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The Impact of Land Fragmentation in Rice Production on Household Food Insecurity in Vietnam

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Abstract: The objective of this study is to examine the impact of land fragmentation in rice production on household food insecurity in Vietnam. This study provides the first evidence on the effect of land fragmentation on household food insecurity in rice production. This study uses a relatively rich panel dataset of rice farming households across different regions from the Vietnam Access to Resources Household Survey (VARHS) 2012, 2014, and 2016. The research applies the ordered probit model to identify land fragmentation and other factors affecting household food insecurity at different food insecurity levels. Findings indicate that land fragmentation and rice seed types are positively correlated with household food insecurity. Importantly, the odds of an increase of 1% fragmentation land index increase the probability of household food insecurity at a very high level of 4.79% after controlling for unobserved heterogeneity. Other factors such as total cultivated area, access to credit, and household savings help reduce household food insecurity. These findings suggest that the government needs to foster the process of consolidating fragmented rice plots to help households produce efficiently and reduce food insecurity for their families. In addition, other approaches such as increasing farm size for each rice farmer and access to credit can increase the probability of food security for rural households in Vietnam.

Keywords: food insecurity; land fragmentation; ordered probit; Vietnam

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1. Introduction

Although Vietnam has been one of the fastest-growing economies in Asia in recent decades, the agricultural sector still plays a critical role in its economic development [1,2]. The Vietnam General Statistics Office reported that agriculture accounts for 23% of the GDP and supplies over 50% of the labor force to the country as of 2020 [3]. In addition, most of the population lives in rural areas [4].

Land is an essential resource in farming, and changes in land-use patterns significantly affect the environment, such as biodiversity, water pollution, soil erosion, climate change, and economic and social welfare [4,5]. As an attempt at land policy reform in Vietnam, the first Land Law was introduced in 1987, in which the State recognized the land use rights of households and individuals [6]. Vietnam's agricultural sector has made remarkable achievements, such as higher crop productivity and improved producer welfare [7]. However, land fragmentation remains one of the most significant challenges deterring agricultural development in general, particularly rice production in Vietnam and many other developing countries [8]. Small and fragmented land is one of the reasons for the low profits of rice-growing activities. Farmland fragmentation is primarily due to a high number of farmed plots or an increased number of plot co-owners, which is a more complex phenomenon. Land fragmentation includes plot size, shape, distances from

buildings, and distance between plots as well as the size of each plot [9]. Thus, assessments of the economic consequences of land fragmentation have a long history in agricultural economics and related disciplines [10].

In terms of rice production in Vietnam, approximately 7.24 million hectares were estimated as the rice field in 2021, which is about 38.3 thousand hectares lower than the previous year. Rice yield is estimated at 60.6 quintals per ha in 2021, which represents an increase of 1.8 quintals per ha relative to rice yield in 2020. A total of 6.2 million tons of rice were exported in 2021, equivalent to 3.3 billion USD, a rise of 5% from 2020, and the export price of rice increased from 496 USD a ton in 2020 to 503 USD a ton in 2021. Rice is the main staple food and also the main income source of farmers in Vietnam and thus sustainable production of rice is important for national food security [3].

Despite the fact that Vietnam has made outstanding achievements in poverty reduction since the reform period, food insecurity still exists at the household level. In 2018, Vietnam had 105,000 households (420,000 people) suffering from hunger [11]. In general, agricultural land protection is a standard policy to deal with food security because 66% of rural households and 77% of poor households are still related to rice production [11,12]. Although the new land policies enhance living standards in rural areas, many poor households still produce rice in small areas with fragmented or noncontiguous plots. This phenomenon raises the question of the connection between food insecurity and land fragmentation in many rural households in Vietnam.

Several studies have indicated the impact of land fragmentation on the livelihoods of rural households. Lu et al. [13] found that land fragmentation caused a decrease in the marginal productivity of agricultural labor and an increase in the non-agricultural labor supply [13,14]. Similarly, farmers increased their labor input, leading to increased total production costs due to land fragmentation in China [15]. In addition, a decrease in production efficiency occurred due to land fragmentation in Nepal [16]. However, land fragmentation shows some positive effects in some areas, such as promoting the growth of agriculture in Bihar, India [17]. Diversification in agricultural production is stimulated by land fragmentation in Albania [9]. In addition, land fragmentation after land consolidation has not been demonstrated to be a significant factor in improving technical efficiency [18]. Regarding the relationship between land fragmentation and house food security, Cholo et al. [19] confirmed that the Simpson index is suitable for identifying land fragmentation and his study explored the relationship between household food security and land fragmentation in Ethiopia. Similarly, food security uses a coping strategy index and month hungry, which is positive for land fragmentation [20]. Tran and Vu [21] found that ethnic minority households with higher Simpson indices suffered from food insecurity. Many previous studies have examined the effect of land fragmentation on household welfare and food security such as in Ethiopia [9,18,21], Nepal [16], and Vietnam [21]; however, there is a lack of studies investing the relationship between land fragmentation and household food security in the rice production in Vietnam using large cross-sectional and temporal dimensions. Therefore, this study aims to fill this gap by employing rich panel data from the rice-cultivating households across regions in Vietnam.

To identify the relationship between land fragmentation and food insecurity, the study first calculates the land fragmentation index by using Simpson's diversification index as in previous studies [6,9,19,22]. The Simpson's index is estimated based on the number of plots, plot size, and farm size [21]. The range of Simpson's index is between zero and one, with the larger index referring to the more fragmented [21]. This research only focuses on the fragmentation index of the rice land. The research classifies individual households into different categories of food insecurity based on the percentage of household expenditure on food (PEF). The research then utilizes the ordered probit model to examine the relationship between land fragmentation and food insecurity of rice producers.

This study contributes to the literature on the economic consequences of land fragmentation, focusing on the links between land fragmentation and household well-being

as measured by food security status. The research is situated as a work in Vietnam, a top exporter of rice, yet many households remain food insecure.

2. Materials and Methods

2.1. Measuring Food Security

Smith and Subandoro [23] introduced a set of indicators for food insecurity assessment at the household level. The percentage of household expenditure on food (PEF) is a key indicator of food insecurity. This study applies this indicator, which refers to the total spending on food over total household income. This approach could be seen as a standard guideline for assessing household food insecurity at different levels, as shown in Table 1. Following Smith and Subandoro [23], at the household level, households that spend more than 75%, 65%, 50%, and under 50% of their income on food are, respectively, experiencing very high, high, medium, and low food insecurity, respectively. There is much research using different food insecurity levels to determine household food security. However, those researchers only indicated household food insecurity based on the status of using or having foods such as the number of foods in household living standard, as a result, they did not refer to the spending on the food of household in a period. Therefore, this research not only uses the PEF as an index to determine the household food insecurity levels, but also can be the first research using PEF for household food security in rice production.

Table 1. Indicators of levels of household food insecurity.

Indicator	Guideline for Interpretation	Ordered Probit
Percentage of expenditure on food (%)(the total spending on food in the total income of a household)	>75: very high food insecurity	1
	>65: high food insecurity	2
	>50: medium food insecurity	3
	<50: low food insecurity	4 (Base)

Source: Smith and Subandoro [23].

2.2. Measuring the Effect of Land Fragmentation on Household Food Insecurity

The Ordered Probit model is used to estimate the impact of land fragmentation and other factors on a household's food insecurity. The model used to identify factors affecting various levels of food insecurity according to FAO guidelines (low, medium, high, and very high food insecurity). The research performs a non-parametric estimation before the probit model estimation to take the "first look" and identify the overall potential relationship between land fragmentation and the food insecurity level of the households.

$$Pr(y_{it} > k \mid \kappa, x_{it}, z_{it}, v_i) = \Phi(x_{it}\beta + \gamma z_{it} + \mu_i + \varepsilon_i - \kappa_k) \quad (1)$$

t = 2012, 2014, 2016
i = 1, …, n

where x_{it} is a vector of explanatory variables for rice land characteristics, z_{it} is a vector of other control variables such as household characteristics, μ_i is an individual-specific time-invariant, ε_i is the independent and identically distributed $N(0, \sigma^2_v)$, and κ is a set of cut-points $\kappa 1, \kappa 2, \ldots, \kappa_{K-1}$, and $\Phi(\cdot)$ is the standard normal cumulative distribution function.

Equation (1) can be written by a model as follows [24]:

$$y^*_{it} = \beta x_{it} + \gamma z_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

where ε_{it} is expected to be autonomously and identically distributed over time, and y^*_{it} is the observed ordinal response, which is generated from latent continuous responses.

The format of estimation is as follows:

$$y_{it} = \{1;\ if\ y_{it}^{*} > 75\ \%\ 2;\ if\ 75\ \%\ \geq y_{it}^{*} > 65\ \%\ 3;\ if\ 65\ \%\geq\ y_{it}^{*} > 50\ \%\ \ 4;\ if\ y_{it}^{*} \leq 50\ \%\} \quad (3)$$

The unobserved heterogeneity μ_i may lead to biased results when estimating Equations (2) and (3). Unobserved heterogeneity refers to the correlation between farming and the observable and unobservable characteristics of farming households. The estimation of Equations (2) and (3) are considered as an ordered probit model specification without controlling for unobserved heterogeneity. Based on previous studies, they suggest that the Mundlak-type Correlated Random Effects (CRE) control for unobserved heterogeneity by adding the means of all time-varying variables ($\bar{X}_{ji}$) to the model [22–24]. The research applied this approach to the ordered probit estimation method. To check the consistency of the results, this research presents the results with and without controlling for unobserved heterogeneity.

3. Data Sources

The study used the Vietnam Access to Resources Household Survey (VARHS 2012, 2014, and 2016) in Vietnam. The VARHS surveys were designed and implemented in 12 provinces across all regions of Vietnam, including the North (Ha Tay, Lao Cai, Phu Tho, Lai Chau, Dien Bien), Middle (Nghe An, Quang Nam), and South (Khanh Hoa, Dak Lak, Dak Nong, Lam Dong, Long An). A commune and home questionnaire were included in the VARHS survey instrument. The following categories of detailed information were gathered, with minor changes made along the way. Every two years, VARHS was implemented to collect data from rural households in the 12 provinces mentioned. The household survey collects detailed information on the size of the household's farmland, the number of plots, other characteristics of the land, agricultural inputs and outputs, land market transactions, and general information about individuals and households. From more than 2000 households collecting data by VARHS, this study kept rice-producing households. After merging the data of VARHS in 2012, 2014, and 2016, the study used 928 rice households in a balanced panel data to analyze the impact of rice land fragmentation on the household food insecurity. Figure 1 shows study sites across regions. Table 2 provides the status of land fragmentation in rice production in locations in Vietnam. The statistical result indicates that the mean fragmentation index in rice production is from 0.24 to 0.59. In addition, the mean fragmentation indexes of provinces in the South are higher than that in the other areas. The highest mean of land fragmentation is 0.59 in Phu Tho province and the lowest mean is 0.24 in Lam Dong Province.

Based on previous research [18,19,25–31], several variables of farming land and household characteristics were added to the econometric model. The gender of the household head and the education of the household head are added to this research. In addition, the research added age to the estimations based on the research of Tran and Vu [21], Baorong Guo [28], and household savings from the research of Abdullah et al. [29]. In addition, Cholo et al. [19] pointed out other variables such as total cultivated area, productivity, number of assets, access to credit, types of seeds, and socks. Meanwhile, other research indicated that irrigation and extension officer visits are variables that can impact household food security [27]. Furthermore, land degradation could pose a challenge to food security; as a result, the research added land quality as one of the factors affecting household food security [19]. Previous studies have also indicated family labor size as an important determinant of food security [19]; therefore, the research used family labor size as an explanatory variable. In addition, Xue et al. [30] also mentioned that internet access could help households access food sources and ensure food security of households; therefore, the research added access to the internet as an explanatory variable in the estimation model. The estimated results of land fragmentation index in different study sites were presented in Tables 2 and 3 provides summary statistics for variables used in the regression analysis.

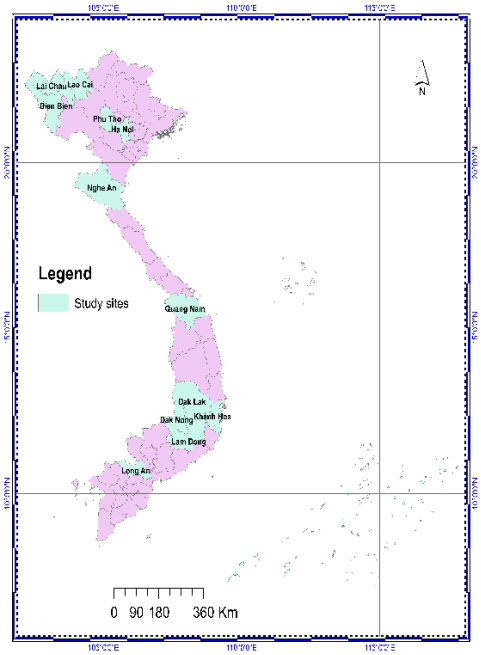

Figure 1. Study area indicating the data collection sites in Vietnam. Source: The Vietnam Access to Resources Household Survey.

Table 2. Land fragmentation index in different study sites.

Provinces	2012	2014	2016	Total
Ha Tay	0.64	0.49	0.46	0.53
Lao Cai	0.38	0.45	0.37	0.40
Phu Tho	0.57	0.61	0.59	0.59
Lai Chau	0.49	0.48	0.57	0.52
Dien Bien	0.46	0.43	0.43	0.44
Nghe An	0.60	0.52	0.43	0.52
Quang Nam	0.48	0.46	0.47	0.47
Khanh Hoa	0.33	0.28	0.25	0.29
Dak Lak	0.33	0.29	0.30	0.31
Dak Nong	0.25	0.28	0.30	0.27
Lam Dong	0.26	0.23	0.25	0.24
Long An	0.37	0.39	0.33	0.36
Total	**0.51**	**0.47**	**0.45**	**0.48**

Table 3. Summary statistics.

Variables	2012		2014		2016		All	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Outcome variables								
1= Very high food insecurity; 2= High level of food insecurity; 3 = Medium level of food insecurity; 4 = Low level of food insecurity	3.613	0.798	3.752	0.789	3.797	0.637	3.721	0.712
Explanatory variables								
Fragmentation index	0.511	0.287	0.471	0.287	0.454	0.285	0.479	0.287
Farm and land characteristics								
Total cultivated area (m^2)	3350.045	5441.889	3298.191	5274.620	3148.765	4770.635	3265.667	5169.105
Irrigation (% of plots irrigated)	0.904	0.269	0.923	0.240	0.956	0.189	0.928	0.236
Rice productivity (kg/m^2)	0.488	0.136	0.502	0.138	0.500	0.127	0.497	0.134

Land quality (1 = lower average; 2 = average; 3 = higher average quality)	1.940	0.351	1.991	0.303	1.994	0.282	1.975	0.314
Household and farm characteristics								
Household labor size (persons)	4.538	1.605	4.516	1.608	4.438	1.646	4.497	1.620
Gender of household head (1 = Male)	0.856	0.352	0.838	0.368	0.836	0.370	0.843	0.363
Age of household head (years)	49.514	12.763	51.105	12.675	52.627	12.593	51.082	12.736
Education of household head (years)	8.075	3.020	8.672	2.849	8.927	2.748	8.558	2.896
Household assets (Number of assets)	6.974	3.456	7.904	3.522	4.751	2.068	6.543	3.359
Types of seed (1 = Hybrid seed from Vietnam)	0.489	0.500	0.606	0.489	0.581	0.494	0.559	0.497
Access to credit (1 = yes)	0.621	0.485	0.664	0.473	0.940	0.238	0.741	0.438
Socks (1 = Experienced illness, droughts, floods)	0.496	0.500	0.408	0.492	0.336	0.473	0.413	0.493
Number of extension officer visits (times/year)	1.388	2.259	1.793	2.722	1.053	1.490	1.411	2.236
Savings (1 = yes)	1.000	0.000	0.841	0.366	0.865	0.342	0.902	0.297
Access to the internet (1 = yes)	0.233	0.423	0.268	0.443	0.449	0.498	0.317	0.465

4. Results and Discussion

4.1. Descriptive Statistical Analysis

The relationship between land fragmentation (Simpson's index) and household food insecurity, including the percentage of expenditure on food, was generated using a descriptive statistical analysis. This is one of the ways to take the "first look" between independent and dependent variables. The research performs a descriptive statistical estimation before statistical modeling to investigate the overall potential relationship between land fragmentation and the food insecurity level of the households.

First, the research shows the relationship between land fragmentation and household food insecurity (FIS) at different levels: a medium level of household food insecurity, a high level of household food insecurity, and a very high level of household food insecurity and fragmentation through visualizations. As shown in Table 4, it can be seen that land fragmentation has a positive relationship with household food insecurity since household food insecurity at the levels of very high and high food insecurity have higher land fragmentation indexes than the others. This means that households with higher land fragmentation could be to face more food insecurity. However, to better understand this, the research applied econometric regression estimation to determine the relationship between land fragmentation and household food insecurity.

Table 4. Land fragmentation index and household food insecurity at different levels.

Levels of Household Food Insecurity	Land Fragmentation Index			
	2012	2014	2016	Total
Very high food insecurity	0.63	0.48	0.53	0.55
High food insecurity	0.56	0.42	0.43	0.50
Medium food insecurity	0.49	0.43	0.49	0.47
Low food insecurity	0.50	0.48	0.45	0.47
Total	0.51	0.47	0.45	0.48

4.2. Estimation Results

This research uses the ordered probit model to examine the impact of land fragmentation and other factors on household food security under the form of both with and without controlling for unobserved heterogeneity. Given the ordinal structure of the dependent variable (i.e., low, medium, high, and very high food insecurity). The ordered probit model is used in this research. Particularly, the model helps determine factors affecting the probability of household food insecurity at different levels.

The regression results are presented in Table 5. The result indicates that land fragmentation has significantly negative effects on household food security. This implies that a household with a higher fragmentation index is more likely to be food insecure than a

household with a lower fragmentation index. Since a household has different plots in rice production, the household owns high land fragmentation that not only to requires a large number of inputs for rice production such as labor, seed, and fertilizer cost, but also to make a decrease in productivity in rice production. Those consequences could bring a household to live under the status of food insecurity since the household could receive low income from rice production. The relationship between total cultivated area and household food security is positive and it is statistically significant. It means that an increase in total area in rice production for each household can reduce household food insecurity. In addition, the sign of the relationship between household food insecurity and types of seed is negative, which indicates that hybrid seeds from Vietnam can cause household food insecurity. The study also finds the significant effect of accessing credit on household food insecurity. This means that families with accessing credit can improve the household food security in rice production. Similarly, a household in rice production with savings can reduce household food insecurity and this effect is statistically significant at the 1% significance level.

Table 5. Factors affecting household food insecurity in rice production.

Variables	Ordered Probit Model	CRE Ordered Probit Model
Fragmentation index	−0.362 ***	−0.558 ***
	(−0.106)	(−0.198)
Total cultivated area [1]	0.105 ***	0.095 **
	(−0.04)	(−0.042)
Irrigation	0.196	0.185
	(−0.124)	(−0.184)
Rice productivity	0.279	0.487
	(−0.25)	(−0.328)
Land quality	0.01	0.097
	(−0.096)	(−0.108)
Household labor size [1]	0.005	−0.02
	(−0.072)	(−0.168)
Gender of household head	−0.011	−0.029
	(−0.082)	(−0.082)
Age of household head [1]	0.166	0.166
	(−0.114)	(−0.114)
Education of household head [1]	0.075	0.017
	(−0.067)	(−0.111)
Household assets	0.010	0.000
	(−0.009)	(−0.013)
Types of Seed	−0.118 **	−0.111 *
	(−0.057)	(−0.057)
Access to credit	0.215 ***	0.321 ***
	(−0.067)	(−0.082)
Socks	0.003	0.028
	(−0.06)	(−0.078)
Number of extension officer visit	−0.017 *	−0.013
	(−0.01)	(−0.014)
Savings	0.266 ***	0.289 ***
	(−0.089)	(−0.09)
Access to the internet	0.022	0.012
	(−0.063)	(−0.082)
Within-household means	No	Yes
Observations	2784	2784

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. [1] in log form.

To better understand the probability of household food insecurity influenced by land fragmentation and factors belonging to household characteristics, the research identifies the factors that influence each level of household food insecurity with marginal effects. The estimations are also considered in the form of both with and without controlling for unobserved heterogeneity, as in Table 6.

Table 6. The marginal effect of factors affecting household food insecurity at different levels.

Variables	Very High Level of Food Insecurity (y = 1)		High Level of Food Insecurity (y = 2)		Medium Level of Food Insecurity (y = 3)	
	Ordered Probit Model	CRE Ordered Probit Model	Ordered Probit Model	CRE Ordered Probit Model	Ordered Probit Model	CRE Ordered Probit Model
Fragmentation index	0.0312 ***	0.0479 ***	0.0155 ***	0.0238 ***	0.0413 ***	0.0635 ***
	(0.0095)	(0.0174)	(0.0048)	(0.0088)	(0.0122)	(0.0225)
Total cultivated area [1]	−0.0090 ***	−0.0081 **	−0.0045 ***	−0.0040 **	−0.0120 ***	−0.0108 **
	(0.0035)	(0.0036)	(0.0017)	(0.0018)	(0.0045)	(0.0048)
Irrigation	−0.0169	−0.0158	−0.0084	−0.0079	−0.0224	−0.0210
	(0.0107)	(0.0159)	(0.0054)	(0.0079)	(0.0142)	(0.0210)
Rice productivity	−0.0241	−0.0418	−0.0120	−0.0208	−0.0319	−0.0554
	(0.0217)	(0.0284)	(0.0108)	(0.0140)	(0.0286)	(0.0374)
Land quality	−0.0008	−0.0083	−0.0004	−0.0041	−0.0011	−0.0111
	(0.0083)	(0.0093)	(0.0041)	(0.0046)	(0.0110)	(0.0123)
Household labor size [1]	−0.0004	0.0017	−0.0002	0.0009	−0.0006	0.0023
	(0.0062)	(0.0144)	(0.0031)	(0.0072)	(0.0082)	(0.0191)
Gender of household head	0.0010	0.0025	0.0005	0.0012	0.0013	0.0033
	(0.0071)	(0.0070)	(0.0035)	(0.0035)	(0.0094)	(0.0093)
Age of household head [1]	−0.0143	−0.0143	−0.0071	−0.0071	−0.0189	−0.0189
	(0.0098)	(0.0099)	(0.0049)	(0.0049)	(0.0131)	(0.0131)
Education of household head [1]	−0.0064	−0.0014	−0.0032	−0.0007	−0.0085	−0.0019
	(0.0058)	(0.0095)	(0.0029)	(0.0047)	(0.0076)	(0.0126)
Household assets	−0.0008	0.0000	−0.0004	0.0000	−0.0011	0.0000
	(0.0008)	(0.0011)	(0.0004)	(0.0006)	(0.0010)	(0.0015)
Types of Seed	0.0102 **	0.0095 *	0.0051 **	0.0047 *	0.0135 **	0.0126 *
	(0.0049)	(0.0049)	(0.0025)	(0.0025)	(0.0065)	(0.0065)
Access to credit	−0.0185 ***	−0.0275 ***	−0.0092 ***	−0.0137 ***	−0.0246 ***	−0.0365 ***
	(0.0059)	(0.0073)	(0.0030)	(0.0037)	(0.0076)	(0.0092)
Socks	−0.0003	−0.0024	−0.0001	−0.0012	−0.0003	−0.0031
	(0.0052)	(0.0067)	(0.0026)	(0.0033)	(0.0069)	(0.0089)
Number of extension officer visit	0.0014 *	0.0011	0.0007 *	0.0006	0.0019 *	0.0015
	(0.0008)	(0.0012)	(0.0004)	(0.0006)	(0.0011)	(0.0016)
Savings	−0.0230 ***	−0.0248 ***	−0.0114 ***	−0.0123 ***	−0.0305 ***	−0.0329 ***
	(0.0079)	(0.0080)	(0.0040)	(0.0040)	(0.0102)	(0.0103)
Access to the internet	−0.0019	−0.0010	−0.0010	−0.0005	−0.0025	−0.0014
	(0.0054)	(0.0071)	(0.0027)	(0.0035)	(0.0072)	(0.0094)
Within-household means	No	Yes	No	Yes	No	Yes
Observations	2784	2784	2784	2784	2784	2784

Standard errors in parentheses, a base mode is the low level of food insecurity (y = 4). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. [1] in log form.

Without controlling for unobserved heterogeneity, the probability of household food insecurity was 3.12% when there is an increase of 1% in the land fragmentation index. The figures for household food insecurity at the high and medium levels were 1.55% and 4.13%, respectively. An increase in 1% of the fragmentation land index would increase the probability of a household's food insecurity by 8.80%. After controlling for unobserved heterogeneity, the probability of household food insecurity is higher with a 1% increase in the land fragmentation index. The odds of an increase of 1% fragmentation land index

increase the probability of household food insecurity at a very high level of 4.79%. Similarly, with a 1% increase in the land fragmentation index, the probability of household food insecurity at the high and medium levels was 2.38% and 6.35%, respectively. Therefore, a 1% reduction in the land fragmentation index could reduce the probability of household food insecurity by 13.52%. Both with and without the control of unobserved heterogeneity, this study confirms that land fragmentation had a significantly positive impact on the food insecurity of rice households. According to previous research, land fragmentation can reduce household food insecurity as farmers can cultivate a variety of crops on various plots [9,18,21]. Farmers can diversify their incomes from different crops to reduce household food insecurity. However, it cannot be clear if a farmer only cultivates one type of crop, for example in rice production. The status of land fragmentation could cause a high cost for rice production and harvest cost [15]; therefore, it would lead to a decrease in household income and increased household food insecurity.

Regarding the impact of the total cultivated area on household food insecurity, an increase of 1% of the total cultivated area reduces the probability of household food insecurity by 0.81% at a very high level. The odds of 1% in the total cultivated area for household food insecurity decreased by 0.40% at the high level. In addition, the figure for household food insecurity is 1.08% at the medium level. Results indicate that an increase in the total cultivated area for rice production has a significantly negative impact on household food insecurity. With the rise in total cultivated area, farmers would orient to produce as a commodity market. Farmers may apply many modern technologies to achieve economic efficiency in rice production on a larger scale.

The present results also showed a positive relationship between using hybrid seeds from Vietnam and household food insecurity. The probability of household food insecurity is reduced by 2.68%, as rice farmers do not use hybrid seeds from Vietnam. In particular, the probability of household food insecurity increased by 0.95% at a very high level because farmers used hybrid seeds from Vietnam. In addition, using hybrid seeds from Vietnam increases the probability of household food insecurity by 0.47% at a high level. Meanwhile, the odds of using hybrid seeds from Vietnam for the probability of household food insecurity increased by 1.26% at the medium level. This result is similar to the conclusion of Cholo et al. [19]. The research points out that using hybrid seeds can reduce household food security in rice production. Hybrid seed is considered a new type of rice seed that is developed by Vietnamese research centers and they could be suitable with almost all geographical characteristics in Vietnam. However, the quality of output is not preferred by consumers and its price is low in the market. In addition, there are many production risks, such as pests and diseases. As a result, farmer income can be lower when they select hybrid seeds to produce in the rice cultivation field.

Access to credit is an important factor in reducing the probability of household food insecurity. The probability of household food insecurity without access to credit was higher, at a total of 7.77%. In particular, without access to credit increases the probability of household food insecurity by 2.75% at a very high level. In addition, access to credit reduces the probability of household food insecurity by 1.37% at a high level. The probability of household food insecurity is 3.65% at a medium level for a farmer without access to credit. In general, the access to credit reduces household food insecurity. This means that the probability of household food insecurity decreases with an increase in access to credit households. This result is similar to in previous studies, such as in Nigeria [27], Pakistan [29], and Ethiopia [19]. Access to credit can increase farmers' ability to pay out input costs during rice production. With substantial financial resources and access to credit, farmers will choose quality inputs such as seeds, fertilizers, and other raw materials, which helps farmers to achieve higher yields and quality products. As a result, it allows farmers to gain the advantage of bargaining the selling price of the product at a higher price and helps farmers increase their income.

The research found a positive relationship between visiting extension officers and household food insecurity regarding the number of extension officer visits. The increase

in the number of extension officer visits will increase the probability of household food insecurity at the very high, high, and medium levels by 0.14%, 0.07%, and 0.19%, respectively. In total, an increase in the number of extension officer visits reduces the probability of household food security by 0.4%. These findings imply that the extension officer does not have a significant role in the rice production of a household. This result is opposite to the finding of research by Nonvide [27], since he found that access to extension services can improve household food security. In Vietnam, many extension offices require farmers to pay a charge to get the services. In addition, some approaches from extension offices do not satisfy with conditions of land characteristics in the local area. This case leads to the inefficiency for the farmer when they apply some approaches from extension offices. However, the results are only statistically significant without controlling for unobserved heterogeneity.

The research also found that household savings decrease the probability of household food insecurity. The probability of household food insecurity increases by 7.01% as households do not save. Specifically, the probability of household food insecurity at a very high level is reduced by 2.48% with household savings. The figures for high and medium levels of household food insecurity decreased by 1.23% and 3.29%, respectively. Likewise, the research indicates that households with savings can reduce their household food insecurity status. This result is in line with the results reported by Guo [28]. Households saving is frequently used to cope with future risks such as diseases and reduction of their income. Therefore, households with savings have a higher probability of ensuring food security than households without savings.

5. Conclusions and Policy Implications

Vietnam implemented a series of policy reforms in agriculture after 1986 to promote economic development and ensure rural people's livelihood. The fragmentation of farming land in Vietnam in the current period is remaining as a critical barrier that deters the development of the agricultural sector. This study aims at determining the link between land fragmentation and food insecurity in rice-growing households in Vietnam over time since previous studies were unable to examine the relationship over a period. The ordered probit model with household panel data is used to estimate the impact of land fragmentation and other factors on household food insecurity. The ordered probit model is estimated with and without controlling for unobserved heterogeneity.

The results show that land fragmentation is positively related to household food insecurity. Land fragmentation would increase the cost of rice production and harvesting, and consequently, it could decrease household income. This would then lead to increased household food insecurity. In addition, findings indicate that land fragmentation and rice seed types are positively correlated with household food insecurity. Other factors such as total cultivated area, access to credit, and household savings help reduce household food insecurity. Findings from the study suggest some policy prescriptions for reducing food insecurity in rice production in Vietnam. First, the results suggest that land fragmentation in rice production increases the food insecurity of rice-producing households. Land consolidation is an adjustment and rearrangement of different plots to form larger size of lands. It is suggested that combining multiple small plots into larger and heterogeneous clusters could enhance food security [19]. This would help households create homogenous production processes; reduce investment costs due to land fragmentation and increase the ability of households to apply machine technologies to agricultural production to achieve high economic efficiency. In addition, the government could encourage production households to work together to consolidate plots and invest in collective agriculture production to make the policy of land consolidation effective. To achieve the objectives of the land consolidation policy, the government could also promote the exchange of rice plots between households through the agricultural land exchange market. This is similar to the suggestion in previous research to improve the farm technical efficiency in Vietnam and help reduce the status of household food insecurity [32]. Second, the research found that

an increase in farm size for rice production can enhance household food security status. As a result, the government should distribute the total cultivated rice with a larger area to each rice farmer. This action can be implemented by combining minor and fragmented production households into one more significant producer or assisting farmers in renting out plots of land that the owner does not use. Third, access to credit would bring enhanced food security for households. The government needs to indicate supportive programs for farmers in credit programs with low-interest rates or loans in the long term. Previous research has also suggested this approach to reduce household food insecurity in Bangladesh [33]. The final suggestion is that the government and private enterprises can cooperate to improve the quality of rice seeds. It can help the farmer receive efficient production practices to benefit rice production.

The study experiences some limitations. First, the panel data in this research are for short periods only, so it may not capture the whole picture of land fragmentation and food insecurity in Vietnam. In addition, rice production is a field that is vulnerable to climate change, and the research does not consider the adaptive strategies that apply to each plot of rice production; as a result, further research is necessary for this concern to have a better picture of land management and food security in Vietnam. Filling those gaps could contribute significantly to the body of literature investigating the relationship between food insecurity and land fragmentation in developing countries.

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