The Decreasing Use of Organic Fertilize in Rural China: the Impacts of Economic Development and Population Concentration*

Abstract

Long-term additions of organic fertilizer onto agricultural land have the most beneficial effects on grain yield, soil fertility, water preserving, and food quality. A notable fact happening in rural China is that the dominance of usage of organic fertilizer, such as human excreta, is under threat by the continuously increasing usage of chemical fertilizer, which could be considered as the result of economic growth and urbanization. Based on stratified random sampling of rural households in five provinces of China, we find that the percentage of human excreta utilized as manure is 85.2% in 2008, which is significantly decreased over the past two decades. Based on econometric analysis, We also find that economic development, population concentration as well as traffic improvement jeopardize the traditional recycling agriculture and the sustainability of the current land use systems. The results indicate that the tradition eco-friend system will gradually become a thing of the past if nothing is done to make them more profitable.

JEL classification: Q53

Keyword: Organic fertilizer; Human excreta; China

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1. Introduction

Over the past three decades, China has achieved notable progress in rural development, but to some extend, at the expense of environment. Rural development is characterized by intensive land use, rapid income growth and urbanization, which makes the traditional village agro-ecocomplex system now in the process of disintegration. Some modern strategies in agricultural resources management were basically designed to raise the production of the land-area rather than to preserve sustainable development (Ulluwishewa 1991), which brought out environmental changes on acidification of aquatic and soil systems, depletion of groundwater, and pollution of aquatic systems (Huang et al. 2008;Sonntag et al.2005). Emphasis was placed on high external input use, ignoring the limitations of the natural resource base. For example, the long-term excessive use of chemical fertilizers did not raise yields but led to heavy environment pollutions and decreased the competitiveness in the world market (Huang et al. 2010;Ju et al. 2009).

The traditional recycling of organic matters in rural China, that has sustained the land for so many generations, is now under threat as a result of economic growth and urbanization. The nature of Chinese traditional recycling agriculture is akin to ecological agriculture, which is a precious heritage for China and the whole world (Bracken et al. 2007;Li 2009). For example, excreta is recycled onto agricultural land, which has the most beneficial effects on grain yield and soil quality (Huang et al. 2010;Liu et al. 2010;Qazi et al. 2009;Schroder 2005), can partly close the nutrient cycle again and minimize artificial aids of chemical fertilizers. This age-old practice is now under threat. For the changes in patterns of fertilizer nitrogen use in Asia, approximately 2.1 Tg N (13.5% of total N applied) was from synthetic sources in 1961, and it increased to 40.2 Tg from synthetic fertilizer N (57.8% of total) in 1994 (Mosier and Zhu 2000). As for the case of human excreta, the percentage of human excreta utilizing as manure is 96% in China until 1993 (Pan et al. 1995). While in the present scenario, the percentage of human excreta recycled is also showing a downward trend mainly due to the unavailability workforce for the task.

Less recycling of the organic matters onto agricultural land was thought to be responsible for increased nitrogen leaching into the environment, which leads to changes in aquatic systems and food quality. Firstly, organic recycling is the most effective practice for controlling non-point-source (NPS) pollution, which is regarded as the dominant contributor to the degradation and eutrophication of water in China (Zhang et al. 2006;Zhu et al. 2005). As a result of decreased recycling practice, increases in nitrate leaching have led to decreased drinking water quality, eutrophication, hypoxia and decreases in aquatic plant diversity (Mosier et al. 2002). For example, due to the absence of sufficient treatment facilities such as septic tanks and sewage system in rural China, the prevalence of flush toilets in recent years induces untreated discharge of human excreta, which results in nitrogen leaching into the aquatic systems (Langergraber and Muellegger 2005). At the same time, as a consequence of less organic recycling, the artificial aids of chemical fertilizers also intensify nitration leaching into the environment (Liu et al. 2008). Secondly, there is a specific need for organic fertilizer to sustain organic farming to insure food quality. Field studies in the north China plain demonstrated that over-using of chemical fertilizer polluted food quality that chive plant samples had nitrate levels more than double the maximum permissible level (Zhen et al. 2006). The production of human food without the aids of artificial fertilizers, namely, organic farming, has become an important part of the human population's greater awareness of environmental issues.

There are still some questions about organic recycling which need to be answered. For example, how intensive is the recycling of organic matters in rural China? Is there any difference among regions? What are the determinants of household’s choice for organic recycling? Will economic development affects the decisions of households to move off the labor-intensive practice of recycling? The answers to these issues are important as they will have significant implications not only on the treatment of organic matters, but also on policy making of promoting the recycling of organic matters to preserve sustainable development.

The overall goal of this paper is to contribute to the ongoing organic recycling in rural China, in facing of the extremely rapid economic and social transition, for example, economic growth, population concentration, and traffic improvement. To examine such a broad topic, it is necessary to limit the scope of the analysis that we focus on human excreta in this paper. We collected stratified and randomly sampled data to describe human excreta treatment in China and to analyze the determinants of household's choice for recycling.

The rest of the paper is organized as follows. In the next section, we introduce the data collected by the authors in the end of 2008. Section 3 presents the descriptive statistics of human excreta treatment. Section 4 uses multivariate analysis to explain the determinants of household's choice. The final section concludes the paper.

2. Sampling and data

The data is from direct interview of heads of the various households, which come from a stratified random selected, nationally representative sample of 101 rural villages in 5 provinces. The sample provinces were randomly selected from each of China's major agro-ecological zone, which including Jiangsu (represent the rich, coastal areas in the east-south of China), Sichuan (represent the west-south of China), Shannxi (represent the west-north of China), Jilin (represent the east-north of China) and Hebei (represent the north of China)[1]. The data were collected in the end of 2008 so that we could gather information of 2008.

The next step is to select the counties, towns and villages. To accurately reflect varying income distributions within each province, one county was randomly selected from within each income quintile for the province, as measured by the gross value of industrial output. After the county selection was completed, the survey team then chose the sample townships and villages following the same procedure used in the selection of the counties. Finally, the team used village rosters to randomly choose 20 households

[1] We would like to involve more samples from the other areas, for example central China, if the foundation is sufficient.

in each village, both those with and without their residency permits (hukou) in the village. In total, 25 counties, 50 towns and 101 villages[2] were included in the survey. A total of 2020 households were surveyed. We used 1998 households in the final analysis because there were 22 households with incomplete information.

The survey team conducted two data collection activities, in which household and the village leader (or accountant) was interviewed respectively. The survey collected information on each household's activities and characteristics, for example, the participation in the human excreta recycling, general characteristics of the household, family income and agricultural production. Furthermore, we gathered detailed village information from the village leader (or accountant). The information is comprised of local conditions about economy, social, population and transportation, with which we could create a set of policy variables for the econometric analysis to measure the impacts on the recycling practice. Descriptive statistics for selected variables used in the analysis are included in Appendix A.

3. Treatment of human excreta in rural China

In this section we statistically descript the treatment of human excreta in rural China, particularly focus on regional differences and the determinants of the recycling practice. The treatment of human excreta could be categorized into three types: manure utilization[3], discharge[4] and biogas utilization. In table 1, we summarize the sharing of

[2] One more village was accidentally involved in our survey.

[3] About 0.8% sample reported more than one kind of treatment method for human excreta. In this case, we just choose the method that has the highest share.

[4] Discharge is defined as dispose to soil, septic tanks, or water body, which accounts for 47%, 27%, and 26%,

treatment in rural China, both in average and regional.

From Table 1, it can be seen that the recycling of human excreta accounted for a considerable proportion in the human excreta treatment in rural China, on the other hand, the percentage of discharge of human excreta also worth while to note. The percentage of human excreta utilized as manure is 85.2% (table 1), very close to the findings of 84.3% from a national survey involving 65,839 households, which is conducted by the National Patriotic Health Campaign Committee in 2006 and 2007 (Yao et al. 2009). It proves that our stratified random sampling can represent the situation of the whole country. The percentages of human excreta discharged and used as biogas are 11.2% and 3.6% respectively, which are both significantly increased compared to those in the early 1990's.

Our data also show the regional differences of human excreta treatment (table 1). For relatively richer households in the coastal areas, for example in Jiangsu province, the percentage of utilizing as manure is lowest (75.7%). While for the relative poorer provinces as Sichuan and Shannxi province, the percentage of excreta utilizing as manure is relatively higher (both are around 85%). But we also notice that there are exceptions, for example, the GDP of Jilin and Hebei province are higher than that of Sichuan and Shannxi, however, the percentage of utilizing as manure in Jilin and Hebei is highest (both are around 90%). We may infer that the recycling of human excreta is

respectively. The samples which discharged into septic tanks mainly come from Jiangsu province (about 95%), the rich coastal areas, where the government implemented its program of promoting toilet facility improvement in recent years. An evaluation on the treatment efficiency of "Three-Grille-Mode" septic tanks in Jiangsu (the most prevalent type of septic tanks in Jiangsu) reported that the water flowed out, which is directly discharged into rivers, fails to meet the criteria of the national standard for wastewater discharge (only reduce COD_{Cr} by 48. 51% , TN by 6. 83% and TP by 23. 92%, respectively), and its discharge will significantly affect the environment (Wang et al. 2008).

not only related to income level, but also affected by other factors. We will further analyze other determinants in the next step.

After the description of human excreta treatment in rural China, we analyze the determinants of households' recycling choice. We studied on several social and economic factors and finally focuse our analysis on three factors: economic growth (represented by per capital income of the village), population concentration (represented by the population density), and traffic conditions (represented by whether the village accessed oil (cement) road or not). We select these variables based not only on our intuitions from the field survey, but also on the following hypothesis: (1) as income increases, the opportunity cost of labor also increased, which makes the household more intend to move off the labor intensive practice of recycling; (2) the trend of population concentration accelerate the transmission of diseases and raise the operational cost in the storage and compost practice; (3) improvement on traffic condition facilitate the outside activities in daily life, such as short-distance off-farm job, which reduce the quantities of the excreta produced at home, and consequently reduce the economies of scale. The statistic description is reported in Table 2.

The percentage of excreta utilizing as manure is negatively correlated with per capita income. To demonstrate that farm households in different stages of economic development tend to have different choices, we divide the samples into income terciles (low, median, and high income subgroups). The recycling rate for households in the low-income subgroup (below 2000 Yuan per capital) is 92.6% (refer to Table 2), which is higher than the ratio for medium-income (between 2000 and 4000 Yuan per capital) and high-income (above 4000 Yuan per capital) subgroups, which is 87.6% and 76.8% respectively.

The percentage of excreta utilizing as manure also negatively correlated with population density. Households from sparsely-populated rural community are more likely to participate in the recycling practice. As the population density arises from low-density subgroup of below 0.036 hundred person/hectare, medium-density subgroup of between 0.036 and 0.082 hundred person/hectare, to high-density subgroup of above 0.082 hundred person/hectare, the percentage of human excreta utilizing as manure decreases from 88.9%, 86.7%, to 79.8% (refer to Table 2).

The recycling choice of human excreta is correlated with traffic conditions. The traditional recycling practice tends to be reserved better in the remote areas. We divide the samples into those households from villages with accessed oil (cement) road and those without. We find that households in villages with oil (cement) road have participated in the recycling practice at the rate of 79.7%, far below than that in villages without oil (cement) road, which is 93.8% (refer to Table 2).

Except for the above three factors, there are other factors, for example household characteristics, may affect the recycling choices. To further explain the determinants of the recycling choices of human excreta, we use econometric models in the next section.

4. Econometric models and estimation

In this section we explain the determinants of the recycling choices of human excreta based on multinomial logit model which is as follows:

Yi=f(Per capital income, population density, traffic condition, household characteristics, household head characteristics, dummy variables of province)

The dependent variable Yi is a discrete variable which is valued as (1,2,3), representing different choice of households, where 1 denotes manure utilization, 2 discharge, and 3 biogas utilization. The independent variables are: (1) per capital income, the average per capital income of the village in 2008; (2) population density, the village population divided by the area of the village covered5; (3) traffic conditions, whether the village accessed oil (cement) road or not (1 is yes and 0 is no); (4) household characteristics, such as planted area, including land of orchard, teagarden, mulberry field, and greenhouse in 2008, and number of family members, which defined as members that at home for above 3 months during 2008 (blood relationship is not taken into account); (5) Household head characteristics, including the age and education information of household head; (6) Dummy variables of province.

5. Results

In almost all respects, the multivariate regression analysis perform well (Table 3). The coefficients from multinomial logit can be difficult to interpret because they are relative to the base outcome. We report the marginal effect of changing each covariates value on the probability of observing an outcome. Most of the coefficients of the variables in the models have the expected sighs and are highly significant.

Although there are three types of recycling choices, we would like to focus our

5 The area included community area, planting land, woodlands, grasslands, and water face area.

interest on the choice of manure utilization and the choice of discharge, because the proportion of samples choosing biogas utilization is comparably trivial and whether household choose biogas utilization depended on the facts that whether the household was equipped with biogas facilities.

According to our simulation analysis, we may conclude that:

High income could result in less recycling and more discharge of human excreta. The income variable is significant at 1% level in both models (row 1-2, table 3). At the average income level of 3600 Yuan, for an additional 1000 Yuan of income, the probability of preferring recycling would be expected to decrease by 2.4% and the probability of preferring discharge increase by 2.1% while holding all other variables in the model constant. Households with higher income have higher opportunity cost of labor and so as more willing to move off the labor intensive practice of recycling.

Population concentration results in less recycling of human excreta. The estimation shows that population density is significant at 1% level in both models (row 3-4, table 3). At the average population density level of 10 person/ hectare, for an additional 100 person/ hectare of density, the probability of preferring recycling decreases by 7.3% and the probability of preferring discharge increases by 9.8% while holding all other variables in the model constant. In areas with high population density, the low availability of nearby arable land, together with the relatively high storage cost and high risk of diseases transmission, results in high costs for recycling.

Improvement on traffic condition also results in less recycling of human excreta. The dummy variable of whether the village accessed oil (cement) road is significant at

1% level in both models (row 5-6, table 3). If villages have oil (cement) road, the probability of preferring recycling decreases by 5.3% and the probability of preferring discharge increases by 4.6% while holding all other variables in the model constant. One interpretation is that as traffic conditions have become more convenient, the short-distance outdoor activity has increased, which reduces the quantities of the excreta produced at home, therefore hardly to achieve economies of scale. It maybe also attributed to regional social and cultural habitudes, which calls for deeper research.

Household characteristic variables, including planted area, number of family members, and education of household head are significant. Planted area is positively correlated with the recycling rate and is significant at 1% level in both models (row 7-8, table 3). At the average planted area level of 0.6 hectare, for an additional one hectare of planted area, the probability of preferring recycling increases by 5.7% and the probability to discharge decreases by 6.2%. Household with large planted area probably more relies on agricultural income and attaches more importance to the organic recycling to maintain soil fertility. The number of family members is positively correlated with recycling practice and negatively correlated with discharge practice at significance of 10% and 1% levels respectively (row 9-10, table 3). This is because the number of family members has impact on economies of scale of the recycling practice. The year of the education of household head is negatively correlated with recycling practice and positively correlated with discharge practice at significance of 5% levels in both models (row 11-12, table 3). This may be attributed to the education system, which highlights the potential risk of disease transmitting of excreta recycling but neglects the important relationship between organic recycling and sustainable development.

6. Conclusions

In this paper, we used human excreta recycling in China as an example to illustrate the linkage between economic development and organic recycling in developing countries. The traditional eco-friendly practice of organic recycling, that has sustained the land for so many generations, is also potential for moderating the increase in reactive nitrogen and its impacts on the environment. But it is now under threat that the percentage of human excreta utilizing as manure is 85.2% in rural China, which is significantly decreased over the past two decades. Economic prosperity, population concentration, and traffic improvement have significant negative effects on the recycling of human excreta.

The results indicate that the tradition organic recycling practice will gradually become a thing of the past if nothing is done to make them more profitable. As demonstrated in this study, economic development and urbanization lead to less recycling of human excreta onto agricultural land. These changes would continue since it is commonly assumed that China would be able to maintain high economic growth and urbanization in the future. As a consequent, manure utilization will decrease further as chemical fertilizer use increases.

Looking into the past may point the way to a sustainable future that organic recycling within communities requires reconsideration. Traditional knowledge needs to be combined with modern scientific know-how to make this practice safer and more acceptable (Oinam et al. 2008). It is also very important to use the economical incentives to motive the farmers to implement the eco-friend technology measures, to coordinate the contradiction between the environment and the economy. For example a subsidy for recycling domestic manure and utilizing compost has the most significant effect on the reduction of nitrogen runoff without reducing household income (Zhang et al. 2006).

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Table 1. Human excreta treatment in rural China, 2008.

	Sample	Percentage of human excreta treatment in rural China (%)			
		Manure utilization	Discharge	Biogas utilization	Total
Average	2004	85.2	11.2	3.6	100
Jiangsu	392	75.7	23.5	0.8	100
Sichuan	395	86.1	4.0	9.9	100
Shannxi	409	85.1	10.0	4.9	100
Jilin	414	89.9	9.9	0.2	100
Hebei	394	88.8	8.6	2.6	100

Sources: Authors' 2008 survey.

Table 2. Relation between human excreta treatment and some related factors, 2008.

	Sample	Percentage of human excreta treatment in rural China (%)			
		Manure utilization	Discharge	Biogas utilization	Total
Average per capital income (thousand yuan)					
<=2	592	92.6	4.9	2.5	100
2-4	688	87.6	7.3	5.1	100
>4	724	76.8	20.0	3.2	100
Population density (hundred person/ha)					
<=0.036	686	88.9	8.3	2.8	100
0.036-0.083	655	86.7	9.6	3.7	100
>0.082	663	79.8	15.7	4.5	100
whether the village accessed oil (cement) road					
No	1229	93.8	3.9	2.3	100
Yes	775	79.7	15.8	4.5	100

Sources: Authors' 2009 survey.

Table 3. Multinomial logit estimates of the impact on human excreta treatment in rural China, 2008.

	Manure utilization	Discharge
Average per capital income (thousand yuan)	-2.4	2.1
	[6.78]***	[6.61]***
Population density (hundred person/ha)	-7.3	9.8
	[2.89]***	[5.36]***
whether the village accessed oil (cement) road	-5.3	4.6
	[3.80]***	[3.58]***
Planted area (ha)	5.7	-6.2
	[4.72]***	[5.24]***
Number of family members	0.6	-0.9
	[1.68]*	[2.81]***
Household head's age (years)	0.1	0
	[1.33]	[0.57]
Household head's education (years)	-0.4	0. 3
	[2.47]**	[1.96]**
Jiangsu	5.2	-2.1
	[2.79]***	[1.48]
Sichuan	7.5	9.8
	[3.72]***	[5.28]***
Shannxi	-1.2	0. 2
	[0.64]	[0.12]
Jilin	6.6	-1.6
	[3.37]***	[1.06]
Number of observations	2004	2004

Note: the symbols * and ** indicate statistical significance at the 10% and 5% levels, respectively. Figures in parentheses are standard errors.

Appendix Table 1. Summary of all variables used in regression analysis in Table 3.

Variable	Mean	Standard deviation
Share of human excreta treatment (%)		
Manure utilization	85.2	35.5
Discharge	11.2	31.5
Biogas utilization	3.6	18.7
Village characteristics		
Average per capital income (thousand yuan)	3.6	2.0
Population density (hundred person/ha)	0.1	0.2
Whether the village accessed oil (cement) road	0.6	0.5
Household characteristics		
Number of family members	4.2	1.6
Planted area (ha)	0.6	0.8
Household head's age (years)	51.3	10.4
Household head's education (years)	7.1	3.4

Note total sample size is 2004.

Sources: Authors' 2009 survey.