Which Factors Influence Chinese Farmers to Adopt Formulated Fertilization Technology?

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Abstract. Soil testing and formulated fertilization program has developed in China for more than ten years. This study examines the influence of psychological factors, farmer characteristics and soil testing policies on farmers’ intention to apply fertilizer. An expanded version of the theory of planned behavior is used as a framework. The results for the all farmer sample show that age, planting type and policy are significant and positively associated with farmers’ intentions. With psychological variables attitude, subjective norms, perceived behavior control and perceived resource levels increase by one unit, the probability of farmers changing fertilization behavior according to the soil testing system increased by 2.20%, 1.57%, 3.26%, 3.24% respectively. With the variable planting type being horticultural crops, age between 35 and 44, agricultural technology training and formulated fertilization system increased by one unit, the probability of farmers changing the fertilization behavior according to the soil testing system increases by 8.05%, 8.48%, 5.05% and 6.08%, respectively. Policy recommendations are made based on these results.

1. Introduction

Soil testing and formulated fertilization technology is a program of planning for fertilizer applications to crop fields in China [1]. Soil testing is a tool which helps farmers to assess current soil fertility of fields, and make fertilizer application decisions based on the soil testing results [2]. This program is one of the agricultural science and technology household projects initiated by the agricultural environmental pollution and ecological environment deterioration in China [3] [4]. The adoption of soil testing and formulated fertilization technology can lead to win-win outcomes in terms of both improving productivity and reducing the environmental impact of farming.

Soil testing and formulated fertilization program has developed in China for more than ten years [5]. However, the farmers who do adopt soil testing often fail to fully translate these testing data into decision making formulated fertilization [6]. The decision to adopt soil testing and formulated fertilization is often influenced by the farm’s characters, such as farm system, plant types, farmer socio-economic factors [7]. The demographic characteristics have a significant impact on the application of chemical fertilizers. The study suggests that farmers with younger ages are more likely to apply fertilizers according to the standard [8]. The degree of education of farmers has a positive effect on the use of fertilizers, but it does not help the efficiency of fertilizer use. According to the different production characteristics, the study found that rice farmers in agricultural production, the scale of
operation affects the application of fertilizer. Very few studies have examined the influence factors of adoption of soil testing and formulated fertilization. This paper seeks to explore which factors influence farmers’ intentions to apply fertilizer on the basis of soil test results in China. This study uses 4 provinces in southwestern China as a case study.

2. Data and Methods

2.1 Survey

The data used in this study was derived from a structured survey of 1026 farmers across 4 provinces in southwestern China. A review of the literature, expert consultations and farmer interviews were used to develop the survey. The final survey included three sections. First, questions were used to collect data on farmer characteristics (e.g. age, education and contact with an agricultural advisor) for use as independent variables in the analysis. The second section collected information on fertilization policy, such as using suggestion card for fertilization based on the soil testing. The third section was based on the TPB where farmers were asked to evaluate various statements designed to reveal their beliefs and intentions towards applying fertilizer on the basis of soil test results [9][10].

The TPB framework has been widely used to explain farmer decisions to adopt agricultural practices [11]. In the TPB, socioeconomic characteristics and background variables are the main factors which influence farmer’s intention through four types of psychological latent constructs. The psychological variables are attitude, subjective norms, perceived behavioral control and perceived resources. These variables were developed and used in our study to measure these latent constructs. The contents in the survey was decided by the information collected during the survey development phase. Respondents were asked to respond on a five-point likert scale, from strongly disagree-1 to strongly agree-5, the extent to which they agreed with the statements in the survey.

In addition to the factors based on the TPB, a number of farmer characteristics are also expected to influence farmers’ intentions to apply fertilizer on the results of soil testing technology. The chosen variables are decided on the literature and include farm types, farmer age, general education and agricultural education, technical training times, fertilization technical training, and policy.

2.2 Methods

The all hypothesized psychological and additional variables can be expressed as follows:

\[ \ln\left[ \frac{P_i}{1-P_i} \right] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} \]  

Where, subscript \( i \) denotes the \( i \)-th observation in the sample, \( P_i \) is the probability of the outcome, \( \beta_0 \) is the intercept, \( \beta_1, \beta_2, \ldots, \beta_k \) are regression coefficients of variables \( X_1, X_2, \ldots, X_k \), respectively [12][13].

A likelihood-ratio (LR) test was performed on the full sample. The influence of each variable is further explained by the marginal effect of the regression result. The marginal effect of the dummy variable is estimated as the difference between the probability of the sample mean when the dummy variable takes values of 1 and 0. The higher the marginal effect, the more significant the influence of explanatory variables on the dependent variable [14].

3. Discussion

3.1 Descriptive statistics

Table 1 provides the basic characteristics of the full samples. The following descriptive statistics are for the full sample of farmers (\( n = 1026 \)). Food crops farms represent 31%, economic crops accounted for 28% and horticultural crops accounted for 41%. Furthermore, 42% of farmers have high school level education or higher, and 6% of farmers have agricultural technology education background. The age of farmers is mainly concentrated in between 35 and 44 years old, 18% of farmers have participated in
organic farming technology training, and 68% of farmers have joined agricultural technology cooperatives.

Table 1. Basic characteristics of the samples

| Variables                  | Description                                                                 | Mean | Std. deviation |
|---------------------------|----------------------------------------------------------------------------|------|----------------|
| Farm type                 | Main plant(1=food crop, 2=economic crop, 3=garden crop)                     | 2.31 | 0.98           |
| Age                       | Age of farm operator (1=under 35, 2=between 35 and 44, 3=between 45 and 54, 4=between 55 and 64, 5= above 65) | 2.58 | 1.12           |
| Education                 | 1=some high school and above, 0=otherwise                                  | 0.42 | 0.45           |
| Agriculture education     | Has some level of agricultural education (1=yes, 0=otherwise)               | 0.06 | 0.34           |
| Technical training times  |                                                                            | 2.18 | 0.47           |
| Soil testing and          | Has formulating fertilization technical training (1=yes, 0=otherwise)      | 0.68 | 0.47           |
| fertilization policy      | Has suggestion card for fertilization (1=yes, 0=otherwise)                 | 0.47 | 0.51           |

3.2 Regression analysis

The regression results of the influencing factors of farmers' fertilization behaviors based on the organic certification system are shown in Table 2. The variables that reach significant levels at the 1% level are: attitude, perceived behavioral control, perceived resources, horticultural crops, ages between 35 and 44, agricultural technology training and formulated fertilization policy; subjective norms of variables reached a significant level at the 5% level; variable ages between 45 and 54 years old reached a significant level at the 10% level. All variables that reached significant levels also passed the significance test of marginal effects. The results of data analysis show that attitudes, subjective norms, perceived behavioral control and perceived resource changes significantly affect farmers' ability to change fertilization behavior according to soil testing; with psychological variables attitude, subjective norms, perceived behavior control and perceived resource levels increase by one unit, The probability of farmers changing fertilization behavior according to the soil testing system increased by 2.20%, 1.57%, 3.26%, 3.24% respectively; with the variable planting type being horticultural crops, age (between 35 and 44 years old), agricultural technology training and formulated fertilization system When the value is increased by one unit, the probability of farmers changing the fertilization behavior according to the soil testing system increases by 8.05%, 8.48%, 5.05% and 6.08%, respectively.

This paper finds that perceived behavior control and perceived resources have a positive impact on farmers' decision-making fertilization behavior based on soil testing system. This is consistent with the conclusions in the theory of planned behavior. The stronger the perceived behavioral control and perceived resources, the greater the possibility that farmers will grow organic agricultural products and the greater the government's support for farmers to grow organic products. Farmers are more likely to rely on the policy environment. Previous studies have shown that subjective norms affect people's intentions and behaviors because people are influenced by the social environment to make decisions. In this study, subjective norms of variables were significant in all samples. This shows that the current soil testing and formulated fertilization system has a small impact on the fertilizer application behavior of farmers in the southeast China. In the course of the investigation, farmers still have doubts about the soil testing system. Many farmers in the southeast China has no suggestion card for formulated fertilization. It is fully confirmed that the current soil testing system still has low recognition, which also explains that the current formulated fertilization system has less constraints on farmers' reduced fertilization behavior, and the subjective norms of variables do not have significant model prediction results in these areas.
Table 2. Results of the binary logistic regression for the prediction of farmers’ fertilization behavior on the basis of organic certification system

| Explanatory                          | Coeff     | Std.err | Marginal effects | Std.err |
|--------------------------------------|-----------|---------|------------------|---------|
| attitude                             | 0.29***   | 0.05    | 0.0220***        | 0.0051  |
| Subjective norm                      | 0.19**    | 0.10    | 0.0157**         | 0.0071  |
| Perceived behavioral control         | 0.41***   | 0.11    | 0.0326***        | 0.0062  |
| Perceived resources                  | 0.43***   | 0.08    | 0.0324***        | 0.0082  |
| Type of crops\(^a\)                  |           |         |                  |         |
| Economic crops                       | 0.81      | 0.50    | 0.0717*          | 0.0388  |
| Garden crops                         | 0.96***   | 0.36    | 0.0805***        | 0.0309  |
| age\(^b\)                            |           |         |                  |         |
| under 35                             | 0.04      | 0.35    | 0.0040           | 0.0375  |
| between 35 and 44                     | 1.27***   | 0.41    | 0.0848***        | 0.0265  |
| between 45 and 54                     | 0.46*     | 0.50    | 0.0390           | 0.0427  |
| between 55 and 64                     | 0.43      | 0.25    | 0.0413           | 0.0242  |
| Education                            | 0.22      | 0.24    | 0.0171           | 0.0194  |
| Agriculture education                | 0.18      | 0.22    | 0.0137           | 0.0187  |
| Technical training times             | 0.65***   | 0.23    | 0.0505***        | 0.0180  |
| Soil testing and fertilization        | 0.24      | 0.30    | 0.0186           | 0.0240  |
| policy                               | 0.80***   | 0.27    | 0.0608***        | 0.0201  |
| Samples                              | 1026      |         |                  |         |
| Pseudo R\(^2\)                       | 0.46      |         |                  |         |
| Prob > chi2                           | 0.0000    |         |                  |         |
| % Correctly classified               | 90.3      |         |                  |         |

Notes: Significance levels *** p < 0.01, ** p < 0.05, * p < 0.1.
\(^a\) Reference group for crops type is food crop.
\(^b\) Reference group for age is group 65+.

4. Conclusion
This paper explores the impact of soil testing and formulated fertilization system on the willing of farmers’ fertilization behavior. We concluded that soil testing system has a significant impact on farmers’ willingness to reduce fertilization. However, the degree of policy constraints is different, and the factors affecting farmers’ willingness to fertilize are also different. The farmers who has the suggestion card of fertilization with strong policy constraints, age and psychological factors are the main factors affecting their fertilization behavior. The benefits of the soil testing system for farmers and the government's policy support for organic agriculture are the key to farmers' response to formulated fertilization policies. For farmers has no suggestion card, farmers' perceptual resources and perceived behavior control ability are
the key factors for their active response to formulated fertilization policies and changes in fertilization behavior. The improvement of the recognition of organic agricultural products by society can improve farmers' perceived resources and perceived behavior control ability.

Based on the results, we suggest the policy implications as follows. Firstly, the suggestion card of fertilization should be applied more widely by the government. This may help the farmers to control applying fertilizer on the basis of soil test results. Secondly, efforts should be made to encourage farmers to further engage with organic technical support. Perceptions of resources were important to farmers and more soil testing and fertilization technology should be provided to the farmers. Finally, encouraging organic food certification may help to increase the use of fertilization technology.

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