J. Resour. Ecol. 2018 9(2) 146-153
DOI: 10.5814/j.issn.1674-764x.2018.02.004
www.jorae.cn

Analysis of the Decisions of Farmers Working Different Sized Farms to Constantly Use Soil Testing Formula Fertilizer

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Abstract: This paper researches the behavior of using soil testing formula fertilizer at farms of different sizes. The study develops a probit model based on peasant household survey data from 11 grain production areas. The results prove that: First, obvious differences exist in the distribution of formula fertilizer use ratio among farms of different sizes; large-scale farmers are the highest, small-scale farmers are the lowest. Second, from external factors, the increased yield of corn, soil testing services, and information dissemination, it is clear that training has a significant positive effect on farmers' use behavior; the influence of soil testing services is the greatest. Third the higher the degree of organization, marketization and scale of a farm, the more likely the farmer is to use soil testing formula fertilizer. Policy recommendations are made on the basis of the empirical research presented in this paper.

Key words: different scale farmers; probit model; fertilization information channels; training

1 Introduction

Food security is closely related to social stability, national welfare and the people's livelihood. China's grain output grew continuously from 2004 to 2013. The sustained increase of grain yield was closely connected to the application of chemical fertilizers, even though water and soil resources are limited. It is estimated that the contribution of chemical fertilizers to grain production accounts for 40% to 50%. Moreover, the use of chemical fertilizers has increased in recent years. Statistics show that current fertilizer consumption has exceeded the optimum application amount as seen from an economic perspective; this over-consumption is excessive fertilization. Excessive fertilization has a marginal effect on grain production. Not only does excessive fertilization make no contribution to grain production, it also has negative effects, such as increasing production costs, diminishing the utilization of fertilizers, the growing of poor quality of crops and causing severe environmental degradation. All of these harmful effects hinder the sustainable development of agriculture. In 2004, the Ministry of Agriculture started the application of soil testing and fertilizer technology in pilot counties, in order to reverse the irrational use of fertilizers by farmers, to improve the efficiency of fertilizer utilization and to promote the sustainable development of agriculture. The purpose of the soil testing formula fertilization project was to guide agricultural producers to employ scientific and rational fertilization methods. The implementation methods focus on doing well in five important areas: measurement, distribution, production, supplement and implementation. Information dissemination, training, demonstrations and guidance were all used to lead farmers to an awareness of the technology of soil testing formula fertilization. The key goal of this project was to introduce this technology to farms, because only in this way can farmers use soil testing formula fertilizers sustainably. The project has achieved remarkable results since its implementation in 2004. It has transformed the concepts of fertilization on farms and optimized the structure of fertilization. However, there are some factors hindering the further implementation of the project, such as the strength of religion in soil testing areas, comparatively high prices and

Received: 2017-09-30 **Accepted:** 2017-12-20
Foundation: The Agricultural Scicence and Technology Innovation Program(ASTIP-IAED-2017-06)
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Citation: LI Shasha, ZHU Yiming, LI Xiande. 2018. Analysis of the Decisions of Farmers Working Different Sized Farms to Constantly Use Soil Testing Formula Fertilizer. *Journal of Resources and Ecology*. 9(2): 146-153.

a lack of pertinence in formula fertilization. The promotion of formula fertilizers still has not achieved a satisfactory result; it is estimated that about 66% of the farmers in corn production use soil testing formula fertilizers (Li 2012). Moreover, the promotion of soil testing formula fertilization technology has been carried out in pilot counties only. For the project to have an impact on a national scale, comprehensive promotion of soil testing formula fertilizer is needed.

Transforming farmland into new agricultural entities is the main path to realize agricultural modernization, but the transformation of land is a gradual process. Small-scale farmers still play an important role in agricultural production and will for a very long time to come. With the diversification of agricultural management entities as a backdrop, what differences do farmers on different sized farms show in their use of formula fertilizers? Does agricultural land management on a larger scale lead to improvement in the utilization rate of the soil testing formula fertilization? What factors can affect the behaviors of farmers working different sized farms? In order to improve the promotion of soil testing formula fertilization, the use conditions and promotion experiences in grain producing provinces are useful references for non-pilot counties. Based on the different scale of the farms they work, what specific measures can guide farmers who are in non-pilot counties to continue using formula fertilizers? The answers to this series of questions have significance in many respects. They can help relevant departments to mobilize the enthusiasm of farmers, increasing the utilization rate of formula fertilization and expanding the scope of technology promotion.

At present, normative analysis and empirical research methods are important means for scholars to study the behaviors of farmers using fertilization. Studies mainly concentrate on the characteristics of individual farmers, the characteristics of farm households, social and economic conditions, and policy systems. For example, He Haoran and Zhang Linxiu (2006) studied the behaviors of farmers using fertilization, and they pointed out that non-agricultural employment can boost the level of chemical fertilizer application, and that agricultural technology training has a positive relationship to the level of use of fertilization by farmers. Zhang Chengyu (2010) studied the economic behaviors of farmers in the promotion of soil testing and fertilization technology. He advanced the idea of fertilizing suggestion cards, and showed that the prices of formula fertilizers and the education levels of farmers are the important factors affecting whether farmers will adopt this technology. Ge Jihong (2010) used the probit model to study whether farmers will choose soil testing fertilization technology. The research concluded that farmers who possess strong ability of scientific fertilization who are from representative peasant households, have the formula cards, and participate in training tend to adopt formula fertilization techniques. Based upon data from an investigation of farmers in Sichuan province, Li Haixia found that the deeper factors which affect the fertilization behavior of households include annual per capital income, educational level and the popularization of agriculture technology. Li Feng (2011) studied the fertilizer usage of farmers in Guangdong, and he pointed out that neither farmers' awareness of fertilizers nor their professional knowledge are sufficient. Han Hongyun (2011) used an econometric model to study the behaviors of farmers in the gradual process of promoting soil testing formulated fertilization technology. It was found that the level of agricultural income, the amount arable land farmers had, the ideas of fertilization, the understanding of techniques, the guidance of technology, and the acquisition of technology all had a highly positive correlation with farmers' "total acceptance". Gong Qianwen (2008) built fertilization decision-making model for farmers, and this analysis showed that the farmer fertilization decisions are affected mainly by the distance between farmland and home, the grades of arable land, the irrigation conditions, the rent of cultivated land, the possibility of receiving technical training, the costs and benefits of grain planting, the proportion of agricultural products sold, etc. From this review of the literature, we can see that, although studies of the behavior of farmers use of fertilization have made progress in recent years, the majority of studies are focused on dispersed, small farmers; there are few studies focused on the use of soil testing formula fertilization by farmers. Such a research method uses a large number of samples to divide farmers into groups according to the scale of agricultural land management.

Based on the problems elaborated above and the review of the literature, this paper employed microscopic survey data that came from 2172 farmers in 11 grain production provinces and developed a probit model in order to explore the distribution of the use of soil testing formula fertilization by farmers working farms of different sizes. Our analysis of the model reveals the degree of effect and the direction of the factors affecting the fertilization behaviors of farmers. If we grasp the intrinsic connections in farmers' behaviors, we can provide reference materials for relevant departments and provide suggestions to the government.

2 Method and data

2.1 Theoretical basis

Scholars at home and abroad have carried out in-depth and comprehensive studies of peasant household behaviors. Schultz used "rational economic man" and "full market information" as assumptions to mean that farmers are constrained by their own characteristics and the market environment; peasants made decisions in order to meet their goal of profit maximization. Willock, Deary & McGregor (1999) pointed out that the factors affecting farmers' behaviors should not be limited to the field of social psychology. Popkin (1979), based on the concept of "economic man", proposed the central hypothesis that "farmers are rational economic men" and "farmers are in pursuit of welfare maximization for the family." Chayanov proposed that farmers engaged in agricultural production designed to meet the needs of household consumption are engaged in a mode of production that belongs to the self-sufficient natural economy and is a kind of means to make a living rather than a way to pursue interests. Scott (2001) believes that the economic behaviors of peasant households are based on principles of survival, that they are intended "to circumvent risk" and "put safety first."

Soil testing formula fertilization is a type of agricultural technology, and research about farmers' adoption of new agricultural technology should be based upon the results of existing studies at the present stage. In consideration of differences in the behaviors of farmers working different size farms and in consideration of the affecting factors, we should take the internal factors that form behaviors into account.

The decisions of farmers to use formula fertilizers are influenced by many factors, such as the individual characteristics, family features, social economic environment, policy systems and so on. The need of farmers to engage in grain production can be attributed to two factors: first, grain cultivation can meet survival needs and, second, farmers can obtain profits from selling grain. With the deepening of reforms in rural areas and the improvement of living standards, farmers have gradually begun paying considerable attention to new agricultural technology that is both capital and labor saving. Under the influence of multiple external factors, like economic development conditions, the policy system, social media and so on, farmers make decisions about integrating production elements to achieve the maximization of investment returns. In doing so, farmers rely on their own experiences to weigh the costs and benefits. Owing to discrepancies in age, educational backgrounds, regional economic development conditions, and policies to support agriculture, different farmers and farmer organizations perform differently when it comes to the promotion of soil testing formula fertilization, with respect to awareness, usage and evaluation. The analysis here frames the reasons why farmers behave differently in the soil testing formula fertilization procedures.

Considering the availability of data, this paper has chosen to examine several factors that influence the behaviors of farmers working different sized farms use soil testing formula fertilizers. The factors include the age and educational background of the head of household, the occupation of the farmers, changes in grain production during the past five years, experience of soil testing, the concept of fertilization, channels for getting fertilization information, training experiences, the policy environment, and so on.

Soil testing formula fertilizer is defined as formula fertilizer meeting one of the following conditions: 1. Fertilizer bags marked with the words "formula fertilizer"; 2. Fertilizers formulated according to formula cards; 3. Fertilizers formulated according to the results of soil measurement; 4. Fertilizers recommended by scientific research units or agricultural workers.

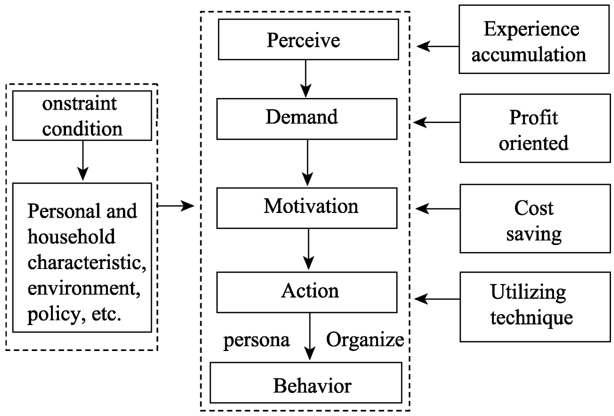

Fig.1 Analysis framework of farmers' different behaviors using soil test formula

2.2 Model Construction

Since the behavior of farmers using soil testing formula fertilization is a qualitative variable, it is difficult to use numbers to quantify. This paper uses the "0—1" index method to express farmers' behaviors (Y) in soil testing: 1 indicates continuous use; 0 indicates never uses or does not use continuously. Because the explanatory variable is two-point variable, this paper chooses to construct bivariate distribution of a probit regression model to analyze.

Based upon the analytical framework of the reasons why farmers behave differently in their use of soil testing formula fertilization, the variable and its meaning, and assignment and descriptive statistics are shown in Table 2.

The basic expression of for the model is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots \beta_{12} X_{12} \quad (1)$$

In expression (1), dependent variable Y is a dummy variable, β_0 is a constant term, coefficients of independent variables β_1—β_{12} are subject to the distribution of logic, X_1 represents the age of head of household, X_2 represents the educational level of head of household, X_3 represents the occupation of farmer, X_4 represents the conditions of farmer joining a cooperative community, X_5 represents the cooperation conditions between farmers and companies, X_6 represents grain yield changes over 5 years, X_7 represents farmers' experience of soil testing, X_8 represents farmers' fertilizer information channels, X_9 represents farmers' fertilizer concept, X_{10} represents farmers' training experience, X_{11} represents farmers' number of training experiences, X_{12} represents the policy environment.

2.3 Data sources

This paper uses the data taken from the research investigation of the Ministry of Agriculture to measure soil testing and fertilization project implementation effects over ten years in 2014. Research teams made thorough household surveys in 11 major grain production areas, including these provinces and autonomous regions: Hebei, Henan, Jiangsu, Anhui, Shandong, Jilin, Shanxi, Heilongjiang, Hunan, Guangxi, Gansu. The investigation involved 44 counties (or cities or districts), 132 townships, and 264 villages. Samples of farmers were selected randomly from the villages; there were 2172 questionnaires in all.

At present, there is no strict theoretical basis to divide agricultural land according to the scale of the land managed. The existing research literature defines small-scale farms as having a planting area under 5 acres and large-scale farms as having a planting area more than 10 acres (Shi Qinghua, 2001; Li Yueyun, 1999). As the process of farmland conversion continues, there have been some changes in the definitions of management scale of agricultural land. According to the sample distribution, farms with a planting area of 6 acres or less are defined as small-scale farms, farms of 7 acres to 30 acres are considered medium-scale farms, and farms with more than 30 acres are considered large-scale farms.

Table 1 reflects the distribution of the constant use of soil testing formula fertilization among farmers working farms of different scales. The results show that the proportion of small farmers who continuously use formula fertilizers is the smallest, but as the size of the farms expand, the proportion of farmers who continuously use soil testing formula fertilizers increases.

Table 1 Farmers use of soil testing formula fertilizer broken down by size of farm

Scale	Constant use		Irregular use		Total
	Sample	Pro (%)	Sample	Pro (%)	
Small	313	38.08	509	61.92	822
Medium	374	41.23	533	58.77	907
Large	229	51.69	214	48.31	443
Whole	961	44.24	1211	55.76	2172

The basic conditions of farmers working different sized farms are shown in Table 2. It can be seen that there are obvious differences in the age and educational backgrounds of farmers, the willingness to join in cooperative communities, the cooperation with the grain enterprises, service in soil testing, training frequency, etc. The difference between small-scale farmers and medium-scale farmers is not great, but the differences between large-scale farmers and the other two groups is rather obvious.

3 Results

This study used Eviews 7.1 software to conduct probit regression analysis of sample data. Indicator variables including the farmers' occupations, the change of grain yield in recent five years, and channels to obtain fertilization information were put into the model as the virtual variables. Adopting other important indicators such as the farmers who are from pure agricultural households, no change or no regular change of grain output, and fertilization information from their own experience were adopted as references. The estimation results of the model, which is about the use behavior of soil testing formula fertilization among different scale farmers, are shown in Table 3. Three models all passed the likelihood ratio test; this suggests that this model has good stability and the explanatory variables could provide valuable information. According to the regression outcomes, the increase of grain yield, soil testing service, channels of getting fertilization information, and training services were the common factors that influence the continuous use of formula fertilizers among farmers working different sized farms, but the influence degree of other factors are different.

Table 2 Descriptive statistics for different scale farmers' main variables

Index	Variable description	Whole (mean)	<=6acre (mean)	7—30acre (mean)	>30acre (mean)
Age	Age	53.57	55.42	54.47	48.28
Education	Education	8.08	7.90	7.85	8.87
Profession	1= Pure agricultural households; 0=unPure agricultural households	0.49	0.41	0.49	0.63
Join cooperate	1=yes; 0=no	0.25	0.19	0.22	0.41
Cooperate with enterprise	1=yes; 0=no	0.07	0.04	0.05	0.15
Grain change	1=no change; 2=reduce; 3=increase; 4=disorder	2.33	2.27	2.34	2.42
Soil test	1=yes; 0=no	0.71	0.69	0.69	0.79
Information channel	1=self; 2=agricultural material store; 3=Agricultural technology service; 4=others	1.91	1.93	1.81	2.05
Fertilize concept	1=right; 0=wrong	0.80	0.81	0.76	0.84
Train experience	1=yes; 0=no	0.63	0.62	0.61	0.67
Train time	Train time	1.31	1.21	1.26	1.58
Policy environment	1=yes; 0=no	0.25	0.18	0.25	0.37

Data resource: Survey data

Table 3 Regression results for use of soil testing formula fertilizer by small-, medium-, and large-scale farmers

Index	Model 1 (Small)		Model 2 (Medium)		Model 3 (Large)	
	Regression coefficient	standard deviation	Regression coefficient	Standard deviation	Regression coefficient	standard deviation
Constant	–1.153***	0.367	–1.284***	0.330	–3.932***	0.614
Age	–0.007	0.005	–0.003	0.005	0.013	0.008
Education	0.000	0.017	0.017	0.015	0.121***	0.030
Profession	–0.004	0.100	0.041	0.090	0.448***	0.151
Member of cooperation	–0.165	0.134	–0.033	0.114	0.426	0.151
Cooperate with enterprise	0.587**	0.251	0.273	0.216	0.081	0.205
Grain change-reduce	–0.245	0.364	0.071	0.248	0.017	0.264
Grain change-increase	0.427***	0.103	0.358***	0.095	0.328***	0.149
Soil test	0.566***	0.122	0.409***	0.109	0.851***	0.205
Fertilize infor-Agricultural material store	–0.055	0.220	0.142	0.181	–0.055	0.463
Fertilize infor –Agricultural technology service	0.339***	0.109	0.319***	0.105	0.570***	0.162
Fertilize infor-others	0.430*	0.230	–0.146	0.229	0.351*	0.217
Fertilize concept	0.071	0.127	0.322***	0.110	0.448***	0.189
Train experience	0.127	0.166	0.288**	0.134	0.275*	0.194
Train time	0.254***	0.064	0.045	0.043	0.023	0.050
Policy environment	–0.073	0.127	–0.122	0.105	0.359***	0.150
Samples	822		907		443	
–2Log likelihood	–887.467		–1087.380		–445.271	
LR statistic	204.879		141.974		168.349	

Note: *, **, *** mean the regression coefficients were shown to be significant at 10%, 5% and 1% respectively.

An analysis of specific effects and reasons follows:

(1) Educational backgrounds of heads of household. This variable has no effect on small- and medium-scale farmers, but has a significant influence on large-scale farmers. The regression results of model 1 demonstrate that the regression coefficient of the educational level of head of household was 0.121, and it was notably below 1% level, proving that educational backgrounds of heads of household were positively associated with the sustainable use of soil testing fertilizers. That is, the higher the educational level, the more likely the farmer was to use soil testing formula fertilizers sustainably. The possible explanation for this phenomenon is that people with higher educational level have accumulated more knowledge and have a stronger ability to adapt to new things, meaning that these people are more willing to accept soil testing formula fertilization technology.

(2) Farmers' occupations. This variable has no effect on small-scale and medium-scale farmers, but has a significant effect on large-scale farmers. Measurement results of model 3 show that the variation coefficient of whether households are pure agriculture households is 0.448. This variable is notable below 1% level, indicating that pure agriculture households are more inclined to use the formula fertilizers by soil testing than households that are not purely agricultural. The cause of this phenomenon may be that, against the background of the transfer of the rural labor force into non-agricultural employment, one prominent trend is the feminization and aging of farm households. These household are partially engaged in agriculture and, because generally the cultural level of women and the elderly is low, their willingness to adopt the application of formula fertilization by soil testing technology is limited to a certain extent.

(3) Cooperation with grain enterprises. The variable has a significant impact on small-scale farmers' decision to use soil testing formula fertilizers, but the effect on medium-sized and large-scale farmers is not notable. The regression coefficient of households cooperating with grain enterprises is 0.587 in model 1, and passed the test of significance under the 5% level. It demonstrated that households that are cooperating with enterprises are more likely to use soil testing formula fertilizers continuously than those households that are not cooperating with companies. The possible explanation for this phenomenon is that farmers who work with grain companies become more acclimated to the market and become more enthusiastic about trying new technology in order to improve food quality and output, and make the price of their output more competitive.

(4) Change of grain yield over five years. This variable has a significant impact on the behavior of using soil testing formula fertilizers among small-, medium- and large-scale farmers. This indicates that farmers who achieve increased grain yields are more likely to use soil testing formula fertilizers continuously than those farmers whose grain output has no change. Increases in grain output are the result of a number of factors, including planting experience, rational allocation of production elements, agricultural technology application and so on. Farmers who realize increased grain output have, to some extent, have invested time, energy and

capital in agricultural technology, labor and other factors. These farmers will take the initiative and try to adopt new agricultural technology.

(5) Soil testing services. The variable soil measurement service has a significant effect on small-, medium- and large-scale farmers. The regression coefficient of soil testing service passed the notable test at 1% level in models 1, 2 and 3; the coefficients are positive numbers. The outcomes showed that soil testing services have a significantly positive effect on farmers, with the continuous use of soil testing formula fertilizers standing at 38.08%, 41.23%, 51.69%, respectively, for small-, medium-, and large-scale farmers who use soil testing services. We can conclude that, as the size of the farms they manage increase, the proportion of the farmers continuously using soil testing formula fertilizers also increases. The absolute value of the regression coefficient of the soil measurement service variable is the largest of the variables in the three models, thus demonstrating that soil testing services are the most important factor affecting farmers' continuous use of soil testing formula fertilizers. This is especially the case for large-scale farmers. The possible explanation of this may be that soil testing is one of the important ways to promote the application of soil testing formula fertilization technology. Soil testing not only introduces farmers to this fertilization technology, it helps farmers understand the conditions of soil fertility, making them more enthusiastic about the technology.

(6) Channels for obtaining fertilization information. The variable for fertilization information, based on data from Agricultural Technology Promotion Stations, has a significant influence on the decisions of small-, medium- and large-scale farmers to use formula fertilizers continuously. According to regression results in models 1, 2 and 3, the regression coefficients for variables of fertilization information provided by Agricultural Technology Promotion Stations are 0.339, 0.319, and 0.570; they are all notable at 1% level. The statistics illustrate that farmers who go through agricultural station channels to obtain fertilization information are more inclined to continue using formula fertilizers than those farmers who make fertilization decisions based on their own experience. We find that the groups of small-, medium- and large-scale farmers have 36.62%, 30.09% and 32.27%, for farmers who get fertilization information from agricultural stations. A look at the statistical results of the total sample shows that 54.97% of farmers made fertilization decisions based on their own experiences, illustrating that, at present, there are many farmers who do not receive fertilization guidance from technical personnel. These farmers commonly make fertilization decisions in accordance with traditional concepts of fertilization.

(7) Fertilization concept. The variable for fertilization concept has no significant effect on the behavior of the small-scale farmers, but it has a distinct effect on the decisions of medium- and large-scale farmers to use formula fertilizers continuously. Although this variable has a positive effect on both medium- and large-scale farmers, the influence on large-scale farmers is greater. Farmers who have correct concepts of fertilization are more inclined to continuously use soil testing formula fertilizers. Concerning the concept of fertilization, the survey questionnaire asked farmers, "Do you think that the more fertilizers used the greater the amount produced?" According to the data, 46.50% of large-scale farmers have a correct concept of fertilization and continuously use soil testing formula fertilizers. However, the proportion of small-scale farmers is 32.24% and the proportion of medium-scale farmers is 34.61%, suggest that medium- and large-scale farmers are better at using the correct fertilization concept to adjust the structure of fertilizer application.

(8) Training services for soil testing formula fertilization technology. The variable for training services has no significant effect on the small-scale farmers, but it has significant influence on the use of soil testing formula fertilizers for medium- and large-scale farmer. All the directions are positive and, judging from the perspective of absolute value, the variable for training services has the greatest impact on large-scale farmers. Compared with farmers who have had no training, farmers who have technical training about the use of soil testing formula fertilization are more likely to use formula fertilizers continuously. The possible explanation for this might be the fact that understanding, recognition and trust of a new technology are prerequisites for adoption. Training in the use of soil testing formula fertilization technology is an important way to educate and promote this technology, and training creates good conditions for farmers to understand and continue to use soil testing formula fertilizers.

(9) Number of training sessions. The number of training sessions has a significant effect on small-scale farmers group, but the effect is not significant for the medium- and large-scale farmers. In comparison with farmers who attend few or no training sessions, the possibility that farmers who join training more frequently will use formula fertilizers is greater. One reason for this might be that with the increase of the number of training sessions, farmers are exposed to different kinds of training, such as collective teaching, experimental demonstrations, expert guidance and so on. The farmers gain theoretical knowledge and get practical guidance as well. Their awareness and understanding of soil testing fertilization technology gradually deepen and they become willing to try this technology.

(10) Policy environment. The variable of policy environment has a significant effect on the behavior of large-scale farmers. The policy environment variable has a remarkably positive effect on the sustainable use of soil testing formula fertilizers because farmers in demonstration areas for promoting the system of soil testing formula fertilization are more likely to use soil testing formula fertilizers continuously. This phenomenon may explain that dem-

onstration areas help to prepare the way for new technology. The technology spreads far and large-scale farmers have access to this technology, have a comprehensive understanding of the technology, and thus have a relatively greater likelihood of adoption.

From what has been discussed above, on the whole, there are some common factors which impact the decisions to use soil testing formula fertilization of farmers from all of the scale groups. In other cases, a factor has an effect on one or two groups, but not on all of the groups. The common affecting factors include: the increase of grain yield, soil testing services, channels for obtaining fertilization information and training services. Among these, training services plays the most important role, and it has the most significant impact on large-scale farmers. The factors that most affect the decisions of small-scale farmers to continuously use soil testing formula fertilizers are, in order of their significance, services for soil testing, households cooperation with grain companies, the increase of grain yield, sources of fertilization information, and the number of training sessions. The factors affecting the continuous use of soil testing formula fertilizers for medium-scale farmers, in order of their significance, are services for soil testing, the increase of grain yield, sources of fertilization information, concepts of fertilization, and the number of training sessions. For large-scale farmers, the factors affecting the continuous use of soil testing formula fertilizers arranged in order of significance are services for soil testing, sources of fertilization information, concepts of fertilization, occupation of farm household, the increase of grain yield, policy environment and the educational background of the head of household.

4 Discussion and conclusions

This paper utilizes micro survey data for 2172 farmers in 11 grain-producing provinces in China to construct a bivariate probit model. The paper makes a systemic analysis of intrinsic factors that influence the decisions to use soil testing formula fertilization by small-, medium- and large-scale farmers and then correlates the behaviors of farmers from different size groups. We can draw two primary conclusions from the analysis. Firstly, increases of grain yields, soil testing services, channels for obtaining information about fertilization, and training services all have a significantly positive impact on all three of the different scale groups Soil testing services generally exert the greatest influence. Secondly, apart from the factors common to all groups, cooperation with enterprises, increase of grain yield and channels of fertilization information are the most influential factors for the continuous use of formula fertilizers among small-scale, medium-scale and large-scale farmers, respectively.

Based on the above conclusions, we make the following policy suggestions:

(1)Strengthen services for soil testing, fertilization information and training. Expand the five key links — "testing, pairing, producing, supplying, fertilizing" — in the service chain for soil testing formula fertilization technology and make the links available to all farmers. This important measure will allow services to realize horizontal development as well as longitudinal extension, expanding coverage and relevance. Soil testing activities must pay attention to the feedback from results and adjust the work of guiding fertilizers. The guidance link depends on developing the primary role of agricultural stations. The training link should include diverse modes of training such as lectures, field demonstrations, and face to face consultations with experts.

(2) Upgrade the degree of marketization, organization and scale. Deepen reforms of the rural market economy system, guide the cooperation between agricultural enterprises and scattered small farmers, and enhance the consciousness and the ability of farmers to participate in market competition. Encourage the development of professional institutes for farmers, improve the organizational level of farmers in order to reduce natural risks and market risks in agricultural production. Promote the moderate focus from land to planting expertise, for the purpose of improving penetration and coverage of soil testing formula fertilizers.

(3) Cultivating a new type of professional grain farmers. The empirical research results indicate that the possibility of nonagricultural households and households partially engaged in agricultural production are less likely to employ soil testing formula fertilizers continuously than pure agriculture households. Some pure agriculture households, nonetheless, did not use soil testing formula fertilizers continuously because the households are aging and the educational levels of household members are not high. We should make "having knowledge, understanding technology, being good at management" the guiding principle used to cultivate a new type of professional grain farmer. Doing this requires improving educational levels, establishing scientific concepts of grain planting and enhancing the awareness of the environment, weakening limitations imposed from above to a certain extent, conforming to the trends of modernized agricultural development, and driving the promotion project of soil testing formula fertilization technology.

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不同规模农户持续使用测土配方肥行为差异分析——基于 11 个粮食主产省 2172 个农户的调查

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摘　要：本文利用我国 11 个粮食主产省不同经营规模农户的微观调研数据，基于二元选择 Probit 模型，探析了不同经营规模农户持续使用测土配方肥行为差异及其影响因素的共同点和不同点。研究得出结论：不同规模组农户中，持续使用测土配方肥的样本比例分布存在明显差异，大规模组农户使用比例最高，小规模组农户比例最低；从外在因素看，粮食实现增产、测土服务、施肥信息渠道、施肥技术培训对三组农户测土配方肥使用行为具有显著正效应，其中测土服务的影响程度最大；市场化程度和规模化程度高的农户倾向于持续使用测土配方肥。在实证研究的基础上，本文提出了相应的政策建议。

关键词：测土配方肥；测土；施肥信息渠道；培训