Information Acquisition and Conservation Farming Practices for Sustainable Agriculture in Rural Vietnam

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ABSTRACT

Soil fertility conservation has become an increasing concern in Vietnamese agriculture owing to excessive use of agrochemicals. The use of organic fertilizers is considered an environment-friendly practice for sustainable agriculture. Although environmental awareness has emerged and production technologies of organic fertilizers have been introduced in recent years, their adoption remains limited among farming households. This study focuses on the causal effects of information acquisition on the use of organic fertilizers from agricultural extension services and from peers of farming households. The estimation results show that land size, land tenure, educational level, family labor endowment, and household wealth are significantly associated with the likelihood of using organic fertilizers. Information acquisition through both information sources positively affects the use of organic fertilizers. However, information acquisition from agricultural extension services has a greater marginal impact than that from peers. Despite its lower influence, information acquisition from peers plays a supplemental role in incentivizing farming households to use organic fertilizers as an environment-friendly agricultural practice among rural communities in Vietnam.

Keywords: information acquisition, sustainable agriculture, organic fertilizers, information channels, Vietnam

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INTRODUCTION

Agriculture is a traditional and important economic sector in Vietnam. Despite a remarkable growth in productivity (World Bank 2016), the prolonged use of chemical fertilizers can harm the biological properties of the soil through the contamination of chemical residuals, and results in land degradation in the long term. Since 1986, application of chemical fertilizers has tripled (Pham and Smith 2013). The consequent land degradation has led to persistent declines in production capacity in Vietnam (Vu et al. 2014). The proportion of organic matter, a critical element for improving soil quality, is lower than tropical standards (Dang and Klinnert 2001; Wambeke 1992). Therefore, national and local governments approved the use of organic fertilizers as a conservation farming practice for sustainable agriculture to provide organic matter and reduce soil erosion (Bernal et al. 2017; Reganold, Elliot, and Unger 1987). However, the increase in using organic fertilizers has been relatively slow, spontaneous, and fragmented in farming households, making it necessary to identify the incentives for and constraints to the uptake.

The first objective of this study is to explore the factors associated with the use of organic fertilizers for sustainable agriculture. Previous works have devoted extensive efforts to explore the determinants of adopting conservation farming practices for sustainable agriculture. The agro-ecological and climatic environment is considered the primary determinant (Lahmar et al. 2007) in which farmers in regions with erosion vulnerability or high rainfall variability are more likely to employ soil conservation practices to mitigate land degradation (Arslan et al. 2014; Mazvimavi and Twomlow 2009; Paudel and Thapa 2004). Farmers may ignore the recommendations for sustainable agricultural practices owing to technological complexity, productivity uncertainty, or unstable profits (Feder and Umali 1993; Ghadim and Pannell 1999; Lahmar et al. 2007).

Land security, farmland size, and location also influence farmers' decision to invest in sustainable agricultural practices, such as conservation tillage, legume intercropping, improved seeds, and animal manure (Kassie et al. 2013; Marenya and Barrett 2007). On the other hand, the adoption of integrated soil management, including agroforestry, stone terraces, and soil bunds, is constrained by limited household resources. However, families with many workers, higher educational attainments, and more wealth and social capital are more likely to adopt different components of land quality enhancement (Hagos and Holden 2006; Marenya and Barrett 2007; Wossen, Berger, and Falco 2015).

Other factors, such as personal perceptions, preferences, and managerial abilities, also influence the adoption decision variously (Ghadim and Pannell 1999). However, there is insufficient research on the factors associated with the use of organic fertilizers. Identifying the underlying mechanism in using organic fertilizers is expected to help policymakers identify suitable incentives to increase the use of such fertilizers.

The second objective of this study is to estimate the causal effects of information acquisition from agricultural extension services and from peer farmers, including relatives, neighbors, and friends, on the use of organic fertilizers as a conservation farming practice, which has not been paid much attention in the literature. An information barrier about the environmental benefits and technological nature of the fertilizers hampers policymakers' identification of effective mechanisms for scaling up the adoption of sustainable agricultural practices (Lahmar et al. 2007). Thus, this study explores effective information channels in reducing information barriers and diffusing the conservation agricultural techniques among farming households by examining the relative importance of information acquisition from key information sources.

Typically, Vietnamese households obtain information about agricultural activities through two principal information sources: agricultural extension services and peers of farming households. Vietnam's agricultural extension system, established in 1993, is an official unit of the Ministry of Agriculture and Rural Development. Its agricultural extension aims to

provide formal education, training, and advice about agricultural technology through periodic visits and meetings with the local farmers. Farmers also get information from their peers, including their relatives, neighbors, and friends. This study aims to measure the causal impacts of information acquisition on the use of organic fertilizers through these information pathways.

Previous studies have offered various perspectives on learning effects for the diffusion of agricultural practices (Maertens and Barrett 2013; Rogers 1995; Takahashi, Muraoka, and Otsuka 2020). However, most of these addressed information acquisition through formal and informal channels separately, and the role of information acquisition in the use of organic fertilizers for environmental benefits is relatively unexplored. In terms of information from formal interventions, the access to agricultural extension services and training positively influenced smallholders to adopt soil conservation and fertility management packages in some Southeast Asian countries (Dalton et al. 2011; Thanh and Yapwattanaphun 2015). In addition, smallholders in Tanzania were also encouraged to invest in interrelated sustainable agricultural practices (Kassie et al. 2013).

Group membership supported organic farming adoption in Thailand (Thapa and Rattanasuteerakul 2011) while institutional support considerably influenced the adoption of different conservation farming techniques in Zimbabwe (Mazvimavi and Twomlow 2009). These studies suggest that organizational support through formal interventions plays a pioneering role in convincing farmers to become familiar with conservation agricultural practices. In terms of information from peers, a large body of literature revealed the positive effect of peers in which farmers' adoption behavior is determined also by other farmers' adoption behavior (Foster and Rosenzweig 1995; Liverpool-Tasie and Winter-Nelson 2012; Mekonnen, Gerber, and Matz 2018; Van den Broeck and Dercon 2011). Acquiring information from neighbors reduced imperfect management of knowledge and increased the adoption of high-yielding varieties in India (Foster and Rosenzweig 1995). Social communication motivated the farmers to adjust the number of inputs to achieve ultimate outcomes in Ghana (Conley and Udry 2010). In Tanzania, social interactions acted as active facilitators for information flows and helped farmers adopt several techniques to increase their output (Van den Broeck and Dercon 2011). Therefore, learning from peers is evident in the diffusion of agricultural innovations.

Although the number is increasing, only a few studies have incorporated the relative importance of information acquisition from both formal organizations and informal peers in the adoption of conservation farming practices. Recent studies in Africa show that information dissemination by farmers can be as effective as the initial training from agricultural extension services (Nakano et al. 2018; Takahashi, Mano, and Otsuka 2019). Others in Asia verify the role of learning from agricultural extension in the early adoption period and learning from peers later (Krishnan and Patnam 2014; Le, Shimamura, and Yamada 2020). After learning from extension, farmers are likely to be convinced by peers who share comparable agricultural conditions (Benyishay and Mobarak 2019). Agricultural techniques in these studies, however, aimed at merely boosting productivity rather than environmental conservation. Information acquisition and the adoption of conservation farming practices have not received as much attention in the literature.

This study makes two crucial contributions. First, it explores a wide range of household and land characteristics as contributing factors to the use of organic fertilizers. Second, it is the first to examine the relative importance of information acquisition through both formal and informal channels specifically on the regular use of organic fertilizers as a sustainable agricultural practice in Vietnam.

BACKGROUND

The Use of Organic Fertilizers in Vietnam

Using organic fertilizers can involve either traditional or innovative practices. In recent years, some rural villages in Vietnam have received technical updates in organic fertilizer production, including raw material choice, the types of effective microorganisms, and composting operations.

Farmers can select a variety of raw materials for organic fertilizers, such as animal manure, crop residuals, and food wastes. Several effective microorganisms are added to effectively support the fermentation process. Instructions for composting operations are given to process organic fertilizers appropriately. These techniques help farmers take advantage of the available resources in farming households and enhance the quality of organic fertilizers.

Key Information Channels of Agricultural Technology in Rural Vietnam

Although environmental awareness has emerged and production technologies of organic fertilizers have been introduced, insufficient knowledge and information barriers may limit their adoption by farming households. Since using organic fertilizers can be knowledge-intensive and requires technical understanding, the dissemination of technology may be difficult in the absence of credible information sources. Information acquisition through different information sources can be a factor in the diffusion of agricultural technology. Typically, farmers can learn about general agricultural technology by acquiring information from formal organizations, such as agricultural extension, and/or through mutual discussions among peer farmers.

Directed by the government and based on farmers' needs, the principles of agricultural extension aim at promoting information dissemination, providing education and demonstrative training, implementing consulting services, and developing collaboration among farmers (Hoang, Castella, and Novosad 2006). Farmers can obtain information about the updates of farming techniques from agricultural extension services through demonstrative training. Despite reform efforts however, agricultural extension has faced the key challenges of a shortage in the quality and quantity of human resources, as well as weak coordination among related stakeholders especially in recent years.

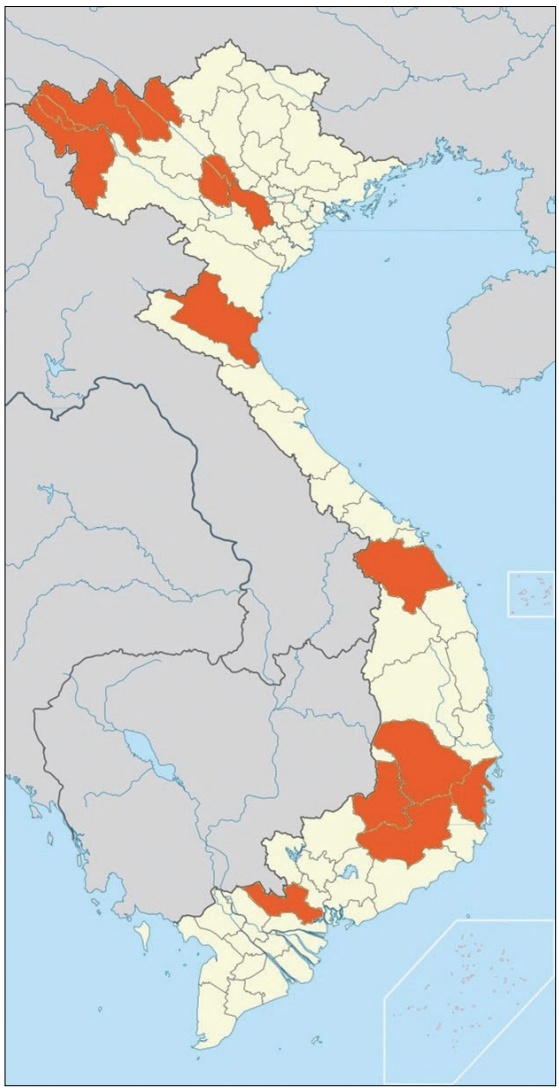
In addition to formal sources, farmers can acquire information about the updates of farming techniques from their peers. Information exchange among peers could be considered another learning pathway for local farmers to receive information on agricultural technology (Pratiwi and Suzuki 2017). When information dissemination to villagers from formal information sources is limited because of resource constraints (Anderson and Feder 2004), farmers can further seek agricultural advice from other reliable agents to make appropriate production decisions. Hence, it is necessary to compare the causal effects of information acquisition from agricultural extension services and from peers of farming households to evaluate the relative efficiency of these channels in diffusing environment-friendly practices toward sustainable agriculture.

DATA AND METHODOLOGY

Data

This study employs the dataset of the Vietnam Access to Resources Household Survey 2012, implemented by the United Nations University World Institute for Development Economics Research (i.e., UNU-WIDER) project on structural transformation and inclusive growth in Vietnam. The survey covers 3,704 households from the rural regions of 12 provinces from the northern, central, and southern regions of Vietnam (see Figure 1). For the analysis, the sample size was confined to 2,901 households that met the criterion of having cultivated at least one crop on at least one plot in the past 12 months. The surveyed provinces were classified into three groups based on topography: upland provinces, delta provinces, and coastal provinces, reflecting the variation of

Figure 1. Map of surveyed provinces in Vietnam



Source: UNU-WIDER (2015)

agro-ecological features. In the sample, 62.0, 21.3, and 16.7 percent of the households were in the upland, delta, and coastal provinces, respectively.

Table 1 describes the use rates of fertilizers in four categories: (1) purely chemical, (2) combined organic and chemical, (3) purely organic, and (4) no fertilizers. The users of combined organic and chemical fertilizers and purely chemical fertilizers make up the biggest proportions of the sample. Chemical fertilizers are largely used by more than 90 percent of the sample and purely chemical fertilizers' users account for 40.3 percent. Organic fertilizers are applied with or without chemical fertilizers. Organic fertilizers have lower adoption rates than chemical fertilizers, ranging from 52.0 percent in the upland regions, 53.6 percent in the delta regions, and 59.9 percent in the coastal regions. Among the four categories, most users adopt combined organic and chemical fertilizers, whereas only a few users choose purely organic fertilizers. Combined fertilizers are used mostly in coastal provinces, whereas purely organic fertilizers are used mostly in upland provinces.

Table 2 illustrates the acquisition of information about the use of fertilizers of the sampled farming households. The acquisition rates were defined by the percentages of households receiving information on the use of fertilizers.[1] The evaluation rates were defined by the percentages of households that consider agricultural information to be important regardless of whether they actually receive information on fertilizers.[2] Overall, an average of 35.8 percent of farmers receive information on fertilizers from agricultural extension services, whereas 17.4 percent of farmers acquire information from relatives, neighbors, and friends. The difference between the two channels shows the traditional and formal bridging by agricultural extension between the government and local farmers in rural villages. This is generally understandable, as Vietnam has transitioned from a

[1] The original question for the acquisition of information on fertilizers was "Has your household obtained information on the following topics in the last 12 months?" Two information channels were selected: agricultural extension; and relatives, neighbors, and friends. The selected information topic was: use of fertilizers.

[2] The original question for the evaluation of agricultural information was "Which sources of information are important to your household, regarding the following issues?" Two sources of information were selected: agricultural extension; and relatives, neighbors, and friends. The selected information topic was: agricultural production.

Table 1. Use rates of organic and chemical fertilizers

Fertilizer categories	Number of Households	No Fertilizers (%)	Purely Organic (%)	Combined Organic and Chemical (%)	Purely Chemical (%)	All (%)
All	2,901	6.1	3.3	50.3	40.3	100
Upland provinces	1,800	8.1	4.6	47.4	39.9	100
Delta provinces	618	2.1	0.2	53.4	44.3	100
Coastal provinces	483	3.7	2.5	57.4	36.4	100

Table 2. Information acquisition from different information channels about the use of fertilizers

Information Channels	Number of Households	From Agricultural Extension Services		From Relatives, Neighbors, and Friends	
		Acquisition rates of information on fertilizers (%)	Evaluation rates for information's importance (%)	Acquisition rates of information on fertilizers (%)	Evaluation rates for information's importance (%)
All	2,901	35.8	42.8	17.4	65.8
Upland provinces	1,800	36.4	42.8	19.6	70.9
Delta provinces	618	32.4	37.1	18.9	58.6
Coastal provinces	483	38.3	50.1	14.2	54.2

Note: Acquisition rate is the percentage of households receiving information on the use of fertilizers. Evaluation rate is the percentage of households that evaluates agricultural information as important for their households regardless of the actual received.

centrally planned economy to a socialist-oriented market economy.

There is no significant difference in information acquisition rates by topographic region. Despite lower coverage, evaluation of information flows from relatives, neighbors, and friends are noticeably higher. The difference between the two channels concerning the evaluation of the importance of the information may indicate the perceived higher reliability of peers' advice than organization-based information. The higher reliability assigned to peers' information is understandable, as these relationships are established based on kinship, neighborhood, and friendship and involve mutual understanding and trust. These findings about the role of information flow through agricultural extension services and peer farmers in disseminating new technologies are consistent with existing literature (Krishnan and Patnam 2014; Rogers 1995; Takahashi, Mano, and Otsuka 2019).

To explore the factors associated with fertilizer choice, several farmland attributes and household characteristics are analyzed, as described in tables 3 and 4. The farmland attributes include land size, distance from farmland to home, irrigation status, land security, land erosion, and crop diversification. Land size and crop diversification denote the production scale of the households. As the tables show, annual crops are planted on greater land sizes and are more diversified than perennial crops. Vegetables and other annual crops are commonly planted around home gardens, while rice fields and perennial crops with larger land areas are located further away from the farmers' houses. The distance from the farmland to home is important when farmers carry inputs to their farmland. Moreover, irrigation coverage can be correlated with the adoption of soil conservation. Irrigation systems are widely accessible to 71 percent of the sampled households.

Table 3. Variable definition

Variable	Definition
Acquisition of fertilizer information	
From agricultural extension services	1 if households acquire fertilizer information from agricultural extension services; 0 otherwise.
From relatives, neighbors, and friends	1 if households acquire fertilizer information from relatives, neighbors, and friends; 0 otherwise.
Evaluation of information's importance	
From agricultural extension services	1 if households evaluate agricultural information from agricultural extension services as important; 0 otherwise.
From relatives, neighbors, and friends	1 if households evaluate agricultural information from relatives, neighbors, and friends as important; 0 otherwise.
Farmland attributes	
Land area of annual crops	Total land area of annual crops (ha)
Number of annual crops	Number of annual crops
Land area of perennial crops	Total land area of perennial crops (ha)
Number of perennial crops	Number of perennial crops
Distance from farmland to home	Average distance from cropping land to home (km)
Land erosion	1 if land has erosion; 0 otherwise
Land tenure	1 if there is a Red Book certificate for land; 0 if otherwise
Irrigation status	1 if land is irrigated; 0 otherwise
Household characteristics	
Educational level of household head	Schooling years of household head (year)
Number of family labor	Number of family laborers (person)
Food expenditure per capita	Food expenditure per capita (million VND)
Distance from home to main roads	Geographic distance from home to main roads (km)

Land allocation from state-owned to household-managed status with legal use rights broaden opportunities for smallholders to carry out production in Vietnam. Land security, denoted by ownership of a Red Book certificate (the legal document for land-use rights of landholders), is expected to be associated with fertility investment. The Red Book certificates are held by 63 percent of the sample. Household characteristics consist of educational level of the household head, number of family workers, food expenditure per capita, and geographic distance from home to main roads. Well-educated farmers comprehend the long-term environmental benefits and production technologies of organic fertilizers, and education thus can be associated with the probability of organic fertilizer use. In the sample, household heads had an average of 6.2 schooling years.

As the use of organic fertilizers can be labor and resource-intensive, labor and wealth conditions are relevant factors while deciding whether to invest in organic fertilizers. In this study, each household has an average of three family agricultural workers, and most of the heads and spouses are farmers. The annual food expenditure per capita is 3.9 million Vietnamese dong (VND),[3] which is lower than the average national level, and this suggests that the sample has little wealth. The geographic location from home to the nearest main roads refers to the connectedness of the households with the centers. The households reside on average 3.2 km from the nearest main roads.

[3] USD 1 = VND 23,053 (https://www.bloomberg.com/quote/USDVND:CUR)

Table 4. Statistical description

	Mean	S.D.	Min	Max
Acquisition of fertilizer information				
From agricultural extension services	0.36	0.48	0	1.00
From relatives, neighbors, and friends	0.17	0.38	0	1.00
Evaluation of information's importance				
From agricultural extension services	0.43	0.39	0	1.00
From relatives, neighbors, and friends	0.66	0.47	0	1.00
Farmland attributes				
Land area of annual crops (ha)	0.63	0.80	0	8.20
Number of annual crops	1.96	1.19	0	9.00
Land area of perennial crops (ha)	0.26	0.64	0	6.70
Number of perennial crops	0.57	0.84	0	10.00
Distance from farmland to home (km)	1.61	1.57	0	15.00
Land erosion	0.08	0.24	0	1.00
Land tenure	0.63	0.43	0	1.00
Irrigation status	0.71	0.37	0	1.00
Household characteristics				
Education level of household head (year)	6.17	3.88	0	16.00
Number of family labor (person)	2.93	1.38	1.00	10.00
Food expenditure per capita (million VND)	3.90	0.28	0.50	25.76
Distance from home to main roads (km)	3.24	6.50	0	48.00

Methodology

Fertilizer choice

This study employed a multinomial probit regression model to investigate the factors associated with the use of different categories of fertilizers as follows:

$$Y_i = arg\ max\, Y_i^j \ (j=1,2,3,4) \quad (1)$$

with latent variables: $Y_i^{j*} = \alpha_{0j} + \alpha_{1j} I_{1i} + \alpha_{2j} I_{2i} + X_{1i} \alpha_{3j} + X_{2i} \alpha_{4j} + \varepsilon_{ij}$,

where j denotes four categories of choice (no fertilizers, purely chemical, combined chemical and organic, and purely organic) used by household i and each category is defined as a mutually exclusive group. Y_i^j denotes whether household i uses fertilizers' category j, and latent variable Y_i^{j*} is assumed to be a linear combination with observed explanatory variables. I_{1i} is a binary variable representing whether household i acquires information on the use of fertilizers from the agricultural extension service. I_{2i} is a binary variable representing whether the household i acquires information on the use of fertilizers from relatives, neighbors, and friends. X_{1i} is a set of farmland attributes of household i. X_{2i} is a set of household characteristics of household i. Lastly, ε_{ij} are error terms assumed to be jointly normally distributed. Equation (1) investigates the factors such as information acquisition from agricultural extension services and from peers, farmland attributes, and household characteristics that are associated with the probability of using different fertilizer categories.

Causal effects of information acquisition from agricultural extension services and from peers on the use of organic fertilizers

The causal effects of information acquisition from agricultural extension services and that from peers on the use of organic fertilizers of households are examined more rigorously by estimating the following equation:

$$Pr\,(OF_i = 1 \mid I_{1i}, I_{2i}, X_{1i}, X_{2i}) = Pr(OF_i^* > 0) \qquad (2)$$

with latent variable: $OF_i^* = \lambda_0 + \lambda_1 I_{1i} + \lambda_2 I_{2i} + X_{1i} \lambda_3 + X_{2i} \lambda_4 + \eta_i$,

where OF_i is a binary variable representing whether household i uses organic fertilizers and η_i is an error term assumed to be normally distributed. The OF_i takes 1 for both the users of mixed organic and chemical fertilizers and purely organic fertilizers and 0 otherwise. Parameters λ_1 and λ_2 are of interest to identify the relative importance of acquiring information from agricultural extension services and from peers in using organic fertilizers.

An empirical challenge may arise because of the endogenous problem of information acquisition from omitted variables. Unobserved characteristics, such as personal attitudes, individual perceptions, and preferences of farming households, could affect their information acquisition behavior and make the variables of information acquisition endogenous. Therefore, IV-probit regression is employed to estimate the causal effects of information acquisition from agricultural extension services and that from peers on using organic fertilizers. For each information channel, the instrumental variables Z_i are the average evaluation rates for the importance of agricultural information of commune aggregates excluding the considered household (Krishnan and Patnam 2014; Songsermsawas et al. 2016).

The commune is the lowest administrative unit in Vietnam's rural structure. The evaluation of the importance of information coming from surrounding households within communes is expected to influence the information acquisition of sampled households and drive their fertilizer choice, Cov $(Z_i, I_i) \neq 0$. Instruments are assumed to be strictly exogenous to the error term of the model of organic fertilizer adoption, Cov $(Z_i, \eta_i) = 0$. To check the validity of the instruments, the first-stage equations are expressed as follows:

$$Pr\,(I_{1i} = 1 \mid X_{1i}, X_{2i}, Z_{1i}, Z_{2i}) = Pr\,(I_{1i}^* > 0) \qquad (3)$$

with latent variable: $I_{1i}^* = \beta_0 + X_{1i} \beta_1 + X_{2i} \beta_2 + \beta_3 Z_{1i} + \beta_4 Z_{2i} + u_i$,

$$Pr\,(I_{2i} = 1 \mid X_{1i}, X_{2i}, Z_{1i}, Z_{2i}) = Pr\,(I_{2i}^* > 0) \qquad (4)$$

with latent variable: $I_{2i}^* = \delta_0 + X_{1i} \delta_1 + X_{2i} \delta_2 + \delta_3 Z_{1i} + \delta_3 Z_{2i} + \theta_i$,

where Z_{1i} denotes the average evaluation rates for the importance of agricultural information from agricultural extension services of commune aggregates excluding the considered household i; Z_{2i} denotes the average evaluation rates for the importance of agricultural information from peers (relatives, neighbors, and friends) of commune aggregates excluding the considered household i; and u_i, θ_i are error terms assumed to be jointly normally distributed. After we confirm that these first-stage equations satisfy the condition of significant correlation between Z_{1i} and I_{1i}, as well as Z_{2i} and I_{2i}, equation (2) is estimated under the assumption that all error terms are assumed to be jointly normally distributed.

RESULTS AND DISCUSSION

Correlates of Fertilizer Choice

Table 5 illustrates the factors associated with the choice of different fertilizer categories. There are four fertilizer categories: no fertilizers, purely organic, combined chemical and organic, and purely chemical. Information acquisition through both channels is significantly correlated with the use of combined chemical and organic fertilizers. Organic and chemical fertilizers are advised through both information channels as this combination can result in optimal productivity and environmental outcomes.

Table 5. Correlates of fertilizers' choice (multinomial probit model)

Fertilizer Categories	No Fertilizer	Purely Organic	Combined Organic and Chemical	Purely Chemical
Acquisition of fertilizer information				
From agricultural extension services	-0.032***	0.001	0.043**	-0.012
	(0.016)	(0.008)	(0.025)	(0.029)
From relatives, neighbors, and friends	-0.052***	0.008	0.038**	0.006
	(0.013)	(0.007)	(0.031)	(0.035)
Farmland attributes				
Land area of annual crops	0.002**	-0.001	-0.034***	0.033***
	(0.003)	(0.005)	(0.013)	(0.013)
Number of annual crops	-0.022***	0.001***	0.138***	-0.117***
	(0.004)	(0.003)	(0.010)	(0.011)
Land area of perennial crops	-0.017**	0.007	-0.005	0.015
	(0.033)	(0.009)	(0.020)	(0.024)
Number of perennial crops	-0.027**	-0.005	0.045***	-0.013
	(0.012)	(0.005)	(0.013)	(0.013)
Distance from farmland to home	0.001	0.005	-0.017***	0.011**
	(0.001)	(0.001)	(0.009)	(0.010)
Land erosion	0.055***	0.027***	-0.042	-0.040
	(0.019)	(0.008)	(0.040)	(0.040)
Land tenure	-0.041***	-0.020	0.210***	-0.149***
	(0.010)	(0.009)	(0.028)	(0.027)
Irrigation status	-0.088***	-0.040	0.191***	-0.063**
	(0.019)	(0.007)	(0.051)	(0.040)
Household characteristics				
Educational level of household head	-0.003***	-0.001	0.008***	-0.005*
	(0.001)	(0.001)	(0.003)	(0.003)
Number of family laborers	-0.004	0.001	0.022***	-0.019***
	(0.003)	(0.002)	(0.009)	(0.009)
Food expenditure per capita	-0.009	0.007	0.043***	-0.041***
	(0.005)	(0.006)	(0.027)	(0.024)
Distance from home to main roads	0.002***	0.001	0.001	-0.003**
	(0.001)	(0.001)	(0.001)	(0.002)
Regional fixed effects	Yes			
Pseudo R^2	0.182			
Number of observations	2,901			

Notes: Coefficients indicate marginal changes; cluster-adjusted standard errors in parentheses consider commune as a cluster;
*** p<0.01, ** p<0.05, * p<0.1.

The marginal changes in information acquisition from agricultural extension services are larger than those from peers, which suggest a greater influence of agricultural extension. While Vietnam has been shifting from a state-run economy to a market-based economy, farming activities have been principally managed by public intervention such as agricultural extension. Despite its lower influence, information from peers in the use of combined organic and chemical fertilizers is relevant for households' choice of fertilizers. In rural villages, farmers face barriers accessing information from formal organizations, thus the advice of peers is an effective information channel to motivate farmers to use organic fertilizers in addition to chemical fertilizers.

In terms of farmland attributes, crop diversification, represented by a greater number of annual and perennial crops, is significantly linked to a higher probability of using combined organic and chemical fertilizers rather than purely chemical fertilizers. By contrast, users with larger cultivation areas of annual crops which are more distant from home are less likely to use combined chemical and organic fertilizers. These findings suggest that their use of organic fertilizers may be hampered by the labor-intensive process which requires them to prepare organic materials, implement composting operations, and follow appropriate technical guidance. Thus, a suitable land scale and land location can create favorable conditions for using organic fertilizers.

The experience of land erosion is associated both with no use of fertilizers and with the use of purely organic fertilizers. In some regions, farmers do not apply fertilizer and adopt only conventional techniques to produce organic fertilizers for low fertile soil, leading to a higher likelihood of erosion. In other regions with degraded erosion prone plots however, land quality may be a crucial driver of farmers' choice of fertilizers, as purely organic fertilizers are more likely to be adopted. Thus, farmers are motivated to use purely organic fertilizers to tackle serious qualitative depletion of their agricultural land.

Land security is associated with the use of purely chemical fertilizers and combined organic and chemical fertilizers. Red Book landholders are more likely to use combined fertilizers than those with less secure ownership. As the use of organic fertilizers is environmentally efficient in the long run, land security is necessary for farmers to invest in soil conservation activities. The coverage of the irrigation system is positively correlated with the choice of combined organic and chemical fertilizers to foster productivity.

As for the household characteristics, the educational level of the household head and the number of family workers are significantly correlated with the use of combined chemical and organic fertilizers. Specifically, households with highly educated household heads and more workers tend to choose combined fertilizers rather than purely chemical or no fertilizer. Educated farmers probably acquire knowledge on prospective environmental benefits of sustainable agriculture in the long term, and thus, are more motivated to invest in organic fertilizers despite the required labor investment for this practice.

Compared to purely chemical fertilizers, the use of combined fertilizers is popular among wealthier households with higher food expenditure. Higher living standards, associated with a higher demand for environmental benefits and food safety, motivate farming households to adopt the combination of organic and chemical fertilizers rather than purely chemical fertilizers. Finally, there is no significant correlation between organic fertilizer use and the geographical distance from home to the nearest main roads.

This study analyzes the observed patterns of farmland and households in the use of organic fertilizers among smallholders in rural Vietnam. In line with the findings of Dalton et al. (2011), Hagos and Holden (2006), Kassie et al. (2013), Mazvimavi and Twomlow (2009), and Thanh and Yapwattanaphun (2015), this study finds that land tenure, land location, land erosion, labor endowment, and household economic status are essential determinants of adopting conservation farming practices for sustainable agriculture. The consolidation of land security and available labor resources and wealth are crucial motivations for farmers to invest in improved soil technologies

for long-term environmental outcomes. In this study, in some regions, farmers use only organic fertilizers as a conservation farming practice when their farmlands are severely vulnerable to land degradation. In addition, unlike high-yielding technologies oriented to greater land holdings (Krishnan and Patnam 2014; Mekonnen et al. 2018; Takahashi et al. 2019), the use of mixed organic and chemical fertilizers seems to be common among farming households of smaller plot size. As the process of using organic fertilizers can be labor intensive, a suitable plot size is required to use organic fertilizers in addition to chemical fertilizers. Moreover, as the environmental efficiency of organic fertilizers is realized in the long term, farmers still hesitate to extend the adoption of organic fertilizers on a wider scale. Similar to the adoption of technologies for boosting agricultural productivity (Krishnan and Patnam 2014), education level is an influential factor in households' decision to use organic fertilizers for environmental benefits, which is consistent with the findings of Thanh and Yapwattanaphun (2015). Noticeably, households with a higher crop diversification are more likely to use organic fertilizers, to some extent, implying that organic fertilizers' use is preferable for multiple cropping systems.

The Relative Importance of Information Acquisition from Agricultural Extension Services and from Peers

Before measuring the effectiveness of the information acquisition from different information sources, the first-stage regressions (3) and (4) were estimated. Excluding considered households, these regressions examined possible correlation between the average evaluation rates of the importance of agricultural information of commune aggregates e and the probability of information acquisition through each channel, that is, whether the instrumental variables satisfied the first condition: Cov $(Z_i, I_i) \neq 0$.

Table 6 shows the estimation results of the first-stage regressions. In each information channel, the average evaluation rates on the importance of agricultural information of commune aggregates positively correlated with the probability of information acquisition. This result suggests that the evaluation of information from surrounding farmers in the commune is significantly related to the probability that the farmer receives information.

The estimation results of the IV-probit regressions for examining the causal effects of information acquisition on the use of organic fertilizers from both channels are presented in Table 7. Wald test of exogeneity with $chi^2(2) = 7.91$ and $Prob>chi^2 = 0.02$ reject the null hypothesis, that is, endogeneity existed, and it is necessary to use instrumental variables to treat the endogeneity problem.

Results show that information flows through both channels significantly and positively impacted the use of organic fertilizers, agricultural extension services having greater effects than peers. In Vietnam, the government controls the management of various resources and farming activities in rural communities by public intervention. As the traditional and popular linkage between the government and farmers, agricultural extension services still provide a fundamental information pathway in rural communities, and farmers are more likely to be influenced by information through this channel. Despite lower influential power, the significant effect of information acquisition from peers suggests that social interactions among peer farmers play a supplemental role in diffusing the use of organic fertilizers as an environment-friendly agricultural practice. It is highly likely that, while agricultural extension services motivate farmers to adopt new farming techniques in the initial periods, peers can be regarded as influential agents for further promoting sustainable agricultural practices when farmers seek for agricultural information and advice from each other (Le, Shimamura, and Yamada 2020).

In this study, information links in social networks are found to actively facilitate the use of organic fertilizers in Vietnam. Whereas the literature has focused on social networks on the adoption of agricultural technologies, such as the adoption of improved seeds and fertilizers (Conley and Udry

Table 6. First-stage regression for probability of acquisition of information on use of fertilizers

Explanatory Variable	Probability of Acquiring Information about Fertilizers	
	From Agricultural Extension	From Relatives, Neighbors, and Friends
Instrumental variables		
Average evaluation rates for the importance of information from agricultural extension	0.175***	0.091
	(0.035)	(0.029)
Average evaluation rates for the importance of information from relatives, neighbors, and friends	0.012	0.128***
	(0.037)	(0.032)
Farmland attributes		
Land area of annual crops	0.008	-0.011
	(0.013)	(0.007)
Number of annual crops	0.033***	0.004
	(0.008)	(0.004)
Land area of perennial crops	0.006	-0.009
	(0.016)	(0.008)
Number of perennial crops	0.003	0.018**
	(0.012)	(0.011)
Distance from farmland to home	-0.006	0.005
	(0.006)	(0.003)
Land erosion	-0.125***	0.094***
	(0.048)	(0.040)
Land tenure	-0.020	-0.022
	(0.028)	(0.018)
Irrigation status	-0.031	0.068***
	(0.039)	(0.039)
Household characteristics		
Educational level of household head	0.013***	-0.005**
	(0.002)	(0.002)
Number of family laborers	0.020***	0.010*
	(0.007)	(0.005)
Food expenditure per capita	-0.010	0.021*
	(0.012)	(0.010)
Distance from home to main road	-0.007***	0.006***
	(0.001)	(0.001)
Regional fixed effects	Yes	Yes
Pseudo R^2	0.139	0.161
Observations	2,901	2,901

Notes: Dependent variable takes the value of 1 when households acquire information about fertilizer s, and 0 otherwise. Coefficients indicate marginal changes; cluster-adjusted standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Instrumental variables denote the average evaluation rates for the importance of agricultural information of commune aggregates excluding the considered household.

Table 7. Causal effects of information acquisition on the use of organic fertilizers

Explanatory Variable	Probability of Using Organic Fertilizers	
	Probit	IV-probit
Acquisition of fertilizer information		
From agricultural extension services	0.048**	0.447**
	(0.025)	(0.093)
From relatives, neighbors, and friends	0.032**	0.264**
	(0.026)	(0.182)
Farmland attributes		
Land area of annual crops	-0.040***	-0.028**
	(0.013)	(0.018)
Number of annual crops	0.147***	0.084**
	(0.012)	(0.059)
Land area of perennial crops	-0.018	-0.011
	(0.020)	(0.011)
Number of perennial crops	0.034**	0.019
	(0.019)	(0.017)
Distance from farmland to home	-0.006	-0.005
	(0.007)	(0.004)
Land erosion	-0.018	0.011
	(0.078)	(0.024)
Land tenure	0.196***	0.145***
	(0.032)	(0.058)
Irrigation status	0.152***	0.101***
	(0.047)	(0.076)
Household characteristics		
Educational level of household head	0.007***	0.001*
	(0.003)	(0.002)
Number of family laborers	0.024***	0.006*
	(0.009)	(0.008)
Food expenditure per capita	0.048***	0.032**
	(0.027)	(0.035)
Distance from home to main road	0.001	0.002
	(0.003)	(0.003)
Regional fixed effects	Yes	Yes
Pseudo R^2	0.173	0.125
Number of observations	2,901	2,901

Notes: Dependent variable takes the value of 1 when households use organic fertilizers (purely organic and combination with chemical fertilizers); and 0 otherwise. Coefficients indicate marginal change; cluster-adjusted standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

2010; Foster and Rosenzweig 1995; Krishnan and Patnam 2014), row-planting (Mekonnen et al. 2018), and other techniques (Van den Broeck and Dercon 2011) with the sole aim of increasing quantitative output, little attention has been given to the adoption of environmentally friendly farming practices for sustainable agriculture. The present study fills this gap by highlighting the role of social networks in the use of organic fertilizers as a sustainable agricultural technique in the context of soil degradation in Vietnam. Using organic fertilizers as an environmentally friendly agricultural practice for long-term environmental significance is suitable for farming knowledge in tropical agriculture.

Unlike previous works that mainly concentrated on formal information channels (Dalton et al. 2011; Kassie et al. 2013; Thanh and Yapwattanaphun 2015; Thapa and Rattanasuteerakul 2011) or informal ones (Bandiera and Rasul 2006; Conley and Udry 2010; Foster and Rosenzweig 1995) separately, this study treats these two information networks simultaneously from a nationwide approach. Several studies have attempted to combine two information channels with time trend (Krishnan and Patnam 2014; Takahashi et al. 2019). A novel feature of this study is its simultaneous consideration of the relative importance of both information channels through social networks and the use of organic fertilizers. It is noteworthy that formal and informal information networks are placed correspondingly to fertilizers' information links. The results indicate that social learning about organic fertilizers' use exists not only through formal institutional interventions but also farmer-to-farmer discussions based on social networks in rural Vietnamese communities. Furthermore, the formal information channels have higher marginal impacts than the informal ones. The findings reflect the socioeconomic context of Vietnam, where state-run organizations play a major role in information propaganda for rural villagers; at the same time, peers' relationships are increasingly acknowledged.

This study attempts to address the endogeneity issues of information acquisition from farmers' social networks, which arise owing to the simultaneity bias or omitted unobservable variables (Krishnan and Patman 2014; Van den Broeck and Dercon 2011). In this study, the solution for endogeneity issues refers to two corresponding valid instruments of information network variables. As information acquisition through both channels has positive impacts on the use of organic fertilizers, information barriers contribute significantly to the low adoption of organic fertilizers in households. Social networks effectively increase the sharing of agricultural information from organizational intervention and rural villagers, considerably facilitate the information flows, and encourage farmers to use organic fertilizers as a soil conservation practice.

CONCLUSIONS AND POLICY IMPLICATIONS

Factors influencing the use of organic fertilizers as an environment-friendly farming practice were examined in farming households in rural Vietnam where the excessive use of agrochemicals and land degradation are considered great challenges for sustainable agriculture. Cropping patterns, land location, land tenure, experience of land erosion, educational level, labor endowment, and wealth level of households are key factors influencing the use of organic fertilizers. As the current process of producing organic fertilizers near households is labor-intensive, carrying organic fertilizers and production materials becomes a heavy burden for workers as plots become more distant from home. Hence, solutions to reduce labor investment in the production and use of organic fertilizers are necessary to increase the use of organic fertilizers.

Secured land ownership and better-equipped land seem to favor investments in organic fertilizers. In some regions, the experience of land erosion is positively associated with using organic fertilizers. Farmers with higher educational levels tend to apply more organic fertilizers. A more precise recognition and deeper understanding of long-term environmental benefits would lay a foundation for further diffusion of environment-

friendly agricultural practices. Moreover, wealthier households may prefer crops produced by organic fertilizers, as they are more likely to be conscious of health and environment.

Information flows through agricultural extension services and that from peers have significant and positive effects on the use of organic fertilizers in rural villages. Information acquisition from agricultural extension services has a greater marginal impact than that from peers, which suggests that agricultural extension services still function as a primary information channel nationwide for rural Vietnam. Meanwhile, information channels from peers play a supplemental role in diffusing information among rural communities. Interestingly, high evaluation rates of information's importance are found in information channels through peers, which may indicate high reliability of peers' advice.

This study suggests some policy implications for long-term strategies to improve the use of organic fertilizers as a sustainable agricultural practice. First, lowering labor investment in producing and using organic fertilizers can be effective in encouraging farmers to use organic fertilizers. Second, the enforcement and consolidation of land tenure should be continuously strengthened, as land security can play a crucial role in fostering agricultural investment for environmental sustainability. Third, farmer-to-farmer information dissemination should be widely utilized together with general education and agricultural training from agricultural extension services to upscale the adoption of soil conservation practices.

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