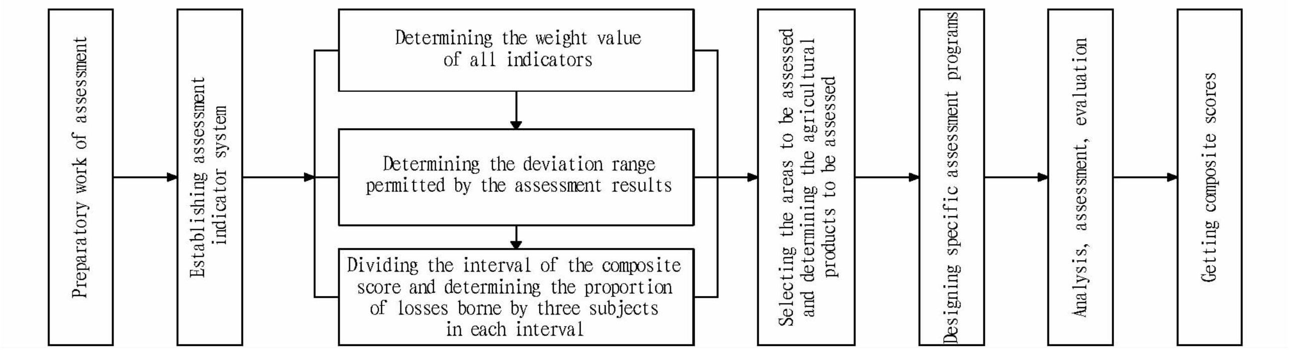

Fig. 2 Assessment process of agricultural catastrophe vulnerability

In Fig. 2, establishing assessment indicator system, determining the weight values of all indicators, dividing the interval of composite score and determining agricultural catastrophe risk fund in each interval, and making clear the proportion of losses that the insurance company and peasant households should bear respectively, is the key to this assessment indicator system.

3.1.2 Framework of assessment indicator system of agricultural catastrophe vulnerability. In assessment indicator system of agricultural catastrophe vulnerability, there are two first-level indicators (one is external vulnerability assessment indicator; the other is internal vulnerability assessment indicator), as shown in Table 1.

Table 1 Assessment indicator system of agricultural catastrophe vulnerability

The target layer	First-level indicator	Second-level indicator	Indicator explanation
Assessment indicator of agricultural catastrophe vulnerability	External vulnerability assessment indicator A_1	Natural conditions B_1	Determinants: the geological conditions; weather conditions; Resources; fluctuation in the average precipitation and average temperature in recent five years.
		Economic conditions B_2	Determinants: total GDP and per capita GDP in local areas in recent five years; gross agricultural products in recent five years; per capita net income of farmers in recent five years.
		Social conditions B_3	Determinants: the ratio of local rural population to total population in recent five years; the average years of education received by rural residents; the level of medical care and health.
	Internal vulnerability assessment indicator A_2	Commodity rate of agricultural products B_4	It is determined by the added value of products, including the added value brought by breeding, cultivation, planting technologies; the added value brought by the uniqueness of the variety; the added value brought by commercial hype of the products.
		Substitutability of agricultural products B_5	It means the relationship between two or more agricultural products with regional differences but the same value in use.
		The extent of agricultural products being related to the national economy and the people's livelihood B_6	It aims to distinguish the difference between sensitive bulk agricultural products (such as grain, cotton, edible oil and sugar) and other agricultural products in compensation for losses.

3.2 Analytic Hierarchy Process method for assessment indicator system of agricultural catastrophe vulnerability

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making, and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. Analytic Hierarchy Process method for assessment indicator system of agricultural catastrophe vulnerability is divided into the following 4 steps.

3.2.1 Establishing hierarchical structure. The first layer: the comprehensive evaluation capacity of assessment indicator system of agricultural catastrophe vulnerability. The second layer: in accordance with the nature of all factors affecting agricultural catastrophe vulnerability, there are 2 first-level indicators, namely external indicators (A_1) and internal indicator (A_2), including 6 second-level indicators, natural conditions in the city (prefecture) (B_1), economic conditions (B_2), social conditions (B_3), commodity rate of agricultural products (B_4), substitutability of agricultural products (B_5), the extent of agricultural products being related to the national economy and the people's livelihood (B_6). The third layer: assessment results of agricultural catastrophe vulnerability of a certain agricultural product in the city (prefecture) and the corresponding compensation for losses.

3.2.2 Establishing pairwise comparison judgment matrix. After the establishment of hierarchical structure of agricultural catastrophe vulnerability, we let the comprehensive evaluation capacity of assessment indicator system of agricultural catastrophe vulnerability at the first layer be criteria, predominating over 6 second-level indicators at the second layer. Through pairwise comparison of 6 second-level indicators, we calculate the weight of relative importance of them to criteria. We give marks to the relative importance between pairwise second-level indicators at the second layer, using 1 –9 scale method, whereby we can get the initial judgment matrix at this layer:

$$A=(a_{ij})_{n\times n}$$

where $a_{ij}>0, i, j=1,2,\cdots,n$.

3.2.3 Calculating the relative weight of assessment indicators using arithmetic average method. The calculation steps are as follows:

First, normalizing the judgment matrix by column, that is, turning $(a_{ij})_{n\times n}$ into:

$$(a_{ij}/\sum_{i=1}^{n}a_{ij})_{n\times n}=(\overline{a}_{ij})_{n\times n}$$

Second, totalling the normalized results by row, to get:

$$\overline{W}_i=\sum_{i=1}^{n}\overline{a}_{ij},\ i\in N$$

Third, normalizing the above results and getting the weight coefficient:

$$W_i=\frac{\overline{w}_i}{\sum_{i=1}^{n}\overline{w}_i},\ i\in N$$

Fourth, calculating the largest characteristic root (λ_{max}) of the judgment matrix:

$$\lambda_{max}=\sum_{i=1}^{n}\frac{(AW)_i}{nW_i}$$

where $(AW)_i$ signifies element i of vector AW.

3.2.4 Conducting consistency test of the judgment matrix. In order to test whether the judgment matrix deviates from consistency, the random consistency ratio ($C.R.$) of the judgment matrix is often introduced for test. The calculation process is as follows.

First, calculating the consistency index ($C.I.$):

$$C.I.=(Y_{max}-n)/(n-1)$$

where $C.I.$ signifies the consistency index; λ_{max} signifies the maximum characteristic root of the judgement matrix; n signifies the order of the judgement matrix.

Second, finding the average random consistency index $R.I.$ corresponding to n. When $n=(1,2,3,\cdots,9)$, the corresponding value of $R.I.$ is (0, 0, 0.62, 0.92, 1.12, 1.24, 1.32, 1.41, 1.45).

Third, calculating the consistency ratio of $C.R.$:

$$C.R.=C.I/R.I.$$

When $C.R.<0.1$, it is believed that the consistency of judgment matrix is acceptable, or else we need to adjust the judgment matrix, until it meets the consistency results of $C.R.<0.1$.

3.3 Weighting results of indicator system

3.3.1 Using analytic Hierarchy Process to get weights of all assessment indicators. Based on the second-level indicators in assessment system of agricultural catastrophe vulnerability, we list the judgment matrix (Fig.3).

A_1	B_1	B_2	B_3
B_1	1	1/3	3
B_2	3	1	5
B_3	1/3	1/5	1

A_2	B_4	B_5	B_6
B_4	1	2	1/3
B_5	1/2	1	1/5
B_6	3	5	1

Fig.3 Second-level indicator judgement matrix

We calculate the judgement matrix of external indicator A_1 and A_2, and the weight vector is as follows:

$$W_1=(0.260\ 498\quad 0.633\ 346\quad 0.106\ 159)^T$$

$$W_2=(0.229\ 871\quad 0.122\ 182\quad 0.647\ 947)^T$$

$$(\lambda_{max})_1=3.038\ 707\ 46$$

$$(\lambda_{max})_1=3.007\ 647\ 33$$

By analysis, each judgment matrix has satisfactory consistency. After calculation, we get the weight of all assessment indicators (Table 3).

Table 3 Weight of assessment indicators

Criteria layer	Weight of criteria layer	Project layer	Weight of project layer
External indicator	0.5	Natural conditions	0.130 249
		Economic conditions	0.316 673
		Social conditions	0.053 078
Internal indicator	0.5	The non-commodity rate of agricultural products	0.114 936
		Irreplaceability of the agricultural products	0.061 091
		The extent of agricultural products being related to the national economy and the people's livelihood	0.323 973

3.3.2 Using fuzzy comprehensive evaluation model to get composite score of assessment system. The assessment panel gives score to the agricultural products. The panel consists of experts from the relevant government departments, experts from insurance company and representatives of peasant households. The assessment panel uses the fuzzy comprehensive evaluation model for marking, and the marking steps are as follows.

First, we establish the state factor set of agricultural products to be assessed, and the factors in the set are the indicators in project layer of vulnerability assessment system: $U=(U_1, U_2, U_3, U_4, U_5, U_6)$, namely U = (natural conditions, economic conditions, social condition, the non-commodity rate of agricultural product, irreplaceability of the agricultural products, the extent of agricultural products being related to the national economy and the people's livelihood).

Second, we determine the comment set V. $V=(V_1, V_2, V_3, V_4)$. Let the comment set be V = (excellent, good, average, poor), V' = (large, comparatively large, comparatively small, small). Taking 100, 80, 60, 40 as score sections, we view V and V' as fuzzy sets in score section set $J=(100, 80, 60, 40)$, and the degree of membership of assessment score section of various states can be shown in Table 4.

Table 4 Degree of membership of assessment score section of various states

State	100	80	60	40
Poor/large	0.8	0.2	0	0
Average/Comparatively large	0.1	0.7	0.2	0
Good/comparatively small	0	0.2	0.6	0.2
Excellent/small	0	0	0.3	0.7

Third, we determine the weight vector. From the vulnerability assessment system, we get the weight vector as follows:

N_i = (0.130249; 00.316673; 0.053078; 0.114936; 0.061091; 0.323973

Fourth, according to the score of agricultural products given by the assessment panel, we establish fuzzy evaluation matrix based on the degree of membership of assessment score section of various states:

$$R_i=\begin{bmatrix} R_{11} & \cdots & R_{14} \\ \vdots & \cdots & \vdots \\ R_{61} & \cdots & R_{64} \end{bmatrix}$$

Fifth, we conduct fuzzy comprehensive judgment of agricultural products:

$$B_i=W_i\times R_i=(R_1\quad R_2\quad R_3\quad R_4)$$

Finally, the assessment score of agricultural products using fuzzy comprehensive evaluation model is as follows:

$$X=B_i\times(100\quad 80\quad 60\quad 40)^T$$

Sixth, we divide the score interval, to set the system of peasant households buying agricultural insurance in each interval, and stipulate the rate of premium charged by insurance company and the maximum compensation in each interval.

4 The use of assessment indicator system of agricultural catastrophe vulnerability – A Case Study of Sichuan Province

4.1 External indicator assessment in assessment indicator system of agricultural catastrophe vulnerability of Sichuan Province In Sichuan Province, it is warm and humid throughout the year, with the average annual temperature of 16 – 18 ℃. Daily range of temperature is small, but annual range of temperature is great. It is warm in winter, hot in summer, with frost-free period of 230 – 340 d. There is abundant rainfall, and the annual rainfall reaches 1 000 – 1 200 mm.

Table 5 The assessment results of external indicators in assessment indicator system of agricultural catastrophe vulnerability of Sichuan Province

Year	Economic indicator				Social indicator	
	Regional GDP 10^8 yuan	Total output value of the primary industry//10^8 yuan	The share of total output value of the primary industry in regional GDP//%	Per capita net income of peasant households//yuan	The share of agricultural population in total population//%	The ratio of expenditure in culture, education, recreation and services to total living expenditure//%
2004	6 379.63	1 394.26	21.85	2 518.93	58.24	6.33
2005	7 385.11	1 481.14	20.06	2 802.78	57.01	9.90
2006	8 637.81	1 595.48	18.47	3 002.38	56.10	6.69
2007	10 505.30	2 032.00	19.34	3 546.69	55.06	6.45
2008	12 506.25	2 366.15	18.92	4 121.21	54.32	5.54
2009	14 151.28	2 240.61	15.83	4 462.05	61.30	4.99
2010	17 185.48	2 482.89	14.45	5 086.89	–	5.61

We give score to the external indicators in assessment indicator system of agricultural catastrophe vulnerability in Sichuan Province, and the results are as follows: natural conditions (excellent); economic conditions (good); social conditions (average).

4.2 Internal indicator assessment in assessment indicator system of agricultural catastrophe vulnerability of Sichuan Province-taking rice as the agricultural product to be assessed Rice is the staple food crop, and we give score to internal indicators of rice in assessment indicator system of agricultural catastrophe vulnerability. The results are as follows: the non-commodity rate of this agricultural product is great; irreplaceability of this agricultural product is great; the extent of this agricultural product being related to the national economy and the people's livelihood is great.

The assessment panel members' scoring of rice in Sichuan Province is excellent, good, average, large, comparatively large, large. We establish the fuzzy evaluation matrix as follows:

$$R_i=\begin{bmatrix} 0 & 0 & 0.3 & 0.7 \\ 0 & 0.2 & 0.6 & 0.2 \\ 0.1 & 0.7 & 0.2 & 0 \\ 0.8 & 0.2 & 0 & 0 \\ 0.1 & 0.7 & 0.2 & 0 \\ 0.8 & 0.2 & 0 & 0 \end{bmatrix}$$

By calculation, we get the fuzzy comprehensive judgment vector as follows:

$$B_i=(0.362\,544\,1,\ 0.231\,034\,7,\ 0.251\,912\,3,\ 0.154\,508\,9)$$

The composite score is 76.032 28 points. Sichuan Province is one of the western provinces, where economic conditions and social conditions lag behind those in eastern provinces. The natural conditions in Sichuan Province are good, but it is affected by economic conditions and social conditions, the score of external factors in assessment indicator system of agricultural catastrophe vulnerability in Sichuan Province is high, so the compensation of agricultural catastrophe risk fund for losses arising from agricultural catastrophe risk in Sichuan Province should be higher than that in developed eastern coastal provinces. For the specific products such as rice, they are staple and basic agricultural products, closely related to the national economy and the people's livelihood, making great contribution to agriculture, so once these agricultural products such as rice suffer catastrophe, there will be huge loss, and the agricultural catastrophe vulnerability is high. In summary, in terms of rice in Sichuan Province, agricultural catastrophe risk management should be considered to force farmers to buy insurance, but the premium rate should be reduced, and the government at all levels should bear the major catastrophe losses. When there is over-compensation in the insurance company, the agricultural catastrophe risk fund should bear the part in excess of compensation.

5 Conclusions

Through the establishment of assessment indicator system of agricultural catastrophe vulnerability, we quantify the establishment and operation principles of agricultural catastrophe risk fund to some extent. The assessment scores can be used to judge the degree of enforcing establishment of this type of agricultural products; the assessment scores can also be used to determine the proportion of disaster losses borne by the government, insurance company and peasant households prior to the occurrence of catastrophe, so that the limited agricultural catastrophe risk fund can be used for agricultural losses, needing compensation most, caused by disasters; the efficiency in operation of agricultural catastrophe risk fund is promoted.

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chemical fertilizer should be ameliorated; fertilizer application technology improved; and fertilizer efficiency increased.

2.5 Exploit and utilize water resource rationally Marx pointed out that "capitals can be fixed on lands, that is invested on land, partially for a short term, such as for amelioration of chemical properties, fertilizer application *etc.*, and partially for a long term, such as for building water channels, construction of irrigation projects, land leveling, construction of management buildings, *etc.*"[1] Since national liberation, tens of thousands of large and medium-sized water conservancy projects have been constructed in China, which is of great use for the increase of agricultural production in China. But it must be noted that water resources in China are neither distributed rather unevenly, nor developed and utilized sufficiently and rationally. In some regions, people's production and livelihood are greatly affected by lack of water resources. In order to change the current situation, irrigation and drainage projects should be vigorously constructed to improve land productivity and agricultural economical benefits. Meanwhile, farmland water conservancy construction must be carried out to improve irrigation conditions and methods, and water must be used scientifically to improve utilization rate of water resources.

2.6 Popularizing improved seeds according to local conditions Increase of intensification level is closely related to using improved seeds and changing farming systems. Experience proves that economical benefits can be greatly increased by adopting improved seeds, reasonable rotation, appropriately enlarging multiple-cropping area. Therefore, improved seeds must be cultivated and popularized, and multiple-cropping area appropriately enlarged, to obtain more agricultural products from nature.

3 Conclusion

Marx's agricultural intensification thought is a historical evolution process to transform traditional agricultural production methods into modern scientific production methods under the guidance of sustainable Scientific Outlook on Development. Based on the characteristics of agricultural industrialization management, it is an organization form of large-scale socialized production, an innovation of agricultural management mode and organization system, an operating mechanism based on the mutual benefits of all participants in agricultural industrialization management. Therefore, Marx's agricultural intensive management thought is of great practical guiding significance to agriculture in China.

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