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Ecological Compensation Standard for Non-point Pollution from Farmland

Propozycja standardu ekologicznej kompensacji dla Obszarowych zanieczyszczeń z rolnictwa

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Abstract
Non-point source water pollution mainly comes from farmland chemical fertilizers which has become an obstacle of agricultural sustainability and ecological health. As a public policy tool for assessing global ecological crisis and environmental pollution, ecological compensation is important for regional agricultural sustainability. Ecological compensation that farmers receive from governments is based on their reduction of fertilizer application at optimal ecological and economic levels. In this study we estimated the ecological compensation standards for nitrogen non-point pollution in Yixng city with contingent valuation method and cost-benefit method. Results showed that the range of theoretical values of ecological compensation of nitrogen in Yixing City depended upon its optimal ecological and economic nitrogen application levels. The willingness of farmers to accept the compensation was positively correlated with their farming experience and education. There were about half of farmers willing to accept the compensation. Based on the present study, we found Yixing's ecological compensation standard for controlling nitrogen non-point pollution was 620.0 yuan/hm^2 at the current economic development level.

Key words: ecological compensation standard; nitrogen; non-point pollution; optimal ecological economic nitrogen application amount

Streszczenie
Obszarowe zanieczyszczeń wód z rolnictwa pochodzą ze stosowania nawozów sztucznych, stanowiących przeszkodę na drodze do osiągnięcia rolniczej zrównoważoności i równowagi ekologicznej. W tym kontekście ekologiczna kompensacja, stanowiąca narzędzie polityczne do oceny kryzysu ekologicznego i ogólnego poziomu zanieczyszczenia środowiska, okazuje się także ważna w wymiarze lokalnej zrównoważoności rolniczej. Wysokość świadczeń, które rolniczy dostają od władz, jest uwarunkowana poziomem redukcji stosowania nawozów, którego celem jest osiągnięcie poziomu optymalnego zarówno zer strony ekologicznej, jak i ekonomicznej. W tym artykule, przy pomocy Metoda wyceny warunkowej i metody kosztów i korzyści, ustaliliśmy standardy ekologicznej kompensacji dla miasta Yixng. Otrzymane rezultaty pozwalają na stwierdzenie, że zakres teoretycznych wartości ekologicznej kompensacji dla azotu w Yixing zależy od ustalenia optymalnych ekologicznych i ekonomicznych pozimów stosowania azotu. Zainteresowanie rolników otrzymaniem odszkodowania okazało się być pozytywnie skorelowane z ich doświadczeniem rolniczym i poziomem wykształcenia. Chęć jego otrzymania zgłosiła połowa z nich. Ustaliliśmy ponadto, że standard ekologicznej kompensacji dla Yixing odnoszący się kontrolowania obszarowych zanieczyszczeń związanych z nawozami azotowymi wynosi 620.0 yuan/hm^2 , przy założeniu obecnego poziomu rozwoju ekonomicznego.

Słowa kluczowe: standard kompensacji ekologicznej, azot, obszarowe źródła zanieczyszczeń, optymalna ekologicznie ilość stosowanego azotu

Introduction

Assessment of ecological compensation standards is a core and key to control nitrogen non-point pollution from farmland (Qu, 2007). It significantly contributes to the success or failure of compensation mechanism operation. Therefore, proper approaches to estimate ecological compensation standard have important theoretical and practical significances. Quantitative research on ecological compensation standard for controlling non-point pollution from farmland has matured overseas. Babcosk conducted theoretical and empirical analysis of compensation standard of reducing agrochemicals (Wu, 1996). Stefano used ecosystem services value method to calculate farmland protection compensation standards in Florida around $ 42·hm-2·a-1 (Pagiola, 2008). At present, ecological compensation standard, for controlling agriculture non-point source pollution was studied in general in China, but especially those for farmland nitrogen non-point pollution controlling were not documented well. Ecological compensation standard for controlling agriculture non-point source pollution mainly considered the potential cost for agriculture environment protection or producers' willingness for compensation (Shen et al., 2009; Cai, Zhang, 2011; Pei, 2010). But a crucial problem on reduction of pollutants after ecological compensation implementation, was not clearly answered. However, the ultimate goal of building ecological compensation mechanism was pollutant reduction. Therefore, the pollution control targets must be clearly set before establishing compensation standard for agriculture non-point source pollution. The objectives of this study were to establish ecological compensation standard for controlling nitrogen non-point pollution from farmland by using cost-benefit method and contingent valuation approach. The outcome will benefit preparation of investment budget for controlling agricultural nonpoint source pollution.

1. Materials and Methods

1.1. Calculation Basis

Agricultural non-point source pollution stems from the highly negative externalities of production activities. Agricultural producers engage in the production of positive externalities or reducing negative externalities of production activities which lead to control the farmland nitrogen non-point source pollution. However, the ecological construction and environmental protection activities with strong positive externalities often are provided directly by the government as public goods in fact. Faced with a regional increasing agricultural population, it is truly meaningful to consider how to stimulate farmers to decrease the intensity of production by means of compensation or changes in production methods to weaken the negative effects of the external environment (Wang, Cao, 2008). The FAO (FAO, 2007) thought that payments for environmental services is compensation for producers' loss of income due to change of operation to provide different combinations or a higher level of environmental services. In many cases, the payment to producers was in order to reduce the environmental damage caused by the final production decisions. Therefore, the authors suggested that calculation of ecological compensation standard for controlling nitrogen non-point pollution from farmland should take account of reduction of negative external environmental effects as a starting point in term of the farmers' crop production loss. Reducing a certain amount of chemical nitrogen fertilizer protects the farmland ecological environment. The foreign experience on the farmland ecological compensation policy showed that the implementation of agricultural environment goals were also promoted by reduction of negative external effects and application of subsidies (Geiger et al., 2010; Baylisa et al., 2008).

However, what extent nitrogen fertilizers reduce for compensation is of importance. Even though the farmers reduced a considerable amount of nitrogen fertilizer on the original basis, if the final nitrogen fertilizer application amount was not sufficient to achieve the pollution control goals, this action to reduce nitrogen fertilizer was still invalid. The farmers received compensation only if they use no nitrogen or less than the optimal ecological economic nitrogen amount (that is the amount that might balance between ecological protection and economic benefits). In other words, the upper limit of compensation was the net production loss due to use no or less nitrogen fertilizers. The lower limit was the production loss caused by reduction of nitrogen fertilizer to the optimal ecological economic nitrogen application amount. As the net loss due to no or less nitrogen fertilizer use might be estimated under the normal production revenue. Therefore, how to determine optimal ecological economic nitrogen amount is the key to assess ecological compensation standard calculation.

1.2. Calculation methods and procedures

1.2.1. Determination of optimal ecological economic nitrogen amount

The optimal ecological economic nitrogen amount fertilizer is known as optimal social amount of nitrogen fertilizer. It promotes the agricultural output with reasonable growth and takes into account the farmers' economic benefits, social and ecological environment. At the same time, it leads to low environmental pollution which is not exceeding the regional environmental capacity. On the basis of the traditional agricultural production, it is modelled by bringing external costs into production costs in terms of agricultural technology economics (Lv, Cheng, 2000). Many studies (Mao et al., 1997; Zhang, Cao, 2009; Xiang et al., 2006) have employed a quadratic function on nitrogen inputs in agricultural production. Grain yield function could be built as follows:

$$Y = a + bX - cX^2$$

Where Y was grain yields; X was nitrogen inputs; a, b, c were constants (all are positive numbers). Let V be production value of grains, then V function may be built as follows:

$$V = YP$$

Where Y was grain yields; P was the price of grains. Supposed that the other input factors were fixed (their corresponding costs K were also fixed in process of grain production, the total costs of the grain production (T) might be expressed as:

$$T = K + XP_f$$

Where Pf was the price of nitrogen fertilizer, let the total Profits be W, then W could be expressed as follows:

$$W = V - T = (a + bX - cX^2)P - (K + XP_f)$$

According to the principle of Benefit Maximization and law of Diminishing Returns, when the marginal benefit equals the marginal cost, there will be the maximum benefit; when the resource inputs o-f the marginal profit is equal to zero, there will be the maximum profit, that is

$$dW / dX = bP - P_f - 2cPX$$

Let the nitrogen amount to farmers' maximum economic efficiency be X_1, then,

$$X_1 = b / 2c - P_f / 2cP = (bP - P_f) / 2cP$$

If over-application of nitrogen fertilizers resulted in ecological environment pollution and negative externality, external costs should be taken into account as a part of the total social cost of chemical fertilizers when calculated the farmer's fertilizer input costs. Considering nitrogen inputs bringing negative externalities and the welfare of whole society, nitrogen as the cost of investment in the resource elements should include the external costs. While, the marginal social cost of nitrogen fertilizer was expressed as

$$MSC = MPC + MUC + MEC$$

Where *MSC* was the marginal social cost; *MPC* represented the marginal production cost; *MUC* was the marginal utilization cost; *MEC* was the marginal external cost. On the basis of the procedures mentioned above, X_1 should be rewriting as

$$X_2 = b / 2c - (P_f + MUC + MEC) / 2cP$$

Where X_2 was the optimal ecological economic nitrogen amount. Compared X_1 and X_2, we may see, $X_1 > X_2$, and the economic interests of the farmers was damaged in accordance with the principle of decreasing returns. Therefore, in order to protect farmland ecological environment, a certain amount of economic loss compensation must be given to the farmers. This will encourage the farmers to apply nitrogen less than X_1 resulting in achieving the purpose of reducing the negative effect of the external.

Solutions of X_1 and X_2 needed to define the values of *b*, *c*, *P*, P_f, *MEC* and *MUC*. The values of *b* and *c* might be solved by regression analysis of the relationship between the chemical fertilizer application and the foodstuff yields per hectare area. *P* and P_f were the market prices of grains and nitrogen fertilizers, regarding the nitrogen fertilizers as no depletion costs (that is *MUC*=0). *MEC* needed to be determined for the solution of X_2.

1.2.2. Determination of external cost of nitrogen fertilizer application

External costs of nitrogen fertilizer application were extensively studied in China and abroad. Energy analysis was used as means by Lai Li (Lao et al., 2009) to estimate external costs of nitrogen fertilizer application, and external environmental costs of nitrogen fertilizer application. However, there was no unified standards available. Here are the steps in estimation of external cost of N fertilizer application:

(1) Nitrogen pollution classification

Pollution caused by nitrogen implication was divided into three categories, namely, air pollution, soil pollution and water pollution, and processes and environmental impacts of the various types of pollution were determined (Table 1).

(2) Environmental impacts: dose of pollutants

Doses of pollutants of nitrogen fertilizers were estimated and as follows:

$$Dose_i = M \times C \times (W_f / W_c),$$

Where $Dose_i$ was the dose of pollutant *i*; *M* was the amount of pure nitrogen; *C* was circulation coefficient of nitrogen; W_f and W_c was the molecular weight of nitrogen and the pollutant.

Circulation coefficients of nitrogen were dynamic therefore it was monitored dynamically. Values of constant C was estimated from previous published data (Zhu, Sun, 2006; Zhang et al., 2007; De Paz, Ramos, 2004) (Table 1).

(3) Quantification of Environmental impacts

Disability Adjusted Life Year method was used to quantify the environmental impact of air, soil and water, and to estimate the human health effects caused by nitrogen pollutants with the following model:

$$DALY_i = C_{di} \times Dose_i,$$

Where $DALY_i$ was the cumulative years of life damage; $Dose_i$ was the dose of pollutant *i*; and C_{di} was the life damage year caused by per kilogram pollutant and the value of C_{di} was from Eco-indictor 99 (Eco-I=indictor, 1999).

(4)Estimation of total energy cost of environmental impacts

The total energy cost of environmental impacts was the product of unit-labor energy at home and abroad and cumulative years of life damage as follows:

Table 1. Environmental impact processes and circulation coefficient C of farmland nitrogen

Pollution types	Processes	Environmental Impact	Circulation Coefficient
NH_3	NH_3 from nitrogen volatilization	Respiratory impairment	11%
N_2O	N_2O emission in the microbiological trans-formation of nitrogen in soil	Greenhouse effect, destruction of the ozone layer	0.67%
NO_X	Nitrogen oxides produced by microbial nitrification or denitrification	Destruction of the ozone layer, respiratory impairment	0.50%
Soil Pollution	Increase the nitrate content in underground water by nitrogen leaching	Soil salinization	0.50%
NO_3^-—N	NO_3^-—N enriched in surface water	Eutrophication,carcinogenic effect	2%
NH_4^+—N	NH_4^+—N enriched in surface water	Eutrophication	5%

$$U = \sum_{i=1}^{n} Energy_i = \sum_{i=1}^{n} (DALY_i \times C_m)$$

Where U was total energy costs of environmental impact of nitrogen; $Energy_i$ was energy costs of pollutant i; C_m was unit-labor energy consumption per year. Its value was 9.35× 1016sej referencing on Odium H T's research data in this paper (Odium, 1996).

(5) Conversion of comprehensive environmental costs

In accordance with energy money ratios of each year in a certain area, comprehensive environmental costs of nitrogen fertilizer application were estimated.

$$E_{rmb} = U / C_g,$$

Where E_{emb} was the macro-economic value of environmental impact of nitrogen fertilizers, C_g was energy loading per macroeconomic value (this was a ratio of energy value for a country or area in unit time and GDP). The value of C_g of Yixing City was 7.15×1011sej/yuan, which was calculated based on the energy consumption of per unit GDP published in Jiangsu Statistical Yearbook with energy conversion coefficient (Li et al., 2001) and conversion rates of solar values (Wang, Cao, 2008).

1.2.3. Ecological compensation amount

According to the discussion above, the farmers might receive the maximum compensation (that was the upper limit of compensation) if they applied no nitrogen and minimum compensation (the lower compensation) when they reduced the nitrogen to the optimal ecological economic nitrogen application amount. If the maximum compensation was Q_u, the minimum compensation was Q_l, then,

$$Q_u = P \times Y\big|_{X=X_1} - X_1 P_f = aP - \frac{bPP_f - P_f^2}{2cP}$$

$$Q_l = (P \times Y\big|_{X=X_1} - X_1 P_f) - (P \times Y\big|_{X=X_1} - X_2 P_f) = \frac{MUC + MEC}{4cP}(bP - 2bP_f - MEC - MUC)$$

1.2.4. Determination of ecological compensation standard

The farmers' willingness of reducing nitrogen and accepting compensation were used to determine the ecological compensation for nitrogen non-point pollution control from farmland via contingent valuation method. Yixing City was the typical farmland nitrogen non-point pollution scenario. A series of questionnaire was designed to survey the farmers' willingness. Determination of the ecological compensation standard was based on the answers of farmers' wishes. A measurement model was built to analyze the factors affecting the farmers' willingness.

(1) Questionnaire design

Contents of survey: ①Basic socio-economic characteristics of the surveyed farmers, including the respondents' gender, age, education level, village cadres or not, agricultural production experience, and family income, main job, and so on. These were used to analyze how socio-economic characteristics of the surveyed farmers affect their willingness of reducing nitrogen fertilizer. ② The surveyed farmers' compensation willingness of reducing nitrogen fertilizers: There was a survey study on whether the farmers are willing to reduce nitrogen fertilizer based on government compensation levels which corresponded their reducing nitrogen amount.

(2) Sampling survey and sample characteristics

After the questionnaire design modification, the survey team carried out investigation in December

2011, by randomly selecting 6 villages in Wanshi town and Zhou tie town in Yixing County. Selection of villages mainly depended upon economic situation, main types of crops, land resource endowment of the village. The farmer personal and household characteristics included sex, age, years of education, household income, the scale of farming, and the main types of work. There were 110 portions of research samples. Among them, 101 were effective, accounting for 91.8% of the total questionnaire. The research village involved, Caodong, Yu zhuang and Wanshi in Wanshi Town, Donghu, Yangxi and Tangxia in Zhou tie town.

Among the responding samples, the male accounted for 60.40% slightly more than the female. The main labor force was middle-aged and elderly who were between 40 to 70 years old, accounting for 91.19% of the total number of samples. About 79.21% of farmers responded contained more than 3 family members were. Farmer education levels were from elementary or junior high school with 29.7% primary school and 49.5% junior high school. About71.79% of farmers' annual household income were more than 20000 yuan. Non-farm families and agricultural household with more than half of the household income accounted for 74.26% and22.77%, respectively.; 95.04% of the households surveyed grew rice and wheat, of which 92.5% applied urea. Peasants with > 20-year farming experience accounting for 81.19% while 68.31% of farmers engaging in farming, and 16.83% with non-agricultural work.

(3) Factors analysis of farmers' willingness of acceptance compensation

Based on age, gender, and education level of farmers, the main types of work, the proportion of farm income of annual household income, farming experience, the scale of planting, the econometric model of *farmers' willingness of reducing nitrogen for compensation* was constructed. The significant factor of decision-making for acceptance compensation was found out.

Multi-factors comprehensively affects farmers' willingness of acceptance compensation. Farmers had only two options of willingness of acceptance compensation: Yes or No. Therefore, this paper reported the main factors of the farmers' willingness of acceptance compensation by constructing a probability model. In this probability model, the dependent variable adopt was explained as whether the farmers were willing to accept compensation. If they were, then adopt was set at 1, otherwise adopt was set at 0. There were nine independent variables, including gender(sex), age(age), education level(edu), village cadre or not(cadre), the farming number in family(numb), proportion of agricultural income(inco), planting experience(expe), farming scale(scale), and the main type of work(job). The profit model was developed as follows:

$$adopt = \alpha_0 + \alpha_1 \times sex + \alpha_2 \times age + \alpha_3 \times edu + \alpha_4 \times cadre + \alpha_5 \times numb + \alpha_6 \times inco + \alpha_7 \times expe + \alpha_8 \times scale + \alpha_9 \times job$$

2. Results and discussion

2.1. External costs of nitrogen fertilizer application

The environmental impact dose of nitrogen was calculated by using the data of used nitrogen fertilizer amount (Wuxi Statistical Yearbook, 2009). Combined with harmful factors for various types of pollutants by using Disability Adjusted Life Years method in Monograph Eco-indictor99, Yixing human health effects of nitrogen fertilizer in 2009 was estimated. Finally, combined with annual energy consumption of per worker and the ratio of energy and money every year, external costs of nitrogen application in Yixing in 2009 was estimated as 1.09×10^7yuan (Table 2). The external cost of per kilogram pure nitrogen was 1.11 yuan.

2.2. Optimal ecological economic nitrogen amount

(1) Function analysis of nitrogen amount for major food crops

Regression analysis showed that a quadratic equation well described the relation between the nitrogen fertilizer amount and the grain yields per hectare from 1993 to 2009 in Yixing. The quadratic model with the determination coefficient R^2 0.9135 was successfully developed as follows: $y=-0.0119x^2+11.423x+4183.8$ (Fig.1). This indicated that the nitrogen fertilizer application amount was highly correlated with foodstuff yields per hectare in the studied area.

(2) Optimal economic nitrogen application amount

The constants were derived from the quadratic equation. In equation (6), the solution of X_1 only determined P and P_f. Wheat and rice were two main crops in this region. Urea was the main fertilizer in Yixing. With the purchase price (P=2.083 yuan per kilogram) and total yields of rice and wheat in 2009, the average price of grains (P) and price of nitrogen fertilizer (P_f) were calculated: P= 2.08 yuan per kilogram and P_f =4.06 yuan per kilogram. Yixing's optimal economic nitrogen application amount in 2009 was estimated as 398.002 (kg/hm^2). This was close to the economic nitrogen application amount of rice and wheat in south of Jiangsu province (391.1 yuan/kg) (Zhu, Zhang, 2010). This proved that production function obtained with regression analysis could better reflect the relationship between grain yields and the amount of nitrogen fertilizers.

(3) Optimal ecological economic nitrogen application amount

Finally the optimal ecological economic nitrogen application amount in Yixing was developed as this

Table 2. Estimated environmental costs of nitrogen fertilization in Yixing City

Project	Air pollution			Soil pollution	Water Pollution	
	NH_3	N_2O	NO_X	nitrate	NO_3^-—N	NH_4^+—N
Impact dose（t）	859.1	180.9	257.73	380.46	1521.83	1104.56
Life damage years of per pollutant dose(kg/a)	5.10×10^{-5}	4.00×10^{-6}	6.79×10^{-5}	4.90×10^{-5}	3.05×10^{-5}	1.67×10^{-5}
Cumulative years of life damage（a）	43.81	0.72	17.5	18.64	46.42	18.45
Total energy（sej）	1.09×10^{19}	6.73×10^{16}	1.64×10^{18}	1.74×10^{18}	4.34×10^{18}	1.73×10^{18}
Macro-economic value（yuan）	5.73×10^{6}	9.42×10^{4}	2.29×10^{6}	2.44×10^{6}	6.07×10^{6}	2.41×10^{6}

Table 3 the parameters of the Probity Model

Explanatory Variables	Coefficient	Z Statistical Value
gender(*sex*)	0.2548	0.57
age(*age*)	-2.1244	-1.53
education level(*edu*)	0.891**	2.62
village cadre or not(*cadre*)	0.4625	0.78
the farming number in a family(*numb*)	-0.7887	-1.65
proportion of agricultural income(*inco*)	-0.3265	-0.42
planting experience(*expe*)	0.6908*	2.01
farming scale(*scale*)	0.1454	0.4
main type of work(*job*)	-0.1565	-0.45

** at 1% significance level and * at 5% significance level

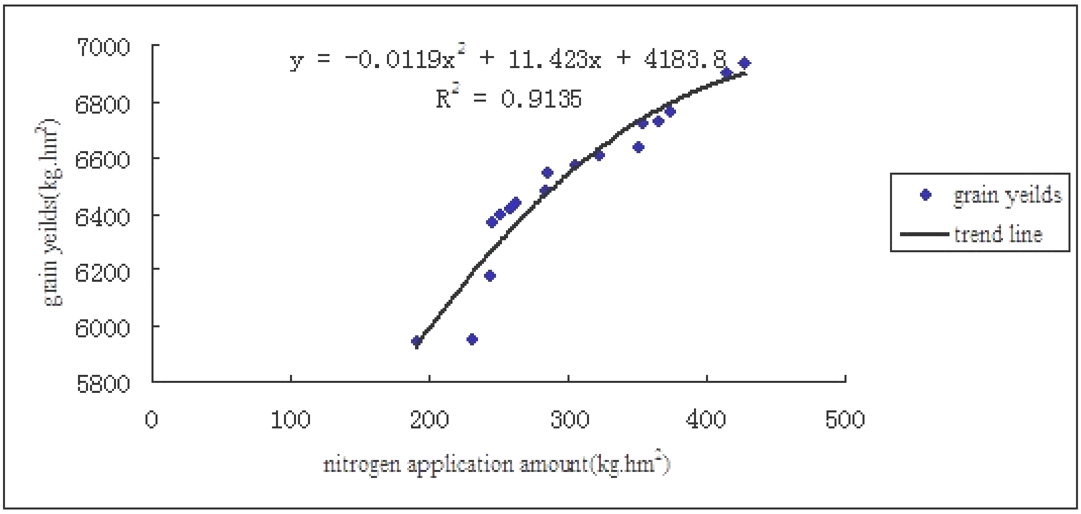

Figure 1 simulated function of grain production in Yixing city

model, $X_2=b/2c\ (P_f+MUC+MEC)/2cP$. Due to the lack of data, the nitrogen was regarded as no exhaustible resources (*MUC*=0) in this paper. Thus, Yixing's optimal ecological economic nitrogen application amount in 2009 was calculated as 375.61 kg/hm^2.

2.3. Compensation limits

With values of X_1, X_2, a, b, c, P, and P_f, values of Q_u and Q_l were calculated as Q_u 629.4 yuan/hm^2 and Q_l=7097.7 yuan/hm^2.These were the compensation limits of the farmers who participated in farmland nitrogen non-point pollution control in Yixing City (629.4～7097.7 yuan/hm^2).

2.*4. Compensation standards*

The local governments control farmland nitrogen non-point source pollution to improve regional farmland ecological environment. At same time agriculture production was not sacrificed. Thus nitrogen application amount for grain production should not be higher than the optimal ecological economic nitrogen application amount and not higher than the target amount. Local farmers were encouraged to reduce the chemical nitrogen application amount voluntarily by constructing good ecological environment – farmland in the Yixing City. Three types of limitation standards (Including the specified amount (375.61 kg/hm^2), the target amount(210 kg/hm^2) and no nitrogen application) of nitrogen were designed in questionnaire: (1) Less than the target amount (L1); (2) Less than the optimal ecological economic nitrogen application amount (L2); (3) Using manure or organic fertilizer with on chemical nitrogen fertilizer (L3). By using calculation Method of compensation limits discussed above, compensation limits in the case of L1, L2, and L3 are 1746, 620, 7098 yuan/hm^2, respectively Famers' willingness with choices of L1, L2, and L3 determined the compensation standard.

The results showed that, 68.31% of the farmers who were visited were willing to accept compensation and reduce nitrogen fertilizer. The farmers' willingness of acceptance of compensation was significantly affected by planting experiences, the farming number of a family, and education levels (Table 3). Both education level and planting experiences significantly and positively affected their willingness. These indicated that the more educated farmers became, the stronger environmental awareness towards the excessive application of nitrogen fertilizers. The more planting experience the farmers had, the more clearly the farmers' understanding the danger of the excessive nitrogen use. The net outcome was that most of farmers will not necessarily seek the higher yields with excessive nitrogen use since it would bring many negative effects such as soil salinization, compaction, and mostly nonpoint source pollution of water body, resulting in increase of production costs. About 50.72% of farmers willing to accept compensation selected L2 while 30.43% selected L1 with 18.85% L3. Since most farmers selected L2 values of compensation in L2 may be considered as Yixing's compensation standards for reducing nitrogen fertilizer. Thus, Yixing's compensation standard for farmland nitrogen non-point pollution control was set as 629.4 yuan/hm^2.

2.5. Discussion

As a public policy tool to respond to global environmental pollution, ecological compensation has become the environmental and economic policies of Western countries to protect farmland (Zhu, Zhang, 2010). Ecological compensation for agricultural pollution control compensated directly for farmers in order for their developing environmentally friendly agriculture. Compensation standard was determined by negotiation between government and farmers (Wu, Babcock, 1996; Pagiola, 2008). The basis for this compensation was that farmers receive government's compensation based on their reduction in nitrogen fertilization in achieving the optimal ecological economic amount. In this study, optimal ecological economic nitrogen application amount for Yixing City was assessed by using environmental economics and agricultural economics theory. The theoretical value of compensation margin for controlling farmland nitrogen non-point pollution in Yixing City was estimated at 620.0 yuan/hm^2. But, there was still further study required for this region. For example, high accuracy of ecological economic nitrogen application amount was based on the shadow price with the reasonable accuracy but not the market price of grains. Therefore further study on estimation of ecological economic nitrogen application amount with the market price of grains were required. In addition, many details were required to develop in the process of compensation implementation, relevant expertise with invited dynamic assessment, and constantly adjustment on the compensation standards in order to maintain the current potentials.

3. Conclusion

The successful practice of farmland nitrogen non-point source pollution control had proved that reduction of nitrogen fertilizer was one of the best strategies for controlling nitrogen non-point source pollution from the source. Implementation of ecological compensation may internalize reduction of nitrogen fertilizers. By using contingent valuation method and cost/benefit approach, the ecological compensation standards for controlling farmland nitrogen non-point pollution in Yixing City was estimated. The farmers would be compensated if they reduced the nitrogen fertilizer to the optical ecological economic nitrogen application amount. The optical ecological economic nitrogen application amount for grain production in Yixing was assessed as 375.61 kg/hm^2 and the compensation standards for farmland nitrogen non-point pollution controlling was at the rate of 620.0 yuan/hm^2 with the theoretical range of 620.0～7097.7 yuan/hm^2. About 68.31% farmers responded were willing to accept compensation to reduce nitrogen fertilizers. The farmers' willingness of accepting compensation were significantly affected by farming experiences and educational attainment.

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