Differences and Influencing Factors of Pesticide and Chemical Fertilizers Application of Different Household Types:

A case study in Wuhan peri-urban area

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Abstract—**Farmers' livelihoods have different effects on farmers' inputs, farmers' production decisions, and farmers' land use behavior, that caused the difference of pesticide and chemical fertilizers application. Based on the farmers' survey data, the STIRPAT stochastic regression model and the gray relational grade were used to analyze the differences in the application of pesticide and chemical fertilizers in different livelihood types. The results show that:(1) There are significant differences in the application of pesticide and chemical fertilizers in different types, the pure agricultural type is the highest, the type one agricultural is the second highest, the non-agricultural type is the lowest.(2) Farmers' agricultural behavior has a significant effect on the application of pesticide and chemical fertilizers. With the increase of non-agricultural activities, the reduction of farmland scale, the decrease of the proportion of agricultural income, the amount of pesticide fertilizer applied by farmers is gradually reducing.(3)The influencing factors of pesticide application in different types of farmers are different. The pure agricultural type is related to the composition of household income, the type one agricultural is related to farmland scale, and the type two agricultural is related to all influencing factors.**

Keywords-livelihood type; pesticide and chemical fertilizer application; farmers; Wuhan peri-urban area

I. INTRODUCTION

China is a large agricultural country, and it is a big country of pesticide and fertilizer application[1]. In 1994, chemical fertilizer application of China was more than that of US, becoming the top one in the world[2]. In recent years, the application of pesticide and fertilizer in China has been increasing. According to *China statistical yearbook*, chemical fertilizer application in China reached 60226000 tons in 2015, accounting for about 35% of the world. And it is equivalent to the sum of the total fertilizer application in India and US. In agricultural production, chemical fertilizer as exogenous input plays a key role in promoting crop production, and it ensures the growth of agriculture and food security in China[3]. However, the increase of pesticide and fertilizer application in China has caused serious agricultural non-point source pollution and the quality problem of agricultural products[4-5].

As the most basic decision-making unit in rural areas, farmers are the main body of pesticide and fertilizer application. At present, there are a lot of researches on the application of pesticides and fertilizers. First, they analyzed the impact of agricultural technical training on farmers' fertilizer application behavior[6]. Second, they analyzed the farmers' willingness to reduce pesticide and fertilizer application and its influencing factors[7]. Third, they calculated the influencing factors of low carbon behavior of farmers based on pesticide and fertilizer application[8], and the farmland ecological compensation based on pesticide and fertilizer application[9], Fourth, they analyzed the effects of pesticide and fertilizer application on environment[10], temporal and spatial differences of pesticide fertilizer[11] , and so on.

However, most of the current studies have ignored the effects of different household types on pesticide and chemical fertilizers application. The farmer livelihood division is taking place in our country now. The farmer livelihood division effects on farmers' inputs, farmers' production decisions, and farmers' land use behaviors[12-19]. Farmer livelihood division is also likely to lead to differences in pesticide application by these factors. Therefore, analyzing differences and influencing factors of pesticide and chemical fertilizers application of different household types is the way to provide the scientific understanding of the factors affecting the application of pesticides and fertilizers, and provide scientific basis for reasonable regulation of pesticide and fertilizer application.

II. RESEARCH AREA AND DATA SOURCES

A. Research area

Wuhan city is located in the Yangtze Plain, and it is in the eastern part of the Jianghan Plain. It belongs to the humid subtropical monsoon climate zone, which with abundant rainfall, abundant sunshine, four distinct seasons, summer and winter precipitation, cool and humid climate. Meanwhile, it is the capital city of China's grain production province —— Hubei Province. The Seven parts including the center of the city and the Huangpi District, Xinzhou District, Jiangxia District, Hannan District, Caidian District, Dongxihu District Six far City Interchange constitute Wuhan peri-urban area. Peri-urban area is located near the large agricultural products consumption market and is the best area for urban residents to enjoy the leisure activities, which provides a convenient way

for farmers to choose part-time activities and is the most obvious area of farmers' livelihood division[17].

Since the reform and opening up, the rapid development of urbanization and industrialization in Wuhan, the expansion of built-up area has also brought a sharp loss of farmland. As of the end of 2014, Wuhan total area is 8494.41km^2, of which central urban area is 863km^2, built area is 552.61km^2. Convenient transportation system, higher non-agricultural income, and other factors have led to a significant differentiation of the farmers' livelihood in Wuhan peri-urban area. According to the *statistical yearbook of Wuhan*, from 2010 to 2014, the number of rural workers engaged in agriculture work in Wuhan has been reduced from 564 thousand to 499 thousand, and the number of people engaged in non-agricultural industries has increased.

B. Data sources

In order to investigate the influence of the farmers' livelihoods on the application of pesticides and fertilizers in Wuhan peri-urban area, a simple random sampling method is used in the investigation. The data used in this study are the survey data of farmers in Huangpi District, Xinzhou District, Jiangxia District, Hannan District, Caidian District, Dongxihu District in November 2015. The scale for investigation is 729 questionnaires, of which 568 are valid questionnaires, accounting for 77.9% of the total.

The contents of the survey: (1) the basic situation of rural families, including family members of age, gender, educational level, family income structure and so on;(2) the livelihood of farmers, including the main source of income, occupation orientation and so on;(3) the agricultural production of farmers, including the current farmland input costs and output benefits, the farmland scale, whether there are any farmland transfer behavior, and the application of pesticides and fertilizers, and so on.

III. THE DIFFERENCE OF PESTICIDE AND FERTILIZER APPLICATION IN DIFFERENT LIVELIHOODS

A. Classification of farmers' livelihood

Because of the advantages of location in peri-urban area, it provides convenience for farmers to choose part-time activities. Because it is located close to the large consumption of agricultural products market and as the best area for urban residents to take part in the short distance tourism and leisure activities, the farmers in peri-urban area usually choose the part-time activities to improve their living standards. The part-time activities, mainly refer to the farmers engaged in agricultural labor, at the same time some will spend spare time in non-agricultural activities, and even some family members are mainly engaged in non-agricultural work and spend spare time in agricultural work[17]. According to the difference of non-agricultural degree and the diversity of farmers' livelihood, we has combined the research results[20-22], then has divided farmers' families into four types based on the direction of household labor input (whether the labor force is engaged in non-agricultural activities or not): the pure agricultural type, the type one agricultural, the type two agricultural and the non-agricultural type (Fig. 1). The pure agricultural type family members are all engaged in agricultural activities, most of the type one agricultural family members are engaged in agricultural activities, most of the type two agricultural family members are engaged in non-agricultural activities, all the non-agricultural type are engaged in non-agricultural activities. According to the classification, in this study, 79 families are the pure agricultural type, 129 families are the type one agricultural, 260 families are the type two agricultural, and 96 families are the non-agricultural type. That is 14.0%, 22.9%, 46.1% and 17.0% of the total survey respectively.

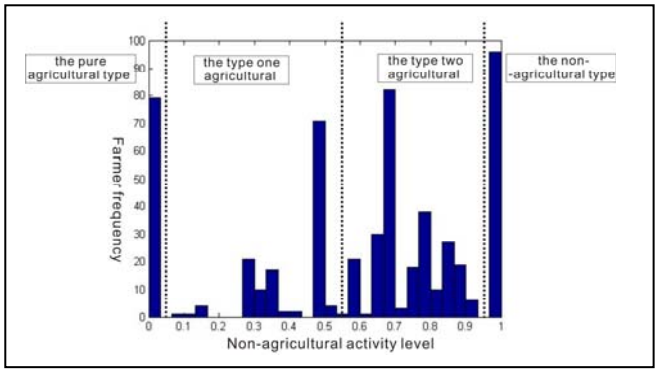

Fig. 1 Classification of Farmers

B. Characteristics of farmer's different livelihoods

There are obvious differences in the agricultural activities of farmers with different livelihood types in Wuhan peri-urban area (Table 1). Farmers who have transferred farmland account for 13.9% of the total number of households in the pure agricultural type, the average cultivated land size reached 8.4 mu, Agricultural income (agricultural income in this study includes all income related to farmland) accounted for 68.4% of total household income, the average annual agricultural income is 9476.63 yuan. The total number of the non-agricultural type is 96, all of which have not been transferred to farmland. The average cultivated land is 1.9 mu. It is mainly used for tree planting or small-scale vegetable cultivation for family demand. The proportion of agricultural income is 3.1%. The average agricultural income is only 874.19 yuan, the main source of agricultural income is from the transfer of land rent, farmland subsidies. With the increase of farmers' non-agricultural activity, the average cultivated land scale and agricultural income ratio are obviously reduced.

C. The use of fertilizer and pesticide by different livelihoods

At present, there are two kinds of measurement methods of pesticide fertilizer application —— quantity and price. Since this study is to study the application of pesticide and chemical fertilizers from the perspective of farmer's livelihood, the livelihood of farmers has the attribute of assets. In order to keep the unit of measurement, this study uses the price to measure the amount of pesticide fertilizer applied.

TABLE I. CHARACTERISTICS OF FARMER'S DIFFERENT LIVELIHOODS IN WUHAN PERI-URBAN AREA

Farmer family type	the pure agricultural type	the type one agricultural	the type two agricultural	the non-agricultural type
The number of households with farmland transfer behavior	11	12	8	0
The proportion of households with farmland transfer behavior/%	13.9	9.3	3.1	0
Average cultivated land scale/mu	8.4	5.8	5.0	1.9
Average annual agricultural income/yuan	9476.63	7396.38	5101.60	874.19
Agricultural income ratio/%	68.4	26.9	18.1	3.1

With the increase of agricultural activities, the application of pesticide fertilizer in farmland households in Wuhan peri-urban area has increased (Table 2). The pure agricultural type has the highest annual investment per acre of cultivated land, and the non-agricultural type has the lowest. Compared with the pure agricultural type, the agricultural investment of the type one agricultural has decreased by 6.9%, the type two agricultural has decreased by 22.9%, the non-agricultural type has decreased by 55.8%. It can be seen that there is little difference in the agricultural investment between the pure agricultural type and the type one agricultural, and between the type one agricultural and the type two agricultural. The turning point of change is between the two households and the non-farm households. There are obvious differences in the use of chemical fertilizers with different livelihood types in Wuhan peri-urban area.

TABLE II. THE USE OF FERTILIZER AND PESTICIDE BY DIFFERENT LIVELIHOODS IN WUHAN PERI-URBAN AREA

Farmer family type	the pure agricultural type	the type one agricultural	the type two agricultural	the non--agricultural type
Chemical fertilizer	309.3	287.0	237.2	142.1
Pesticides	209.1	205.4	167.8	95.6
Pesticide and fertilizer application	572.8	533.4	441.5	253.3

In order to further verify whether there were significant differences in the application of chemical fertilizers and pesticides in different types of households, this study carried out the independent variable t-test between the two types of farmers’. The results are as follows (Table 3).

The results showed that the difference in the application of chemical fertilizers and pesticides between the type one agricultural and the type two agricultural is rejected at the significant level of 0.15. The other two types of pesticide fertilizers were significantly different under the 0.1 significant level, and the quantitative relationship between the amount of pesticide fertilizer applied in four types: the pure agricultural type > the type one agricultural > the type two agricultural > the non-agricultural type.

TABLE III. THE RESULTS OF T - TEST OF PESTICIDE APPLICATION BY DIFFERENT LIVELIHOODS

	Original hypothesis (quantitative relation)	The value of *t*	Result
Situation 1	the pure agricultural type ≤ the type one agricultural	0.0904	Reject original hypothesis
Situation 2	the pure agricultural type ≤ the type two agricultural	0.0069	Reject original hypothesis
Situation 3	the pure agricultural type ≤ the non-agricultural type	0.0006	Reject original hypothesis
Situation 4	the type one agricultural ≤ the type two agricultural	0.1321	Reject original hypothesis
Situation 5	the type one agricultural ≤ the non-agricultural type	0.0018	Reject original hypothesis
Situation 6	the type two agricultural ≤ the non-agricultural type	0.0119	Reject original hypothesis

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IV. INFLUENCE OF LIVELIHOODS ON PESTICIDE AND FERTILIZER APPLICATION

A. STIRPAT stochastic regression model

This study used a stochastic model of environmental stress (Stochastic Impacts by Regression on Population, Affluence, and Technology, referred to STIRPAT stochastic regression model) to analyze influence of livelihoods on pesticide and fertilizer application. STIRPAT stochastic regression model refers to the impact on the environment and ecological system of the country or region (*I*) is the population (*P*) and rich (*A*) product, and supported by the specific technology of the prosperous of the (*T*) influence, its essence is the measurement of human activities on the environment impact or pressure input[23]. Based on the existing research results[24], in order to study the impact of livelihood on the energy consumption of rural households, STIRPAT random regression model was used to analyze the effects of household characteristics, income and energy availability on the household energy consumption in Zhao Xueyan’s. Combined with the actual situation of the survey area, in this study, *I* is the pesticide and fertilizer application rate of the household, *P* is expressed by the non-agricultural activities of the household, reflecting the agricultural labor force of the household; *A* is expressed by the scale of farmland, reflecting the economic assets of farmers; *T* is represented by the income structure of the household, reflecting the difference of the income of the farmer's family.

The expression of the STIRPAT stochastic regression model is usually as follows:

$$I = aP^b A^c T^d e$$

Formula: *a* is the coefficient of the model; *b*, *c*, *d* is *P*, *A* and *T* driving force index; *e* is the error term.

After taking the logarithm of the model, the original model is becoming:

$$\ln(I) = \ln a + b\ln P + c\ln A + d\ln T + \ln e$$

The advantages of the model are expressed in logarithmic: The parameters in the equation can direct response dependent variables for the independent variables of the elastic. Therefore, the driving force index (*b, c, d*) said that if other factors remain unchanged, the driving force factors (*P, A , T*)of changes in the use of pesticides and fertilizers the percentage change caused by the 1%.

B. Gray incidence degree of influencing factors

In order to determine whether there is a correlation between the selected variables (non-agricultural activities, farmland scale, the proportion of agricultural income) and the amount of pesticides and fertilizers applied to the household, the grey correlation degree is used to conduct the preliminary test. The grey correlation analysis method can identify the relationship between various factors and the development trend of the system[25], and quantitatively analyze the relationship between the amount of pesticide and chemical fertilizer and the selected variables, thus providing the basis for the selection of the influencing factors. The results of the grey correlation degree value of the factors affecting the pesticide and fertilizer application amount of farmers are shown in Table 4.

TABLE IV. GRAY INCIDENCE DEGREE OF INFLUENCING FACTORS OF FERTILIZER APPLICATION

Factor	Farmers income structure（*T*）	The scale of farmland（*A*）	The non-agricultural activity level（*P*）
Gray Incidence Degree	0.7537	0.7393	0.6437

The degree of importance of the factors affecting the use of pesticides and fertilizers was obtained by the method of grey correlation analysis, and the order of the factors was as follows: the income structure of farmers, the scale of cultivated land, the degree of non-agricultural activities. The three factors, such as the income structure of farmers, the scale of cultivated land and the degree of non-agricultural activities, have a great impact on the amount of pesticide and fertilizer application.

C. Analysis of the influence of livelihoods on pesticide and fertilizer application

Pesticide and fertilizer application is taken as the dependent variable, the degree of non-agricultural activities, the scale of cultivated land and the income structure of farmers are taken as independent variables, and the STIRPAT stochastic regression model is used to analyze the influence of livelihood on the use of pesticides and fertilizers (Table 5). The least square method is used to fit the model of farmers' livelihood and the use of pesticides and fertilizers. The goodness of fit of the model is 0.678, the F statistic is 11.95, which is significant at the level of 0.001. It is stated that the equation is fitted well.

TABLE V. THE IMPACT OF LIVELIHOOD ON THE USE OF FERTILIZER AND PESTICIDE IN WUHAN PERI-URBAN AREA

Regression model	Coefficient	standard deviation	Pr>|t|
constant	-2.34	0.58	0.0008
The non-agricultural activity level	-3.72	1.10	0.0025
The scale of farmland	0.45	0.20	0.0363
Farmers income structure	0.05	0.11	0.0636

The results showed that there is a significant negative correlation between the degree of non-agricultural activities and the amount of pesticide and fertilizer application at the 0.01 significant level, indicating that with the increase of non-agricultural activities, the amount of pesticide and fertilizer application is significantly decreased. And the non-standardized coefficient of non-agricultural activities is less than -1, which shows that the reduction rate of pesticides and fertilizers caused by the increase of non-agricultural activities is higher than that of non-agricultural activities. There is a significant positive correlation between the scale of cultivated land and the amount of pesticide and fertilizer application at the 0.05 significant level, and a significant positive correlation between the income structure of farmers and the amount of pesticide and fertilizer application at the 0.1 significant level, indicating that with the increase of the scale of cultivated land and the proportion of agricultural income, the amount of pesticide and fertilizer application is significantly is increased. But the non-standardized coefficients of the scale of cultivated land and the proportion of agricultural income are both less than 1, which show that the increment rate of pesticides and fertilizers caused by the increase of the scale of cultivated land and the proportion of agricultural income are lower than that of themselves.

D. The impact of livelihood on the use of fertilizer and pesticide by different livelihoods

Because there are significant differences in the use of pesticides and fertilizers in different types of farmers, in order to further analyze the impact of livelihood patterns on the use of pesticides and fertilizers, this study carries out a quantitative analysis of four different types of livelihoods. STIRPAT stochastic regression model is used to construct the stepwise regression of pesticide and chemical fertilizer application. The least square method is used to fit the model of farmers' livelihood and the use of pesticides and fertilizers, and the results were as follows (Table 6).

The results show that there is a significant positive correlation between the income structure of farmers and the amount of pesticide and fertilizer application in the pure agriculture type at the 0.1 significant level, indicating that with the decrease of the proportion of agricultural income, the amount of pesticide and fertilizer application is significantly decreased. For the type one agricultural, the amount of pesticide and fertilizer application is mainly related to cultivated land scale. There is a significant positive correlation between the scale of cultivated land and the amount of pesticide and fertilizer application at the 0.01 significant level. It indicates that with the increase of the scale of cultivated land,

the amount of pesticide and fertilizer application is significantly increased. But the non- standardized coefficients of the scale of cultivated land is more than 0 and less than 1, which shows that the increment rate of pesticides and fertilizers caused by the increase of the scale of cultivated land is lower than that of itself. The analysis results of the influence of the type two agricultural family livelihood on the use of pesticides and fertilizers is similar to the overall results. This shows that the proportion of the type two agricultural in Wuhan peri-urban area is the largest proportion, which is consistent with the reality. For the non-agricultural type, there is no correlation between the amount of pesticide and chemical fertilizer application and the influencing factors.

TABLE VI. THE IMPACT OF LIVELIHOOD ON THE USE OF FERTILIZER AND PESTICIDE IN WUHAN PERI-URBAN AREA BY DIFFERENT TYPES

* The significance level is0.1,* * The significance level is0.05,* * * The significance level is0.01.

Notes: Stepwise regression is used to select multicollinearity, and the significance of the variables is not high. Therefore, the number of variables in the regression model of different livelihood types of farmers is different.

Farmer family type	the pure agricultural type	the type one agricultural	the type two agricultural	the non--agricultural type
constant	6.35	5.55	3.56	4.07
The non-agricultural activity level	-	-	-4.27**	-
The scale of farmland	-	0.73***	0.45*	-
Farmers income structure	0.88**	-	0.06*	.-

V. CONCLUSION AND DISCUSSION

This study takes Wuhan peri-urban area as the research area. Based on the farmer 's survey data, the STIRPAT stochastic regression model and the gray relational grade are used to analyze the differences in the application of pesticide and chemical fertilizers in different livelihood types. The results show that:

- There are significant differences in the application of pesticide and chemical fertilizers in different types, and the quantitative relationship between the amount of pesticide fertilizer applied in four types: the pure agricultural type > the type one agricultural > the type two agricultural > the non-agricultural type.
- Farmers' agricultural behavior has a significant effect on the application of pesticide and chemical fertilizers. With the increase of non-agricultural activities, the reduction of farmland scale, the decrease of the proportion of agricultural income, the amount of pesticide fertilizer applied by farmers is gradually reducing.
- The influencing factors of pesticide application in different types are different. Because of the relative singularity of the source of income, the pure agricultural type has the highest dependency on cultivated land. Regardless of the size of farmland, this kind of farmers will increase the use of chemical fertilizers and pesticides to maximize the output. Therefore, the amount of pesticide fertilizer applied to this kind of farmers is mainly related to the income composition. For the type one agricultural, the larger the farmland scale is, the higher the opportunity cost of the choice of non-agricultural activities will be, which will lead to more agricultural activities. And also that will lead to the reduction of non-agricultural activities and the increase of the proportion of agricultural income. Therefore, the amount of pesticide fertilizer applied to this kind of farmers is mainly related to the scale of cultivated land. Due to the lack of agricultural labor time, the type two agricultural will use extensive farming. For this kind of famers, the expansion of the scale of cultivated land will increase the amount of pesticide fertilizer applied but not necessarily bring more agricultural income. Therefore, the amount of pesticide fertilizer applied to this kind of farmers is mainly related to all those impact factors.

The study on the application of pesticides and fertilizers is of great significance to the protection of cultivated land ecological environment. As the main body of pesticide and fertilizer application, famers' agricultural behavior directly affects the application of pesticides and fertilizers. In this study, the effects of different livelihoods of farmers on the use of pesticides and fertilizers are analyzed. The results show that there are significant differences in the amount of pesticide and chemical fertilizer and its influencing factors among different types of farmers. Therefore, it is necessary to pay attention to the differences of livelihood differentiation. And it is vital to analyze the farmer's agricultural behavior for different livelihood types and develop different cultivated land conservation strategies. However, what kind of specific agricultural actions can control the amount of chemical fertilizers and pesticides? How to simulate the change curve of fertilizer and pesticide application? So many questions need further study and discussion.

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