Original Research

Management of Crop Rotation Fallow in Heavy Metal Contaminated Areas: Effectiveness, Influencing Factors And Verification of 'Rational Farmers' – Based on Chinese Practice

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Abstract

Significant progress has been made in environmental management since 2016, when crop rotation and fallow were introduced in heavy metal-contaminated areas. The result shows that the satisfaction of farmers with the treatment effect of heavy metal pollution and their income after crop rotation and fallow was higher. Using the cumulative logistic regression model, this paper makes an empirical study on the factors influencing of 400 households in 10 villages and towns of 4 districts and counties in Hunan Province. The results show that education level, pollution degree have positive influence on the satisfaction degree of environmental governance and income, but family income has a negative influence. Age level has positive influence on the satisfaction degree of environmental governance, but negative influence on income.

Keywords: heavy metal polluted region, crop rotation and fallowing, cumulative logistic model, rational farmers

Introduction

The General Secretary Xi Jinping underlined at the 18th CPC Central Committee at its fifth plenary session: "Sustainable development of agricultural is very important due to the soil fertility overdraft". As the CPC Central Committee's Proposal for Formulating the 13th Five-Year Plan for National Economic and Social Development adopted since 29th October of 2015 clearly point out: "A system of rotation and fallow of cultivated land should be implemented", and as notice on the issuance of an action plan for the prevention and control of soil pollution from State Council since 28th May of 2016 clearly point out: "government should clearly

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deploy experimental rotation and fallow of cultivated land" [1]. In 2016, the total experimental areas of rotation and fallow was over 10 millions acres, and this number increased to about 20 millions acres in 2017, and 39 millions acres in 2018. In the end of 2020, this number will increase to over 82 millions acres. It can be seemed that, the experimental works of rotation and fallow of cultivated in heavy metal-contaminated and ecological degradation areas have made remarkable achievement in past four years. There are some advantages at macro level, such as development of ecological effect of crop rotation and fallow of cultivated land, upgrading industrial structure and more normative management systems. However, at micro level, it is necessary to consider about the degree of local peasants' satisfaction about the heavy metal pollution treatment, and the elements which can affect their satisfaction.

Farmers are micro-entity actors to implement experimental works of rotation and fallow, they are contributors and stakeholder. Therefore, to evaluate their satisfaction of effectiveness of experimental works of crop rotation and fallow might be in reality and directly to understand satisfaction about the heavy metal pollution treatment. However, there are two different arguments to define peasants depending on their activities which might impact their evaluation to effectiveness of current environment protection. First is rational small-scale peasant, these people aims to work for maximum benefits. On the other hand, ethical small-scale peasant is more willing to focus on the security of production and life [2]. Normally, the peasants' evaluation in macro level will mainly rely on the effectiveness of environmental protection and the compensation of the fallow [3]. The elements which can impact peasants evaluation are some distinctions, it includes family, land, decision making from personality of peasant households, the relevant polities from government and the environment awareness [4-5]. The officials of village and town, agricultural technology personnel and peasant households will have different and distinct awareness and evaluation about the effectiveness of heavy metal pollution treatment [6]. Besides, some researchers has study the satisfaction of the fallow based on binary logistic regression model [7-8]. However, the satisfaction to the effectiveness of restoring and improving cultivated land in countryside contaminated by heavy metals could not simply be described as one or zero, it means binary logistic regression model might not be the most appropriate method. The field survey of this research has set four levels: very satisfied, satisfied, fairly satisfied and dissatisfied. In this way, this paper can describe the effectiveness about the implementation of environmental protection more comprehensively, and the elements which can impact peasants' evaluation to the crop rotation, fallow and the treatment of heavy metal contaminated cultivated land. This survey could specifically describe and analyze the elements which can impact peasant households attitudes about

the effectiveness of restoring and improving cultivated land in countryside contaminated by heavy metals in China. Then, it is necessary to use cumulative logistic regression model because it is an appropriate model to make quantitative analysis of multiple dependent variables, and this model can be widely used. For example, based on the cumulative Logistic model, Duan Jin studied residents' heterogeneous feelings of inflation [9], Feng Sha conducted an empirical study on the income gap and subjective well-being [10], Liu Jixin predicted the stress degree of air traffic controllers [11]. It can be seemed that, compared with binary logistic regression model, cumulative logistic regression model can bring more advantages to make quantitative analysis. So, this paper will choice cumulative logistic regression model to evaluate the degree of how the elements can impact satisfaction, then assess and verify current development of peasant consciousness.

Hunan province not only is a large agriculture province with the largest cultivable area of rice but also is a non-ferrous metals producer, this industry is harmful for agricultural ecosystem, especially for food security and it can result the heavy metal exceed the standard issues of agricultural products. Besides, Hunan province is one of the main experimental area of heavy metal pollution treatment, so there are 16474 acres of experimental works in heavy metal-contaminated and ecological degradation areas in 2016, and this number increased to 32974 acres in 2018. Besides, there are some reasons to choice Hunan as the research target of heavy metal contaminated areas. First, it can examine the effectiveness of works in heavy metal-contaminated areas by the field surveys. On the other hand, it also could provide some advice to other Chinese cities where occur any similar issues. This paper has investigated in heavy metal-contaminated areas of Hunan province from July of 2018 to July of 2019, the investigating targets include Shilong village, Qingquan village and Qunli village of Xiangtan; Bailu village and Weihan village of Changsha; Huangtuling, Ningjiaping, Hongjiazhou, Shuangwu village and Hengfeng village of Zhuzhou. Only Weihan village is not the experimental area of crop rotation and fallow works, but it is near the experimental village of crop rotation and fallow. This research mainly investigates farmers' satisfaction of crop rotation and fallow works, and surveys agricultural technology personnel of crop rotation and fallow works, village heads, Communist Party leaders of villages, representatives of farmers' cooperative, 500 peasant households.

Methods and Analysis

Model Building

There are three kinds of logistic regression: binary logistic regression, Multinomial logistic regression

and cumulative logistic regression model, it also named as sequential logistic regression, the formula is below:

$$y_j^* = \partial_j + \sum_{n=1}^{N} \beta_n X_n + \varepsilon$$

y_j^* is the internal trend of the observed phenomena, ε is an error term and subject to logistic distribution. Suppose Y has J scenarios, J = 1,2, ... , J-1. ∂j is the threshold between the two points, the intercept term, J = 1,2, ... , J-1.

$$\text{If } y^* \leq \mu_1 \text{ then } y = 1$$
$$\text{if } \mu_1 \leq y^* \leq \mu_2, \ y = 2$$
$$\text{when } \mu_{j-1} \leq y^*, \ y = j$$

So the cumulative probability of x is expressed as

$$P(y \leq j|x) = P(y^* \leq \mu_j)$$

$$= P\left(\partial_j + \sum_{n=1}^{N} \beta_n X_n + \varepsilon \leq \mu_j \right)$$

$$= F\left[\mu_j - \left(\partial_j + \sum_{n=1}^{N} \beta_n X_n \right) \right]$$

F(·) is the cumulative distribution function, if ε follows the logistic distribution.

$$P(y \leq j|x) = P\left[\mu_j - \left(\partial_j + \sum_{n=1}^{N} \beta_n X_n \right) \right]$$

$$= \frac{\exp[\mu_j - (\partial_j + \sum_{n=1}^{N} \beta_n X_n)]}{1 + \exp[\mu_j - (\partial_j + \sum_{n=1}^{N} \beta_n X_n)]}$$

After the natural logarithm Transform, we get the cumulative logistic regression

$$\ln\left(\frac{p_j}{1 - p_j} \right) = \partial_j + \sum_{n=1}^{N} \beta_n X_n$$

Data Description and Analysis

The survey includes two ways to investigate and analyses the effectiveness of crop rotation and fallow implementation. First is the survey about the satisfaction of effectiveness to heavy metal pollution treatment. Second is the satisfaction about the income after the implementation of rotation and fallow. The satisfaction survey of peasants' income mainly include the subsidies of fallow and to compare with the difference of income of works in leisure time and farming after implementation of crop rotation fallow. The satisfaction evaluation includes four levels: dissatisfied, fairly satisfied, satisfied and very satisfied. The elements which can impact evaluation of satisfaction include age, education level, family income, polluting degree of cultivated land and the concern of interviewees' extent about pollution abatement of land. It will be showed as Table 1.

Description Statistics

The survey have collected 400 valid questionnaires from total survey, it includes 54% male interviewees and 46% female interviewees account. There are 48% interviewees who are 41 to 50 years old, 26% interviewees over 50 years old, and only 26% interviewees younger than 40s. Besides, interviewees' education level is low, there are 87% interviewees only received education in secondary school. It is because peasants who had received higher education are migrate workers in city, which limits the scale of survey. In the terms of annual income, only 6% of surveyed family's annual income is more than 50000 yuan, and there are 41% family's annual income is less than 20000 yuan. The household cultivated land that is moderately

Table 1. Variable Definition, Assignment.

	Variables	Definition of Variables
Explained Variables	Y1: Satisfaction to the effectiveness of environmental governance.	dissatisfied = 1, fairly satisfied = 2, satisfied = 3, very satisfied = 4
	Y2: Satisfaction to income after the fallow and environmental governance.	dissatisfied = 1, fairly satisfied = 2, satisfied = 3, very satisfied = 4
Explaining Variables	X1: age	25-34 = 1, 35-40 = 2, 41-50 = 3, 51-60 = 4, 61-70 = 5, elder than 70 = 6
	X2: education level	uneducated = 1, primary school = 2, secondary school = 3, high school = 4, junior college and higher level = 5
	X3: income (CNY)	10000-20000 = 1, 20001-30000 = 2, 30001-50000 = 3, 50001-80000 = 4, more than80000 = 5
	X4: polluting degree of cultivated land	low = 1, fairly severe = 2, severe = 3, very severe = 4
	X5: concern of interviewees' extent about pollution abatement of land.	pay no attention = 1, sometime = 2, usually = 3, all the time = 4

polluted account 79%, and there were 79% of severe contaminated household. In terms of the effect of current environmental governance, proportion of very satisfied was 24%, satisfied was 41%, fairly satisfied was 31%. In terms of satisfaction to income after the fallow and environmental governance, proportion of very satisfied was 18%, satisfied was 32%, fairly satisfied was 41%.

Evaluation of the Effectiveness

During summer 2018 and 2019, researchers had respectively investigated crop rotation and fallow in Hunan. The result shows that the soil has been improved, and the organics in soil has increased. For example, the pH value has increased from 5.5 to 5.8, and the available cadmium content in soil has decline 20% to 30%. The manganese content in the source of water around the areas contaminated with manganese has decreased lower than the national standard for 0.1 milligram/litre, local people can start fish culture, and cancer cases drastically reduced. Besides, peasants' annual income has increased from work in leisure time due to the fallow. However, researchers has found that there were some deficiency in the crop rotation and fallow process. For example, weed infestation on some field, water conservancy facilities of paddy field were destroyed or need to maintain, compactability of soils and contradiction of water sources between users of fallow field and cultivated field, more details of analysis of the investigation and survey has been shown in the journal named 'Environmental Protection', the 12 period of 2019. As a whole, local peasant households were satisfied to the effectiveness of works in heavy metal-contaminated. In the long-term, peasants' satisfaction will continuously increasing with the environmental improvement, increasing income and the improvement of governance mechanism. The current evaluation to effectiveness of current environment protection will be shown below:

Results and Discussion

The peasants of traditional agriculture have been considered as the rational peasants by Schultz [12]. As he said when he won the Nobel Prize in Economics: Farmers around the world weigh costs and benefits against risks, all of them are economic man. Although they have different education and experiences background, and variable ways to observe, understand and react new information, but they still have entrepreneurial spirit to maximize their benefits. On the other hand, Popkin thinks that peasants are decision maker for maximum benefits when they weigh long-term and short-term benefits. So, treatment of heavy metal pollution should be concerned by peasants. Some scholars have made a point of ethical peasants that also named as modern socialized peasants who should be responsible for the stress from production, life style and social communication [13], and pay more attention to the security of production and life, and their life behavior also would be limited by subsistence ethics. In fact, the arguments of rational peasants and ethical peasants are mainly basis on their tendency claims that peasants will pay more attention to benefits while they are rich with high degree of commercialization [14]; on the other hand, the poor peasants with low degree of commercialization will focus on their livelihood. The current trend in Chinese industry are in the process of transformation between primary industry, secondary industry and tertiary industry, and the indication of agricultural modernization should be the modernization of peasants' consciousness. It means that ethical peasants should dominate the trend, and they will pay more attention to the production environment and life environment issues.

If peasants' perspectives changes, the treatment of heavy-metal and crop of rotation and fallow will be implemented more easily, and peasants would be more willing to consider about environment protection rather than more benefits. This paper aims to consider about peasants' age, education level, household income, pollution level of cultivated land, environmental awareness. The household income is the index of the request for maximum benefits, when household income increase, peasants will be more willing to identity environment protection, it means higher satisfaction, and current awareness of peasants will transfer to ethical peasants from rational peasants.

Assumption

Assumption 1: Age has a positive relationship with satisfaction of effectiveness of environmental protection, and has a negative relationship with

Table 2. Satisfaction Survey Statistics.

Evaluation to Environment Protection	Frequency	Proportion	Evaluation to Income After Environment Protection	Frequency	Proportion
1 = unsatisfied	12	3.00	1 = unsatisfied	32	8.00
2 = fairly satisfied	126	31.00	2 = fairly satisfied	166	41.00
3 = satisfied	166	41.00	3 = satisfied	130	32.00
4 = very satisfied	96	24.00	4 = very satisfied	72	18.00

satisfaction of income after the fallow. Because people will have stronger perception with the growth of age, and have stronger environmental cognition and make more positive evaluation to environmental protection. The income might decrease with the growth of age, and they will be more willing to concern about their benefits, so it will result the low satisfaction rate after the fallow.

Assumption 2: Education level have a positive relationship with satisfaction of the effectiveness of environmental protection and the satisfaction of income after the fallow. The higher level of education, the consciousness of modern socialized peasant will be stronger, these peasant also can perceive to issues more comprehensive and have better environmental cognition, and might have positive evaluation to environmental protection; higher level of education leads to higher satisfaction rate after the fallow.

Assumption 3: According to the rational peasants theory, the household income has a negative relationship with effectiveness of environmental protection and the satisfaction of income after the fallow. The reason is that the current income level of rural residents is at low stage in China. Compared with urban residents, households which have higher income now have increasing request of benefits, and have weaker awareness to the changes of environment and higher request of income after fallow. On the contrary, the households which hse lower income might be satisfied more easily. According to the modern socialized peasants theory, the household income have positive relationship with the satisfaction to the effectiveness of environmental protection and the satisfaction of the income evaluation after fallow. Because modern socialized peasants' sources of income are diversification and socialization, and the ways of production and life style are more important for them, they will be easier to access environmental protection and have better evaluation.

Assumption 4: The degree of cultivated land contamiantion has positive relationship with the satisfaction of effectiveness of environmental protection and the household income after fallow. The worse degree of cultivated land contaminationrequires stronger of environmental protection, and peasants will be easier to have better evaluation of their income and environmental protection.

Assumption 5: The degree of environmental cognition has positive relationship with effectiveness of environmental protection, and the evaluation of household income after fallow. Peasants will pay more attention to environment around them and have better environmental cognition, it can result more positive evaluation.

Results and Discussion

The result by running EVIEWS8.0, are shown in Table 3.

Model 1 is the cumulative logistic regression results of effectiveness evaluation of environmental protection, the LR statistics are 32.59. Model 2 is the cumulative logistic regression results of satisfaction of household income after environmental protection, LR statistics is 14.07. It means the regression equation is generally significant. Model 1 includes five dependent variables, and there are three dependent variables have been tested in confidence interval of 5%, and one dependent variable has been tested in confidence interval of 10%, and dependent variable X5 have not pass the test. There are five dependent variables of model 2, and two dependent variables have tested in the confidence interval of 10%, and rest of three dependent variables have been tested in confidence interval of 15%. The dependent variables X1 and X3 of Model 2 can prove the assumption 1 and 3.

Parameter X1 of the model 1 is 0.1632, and $e^{0.1632} = 1.80$, parameter X2 of model 2 is -0.1018,

Table 3. Multiple Classification Cumulative Logistic Regression Results.

Independent Variable	Model 1 (Dependent Variable: Effectiveness Evaluation of Environmental Protection)				Model 2 (Dependent Variable: Satisfaction of Household Income After Environmental Protection)			
	Coefficient	Std. Error	z-Statistic	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
X1	0.1632	0.0826	1.9756	0.0482	-0.1018	0.0788	-1.6918	0.0964
X2	0.5872	0.1134	5.1782	0.0000	0.2144	0.1086	1.9732	0.0485
X3	-0.1710	0.0785	-2.1769	0.0295	-0.1060	0.0789	-1.5446	0.1188
X4	0.2068	0.1096	1.8868	0.0592	0.1505	0.1042	1.4443	0.1486
X5	0.0266	0.0856	0.5106	0.3561	0.1309	0.0863	1.5167	0.1293
ϑ_1	-1.2696	0.6918	-1.8350	0.0665	-1.7608	0.6319	-2.7862	0.0053
ϑ_2	1.6466	0.6457	2.5501	0.0108	0.6939	0.6153	1.1276	0.2595
ϑ_3	3.5517	0.6660	5.3326	0.0000	2.2729	0.6264	3.6283	0.0003
	LR Statistics: 32.59				LR Statistics: 14.07			

and $e^{-0.1018} = 0.90$, it means peasants will have more positive evaluation of the current effectiveness of environmental protection with the growth of age, and every stage of age can increase the possibility to increase the positive evaluation. However, there was a negative relationship between age and income satisfaction. With the age increasing, the probability of income satisfaction decreased by 10%. It shows that the older you are, the more you worry about your income. It reflects that the income of rural residents are still at a low level, especially the old-age security of rural residents are worthy of attention.

The Parameter X2 of Model 1 is 0.5872, and $e^{0.5872} = 1.18$, parameter X2 of model 2 is 0.2144, and $e^{0.2144} = 1.24$. It means peasant who has higher education level can have more active evaluation of the current effectiveness of environmental protection, and every higher level of education can increase to 18% of possibility of better satisfaction degree. Education can also bring positive influence to income evaluation, and for each level of improvement in education, the possibility of income satisfaction rising to higher level will increase by 24%. It means it is necessary to develop education level of rural residents, because it can improve satisfaction of environmental protection and household income.

The Parameter X3 of Model 1 is -0.1710, and $e^{-0.1710} = 0.84$, parameter X3 of model 2 is -0.1060, and $e^{-0.1060} = 0.90$. It means peasant households who have more income will have negative evaluation to the effectiveness of environmental protection. With household income increasing, the reduced probability of environmental governance satisfaction is increased by 16%, and the reduced probability of income satisfaction is increased by 10%. It means peasants are maintaining high degree attention to their income, which is more important than environment. It also means that the idea of rational peasant is predominant, and to enhance the ethical peasant consciousness and increase income is the one of the most important issues for the rural economic development at the president.

The Parameter X4 of Model 1 is 0.2068, and $e^{0.2068} = 1.23$, parameter X4 of model 2 is 0.1505, and $e^{0.1505} = 1.16$. It means when peasants' cultivated land has been contaminated at more serious degree, their evaluation will be more positive about current effectiveness of environmental protection, and each rising degree of contamination can increase the possibility of more satisfaction of environment protection works by 23%. Besides, a more serious degree of contamination can result in more positive evaluation about the satisfaction of income, and each rising degree of contamination can increase the possibility of more satisfaction about income by 16%. It means peasant's household will have more requests about the environmental governance of contamination.

No parameters passed the test of significance test, z-statistic of model 1 and 2 are respectively are 0.5106 and 1.5167, it might include error. However, the coefficient is positive, it means the degree of environmental cognition might have positive relationship with effectiveness of environmental governance and the satisfaction about the income after fallow.

Conclusions

First, the government has made great achievement about the implementation of crop rotation and fallow on rural cultivated land and heavy metal contaminated areas, improved ecosystem and land pollution issues. The scope of the survey is limited by the fact that well-educated farmers work in the cities, but local peasants still have high degree of environmental satisfaction with 97%, and the degree of income satisfaction with 92%. With the continuous environmental protection, policy advocacy, constantly improved governance mechanism, peasants' satisfaction will continuously increase. Second, the education is one of the most important elements which can impact the satisfaction. As the result of the model shows, education degree of peasants has strong positive relationships with the satisfaction about the effectiveness of environmental protection and the income of peasants household. These data has been tested, it means peasants will have more positive evaluation and to be more willing to access and implement crop rotation and fallow of cultivated land. However, the result of survey shows that current education degree of peasant household is low, and only 13% of respondents who have access high school or better education. Certainly, the reason is that there are many well educated migrant workers from rural areas, and it was the limitation of the survey. Third, the household income can bring negative impact to the effectiveness of environmental protection and the satisfaction about the income after the rotation and fallow. It means there are many peasant households still are rational peasants in Chinese rural areas. It is concordant with the state of rural economic development that peasants have single income sources and the development of income are generality related with environmental deterioration. In addition, compared with urban residents, peasant households who have more income have increasing request about the benefits, and they will pay more attention to their own benefits than environment. So, the environmental protection of crop rotation and fallow on cultivated land might bring more influences to higher income peasant households, and lower income households might be more easily to be satisfied. Within the economic development, while the income of peasants household develop to a certain level, peasants will have more request about the environmental protection than their own benefits. Fourth, the environmental cognition level has the positive relationship with the satisfaction, and the environmental governance and relevant policy can bring positive influences to satisfaction.

First, strengthening the publicity of the policy about the governance of cultivated land contaminated by heavy metals, especially in the rural areas where have been contaminated by heavy metals, and the government needs to improve the consciousness of cultivated land protection and guild the peasant in the process of cultivated land protection. At the same time, government should publicize the result of every stages of cultivated land protection works, then peasants can understand the effectiveness of the environmental protection governance, it might be one of the most powerful way to encourage peasants to participate environmental protection works. Second, it is necessary to improve the education of Chinese peasants to develop their consciousness of ethical peasant. Although there was great improvement about higher education and vocational education in China, the rural residents who are engaged in agricultural production only have low level of education, it is one of the main reasons that hardly to develop rural economic and implement the policy which can bring benefits to peasants. As well as to motivate and encourage peasants who have access to education to return and invest in their hometown, in order to develop the local economic and education level, then to develop consciousness of ethical peasants. Third, in order to develop peasant households' income and life quality, it is necessary to change their traditional agriculture production and single income sources, and gradually change the mode of production by the cost of environmental deterioration. Then make them have the concept of ethical peasants. Finally, to develop their consciousness around their environment, government should develop the publicity and education of the environmental protection, especially for the importance of the protection of rural cultivated land, and to show the changes after the heavy metal pollution governance.

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Conflict of Interest

The authors declare no conflict of interest.

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