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Developing risk indicator system of non-compliance for organic crop farms based on China organic regulations

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ABSTRACT

Farming management and certification are essential for organic agriculture development to make sure that farming practices are compliant with organic regulations. To improve the efficiency of organic certification and farm management, a risk-based indicator system of organic crop production was established according to literature review and Chinese organic regulations. Three dimensions, 11 themes, and 25 indicators were selected and the weights of which were determined through Analytic Hierarchy Process. The highest weight was assigned to the production dimension (0.59), followed by management (0.24) and environment (0.17). The three highest risk themes in the sequence were plant protection, detection and soil fertility management with a weight of 0.17, 0.15 and 0.12, respectively. At the indicator level, pesticide detection rate, nutrient satisfaction rate, the proportion of non-chemical treatment, the severity of crop diseases, pests and weeds, and the quality of soil environment ranked top five according to the weight of their risk. Chemicals application including pesticides and fertilizers was the main concern in organic production and certification. The results will provide producers, inspectors, and certifiers useful references to reduce the risk of non-compliance, and increase the integrity and credibility during organic production and certification.

1. Introduction

About 69.8 million hectares of land were certified organically in 2017 in countries around the world, among which China ranked third with 3.02 million hectares (Willer and Lernoud, 2019). A total of 18,675 organic certificates have been issued in China in 2017(CNCA and CAU, 2018). The domestic market of certified and labeled organic products has grown significantly since 2005 when Chinese organic regulations were issued and implemented, particularly in first-tier cities (Yin et al., 2010; Xie et al., 2015). China is now the fourth largest organic market in the world in terms of sales (Willer and Lernoud, 2018). Despite its strong growth, the organic sector in China is still in its "early infancy" with less than 2% organic share of China's arable area and only 0.29–0.44% share of total food consumption (Dendler and Dewick, 2016).

During its growth and development, the organic agriculture/food industry also faces some significant challenges such as the trust of consumers, the credibility and integrity of organic standards and certification, etc. Consumer surveys in Europe found that food scandals happened in the supply chain result in consumers' distrust of the organic certification, which further leads to doubts about the value of organic food and impedes the consumption and development of organic products (Cai, 2013). Similar results were also found in Thailand and Australia (Lea and Worsley, 2005; Roitner-Schobesberger et al., 2008).

Certification as a third-party verification is an important governance tool to ensure and transfer trust from producers to consumers. Organic certification is an important procedure for ensuring the quality and compliance of organic products. However, a criticism heard frequently in China also in other countries is that certification bodies are in fierce competition with each other and thus interpret the organic standards with different degrees of stringency. Such prominent procedural criticism has had serious negative impacts not only on consumers' confidence but also on corporate legitimacy judgments (Scott et al., 2014; Xie et al., 2015; Dendler and Dewick, 2016).

It is time to explore new potential management techniques involved in the certification procedure. FAO (2008) highlighted how food

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inspection, based on risk analysis, is a vital component of a modern food control system. The issue of risk approach related to inspections was proposed. Food inspection is essential to protect consumers by implementing adequate food controls to ensure domestically produced or imported food is properly handled, stored, manufactured, processed, transported, prepared, served and sold in accordance with the requirements of national laws and regulations. Also, inspection and verification of food exports promote confidence in the safety and quality of exports, which are essential for international trade.

The definition of risk in the context of organic production and certification has been reviewed by Zanoli et al. (2014b) and the probability of noncompliance occurrence was used based on the organic regulation EC Reg. No 834/2007. Risk can be considered as an occurrence of irregularities and infringements as regards compliance with the requirements laid down in the organic regulation (Gambelli et al., 2014a). Accordingly, risk in this study refers to the seriousness and possibility of not complying with organic standards in the production operation of organic products, resulting in the consequences of destroying the integrity of organic products.

European Council Regulation—EC Reg. No 834/2007 specifically indicates that: “the nature and frequency of the controls shall be determined on the basis of an assessment of the risk of occurrence of irregularities and infringements as regards compliance with the requirements laid down in this Regulation.” Risk assessment based certification is also widely required in the organic regulations including China. *Chinese Rules for Implementing the Certification of Organic Products* (CNCA-N-009: 2014) require that on-site and unannounced inspections should be based on risk assessment. In addition, the supervisory and administrative department should establish a risk monitoring and early warning system, supervises the organic product certification activities according to the risk assessment, and conducts risk warnings on related products and regions according to the risk level.

The risk-based inspection system is important for the integrity of organic products and organic certification which can enhance the effectiveness and efficiency of the organic farming certification by prioritizing and directing resources towards relatively operators with higher risk (Albersmeier et al., 2009). Control bodies currently apply simple quantitative methods in combination with qualitative assessments to categorize operators into risk classes (Zorn et al., 2013). Zorn et al. (2013) quantitatively analyzed the risk of non-compliance with European regulations on organic farming in Germany based on the theory of the economics of crime. Zanoli et al. (2014a) analyzed the risk factors influencing non-compliance in organic farming in the UK by econometric analysis, they also applied zero-inflated count data models to farm-level panel data from inspection results and sanctions obtained from control bodies in Italy. Gambelli et al. (2014b) identified the factors that can affect the risk of non-compliance by using Bayesian networks. The risk of non-compliance in organic farms was analyzed according to the inspection data from control bodies (Gambelli et al., 2012; Zorn et al., 2013; Gambelli et al., 2014a; Gambelli et al., 2014b; Zanoli et al., 2014a). However, the data recorded by control bodies appear to be insufficient to establish an effective risk-based approach for inspections (Gambelli et al., 2014b). An efficient risk-based inspection system should be designed to weigh the known probability of occurrence of a given non-compliance according to the severity of its impact (Zanoli et al., 2014b).

Currently, there is still no quantified and applicable risk management system for organic agriculture in China. Therefore, a risk indicator system of non-compliance upon organic regulations needs to be established as a universal tool for Chinese organic certification bodies to conduct inspection and certification of organic products. Risk ranking is the first step of risk-based control and was an important step to define the key risks (van Asselt et al., 2012). According to the definition of non-compliance risk, a risk indicator evaluation system will be established in line with the organic regulation. The method elicitation of expert judgment was applied to select the risk indicators in this specific study given the insufficiency of prior empirical research, lack of data, and unique circumstances (Burgman et al., 2011). It has been found group elicitations have favorable consequences for the quality and uncertainty of risk judgments (Singh et al., 2017). The analytic hierarchy process (AHP) was a useful method to determine the weight of indicators in a multi-level evaluation system that was suitable in this scenario (Saaty, 1980).

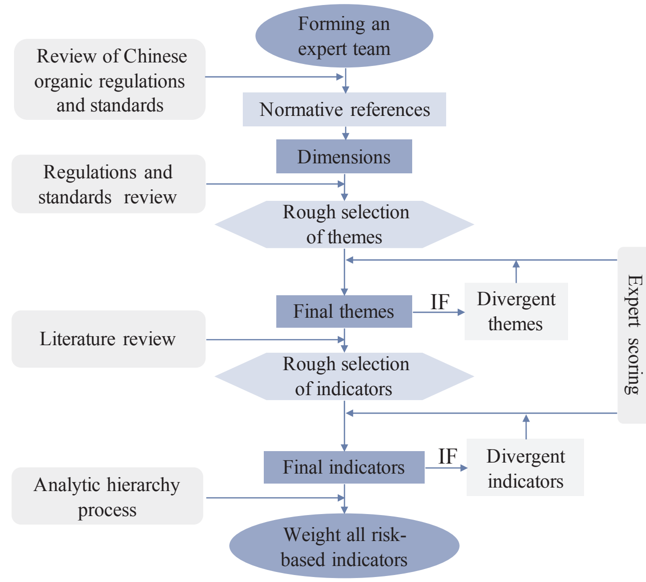

Fig. 1. Flow chart of establishment of risk-based indicator system.

Risk-based assessment system is crucial for organic certification and production to ensure the integrity of organic products. All the requirements of Chinese organic regulation should be systematically reviewed and comprehensively analyzed to reach an overall evaluation of the most relevant risk factors that are more likely associated with non-compliance in organic crop production farms. Specifically, the objectives of this study were to (1) screen out the key risk indicators with high possibility of non-compliance in organic crop production based on Chinese organic regulations; and (2) weight the importance of selected key risk indicators with the methodology of AHP.

2. Methodology

Generally, the methodology applied in this study was showed in Fig. 1. Firstly, an expert team was established in charge of the selection and weighting work. Then the risk-based indicators were selected step by step according to the regulation and literature review with expert scoring in a workshop. Finally the seleted risk-based indicators were weighted by experts through AHP. The methods were elaborated in detail as follows.

2.1. Forming an expert team

To ensure the quality and credibility of the selected indicators and their weights, the comprehensive evaluation system should include stakeholders from different fields of organic agriculture. During this study, stakehoulders were invited to help screening the indicators and weighing them in the workshop. All experts and farmers should have experience in organic farming for more than 10 years and must have well knowledge on the whole processes of organic agriculture. In all, 48 stakehoulders involved specilize in the field of food science (8), agricultural resource and environment (10), plant protection (7), organic certification and accreditation (15), as well as organic farming producers (8). Stakehoulders engaged in the above fields came from universities (18), institutions (5), farms (8), governments (5), certification bodies (11) and NGOs (1) in the indicator selection and analytic hierarchy weighing process.

2.2. Chinese organic certification system and normative references

China has established a complete system of laws and regulations, rules and technical standards on certification and accreditation. In 2003, the State Council issued the *Regulations on Certification and Accreditation*, which serves as an administrative regulation for the government to standardize certification and accreditation activities conducted by domestic and foreign certification bodies in China territory. For organic product certification, Chinese State Administration for Market Regulation issued the regulations of *Administrative Measures on Organic Product Certification*, *Rules for Implementation of Organic Product Certification*, and *Organic Products* (GB/T19630). Organic product production, certification and marketing must be performed following these national organic regulations.

Every step of organic crop production is regulated by standards and rules of organic agriculture. Organic certification is a supervision process to ensure organic products in full compliance with organic standards and principles. Therefore, the risk evaluation basis of normative references in this study were China organic regulations including: *Organic products -Part 1: Production* (GB/T 19630.1-2011), *Organic products -Part 4: Management system* (GB/T 19630.4-2011) and *Chinese Rules for Implementing the Certification of Organic Products* (CNCA-N-009:2014).

2.3. Methods of indicator selection

Based on the normative references, risk indicator system was divided into three structural layers: dimension, themes and indicators. Dimensions included environment, production and management according to Chinese organic agriculture standards. Themes and indicators were selected according to the criteria showed in Table 1. Firstly, indicators should be relevent with the risk of non-compliance in organic crop certification. Secondly, the data of indicators ought to be available to obtain. Thirdly, indicators should also be measurable. In addition, indicators should be independent with each other and avoid redundancy. Lastly, indicators should be broadly applicable and comparable among different crop farms. The dimensions of environment and management will be evaluated at farm level, while the risk of production dimension will be evaluated at crop level.

Themes were selected roughly based on the regulations and standards review before they were scored by experts. The experts were asked to rate the themes and indicators on a scale of 0 (least important) to 9 (most important). The most important indicators were determined by calculating the average scores for each. Due to the similarity of scores, only indicators with an average score of 7 or more (very important) were considered as the final selected indicators. The divergent themes were re-scored by experts after a discussion in the workshop (Fig. 1). A literature review was performed to select the collection of indicators based on the screened themes. Then, the same method for themes selection was applied to indicators.

Table 1
The criteria of theme and indicator selection.

Number	Criteria	Content
1	Relevance	Will indicate the risk in organic crop production whether directly or indirectly.
2	Availability	The data is easy to obtain
3	Measurability	Easy to quantify
4	Independence	Avoid the redundancy of indicators
5	Comparability	Indicators should be broadly applicable and comparable among different farms

2.4. Weight the indicators by AHP

AHP was a multi-criteria decision-making method used to estimate, compute, and then derive relative weights for the contributing variables of the risk assessment indicators of non-compliance in organic certification. The primary phase of AHP can be devided into three parts. First, the hierarchical indicator tree in terms of the non-compliance in organic crop production should be structured. The second phase consists of formulating and collecting judgments on the relative importance of indicators by experts. Finally, the indicator weights for each indicator is determined.

In this case study, the hierarchical indicator tree is established by literature review and expert scoring under the framework of Chinese organic regulations. The comparison used pairwise matrices in which the decision makers filled each upper diagonal element with a value obtained from the fundamental rule scale for pairwise judgments. The pairwise comparisons and judgement matrixes were completed according to the indicators system through a workshop after a full explanation of the AHP.

Assignment of weightings was guided by discussions with stakeholders. In the construction of pairwise comparison matrices, each indicator was rated against every other by assigning a relative dominance value and referred to Sajadian et al. (2017). Consistency check of hierarchical single ordering and total ordering were conducted for every questionnaires (Bertolini et al., 2006). If the consistence ratio (CR) is smaller than or equal to 0.1, the consistency is acceptable. Otherwise, the consistency is unacceptable. A total of 48 questionnaires were issued, 39 questionaires passed the consistency test. The average indicators weights of the 39 questionnaires were used.

3. Results

3.1. Selected key risk indicators

3.1.1. Final themes

Twenty one themes were regulated by Chinese organic regulations (Fig. 2), 11 of them were scored over or equal to 7 by the experts finally. Ticks denoted that the particular theme was taken into consideration while cross indicated the opposite. Conversion period was not considered as a separated theme because the whole processes of certification and production of conversion farms were the same as organic farms except that they can not sale the products as organic. Resource management was also excluded from the 21 themes because the importance of human resource management was the basic requirement for organic farms and was hard to be quantified.

The theme with dark circle and same letter was considered and merged into the theme of certain process. The risks of irrigation come from the quality of irrigation water and the possibility of being polluted by the conventional production, which has been reflected by the aspects of the endogenous environment and management mode. Complaints and continuous improvement were merged into operational status since the similarity of both themes. The process of parallel production, harvest, post-harvest processes, and packing and transportation has the risk of contamination or mixture, which has been combined into the risk of management mode.

3.1.2. Final indicators

Finally, 25 indicators related to the risk of non-compliance in organic crop production were selected. The hierarchical indicator tree was established in Table 2. To meet the requirement of the environment, the soil, irrigation water, and air quality were the key indicators for the endogenous environment; Width of buffer zone and distance from pollution sources are important for the external environment.

Seeds and propagation materials, soil fertility management, plant protection, cultivation, storage, and product detection are the 7 key themes under the production dimension. To make sure the organic

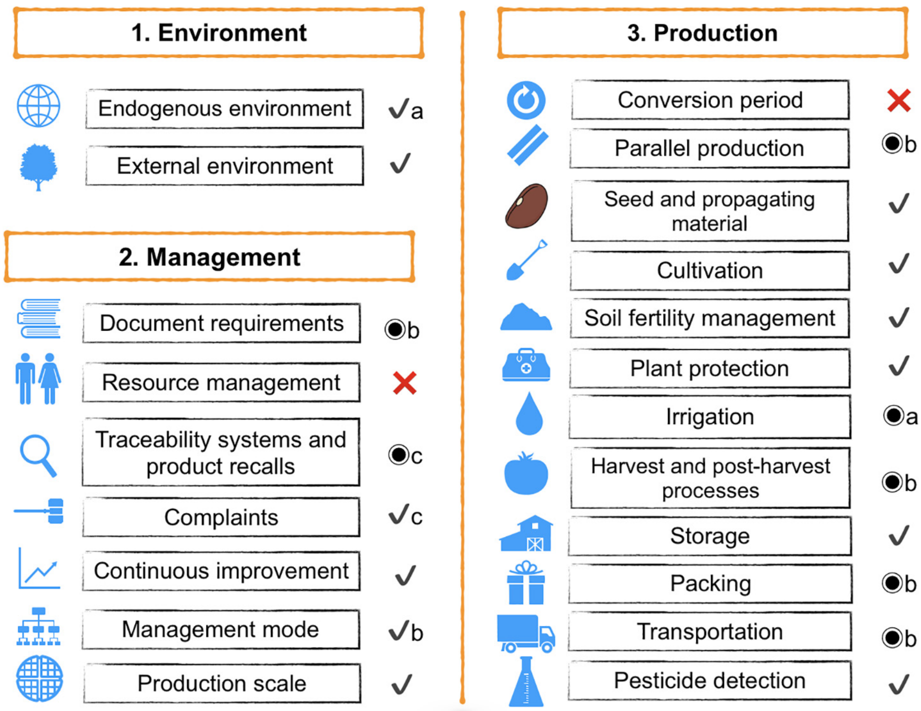

Fig. 2. Whole processes (themes) of organic farming according to Chinese organic regulations. Ticks denoted the certain theme was taken into consideration while cross indicated the opposite. Dark circle with letter means the certain process was classified into the themes with the same letter plus ticks.

integrity of the whole process, the possibility of genetically modified organisms and the possibility of chemical treatment are screened as indicators under the theme of seeds and propagation materials. Both insufficient and overloaded nutrient supply will infringe the organic standards, the nutrient satisfaction rate is selected as an indicator to show the risk of chemical fertilizer application and environment pollution if the soil fertility is not managed well.

The severity of crop diseases, pests and weeds, the proportion of non-chemical treatment and the number of available biological pesticides are selected for the theme of plant protection. Rotation is also a very important measure for organic farming to avoid the continuous cropping and cultivation area will also yield different compliance risks. For vegetable and fruit, storage will affect the compliance risk. The detection rate for the final products is also selected.

For the farm management dimension, management mode of ownership, organization, and production scale as listed in Table 2 will affect the risk of non-compliance, such as cooperatives and farmers organizations with internal control systems normally have a higher risk than that of companies. Finally, for the farm production scale theme, numbers of crops, and products with high demand/added value and multiple certifications are selected as the key indicators. The detail definitions of the selected 25 indicators are also showed in Table 2.

3.2. Weight of key risk indicators

3.2.1. Weight of dimensions

Under the main target (Risk of non-compliance for organic crop farms), the relative weight of production had the highest weight of 0.59. The risk weight of management (0.24) was higher than that of the environment (0.17) since management could influence production directly. The dimension of the environment possessed the lowest weight because a farm would not get an organic certificate if the environment is not compliant with the requirement of the organic standards.

3.2.2. Weight of themes

The first three themes which were plant protection (0.17), detection (0.15), and soil fertility management (0.12) all belonged to the dimension of production and got weights higher than 0.1 (Fig. 3). As for the dimension of the environment, the endogenous environment got a weight of 0.10, while the weight of the external environment was 0.07, which shows the medium risk of non-compliance. It was indicated the quality of the endogenous environment was relatively more important than the external environment. Management mode got the highest weight (0.09) under the management dimension followed by the operational status with 0.08. The weights of seed and propagating material, storage and cultivation were no more than 0.10, which showed a lower risk compared with the other themes.

3.2.3. Weight of indicators

Four of the first five indicators belonged to the dimension of production and three were under the theme of plant protection. Pesticides detection rate, nutrient satisfaction rate, the proportion of non-chemical treatment, the severity of crop diseases, pests and weeds and quality of soil environment were the main risk factors in organic crop production. The pesticide detection rate ranked first with a weight of 0.153 and followed by the nutrient satisfaction rate that reflect the risk of applying chemical fertilizers with a weight of 0.083 (Fig. 4). The third and forth were proportion of non-chemical treatment and severity of crop diseases, pest and weeds weighted with 0.075 and 0.058, respectively. The quality of the soil environment ranked fifth with a weight of 0.057 because heavy metals are a concern when it comes to the quality of the soil environment. Therefore, the soil environment would be under pollution risk when the heavy metals content of the soil was approaching standard values, even though the current concentration complied with the standard.

4. Discussion

4.1. Risk of non-compliance in organic crop farm

Control bodies currently apply simple quantitative methods to quantify the risk of organic operation (Zorn et al., 2013). The risk of

Table 2
Hierarchical indicator tree of risk of non-compliance for organic crop production.

Target	Dimension	Theme	Indicator	Definition	Reference
Risk of non-compliance for organic crop production	Environment	Endogenous environment	Quality of soil environment	The highest single factor index of soil environment	(Chen et al., 2013; Tian et al., 2015)
			Quality of irrigation water	The highest single factor index of irrigation water	(Ai et al., 2018)
			Quality of atmosphere environment	The highest single factor index of atmosphere environment	(Pandey and Pandey 2009a,b)
		External environment	Width of buffer zone	Width of buffer zone of the organic production base (m)	(Byrne and Fromherz 2003; Damgaard and Kjellsson 2005; Hanson et al. 2007; Damgaard and Kjellsson 2005, Hanson et al., 2007; Bloem et al., 2017)
			Distance from pollution sources	Distance between organic production base and pollution sources (km)	Organic products-Part 1: Production (GB/T 19630.1-2011)
	Production	Seeds and propagation materials	Possibility of GMOs	The application extent of a certain genetically modified crop nationwide	(Hanson et al., 2007; Verhoog, 2007; Oguamanam, 2015)
			Proportion of chemical treatment	The proportion of seeds being chemically treated for a certain crop nationwide	(Nagel, 2017)
		Soil fertility management	Nutrient satisfaction rate	Nutrient satisfaction rate = (Actual amount of fertilizer applied × nutrient content of fertilizer × utilization rate of fertilizer in the current season)/(Nutrient requirement of target yield − soil nutrient supply − legume nutrient supply − straw nutrient supply)	(Sturm et al., 2011; Zorn et al., 2013)
			Nutrient surplus ratio	The same as Nutrient satisfaction rate	(Röös, et al., 2018)
		Plant protection	Severity of crop diseases, pests and weeds	For vegetables, the number of common diseases, pests and weeds were used, while for the other crops the regional severity of diseases, pests and weeds were used	(Carvalho, 2006; Geary, et al., 2008, Pynenburg et al., 2011)
			Proportion of non-chemical treatment	The proportion of non-chemical treatment methods in the Technical Regulations for Pollution-Free Production of a certain crop	(MARA, 2001)
			Number of available biological pesticides	The number of available biological pesticides for a certain crop	(Chandler et al., 2008a; Chandler et al., 2008b; Kamarulzaman et al., 2012)
		Cultivation	Severity of continuous cropping obstacle	The severity of continuous cropping obstacle of a certain crop	(Rasul and Thapa 2004; Koocheki et al., 2009; Li et al., 2016)
			Planting area	The area of organic cultivation base (ha)	(Zorn, et al., 2013; Gambelli et al., 2014a; Gambelli et al., 2014b)
		Storage	Difficulty of storage	The extent of difficulty for vegetables and fruits storage	(Johannessen, 2007; Schulzová et al., 2007)
		Detection	Pesticides detection rate	Detection rate of pesticides of a particular organic product nationwide	(Lesueur et al., 2007; Lesueur et al., 2010; Kawashima and Kariya, 2016)
	Management	Management mode	Ownership mode	Ownership mode of production unit includes farm owned and subcontracted	(Van Cauwenbergh et al., 2007)
			Organization mode	Organization modes includes company, cooperatives, and company plus small householders, which has different risk level	(Yue and Yang, 2013; Zhang and Zhao, 2013)
			Production mode	Production mode includes complete organic farming, parallel production of organic and conventional production of the same crop, separated production of organic and conventional production of different crops	(Zorn et al., 2013)
		Operational status	Number of serious non-compliances	Number of serious non-compliances inspected by organic certification body	(Gambelli et al., 2014a; Gambelli et al., 2014b; Zanoli et al., 2014b)
			Number of duplicated non-compliances	Number of duplicated non-compliances inspected by organic certification body	(Gambelli et al., 2014a, Gambelli et al., 2014b, Zanoli et al., 2014b)
			Number of complaints	Complaints that organic farm got due to quality of organic products	(Ahmad et al., 2017)
		Production scale	Number of crops	Number of crops cultivated in the organic farm	(Gambelli et al., 2014b)
			Number of crops with high risk	Number of crop products with higher demand or added value	(Zorn et al. 2013)
			Multiple certification	Number of organic certification body the organic farm has applied for	Chinese Rules for Implementing the Certification of Organic Products (CNCA-N-009:2014)

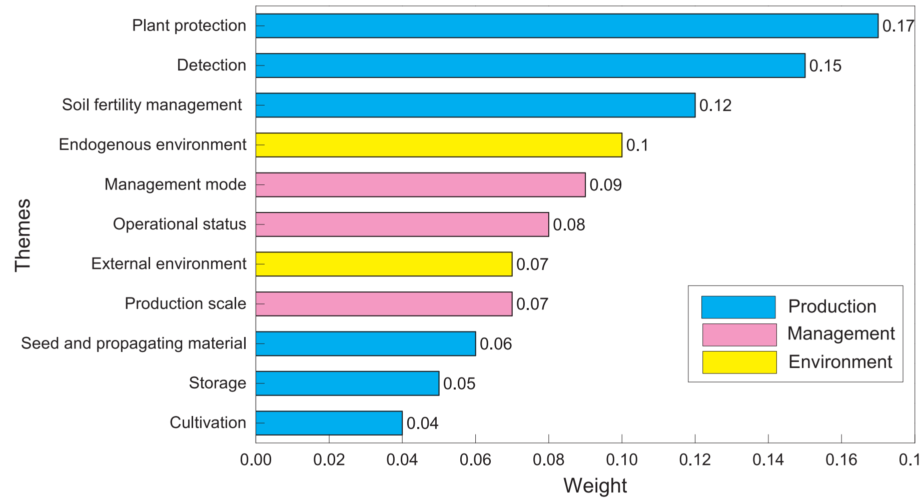

Fig. 3. The final weights of different themes for the risk of non-compliance.

non-compliance in organic farms was analyzed according to the previous inspection data from control bodies (Gambelli et al., 2012; Zorn et al., 2013; Gambelli et al., 2014a; Gambelli et al., 2014b;Zanoli et al., 2014a) which were insufficient to establish an effective risk-based approach for inspections (Gambelli et al., 2014b). In this study, a risk-based indicator system was established systematically based on Chinese organic regulations, standards and literature review.

Normally, production is the most difficult and complex part of organic agriculture. Pests, diseases, weeds, and shortages of certified organic seeds and biological pesticides are the risks faced by organic farmers (Hanson et al., 2007). Plant protection is strictly regulated by the organic standards/regulations; such as EU's 'organic regulation', the National Organic Program of the USA, the guidelines of the Codex Alimentarius and the basic standards of the International Federation of Organic Agriculture Movements (IFOAM) (Speiser and Tamm, 2011) as well as the Chinese organic agricultural standard. Consumers believe that pesticides are the most serious risk to human beings and they deem fruits and vegetables produced organically without pesticides to be healthier (Saba and Messina, 2003). Likely, pest and disease management, soil nutrient management, and chemical fertilizers consumption rate were laso included in a indicator system developed for organic farming (Sajadian et al., 2017).

Agricultural, physical, biological and chemical methods in treating crop pests, diseases and weeds were listed in the *Technical Regulations for Pollution-free Production* (MARA, 2001), from which the proportion of chemical measures could reflect the probability of being treated with chemicals. Besides, the farm operation status will also reflect the management of the farm (Gambelli et al., 2014a; Gambelli et al., 2014b; Zanoli et al., 2014b), such as number of serious as well as duplicated non-compliances and complaints from external stakeholders. Management mode includes indicators of ownership, organizations like small households and parallel production, which will result in a different risk of non-compliance resulted from different management ability.

The method elicitation of expert judgment was applied to this study since risk extrapolations in organic crop production concerned diverse disciplines and are required for novel, future and uncertain situations (Burgman et al., 2011). Group elicitation approaches are proposed to address shortcomings like over confidence and anchoring bias of experts during elicitation of judgment (Singh et al., 2017). However, "groupthink" effects can eventuate if like-minded participants crowd out those who don't agree. So, to address this challenge we established a

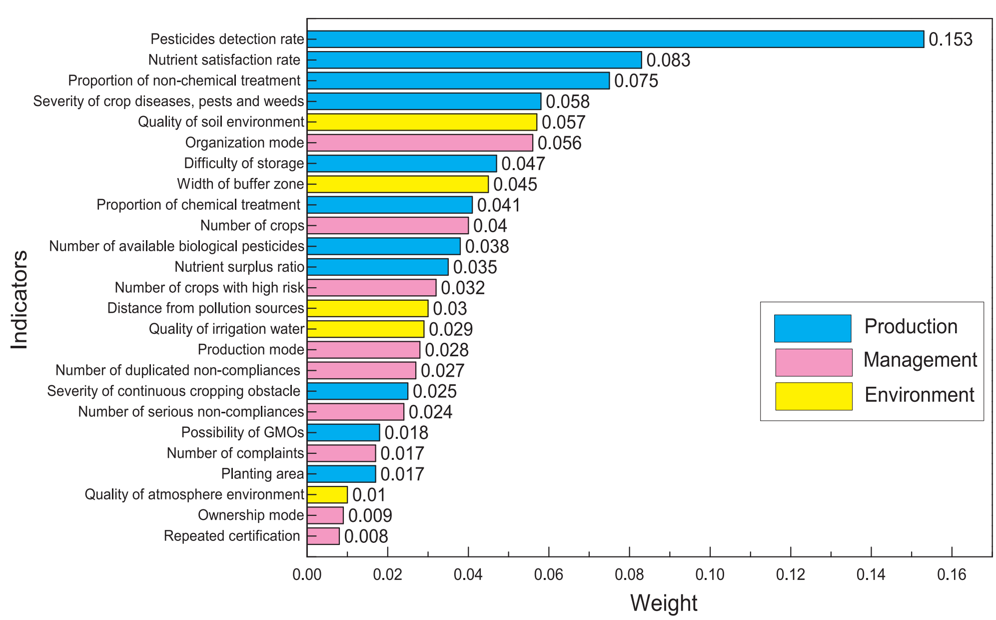

Fig. 4. The final weights of indicators of the non-compliance risk assessment system.

diverse expert team composed of different stakeholders of organic crop production. Previous study has found that diverse groups of experts tend to mitigate groupthink (Fish et al., 2009). Then, a discussion procedure was performed on divergent themes or indicators to make their importance re-evaluated before they were re-scored by experts. Despite all this, there might still exsit some inevitable "groupthink" effects in this study because experts are still humanbings that may susceptible to cognitive biases and unreliable mental shortcuts (Singh et al., 2017). Moreover, the 'right' answer is hard to obtain to many risk problems; and all that we can hope to do is avoid the mistakes to which each of us is attuned (Fischhoff et al., 2011).

4.2. Ranked importance of risk

Key risks of non-compliances in organic crop production were ranked by the method of AHP, which is the first step of risk-based control (van Asselt et al., 2012). In this study, the weight of production ranked the first among three indicator dimensions. Likely, indicator category of agriculture also weighted the first with 0.59 according to a quantified indicator system based on organic farming (Sajadian et al., 2017).

Plant protection is of particular concern for consumers (Saba and Messina, 2003) and ranked first in the theme level with a weight of 0.17 in this study (Fig. 3). The indicator pest and disease management in organic agriculture was also weighted the first with 0.16 (Sajadian et al., 2017). Besides, detection can reflect the application of prohibited substances during the organic production process (Lesueur et al., 2007; Lesueur et al., 2010); therefore, the weight of it was 0.15 in this study (Fig. 3). In line with that the weight of indicator pesticides detection rate ranked the first with 0.153 (Fig. 4).

The theme of soil fertility management got a weight of 0.12 acordign to our study (Fig. 3). Since chemically synthetic fertilizers were forbidden by all the organic regulations/standards, the application of chemical fertilizer got a high risk in the context of low yield in organic agriculture (Seufert et al., 2012; Zorn et al. 2013; Röös et al., 2018). The yield of organic agriculture is 5% to 34% lower than that in conventional agriculture (Seufert et al., 2012). The application of chemical fertilizer is difficult to test in soils (Sturm et al., 2011). Therefore, it was reasonable that the weight of indicator nutrient satisfaction rate was as high as 0.083 (Fig. 4).

As for the management dimension, the previous behavior played an important role in predicting future non-compliance (Zanoli et al., 2014b). Significant co-dependence was found between minor non-compliance and critical non-compliance (Gambelli et al., 2012; Gambelli et al., 2014a; Gambelli et al., 2014b; Zanoli et al., 2014a; Zanoli et al., 2014b), which meant a minor non-compliance could be followed by a series of non-compliances. Also, it was found the size of a farm plays a role in an increased probability of noncompliance (Zorn et al., 2013; Zanoli et al., 2014a; Zanoli et al., 2014b).

In view of environmental dimension, a farm might not be certified as organic when the heavy metals content of the soil fails to meet the standard requirement. However, manures from conventional farms usually have a higher content of heavy metals and biotics (Alvarenga et al. 2015) and the accumulation of heavy metals in organic land threatens the quality of the soil environment (Chen et al., 2013). Denmark has decided to phase out the use of conventional livestock manure in organic agriculture by 2020 (Oelofse et al., 2013).

By ranking the risk-based indicators according to organic standards/regulations, organic certification bodies can use this ranked and risk-based indicator system as a practical reference to focus on the critical indicators during inspection and certification. Furthermore, organic certification bodies could also quantify the risk of organic cropping farms when scoring methods of each indicators were established. Quantification of risk helps to classify the farms into different risk levels and take different countermeasures, which will reduce the cost and improve the efficiency of organic certification and inspection. In addition, organic cropping farms could also have themselves improved by taking corrective or improvement measures after conducting a self-check based on this risk-based indicator system. To prove its helpfulness, a compared experiment could be applied to test its helpfulness. To put it simply, farms could be classified into two groups, one applied this framework but the other not. After 2 or more years, the number of non-compliances could be compared between the two groups, which could verify the helpfulness. Besides, the certification bodies could also be classified into two groups, the expenses of inspection could be compared between them after a period to find out whether the expense was decreased or not.

5. Conclusion

Despite the dramatic growth and development of organic agriculture, it still faces some significant challenges such as the trust of consumers, the credibility and integrity of organic standards and certification etc. Risk assessment system of non-compliance could improve the efficiency of organic production and certification. However, there is still no quantified and applicable risk management system for organic agriculture currently. In this study, a risk-based indicator system of organic crop production was established according to Chinese organic standards, regulations and literature review. Three dimensions, 11 themes and 25 indicators were selected and weighted by expert scoring and AHP, respectively.

Production was the dimension with the highest weight (0.59) followed by management (0.24) and environment (0.17). In view of themes, plant protection, detection rate and soil fertility management were the top three risk themes with weights of 0.17, 0.15 and 0.12, respectively. Pesticides detection rate, nutrient satisfaction rate, proportion of non-chemical treatment, severity of crop diseases, pests and weeds, and the quality of soil environment were the top five important risk indicators in organic certification with weights of 0.153, 0.083, 0.075, 0.058 and 0.057, respectively. Application of chemical pesticides and fertilizers are the main risks in organic certification. Scoring methods of each indicator should also be established for the application in the practice to filter out the farm with high risk of non-compliance. The results will provide the producers, inspectors and certifiers useful references to reduce the risk of non-compliance of organic standards, and increase the integrity and credibility during organic production and certification. Furthermore, it also can provide a reference of methodology for organic agricultural risk control in other countries.

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CRediT authorship contribution statement

Huayang Zhen: Writing - original draft, Methodology, Visualization, Formal analysis. **Yuhui Qiao:** Funding acquisition, Conceptualization, Supervision. **Fanqiao Meng:** Investigation, Conceptualization. **Huafen Li:** Methodology, Investigation. **Yuexian Liu:** Investigation. **Yan Jia:** Investigation. **Raffaele Zanoli:** Writing - review & editing. **Danilo Gambelli:** Writing - review & editing. **Francesco Solfanelli:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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