DOI 10.15302/J-SSCAE-2018.05.017

Analysis of Reasons for the Overuse of Chemical Fertilizers from Distributors' Perspective

Lian Yuyang[1], Liu Jing[1], Jin Shuqin[2], Liu Hongbin[3], Wu Shuxia[3]

1. Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences, Beijing 100081, China
2. Research Center for Rural Economy, Ministry of Agriculture and Rural Affairs of the PRC, Beijing 100810, China
3. Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

Abstract: This paper analyzes the reasons behind the overuse of chemical fertilizers from the perspective of distributors. We introduce the traditional bi-level fertilizer distribution model and the current status of fertilizer circulation, followed by an empirical analysis of the behavior of fertilizer distributors using field research data and questionnaires. Results of these analyses show that credit sales are a major factor responsible for the increase in the cost of circulation and the price of fertilizers. Promotion of fertilizer products and financial risks arising from credit buying by farmers have increased the operating costs of distributors. To make a profit, distributors are forced to increase the application rates that they recommend to farmers, resulting in excessive use. In addition, fertilizer distributors usually have a low level of expertise and, thus, need proper agricultural training to facilitate the recommendation of appropriate application rates based on scientific data. To this end, we recommend raising the threshold of market access for fertilizer distributors, improving training opportunities targeting the distributors, and alleviating the pressure placed on distributors by frequent credit purchases.
Keywords: fertilizer; distributors; credit sales; recommended dosage

1 Introduction

In 2016, the annual fertilizer application rate in China declined for the first time to a total quantity of 5.984×10^7 t. Nevertheless, future prospects of fertilizer application in China are not optimistic, as the current scalar quantity for fertilizer application in cultivated areas is 443.53 kg/hm^2 and that in unit sown areas is 323 kg/hm^2. Both of these values exceed the upper safe limit of 225 kg/hm^2 recommended by developed countries to prevent environmental damage [1]. Frequent improper application of fertilizer might cause numerous issues [2], such as polluted water, land, and air and potentially reducing the quality of agricultural products, which increases agricultural non-point source pollution and inhibits sustainable agricultural development.

Fertilizer overuse in China has been studied by many researchers. Economists commonly measure and calculate fertilizer utilization efficiency using the energy ratio method, stochastic frontier production function (SFA), and data envelopment analyses (DEA) [3−8]. Their results attribute the excessive application of fertilizer to the low utilization of crop fertilizers in China. In recent years, an increasing number of studies have analyzed farmers' fertilizer application behavior using statistical modelling (e.g., the sample selection (Tobit) model, Probit model, evaluation

Received date: September 10, 2018; **Revised date:** September 20, 2018
Corresponding author: Liu Jing, Institute of Agricultural Economics and Development, CAAS. Major research fields include agricultural resources and environmental economy, rural development and utilization of water resources. Email: liujing02@caas.cn.
Funding program: CAE Advisory Project "Research on Key Strategic Issues of Agricultural Resource and Environment in China" (2016-ZD-10); topic of National Key R&D Program of China "Research on the Design of Management Policy for Application Decrease and Efficiency Increase of Fertilizer" (2016YFD0201304).

Chinese version: Strategic Study of CAE 2018, 20 (5): 112–119

Cited item: Lian Yuyang et al. Analysis of the Reasons for Overuse of Chemical Fertilizer from Distributors' Perspective.*Strategic Study of CAE*, https://doi.org/10.15302/J-SSCAE-2018.05.017

Logit model, Heckman model, and general linear model) at the micro level, which includes farmers' individual characteristics, farmers' family characteristics, production means characteristics, production activity characteristics, and agricultural market characteristics [9−18]. Some scholars believe fertilizer overuse can be attributed to other factors: an incomplete national system [11,19−21], increased labor costs [22,23], failure to properly utilize the agricultural extension system [24], and the adjustment of plant industry structure [25−27]. Jin Shuqin et al. [28] investigated overuse from another point of view and revealed that interactions between the farmer and the distributor in terms of information transfer and credit purchases also play a major role in fertilizer overuse. In Jin's opinion, the poor information provided by distributors and the low credit of farmers often lead to fertilizer overuse. In this article, the reasons for fertilizer overuse have been analyzed from distributors' perspective.

2 Analysis of the traditional two-level fertilizer marketing model

Currently, fertilizer distribution in China follows a traditional two-level marketing model, as shown in Fig. 1. Fertilizer manufacturers assign provincial sales managers and county-level salespeople to develop county-level (municipal) agents, and the county-level (municipal) agents then develop township- and village-level retailers within their respective jurisdictions. Fertilizer products are sold to farmers through the retailers.

As instructions are issued level by level and all links are closely connected, this strategy aids manufacturers in establishing a fixed sales network. Manufacturers can then integrate capital, brand, personnel, and sales network improvements effectively through agents and retailers, and the manufacturer and distributors can set up joint brands to stabilize customer loyalty, ensure the steady growth of product sales, and to reduce advertisement costs. However, this marketing model has its disadvantages. For example, it requires high terminal investment owing to the simultaneous price rise at two levels. In particular, the sale of new-type fertilizers, considering their high production costs, will be severely restrained by their price if promoted using this model.

According to surveys and panel discussions, at the second level, the primary cause for price increase is the limited sales volume of retailers, which is primarily caused by their small areas of responsibility and low number of consumers. In order to make a profit, retailers must charge higher prices for their wares. In addition, product advertisement and credit purchases by customers are also two key factors that can drive price increases. In terms of product promotion and the technical training required for proper fertilizer application, fertilizer manufacturers offer training to both retailers and farmers, and similarly, agents and retailers provide training for farmers. These training are usually free for participants, with all costs covered by the manufacturers themselves. The training costs are substantial (including board, lodging, and travel expenses for participants, as well as expenses associated with hiring expert lecturers and consultants). Similarly, significant capital turnover costs are generated by allowing product credit purchase. As shown in Fig. 1, manufacturers sell fertilizers to county-level (municipal) agents by C/C or advance payment, because manufacturers do not allow credit purchase. However, credit purchases occur in the second and third resale levels, and farmers' credit purchases are often highly detrimental. Consequently, agents and retailers incur the risks of bad debts and capital turnover costs, and such risks subsequently drive the increase in fertilizer price.

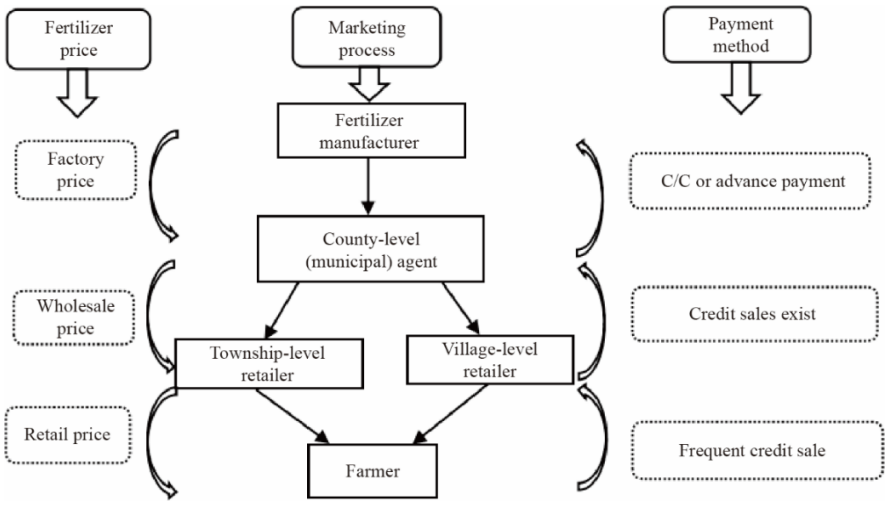

Fig. 1. Diagram of the traditional two-level marketing model.

DOI 10.15302/J-SSCAE-2018.05.017

3 Survey of fertilizer distributors

3.1 Sources

A survey (Table 1) has been performed targeting fertilizer agents and retailers in July and August of 2017, to understand the fertilizer sales web. In Henan Province, the survey was conducted at retailer training events performed by a Shandong manufacturer. Questionnaires were distributed at three training venues: Shandong manufacturer; Shangshui County, Henan Province; and Ye County, Henan Province. Considering the limited duration of these training events, the questionnaires were distributed to respondents and then collected by investigators who were responsible for reviewing and/or revising the questionnaires. The recovery rate of questionnaires was low, with only 30 of the 60 questionnaires distributed being recollected. We also surveyed rice farmers in Zhejiang Province by generating a random sample of local fertilizer distributors and talking with them in person. From these discussions, we collected 11 valid questionnaires. Therefore, the total number of valid questionnaires was 41, which included 2 questionnaires completed by county-level agents, 19 completed by township-level retailers, and 20 completed by village-level retailers.

The questionnaire requested personal information concerning the shop owner and his/her family, basic information about their sales outlets, fertilizer application technologies, training, and fertilizer sales in 2016.

Table 1. Fertilizer distributors participation in the survey. Pieces

Region	County-level agent	Retailer		Total
		Township- level	Village- level	
Henan Province	0	16	14	30
Zhejiang Province	2	3	6	11
Total	2	19	20	41

3.2 Results

3.2.1 Basic personal information

The interviewed distributors were representative of the sample to some degree (Table 2). Among the 41 interviewed distributors, male shop owners were the most common demographic, making up 85.37% of samples. The average age of the interviewees was 48.8 years, and most of them were 40−60 years old. The average number of years spent in the education system was 9.76 years, with a minimum of 5 years, and a maximum of 15 years. Ten of them, 24.39% of the interviewees, had secondary technical education or above; 27 sales outlets had been in operation for at least 10 years, which accounted for 65.85% of all samples.

Table 2. Basic information of the interviewees.

Feature	Classification	Frequency (Person)	Proportion (%)
Gender	Male	35	85.37
	Female	6	14.63
Age	< 30 years old	2	4.88
	30−40 years old	3	7.32
	40−50 years old	18	43.90
	50−60 years old	12	29.27
	≥60 years old	6	14.63
Education Years	<6 years	4	9.76

Table 2 (*continued*)

Feature	Classification	Frequency (Person)	Proportion (%)
	6-9 years	19	46.34
	9−12 years	14	34.15
	≥ 12 years	4	9.76
Operation Years	< 3 years	4	9.76
	3−6 years	4	9.76
	7−10 years	6	14.63
	≥ 10 years	27	65.85

Source: Survey data.

3.2.2 Technical training in fertilizer application

Over the past year, both county-level distributor agents participated in technical fertilizer application training. The proportion of township-level retailers who had participated in technical fertilizer application training was 78.95%, whereas only 60.0% of village-level retailers had taken part in training. Each village-level retailer undertook training 3.42 times per year on average, which was higher than that undertaken by county-level agents and township-level retailers (Table 3). Although the number of trained village-level retailers was small, they participated in the training more frequently.

Table 3. Participation in training events held be distributors in the previous year.

Type of distributor	Number of people participating in the training	Proportion in total number (%)	Total times	Average times
County-level agent	2	100.00	3	1.50
Township-level retailer	15	78.95	44	2.93
Village-level retailer	12	60.00	41	3.42
Total	29	70.73	88	3.03

Source: Survey data.

3.2.3 Retailer training for farmers

Following the traditional two-level distribution model, township-level and village-level retailers were in close interaction with farmers (Table 4). According to this study, more than 40% of township- and village-level retailers offered technical training to local farmers every year. Farmers were trained on fertilizer application, insecticide spraying techniques, field management, and product properties by centralized lectures and field demonstrations. In particular, the average number of training events hosted by village-level retailers for farmers was 3.13/person/year, which was more frequent than that of township-level retailers.

Table 4. Participation of farmers in training events held by retailers in the previous year.

Type of retailer	Number of trainees	Proportion in total number (%)	Total times	Average times
Township-level retailer	7	41.18	13	1.86
Village-level retailer	8	42.11	25	3.13
Total	15	41.67	38	2.53

Source: Survey data.

DOI 10.15302/J-SSCAE-2018.05.017

3.2.4 Sources of information concerning fertilizer application for distributors

Distributors collected fertilizer application information from a diverse range of sources, mainly from fertilizer manufacturers, their own experience and knowledge, and product instructions (Table 5). As described above, fertilizer manufacturers provide technical information on fertilizer application by providing training and hosting product introduction meetings for retailers. Some retailers obtain technical details from product instructions, which is considered a scientific method of learning. With the development of information technology, smart devices such as mobile phones and computers will likely become the predominant means by which retailers acquire technical information.

Table 5. Information sources concerning fertilization technology for distributors.

Information source	Frequency (Person)	Proportion in total number of people (%)
Fertilizer manufacturer	24	58.54
Own experience and knowledge	22	53.66
Product instructions	21	51.22
Governmental agricultural technology department	13	31.71
Mobile phone−WeChat/App etc.	10	24.39
Newspapers and books	7	17.07
Computer−Internet	6	14.63
Superior agricultural material company	3	7.32
Agricultural organization	2	4.88
Radio and television	1	2.44

Source: Survey data

3.2.5 Difficulties encountered by distributors relating to fertilizer distribution

Credit purchases are the greatest difficulty encountered by fertilizer distributors. As shown in Fig. 2, 81.58% of respondents believed that credit purchases were the most common difficulty encountered in fertilizer sales, followed by high operation costs, small interest margins, and inferior, counterfeited, and defective products. Distributors also encounter farmers with poor knowledge of fertilizers. Some distributors also have poor capital turnover and are not trusted by others. These phenomena validated the previous analysis regarding the reasons of high fertilizer prices affecting the second level distributors. Fertilizer manufacture, distribution, and sale are a high operation cost industry, and distributors are frequently hindered by credit purchases, market chaos, and ignorance and lack of knowledge of farmers.

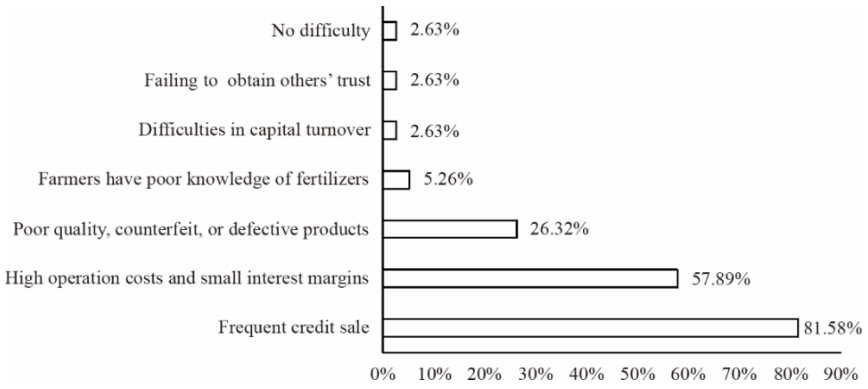

Fig. 2. Difficulties frequently encountered by distributors.

Source: Survey data

4 Empirical analysis of the behavior of fertilizer distributors

4.1 Source

Distributors are those most closely associated with farmers, and as such are in the best position to directly transmit information to them. To understand the influence of distributors in this type of information transmission, we established an econometric model by using the amount of fertilizer recommended by each kind of distributor as the response variable. During the investigation, we inquired about the distributors' fertilizer operations in 2016, including queries concerning the best-selling fertilizer variety in 2016 and its purchasing and sales price, payment mode, sales volume, recommended application rate, and the crops to which it is mainly applied, with a specific focus on wheat cultivation in Henan Province and rice cultivation in Zhejiang Province. This resulted in a dataset of 106 types of fertilizer, of which 55 were used in Henan Province and 51 were used in Zhejiang Province. The fertilizers were predominantly compound fertilizers and urea-based fertilizers, accounting for 75.47% of the total (Table 6).

Table 6. Fertilizer variety data.

Fertilizer variety	Henan Province	Zhejiang Province	Total
Compound fertilizer	35	23	58
Urea	10	12	22
Potassium chloride	1	6	7
Superphosphate	1	4	5
Ammonium bicarbonate	0	4	4
Commodity organic fertilizer	2	2	4
Mixed and compound fertilizer	2	0	2
Foliar fertilizer	2	0	2
Phosphate diamine	1	0	1
Potassium sulphate	1	0	1
Total	55	51	106

Source: Survey data

4.2 Model setup

A multiple regression analysis [29] was used to analyze the distributors' influences in the transmission of information to farmers, using the application rate that specific distributors recommended to farmers as the response variable. The model is detailed below:

$$\text{Recommendation} = \alpha_0 + \alpha_1 \text{ Priced} + \alpha_2 \text{ Credit} + \alpha_3 \text{ Education} + \alpha_4 \text{ Training} + \alpha_5 \text{ Year} + \alpha_6 \text{ Province} + \alpha_7 \text{ Location} + \alpha_8 \text{ Fertilizer} + \varepsilon_1 \quad (1)$$

As the degree of education of shop owners influenced their involvement in agricultural training, we added both as an interaction term in a second model, which is detailed below:

$$\text{Recommendation} = \beta_0 + \beta_1 \text{ Priced} + \beta_2 \text{ Credit} + \beta_3 \text{ Education} + \beta_4 \text{ Training} + \beta_5 \text{ Education} \times \text{Training} + \beta_5 \text{ Year} + \beta_6 \text{ Province} + \beta_7 \text{ Location} + \beta_8 \text{ Fertilizer} + \varepsilon_2 \quad (2)$$

In (1) and (2), the recommended application rate that each fertilizer distributor recommended to farmers is used as the response variable, with fertilizer price (Priced), payment mode (Credit), degree of education of the shop owner (Education), shop owner's participation in technical agricultural training (Training), and the number of years of operation of the sales outlet (Year) used as explanatory variables. The recommended application rate (kg/mu, 1 mu $\approx$ 666.667 m^2) refers to the amount of fertilizer a distributor recommends a farmer to apply to a unit area for a certain crop. The influence of payment method on the recommended application rate is evaluated by whether credit purchase is a viable method of payment when purchasing from a specific distributor. The condition of technical agricultural

DOI 10.15302/J-SSCAE-2018.05.017

training is assessed by the distributor's involvement in technical agricultural training over the past year. Fertilizer price is expressed as the difference between the average selling price and the average purchasing price (i.e., average sales profit), in consideration of the fact that fertilizer sellers aim to make profits and that different fertilizers vary in their costs, purchasing prices, and selling prices. We also included three dummy variables in the model: province, distributor's location, and fertilizer type. As agricultural practices in Henan Province and in Zhejiang Province typically focus on different types of crop, we included a provincial dummy variable (Province) in the model to control for any unobservable heterogeneity in other variables at the provincial level. Distributor's location (Location) was also included in the model, and includes information about a distributor's county, township, and village to control for differences in distributor recommendations based on their location. Fertilizer type is also included in the model to control for differences in application rate between different varieties of fertilizer used for different crops. ε_1 and ε_2 are random disturbance terms, which are assumed to be related to other explanatory variables included in the model.

According to our prior discussion about distributors' behavior concerning credit purchases, distributors are at a high risk of having irrecoverable debt and suffering significant capital turnover costs when they offer the option to purchase fertilizer using credit. Distributors can make up for the associated losses by increasing fertilizer selling prices or sales volumes, but higher prices may decrease sales according to the supply and demand theory. Therefore, to reduce the costs associated with allowing credit purchases of fertilizer, distributors commonly recommend application rates higher than is necessary to increase sales volumes without changing selling prices. If customers use credit to purchase from such distributors, the distributors may increase their recommended fertilizer application rate, i.e., the coefficient symbol is positive. Distributors which have participated in technical agricultural training will likely provide more scientifically accurate and environmentally friendly information to farmers, possibly recommending lower fertilizer application rates to customers, i.e., the coefficient symbol is negative. The higher the shop owners' degree of education, the more likely they are to realize the significance of participating in technical agricultural training.

4.3 Variable descriptive statistics

See Table 7.

Table 7. Definition and descriptive analysis of model variables.

Variable	Unit or response	Observed value	Average value	Standard difference	Minimum value	Maximum value
Recommended fertilizer application rate	kg/mu	106	38.76	28.62	0.5	200
Difference between selling price and purchasing price	RMB	106	0.40	1.94	−0.275	20
Allows credit purchase?	Yes=1, No=0	106	0.58	0.50	0	1
Shop owner's time in education	Year	106	10.07	2.62	5	15
Shop owner's involvement in training	Yes=1, No=0	106	0.67	0.47	0	1
Duration of operation of sales outlet	Year	106	18.94	16.54	1	68

Source: Survey data.

4.4 Empirical analysis results

The results of the empirical analysis (Table 8) show that credit purchases and the extent of technical agricultural training influence the fertilizer application rate recommended by distributors to a certain extent. After controlling for fertilizer price, number of years of operation, variety of fertilizer, and the location of distributors, the influence of credit purchases is obvious, affecting recommendation by 10% and producing a positive coefficient when using model (1). Using model (2), the coefficient of the variable is also positive but not obviously so, suggesting that credit purchases result in increased recommended application rates.

In model (1), the influence of the distributor's participation in training on their recommended fertilizer application

rate is obvious and results in a negative coefficient. After the interaction term is added to the model, the interaction term explains 1% of the variation in recommended application rate and the model produces a negative coefficient. If the average number of years a distributor has spent in education is at least 10.07, the application rate recommended by the distributor is 9.87 kg/mu less relative to untrained distributors. Empirical analysis suggests that distributors' participation in technical training results in their recommendation of lower application rates to farmers.

Table 8. Empirical regression results.

Response variable: recommended fertilizer application rate	Formula (1)	Formula (2)
Difference between selling price and purchasing price	−0.815	−1.070
	(1.906)	(1.855)
Allows credit purchase? (yes=1)	9.738*	7.379
	(5.431)	(5.360)
Shop owner's time in education	0.432	−3.049*
	(0.956)	(1.675)
Shop owner's involvement in training (yes=1)	−12.34*	−62.32
	(6.266)	(20.91)
Interaction term: training × education		5.209**
		(2,085)
Duration of operation of sales outlet	0.0593	0.0380
	(0.185)	(0.180)
Constant term	40.43*	86.09***
	(22.82)	(28.73)
Observed value	106	106
R^2	0.414	0.453

Note: *, **, and *** indicate statistical significance at the level of 10%, 5%, and 1%, respectively. Regression results for dummy variables are omitted in this table.

5 Conclusions

5.1 Fertilizer distributors have a low level of overall professional knowledge

Overall, fertilizer distributors have a low education level and typically lack fertilizer application knowledge. The business license can be acquired at a low cost and there is no constraint or supervisory mechanism in place. They improve their knowledge through training classes and introductory meetings held by fertilizer manufacturers, and their motivation for improving their professional skills and knowledge is typically low. In conclusion, the professional knowledge of distributors needs to be improved.

5.2 The pressure of credit purchases results in distributors increasing their recommended application rates to increase sales volumes

Credit purchases are incredibly common in the circulation of chemical fertilizer, which dramatically increase circulation costs and result in high fertilizer prices. The promotion of fertilizer products and the capital risks resulting from farmers' frequent credit purchases increase the operation costs as well. To make profits, distributors tend to increase the fertilizer application, which leads to fertilizer overuse.

DOI 10.15302/J-SSCAE-2018.05.017

5.3 Distributors will recommend more scientifically appropriate fertilizer application rates after participating in technical agricultural training

According to the empirical analysis, participating in technical agricultural training reduces the application rate recommended by distributors. As training promotes scientific thinking and environmental awareness, distributors are more likely to recommend safe and appropriate application rates to farmers.

6 Countermeasures

6.1 Improve market access thresholds for fertilizer distributors

Government departments should more thoroughly manage the sale of fertilizer, explore the possibility of a distributor qualification recognition system, and prevent the unlicensed operation of distributors. As distributors are the primary way in which farmers gains information about fertilizer use, they should be well-informed to properly transmit accurate information to users. In terms of issuing business licenses regarding agricultural material, the holding of more frequent training classes and the implementation of distributor assessments could help to solve this issue. It is also recommended that more rigorous checks and stricter punishments be used when assessing distributor operation.

6.2 Optimize training for fertilizer distributors

The fertilizer application training should be optimized to ensure the proper use of fertilizers. The government should promote distributor training on fertilizer application technologies, new fertilizer varieties, as well as relevant policies and regulations, which is the way to improve distributors' environmental awareness and overall competency and to enable a more accurate and scientific information transfer between distributors and farmers.

6.3 Try to relieve credit purchase pressure in fertilizer circulation links

We suggest that the expansion of the financing channel for distributors would aid in the alleviation of the pressure placed upon them by frequent credit purchases by farmers. The enactment of a loan interest discount policy for distributors would also aid in reducing the pressure on them from credit purchases. Moreover, the quality of fertilizers should be ensured by the manufactures, such that farmers will have confidence in their fertilizer products and stop purchasing the fertilizers by credit.

References

[1] Wang X, Zhang F. Analysis on present situation and regional disparity of agricultural chemical fertilizer input in China [J]. Acta Agriculturae Jiangxi, 2011, 23(12): 169–173. Chinese.

[2] Zhu Z L, Sun B, Yang L Z, et al. Policy and countermeasures on control non-point pollution of agriculture in China [J]. Science and Technology Review (Beijing), 2005, 23(4): 47–51. Chinese.

[3] Shi C L, Zhu J F, Luan J. Analysis on the efficiency of wheat fertilizer input and its influencing factors in China [J]. Journal of Agrotechnical Economics, 2015 (11): 69–78. Chinese.

[4] Zhou F, Jin S Q. International comparison of agricultural fertilizer utilization efficiency from the perspective of output rate [J]. World Agriculture, 2016 (4): 35–44. Chinese.

[5] Gong Q W. A study on efficiency in the use of agricultural fertilizers and farmers behavior of fertilization [D]. Wuhan: Huazhong Agricultural University (Master's thesis), 2007. Chinese.

[6] Yang Z X, Han H Y. Technical efficiency of fertilizer and its influencing factors: Based on wheat and corn empirical study [J]. Journal of China Agricultural University, 2011 (1): 140–147. Chinese.

[7] Li J Y. Fertilizer using efficiency of China's grain production and its determining factors [D]. Hefei: Hefei University of Technology (Master's thesis), 2012. Chinese.

[8] Liu D W, Li Q, Song X H. Analysis on fertilizer application efficiency of grain production in China——Based on stochastic frontier function [J]. Resource Development & Market, 2017, 33(4): 401–407. Chinese.

[9] Yan X, Jin J Y, Liang M Z. Grain crop fertilization status and factors influencing farmers' decision making on fertilizer use: China case study [J]. Agricultural Science & Technology, 2016, 17(10): 2394–2398, 2440.

[10] Ma J, Zhang W F. The influencing factors of farmers' fertilization decision [N]. Chinese County Economic Newspaper, 2007-04- 16(011). Chinese.

[11] Ji Y Q, Zhang H, Lu W Y, et al. Differentiation, incomplete information and excessive application of fertilizer to farmers [J]. Journal of Agrotechnical Economics, 2016 (2): 14–22. Chinese.

[12] Ru J X. Analysis of farmers' fertilization behavior and influencing factors [D]. Hangzhou: Zhejiang University (Master's thesis), 2008. Chinese.
[13] Ma X Y. Risk avoiding behavior of Chinese farmers: An empirical study in Shaanxi [J]. China Soft Science, 2006 (2): 22–30. Chinese.
[14] Qiu H G, Luan H, Li J, et al. The effect of risk aversion on the excessive fertilizer application behavior of farmers [J]. Rural Economy, 2014 (3): 85–96. Chinese.
[15]He H R, Zhang L X, Li Q. Study on farmers' fertilization behavior and agricultural non-point source pollution [J]. Journal of Agrotechnical Economics, 2006 (6): 2–10. Chinese.
[16] Yan L. Theoretical and empirical analysis of farmers' fertilizer application behavior and influencing factors——A case study of farmer survey in the southern part of Xinjiang [D]. Urumqi: Xinjiang Agricultural University (Doctoral dissertation), 2013. Chinese.
[17] Zhang F S. Why does the amount of chemical fertilizer increase with the implementation of soil testing formula implementing for many years [J]. Farmhouse Advisor, 2012 (5): 4–6. Chinese.
[18] Huang W F. Analysis of the policy causes of pollution from agriculture fertilizers and its countermeasures [J]. Ecology and Environmental Sciences, 2011, 20(1): 193–198. Chinese.
[19] Ge J H, Zhou S D. Whether factor market distortions stimulate agricultural non-point source pollution—with chemical fertilizer as an example [J]. Issues in Agricultural Economy, 2012 (3): 92–98, 112. Chinese.
[20] Yu W Y, Qi Y B, Yu H. An empirical study on the effect of agricultural subsidy on fertilizer surface pollution——Based on Provincial panel data [J]. Rural Economy, 2017 (2): 89–94. Chinese.
[21] Hu H, Yang Y B. Study on the fertilizer application of farmers from the perspective of factor substitution——Based on farmers' data in rural fixed observation points in China [J]. Journal of Agrotechnical Economics, 2015 (3): 84–91. Chinese.
[22] Shi C L, Li Y, Zhu J F. Rural labor transfer, excessive fertilizer use and agricultural non-point source pollution [J]. Journal of China Agricultural University, 2016, 21(5): 169–180. Chinese.
[23] Ebenstein A Y, Zhang J, McMillan M S, et al. Chemical fertilizer and migration in China [R]. Massachusetts: National Bureau of Economic Research, 2011.
[24] Huang J K, Hu R F, Zhi H Y. 30 years development and reform of agricultural technology extension system at the grass-roots level: Policy evaluation and suggestion [J]. Journal of Agrotechnical Economics, 2009 (1): 4–11. Chinese.
[25] Zhang W F, Ji Y X, Ma J, et al. Driving forces of fertilizer consumption in China (II planting structure) [J]. Resource Science, 2008, 30(1): 31–36. Chinese.
[26] Luan J, Qiu H G, Jing Y, et al. Decomposition of factors contributed to the increase of China's chemical fertilizer use and projections for future fertilizer use in China [J]. Journal of Natural Resource, 2013, 28(11): 1869–1878. Chinese.
[27] Dave A. Why do farmers in China use so much fertilizer? [C]. Chongqing: Chinese Economists Society 2015 Annual Conference, China, 2015.
[28] Jin S Q, Shen G Y, Liu H B, et al. Technical choice and institutional arrangement for agricultural non-point source pollution control [M]. Beijing: China Social Sciences Press, 2017. Chinese.
[29] Chen Q. Advanced econometrics and stata applications (second edition) [M]. Beijing: Higher Education Press, 2014. Chinese.