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The impact of land fragmentation on food security in the North Central Coast, Vietnam

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Abstract

While the effect of land fragmentation on farm efficiency and production diversification in Vietnam has been well established, no evidence exists for its effect on household food security. Using a unique dataset from household surveys in combination with micro-econometric models, the current study examines the impact of land fragmentation on food security in the poorest districts of Vietnam's North Central Coast. Even after controlling for other factors in the models, we provide the first evidence that in Vietnam, ethnic minority households whose land holdings are fragmented are more likely to suffer from food insecurity. A higher likelihood of achieving food security is found for households whose members have better education and non-farm self-employment. The findings suggest that land policies that encourage land consolidation and improve the access of ethnic minorities to better education and non-farm self-employment would help them improve their food security. Such policies should be promoted in the study area.

KEYWORDS

ethnic minorities, food security, land fragmentation, land policies, North Central Coast, Vietnam

1 | INTRODUCTION

Vietnam has made great progress in poverty reduction and food security over the past few decades. In the early 1980s, Vietnam was one of the world's poorest countries with a high incidence of poverty and inadequate food consumption, especially of rice (World Bank, 2012). The economic reform begun in 1986 transformed the country from a chronic rice importer in the 1980s to the second-largest rice exporter in 1997 (Nielsen, 2003) and the third-largest in 2016 (IBP Inc, 2016). Vietnam is one of a group of countries with moderate food security, according to the Global Food Security Index 2015 (World Bank, 2016).

A large proportion of the Vietnamese population resides in rural areas, and mainly consists of low-income, small-scale farmers producing paddy rice, either for subsistence or commercial purposes or both (Rutten et al., 2014). Although Vietnam has emerged as the world's third-largest exporter of rice behind India and Thailand (IBP Inc, 2016), food insecurity is still a common issue for the poorest and for ethnic minorities in some regions. A survey in the North Central rural districts by the Mekong Development Research Institute ([MDRI]; 2016) revealed that food insecurity is a common problem for all ethnic minorities, with about one-third of households experiencing hunger in the previous 12 months. A relatively high percentage (24%) of the non-poor also suffered from food shortages.[1]

A number of studies have investigated the impact of land fragmentation on rural households in Vietnam. Hung et al. (2007) found that land fragmentation reduces crop productivity and increases the need for family labour and various cash expenses in two provinces of North Vietnam. Similarly, using panel data with different methods to account for unobservable heterogeneity and variation in land fragmentation, Nguyen (2014) finds that such fragmentation increases farm labour supply and labour intensity, and reduces farm profits and productivity. While numerous studies have examined the effect of land fragmentation on farm efficiency (Hung et al., 2007; Kompas et al., 2012; Nguyen, 2014; Wang et al., 2017), no study as yet has analysed the role land fragmentation plays in food security in Vietnam. A better understanding of whether land fragmentation improves or reduces food security is of great importance when adjusting and designing policy interventions to meet people's basic needs. Our study attempts to fill this gap.

The study focuses on rural districts in the North Central Coast—one of the poorest regions in Vietnam—where a high proportion of ethnic minority households suffer from food shortages (MDRI, 2016). The study used data for around 2500 households characterised by annual cropland fragmentation, measured by the Simpson's diversification index. Food security is measured by respondents' self-reported perception concerning their household food security status in relation to two indicators. The first indicator measures either a lack of food in the household or a significant shortage in the daily diet over the previous 12 months, while the second indicator measures the lack of food rich in protein in household diets in the previous 7 days.

Our study provides the first evidence that households in Vietnam with more fragmented land are more likely to suffer food insecurity, even controlling for other factors in the models. Also, a higher probability of maintaining food security is found for households with better education, non-farm self-employment, and that include migrant workers. The findings suggest

[1] In our study, food shortage is measured by the question in the survey, 'Has your household experienced hunger during the past 12 months?'

that government policies of practical use in the study area would encourage land consolidation and improve the access of local households to better education and non-farm self-employment.

The article proceeds as follows. Section 2 provides a literature review. Section 3 briefly explains land reform and land fragmentation in Vietnam. Section 4 outlines the methodology and Section 5 discusses the empirical results. Section 6 concludes and outlines some policy implications.

2 | LITERATURE REVIEW

Examining the economic impact of land fragmentation—defined as the division of land into discrete plots dispersed over a wide area but owned by a single household—has long been investigated in agricultural economic literature and related disciplines (Knippenberg et al., 2020). Empirical evidence often reveals that land fragmentation has a negative effect on farm production because fragmentation not only prevents farmers from using modern, mechanised equipment, such as tractors and harvesters, but also prevents the adoption of high profit crops that can only be cultivated on a large scale (Manjunatha et al., 2013). A large labour force is often required to work on fragmented farms, not only because of obstacles to the deployment of agricultural machines but also because more time is needed for travel between plots (Ciaian et al., 2018; Kompas et al., 2012). Fixed costs, for example for fencing (Demetriou et al., 2013) and irrigation, tend to be higher for multiple small plots (Hung et al., 2007). Thus, land fragmentation has had a negative influence on the efficiency and growth of agricultural production in South Asia (Niroula & Thapa, 2005), Japan (Kawasaki, 2010), India (Manjunatha et al., 2013) and Vietnam (Hung et al., 2007; Kompas et al., 2012).

While many studies have demonstrated the negative effect of land fragmentation, not all types of fragmentation have harmed farming households (Ntihinyurwa et al., 2019). For instance, part of a fragmented farm may have better soil quality and therefore be less likely to suffer from the risk of crop disease or natural calamities (Markussen et al., 2016). Land fragmentation may be found where farmers own multiple plots of different quality, allowing them to diversify their crops, optimise labour costs, and reduce production and price risks (Ciaian et al., 2018; Hung et al., 2007; Ntihinyurwa et al., 2019). By farming on plots in different locations (e.g., lowland and upland areas), farming households can minimise the fluctuation in agricultural outputs resulting from various risks, such as drought, floods and disease (Hung et al., 2007).

The bulk of the existing literature on fragmentation emphasises how it affects agricultural production, possibly because farm production is a crucial indicator of the economic well-being of farming households. However, food security is a vital measure of rural household well-being, especially given seasonal variations and market failures (Knippenberg et al., 2020). While numerous studies confirm the negative effect of land fragmentation on farm production (Knippenberg et al., 2020) and household income (Tran & Vu, 2019), which in turn can reduce food security, some studies show that fragmentation may have a positive effect on food security in several countries. Cholo et al. (2019) found that fragmentation has both positive and negative effects and, notably, creates potential advantages for enhancing food security as well as disadvantages. In rural Albania, land fragmentation spurred farmers to actively diversify their crops, thereby enhancing food security, and the effects were greater among subsistence farming households than market-oriented households (Ciaian et al., 2018). A similar finding was recorded for farming households in Rwanda, where

land fragmentation was shown to improve food quality, food sustainability and food security (Ntihinyurwa et al., 2019). Similarly, it was found that Ethiopian households tend to cultivate a wide variety of crop types on very small parcels of land, enabling them to reduce food insecurity by minimising the negative effect of low rainfall (Knippenberg et al., 2020).

The literature review suggests that land fragmentation may have either positive or negative effects on food security, depending on each particular case. While the effect of fragmentation has been well analysed in several developing countries, no similar evidence exists for Vietnam. Responding to the gap in the literature dealing with such an important topic, our study examines the impact of land fragmentation on food insecurity in Vietnam's poorest district on the North Central Coast.

3 | LAND REFORM AND LAND FRAGMENTATION IN VIETNAM

The collectivisation of agricultural land began in the late 1950s in North Vietnam and was extended to the whole country in the late 1970s. In 1981, the Vietnamese Communist Party's Central Committee introduced an official change in policy, implementing a 'product contract' system. The Contract 100 policy formally allowed cooperatives to assign parcels of land to individual households on an annual basis and to contract directly with these households for 'the planting, tending, and harvesting of rice and other crops' (Hirsch et al., 2015). Resolution 10 in 1988 recognised farm households as autonomous economic units, freed up markets for inputs and outputs, recognised private ownership except for land, and also made allowance for longer terms for land use (Hung & Murata, 2001).

The decollectivising process begun under Resolution 10 in 1988, together with the implementation of the 1993 Land Law and Decree 64, formally made stable, long-term allocations of land to farming households and included five land use rights—the rights of transfer, exchange, lease, inheritance and mortgage. While land allocation has resulted in a boost in agricultural output and significant improvement in living standards in rural areas (World Bank, 2016), it has also been the main cause of land fragmentation in Vietnam (Hung et al., 2007), because the egalitarian allocation of agricultural land was based on two principles, namely (i) the number of family members and (ii) the quality of land and other farming factors. Consequently, most households had more than one parcel of land, differing in quality and location, resulting in a high degree of land fragmentation (Hoang, 2018).

4 | DATA AND ANALYTICAL METHOD

4.1 | Data sources

The current study utilises household data from the Quantitative Socio-Economic Survey for Emission Reduction-Program (ER-P) Provinces Areas (QSESERPA), carried out by the MDRI in 2016 (MDRI, 2016). The main purpose of the survey was to gather data on the socio-economic characteristics of the communities in the proposed ER-P, consisting of vulnerable groups and forest-dependent households and communities (mainly ethnic minorities). The survey covered six provinces on the Northern Central Coast, namely Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri and Thua Thien Hue (MDRI, 2016).

The survey used a multi-stage sampling procedure, as follows. First, from the six provinces, 102 communes were randomly selected, following probability proportional to the population size of the provinces. Then, from each of the selected communes, two villages were randomly chosen and 15 households in each village randomly selected for the interviews, giving a total sample size of 3060 households (MDRI, 2016). The survey consists of numerous households from different ethnicities, such as Thai, Muong, Bru-Van Kieu, H'Mong, Co Tu, Ta Oi-Pa Co, and other ethnic minorities. The survey data included various items of information about households and individuals, namely characteristics of family members, education and occupation, income sources, food security, housing, durable goods and detailed information about land (MDRI, 2016).

4.2 | Analytic methods

4.2.1 | Measuring food security

In the current study, based on the information available in the survey data by the MDRI (2016), food insecurity refers to a household's inadequate access to food at certain times during the year and the absence of foods rich in protein in the household diet. Specifically, two questions were used to ascertain household food insecurity: (1) 'Has your household experienced hunger during the past 12 months?'; and (2) 'For how many days within the last 7 days has your household lacked food rich in protein (e.g., meat, fish or eggs)?' Thus, the first indicator of food security takes a dichotomous value, with one for food insecurity and zero for food security. The second indicator has a continuous value but is truncated between 0 days and 7 days.

4.2.2 | Measuring land fragmentation

Land fragmentation is often understood to refer to a single farm that includes several parcels of land. Actually, land fragmentation has many other variations, including the number of plots, plot size, the shape of individual plots, the distance of plots from home and distances among plots (Latruffe & Piet, 2014). However, it is not practical to measure all aspects of land fragmentation (Ciaian et al., 2018), so this is often measured by the Simpson's diversification index, which accounts for the number of plots, plot size and farm size (Ciaian et al., 2018; Latruffe & Piet, 2014; Nguyen, 2014).

The Simpson's fragmented land index is estimated as $[1 - (\sum_j^2 a/A^2)]$ where a_j is the size of plot j, A is the farm size and $A = \sum a_j$. The value of the index ranges between zero and one, with a larger value meaning that land is more diversified or more fragmented (Ciaian et al., 2018). A zero value indicates that the farming household owns only one parcel or plot of land, showing complete land consolidation, while a value close to one means that the household has numerous plots, showing that their farm is 'very fragmented'. In the current study, since fragmentation is most common with annual cropland, the degree of fragmentation was only measured for this type of land, not for other types. We also excluded from our research households without annual cropland.

4.2.3 | Model specification

Factors associated with the first food security indicator were examined using a logit model in Equation (1), where the dependent variable F_i is a binary variable that has a value of one if a household was classified as food insecure and a value of zero if secure; X_i is a vector of household characteristics, such as demographic variables, assets, employment and education; Z_i represents some types of lands (annual cropland, perennial cropland and forestland); G_i indicates land fragmentation, which is the variable of interest in our study. D_i is the dummy variable of villages and e_i is an error term.

$$F_i = \beta_0 + \beta_1 X_i + \beta_2 G_i + \beta_3 Z_i + \beta_4 D_i + e_i \quad (1)$$

Because the second food security indicator, 'the number of days without meals with food rich in protein', is censored at the zero level (i.e., no day), a Tobit model as given in Equation (2) was employed to examine factors affecting food security using the same explanatory variables as those in Equation (1).

$$P_i = \beta_0 + \beta_1 X_i + \beta_2 G_i + \beta_3 Z_i + \beta_4 D_i + e_i \quad (2)$$

Following previous studies (Abdullah et al., 2019; Kidane et al., 2005; Maziya et al., 2017), we included a number of variables at the individual and household levels as explanatory variables in the econometric models. These are the age, education and gender of household heads, household size and the dependency ratio. Other household features were included in the models, such as landholding, wage and non-farm self-employment activities and some assets. Dummy village variables were included to control for village fixed effects. The fragmentation of annual cropland is the variable of interest in our analysis, and is measured by the Simpson's index of fragmented land. We did not include the quality of annual cropland as a control variable in the models.[2] This is because there is a high correlation between it and land fragmentation, indicating a serious multicollinearity issue.[3] The definition, measurement and descriptive statistics of the explanatory variables are given in Tables 1 and 2 in Section 5.1.

Applied econometricians often take the logarithm of variables in order to make the resulting interpretation easier, to obtain an approximately normal distribution, and to minimise heteroscedasticity or the presence of outliers (Bellemare & Wichman, 2020; MaCurdy & Pencavel, 1986). A problem with such a log-transformation is that it does not allow for retaining zero-valued observation because the logarithm of zero is undefined.

[2]The quality of annual cropland plots was measured by the subjective judgement of the household. It takes the values from 1 to 5, namely very infertile (1); infertile (2); normal (3); fertile (4); and very fertile (5). Also, the quality of annual cropland is calculated by a weighted average that takes into account the varying size of plots.

[3]The correlation coefficient between land fragmentation and land quality is −0.86. As noted by Midi et al. (2010), the rule of thumb for identifying a serious multicollinearity is whether the simple correlation coefficient between two regressors is larger than ±0.8. Following suggestions by Allison (2012) and Midi et al. (2010), we also detect multicollinearity by using a linear regression (ordinary least squares) with the variance inflation factor (VIF) statistic. The VIF of land quality and land fragmentation is 3.79 and 4.03, respectively, which are values above 2.5, causing serious concern about multicollinearity in logistic regression (Allison, 2012). Such large VIFs indicate a considerable collinearity, implying that there will be difficulty in separating out the independent contribution of the variables (Johnston et al., 2018).

However, economic data frequently consist of meaningful zero-valued observations. As a result, researchers have often addressed this by adding 1 to the variable prior to its transformation (Bellemare & Wichman, 2020; MaCurdy & Pencavel, 1986). Following this method, we also use $\ln(x + 1)$ when taking the logarithm of perennial cropland and forestland variables.

5 | EMPIRICAL RESULTS AND DISCUSSION

5.1 | Descriptive analysis of household characteristics

Table 1 reveals that there are substantial differences between the ethnic minorities and Kinh/Hoa (majority) group in the mean values of most household characteristics. The proportion of male-led households is 5% higher for ethnic minorities than that for the Kinh/Hoa group. A difference between the two groups in the age and education of household heads was also observed. On average, the household heads of the Kinh/Hoa group were approximately two and a half years older than those of EM households. Notably, the data show that the household heads of the former group had a higher rate of school completion at lower secondary level and higher than did those of the latter group. The mean household size and dependency ratio are slightly smaller for the former than for the latter. Table 1 also reveals that the percentage of households with at least one member engaging in wage-paying or self-employed activities was higher for the Kinh/Hoa than for ethnic minority groups.

The average housing area was larger for the Kinh/Hoa (71 m^2) than for the ethnic minority groups (50 m^2). The former also lived closer to fresh water sources than did the latter. For instance, the closest distance from the house to a fresh water source is 10 m for the former while it is 166 m for the latter. Table 2 indicates that there were also disparities between the two groups in landholdings. Specifically, the mean area of annual cropland managed by Kinh/Hoa households was slightly less than that farmed by ethnic minority households. However, the former held a larger average size of perennial cropland and forestland than did the latter. For the Kinh/Hoa group, each household owned an average of 2.3 plots of annual cropland while the corresponding figures were about 1.9 plots for the ethnic minorities. Also, the data on land fragmentation in Table 2 reveals that the former tended to own annual cropland that was more fragmented than did the latter (0.53 vs. 0.42). Table 2 also reports the quality of annual cropland as measured by the subjective judgement of the household. It shows that the mean score of land quality is somewhat higher for ethnic minorities than for Kinh/Hoa households.

For the whole sample, the data in Table 1 show that 35% and 78% of households, on average, owned at least a motorbike and a water pump, respectively. However, the figures were much higher for the Kinh/Hoa group (78% and 92%) than for the ethnic minority group (21% and 73%). Table 1 also indicates that Kinh/Hoa households attained a much higher level of income and food security than did ethnic minority households. Specifically, the monthly per capita income earned by the former was nearly twice as much as that of the latter. Over the previous 12 months, 26% of Kinh/Hoa households suffered from hunger, while the corresponding figure is 51% for ethnic minority households. In addition, the average number of days without protein-rich food was much higher for the latter (3.67 days) than for the former (1.53 days). This suggests that ethnicity may be closely linked with food insecurity in the study area.

TABLE 1 Comparing household characteristics by ethnicity

Variables	Ethnic minorities		Kinh/Hoa (Ethnic majority)		Total	
	Mean	SD	Mean	SD	Mean	SD
Characteristics of household head						
Gender of household head (1 = male; 0 = female)	90%		85%		89%	
Age of household head (years)	33.17	7.11	35.68	7.98	33.80	7.42
No education (1 = yes; 0 = no)	38%		16%		33%	
Primary education (1 = yes; 0 = no)	27%		26%		27%	
Lower secondary (1 = yes; 0 = no)	24%		42%		29%	
Upper secondary (1 = yes; 0 = no)	6%		10%		7%	
Above secondary (1 = yes; 0 = no)	4%		6%		5%	
Household characteristics						
Household size (numbers)	4.76	1.67	4.12	1.47	4.60	1.65
Dependency ratio (ratio)	86%		75%		83%	
Wage employment (1 = yes; 0 = no)	63%		70%		65%	
Non-farm self-employment (1 = yes; 0 = no)	8%		14%		10%	
Water pump (1 = yes; 0 = no)	21%		78%		35%	
Motorbike (1 = yes; 0 = no)	73%		92%		78%	
Housing area (m^2)	50	32	71	40	55	36
Closest distance to a fresh water source (m)	166	499	10	87	127	439
Monthly income per capita (1.000 Vietnam dong: VND)	661	841	1334	1875	831	1225
Hunger over the last 12 months (1 = yes; 0 = no)	51%		26%		45%	
Number of days without protein-rich food within the last 7 days	3.67	2.44	1.53	2.03	3.13	2.52
Observations	1845		602		2447	

Source: Authors' calculations using data from the Quantitative Socio-Economic Survey for Emission Reduction-Program Provinces Areas (QSESERPA) survey.

Abbreviation: SD, standard deviation.

5.2 | Econometric results

5.2.1 | Impact of land fragmentation on hunger

Table 3 reports the empirical results from the logit regression models with three different specifications. All households in Model 1, only ethnic minority households in Model 2 and only Kinh/Hoa households in Model 3. It can be seen that the coefficient on land fragmentation variables is positive and statistically highly significant in Models 1 and 2 but not in Model 3. We also provide the results in terms of odd ratios as given in Appendix 1. The result from Model 1 in

TABLE 2 Land holdings by ethnicity

Land variables[a] (m^2)	Annual cropland (m^2)	Perennial cropland (m^2)	Forestland (m^2)	Number of plots (numbers)	Average size of plots (m^2)	Land fragmentation (Simpson index)	Land quality[b]
Ethnic minorities							
Mean	6276	370	10,171	1.91	3141	0.42	1.99
SD	9559	2053	18,669	1.06	4501	0.39	1.05
Min	20	0	0	1	20	0	0.22
Max	100,000	50,000	240,000	8	60,000	0.98	5
Kinh/Hoa							
Mean	5957	709	13,106	2.29	2760	0.53	1.78
SD	9652	1634	27,500	1.42	4456	0.38	1.06
Min	50	0	0	1	50	0	0.21
Max	92,150	20,000	380,000	9	45,600	0.98	5
Whole sample							
Mean	6196	456	10,912	2.01	3045	0.45	1.93
SD	9581	1961	21,279	1.17	4492	0.39	1.06
Min	20	0	0	1	20	0	0.21
Max	100,000	50,000	380,000	9	60,000	0.98	5

Source: Authors' calculations using data from the Quantitative Socio-Economic Survey for Emission Reduction-Program Provinces Areas (QSESERPA) survey.

Abbreviation: SD, standard deviation.

[a]Lands that are operated by households.

[b]The quality of annual cropland plots was measured by the subjective judgement of the household, using values from 1 to 5, namely very infertile (1); infertile (2); normal (3); fertile (4); and very fertile (5). Also, the quality of annual cropland is calculated by the weighted average that takes into account the varying size of plots.

Table 3 indicates that for a 10 percentage point increase in the Simpson index of land fragmentation, it is expected to see about a 5% increase in the odds of a household suffering from hunger, holding all other variables constant in the model. Model 2 reveals that the effect is much larger for ethnic minority households, with about a 9% increase in the odds of going hungry.[4]

Our study confirms that the more fragmented a household's annual cropland, the more likely it is that the household will suffer from food insecurity, even after controlling for all other factors in the model. The explanation may be that land fragmentation results in greater costs than benefits for farming households, as already suggested in the literature review. In addition, our study shows that land fragmentation tends to be less fertile,[3] which in turn can reduce farm productivity and increase the risk of going hungry. Our finding is inconsistent with that of

[4]We can get the odds ratio by exponentiating the coefficient for a variable, for instance land fragmentation in Model 2. For a 10 percentage point increase in the land fragmentation, the odds of going hungry can be expressed in terms of exponential function, as: $\exp(0.86 * 0.1) = 1.0898063 \approx 1.09$.

TABLE 3 Logit estimates for the impact of land fragmentation on hunger

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Land fragmentation	0.49*	0.86***	0.09
	(0.259)	(0.246)	(0.514)
Ethnicity	−0.58**		
	(0.266)		
Age	0.01	0.00	0.01
	(0.011)	(0.010)	(0.016)
Gender	−0.26	−0.51*	−0.06
	(0.206)	(0.282)	(0.298)
Primary education	0.03	0.02	−0.16
	(0.212)	(0.173)	(0.428)
Lower secondary education	−0.02	−0.09	−0.11
	(0.216)	(0.187)	(0.382)
Upper secondary education	−1.55***	−1.26***	−2.32***
	(0.260)	(0.334)	(0.619)
Above upper secondary	−1.51***	−1.55***	−1.93*
	(0.457)	(0.410)	(1.141)
Household size	0.27***	0.17***	0.46***
	(0.061)	(0.043)	(0.120)
Dependency ratio	−0.18	−0.06	−0.32
	(0.139)	(0.099)	(0.260)
Annual cropland	−0.19***	−0.25***	−0.08
	(0.060)	(0.075)	(0.063)
Perennial cropland	−0.04	−0.00	−0.05
	(0.026)	(0.024)	(0.048)
Forestland	−0.04*	−0.03*	−0.06
	(0.024)	(0.016)	(0.047)
Wage employment	0.01	0.10	−0.28
	(0.148)	(0.193)	(0.286)
Self-employment	−0.57**	−0.44**	−0.76
	(0.267)	(0.205)	(0.509)
Water pump	0.13	0.18	−0.01
	(0.161)	(0.188)	(0.298)
Motorbike	−0.80***	−0.85***	−0.92
	(0.203)	(0.134)	(0.567)

TABLE 3 (Continued)

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Housing area	−1.31***	−1.02***	−1.67***
	(0.286)	(0.169)	(0.565)
Closest distance to a fresh water source	0.12***	0.12***	0.09
	(0.036)	(0.037)	(0.105)
Constant	5.84***	5.73***	5.95**
	(1.153)	(0.871)	(2.703)
Pseudo R^2	0.25	0.23	0.18
Observations	2447	1845	602

Note: Robust standard errors (SEs) in parentheses. Estimates were accounted for by sampling weights and clustered at the commune level. Response variable: food hunger (1 = yes; 0 = no).

Source: Authors' calculations using data from the Quantitative Socio-Economic Survey for Emission Reduction-Program Provinces Areas (QSESERPA) survey.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

earlier studies in Ethiopia (Cholo et al., 2019; Knippenberg et al., 2020), which found that land fragmentation reduces food insecurity because of its positive influence on crop diversification. In our study, it should be noted that while land fragmentation threatened food security among ethnic minorities, this was not the case for the Kinh/Hoa population.

Regarding the role of land holdings in food security, the result in Model 1 shows that having more annual cropland and forestland lowers the odds of experiencing hunger. However, the result for each group of households in Models 2 and 3 reveals that such an effect is found only for ethnic minorities. Our research finding is in line with previous studies in some African countries (Kidane et al., 2005; Mango et al., 2014) or in rural Myanmar (Rammohan & Pritchard, 2014), where annual cropland plays a significant role in improving food security. While household size, the dependency ratio and forestland were major factors affecting household income and poverty reduction in the North Central Coast (Nguyen & Tran, 2018), our research reveals that a larger household size reduces food security, while owning forestland has a small effect on reducing hunger among ethnic minorities in the same region. Each additional household member increases the odds of experiencing hunger by about 31% for the whole sample. The corresponding effects are 18.50% and 58.40% for ethnic minorities and Kinh/Hoa households, respectively.

We also found that other factors, such as ethnicity, better education and participation in non-farm self-employment, all have a significant influence on the reduction of food insecurity. This can be explained with the observation that better education can help households improve their productivity and income, which in turn can reduce the risk of experiencing hunger. Also, participation in non-farm self-employment enables households to diversify their income, thereby lowering the likelihood of suffering from hunger. Specifically, Model 1 shows that households whose heads belong to the ethnic majority group are 44% less likely to suffer from hunger than those whose heads belong to ethnic minorities.[5] Better education also helps reduce

[5]The odds ratio is calculated as exp (−0.58 * 1) = 0.56, which means the odds of experiencing hunger are (−0.44) about 44% lower for females than those for males.

the probability of households experiencing hunger. For example, the odds of going hungry for a household whose head has attained an upper secondary education are 79% lower than those for a household whose head lacks formal education. Such an impact was found for both ethnic minority and Kinh/Hoa households, with the corresponding odds being −72% and −90%, respectively. Similar findings were also found in Ethiopia (Kidane et al., 2005) and Pakistan (Abdullah et al., 2019).

Table 3 shows that households with non-farm self-employment are less likely to suffer from hunger. Specifically, the odds of experiencing hunger are about 43% lower for a household with non-farm self-employment (relative to one without non-farm self-employment). A similar result was recorded for ethnic minority households but not for Kinh/Hoa households. Our finding is in line with that in Ghana (Owusu et al., 2011) and rural Myanmar (Rammohan & Pritchard, 2014). We also discover that having a motorbike and living in a larger housing area closer to a fresh water source reduce the odds for the whole sample of a household experiencing hunger. The same effects were observed for ethnic minority households, while only the impact of the housing area was confirmed for Kinh/Hoa households.

5.2.2 | Impact of land fragmentation on protein-rich foods

Table 4 shows the impact of land fragmentation on the number of days that a household had meals without protein-rich food (e.g., eggs, meat, and fish) within the previous 7 days. As in Table 3, Table 4 provides the estimated effects from the Tobit regression models with three

TABLE 4 Tobit estimates for the impact of land fragmentation on the availability of protein-rich food

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Land fragmentation	1.14***	0.94***	1.11
	(0.389)	(0.298)	(0.889)
Ethnicity	−1.37***		
	(0.376)		
Age	−0.03	−0.02	−0.03
	(0.019)	(0.012)	(0.034)
Gender	−0.25	−0.38	0.13
	(0.261)	(0.324)	(0.387)
Primary education	−0.45*	−0.45**	−0.31
	(0.250)	(0.193)	(0.624)
Lower secondary education	−0.44	−0.54**	−0.57
	(0.272)	(0.242)	(0.610)
Upper secondary education	−1.49**	−0.99***	−1.81*
	(0.593)	(0.360)	(1.100)
Above upper secondary	−1.87***	−1.22*	−2.51*
	(0.703)	(0.623)	(1.384)

TABLE 4 (Continued)

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Household size	0.09	0.19***	−0.03
	(0.074)	(0.058)	(0.193)
Dependency ratio	0.08	0.16***	0.04
	(0.126)	(0.084)	(0.258)
Annual cropland	−0.22**	−0.01	−0.59**
	(0.102)	(0.085)	(0.230)
Perennial cropland	0.04	−0.09***	0.11
	(0.050)	(0.031)	(0.070)
Forestland	−0.02	−0.01	−0.03
	(0.023)	(0.019)	(0.043)
Wage employment	−0.08	−0.32*	0.16
	(0.359)	(0.171)	(0.693)
Self-employment	−1.07***	−1.01***	−1.06***
	(0.290)	(0.310)	(0.407)
Water pump	−0.71**	−0.69**	−0.55
	(0.343)	(0.350)	(0.717)
Motorbike	−0.96***	−0.78***	−1.09*
	(0.219)	(0.159)	(0.587)
Housing area	−0.79***	−1.01***	−0.66*
	(0.210)	(0.200)	(0.348)
Closest distance to a fresh water source	0.18***	0.14***	0.16
	(0.043)	(0.039)	(0.160)
Constant	10.06***	8.33***	11.08***
	(1.185)	(1.029)	(2.602)
Sigma	2.76***	2.37***	3.03***
	(0.105)	(0.091)	(0.252)
Pseudo R^2	0.09	0.08	0.07
Observations	2447	602	1845

Note: Robust standard errors in parentheses. Estimates are accounted for by sampling weights and clustered at the commune level. Dependent variable: number of days without food rich in protein within the last 7 days. 736 households with food-security.

Source: Authors' calculations using data from the Quantitative Socio-Economic Survey for Emission Reduction-Program Provinces Areas (QSESERPA) survey.

***$p < 0.01$, $p < 0.05$, $p < 0.1$.

different specifications. All households in Model 1, only ethnic minority households in Model 2 and only Kinh/Hoa households in Model 3. Table 4 reveals that while the coefficient on the Simpson index variable is positive and statistically significant at the 0.05 level in Models 1 and 2, this is not the case for Model 3.

The Tobit coefficients can be interpreted in the same way as the ordinary least squares regression coefficients. Nevertheless, the linear effect is on the uncensored latent variable, not the observed outcome (McDonald & Moffitt, 1980). The result in Model 1 shows that for the whole sample, a 10 percentage point increase in land fragmentation would increase the number of days without protein-rich food by 0.114 in a week. The corresponding effect is 0.094 days for ethnic minority households. The finding suggests that land fragmentation increases the number of days without protein-rich food for ethnic minority households, even after controlling for various individual and household variables in the models. However, a similar effect was not found for Kinh/Hoa households.

Considering the role of land holdings in ensuring a supply of protein-rich food, Table 4 shows that annual cropland plays a major role in reducing food insecurity for Kinh/Hoa households but not for ethnic minority households. By contrast, perennial cropland helps reduce food insecurity for the latter but not for the former. As with the findings in Table 3, the results in Table 4 confirm the important role of ethnicity, education and non-farm self-employment in reducing the number of days without protein-rich food for local households. For instance, the number of days in a week without protein-rich food would be 1.37 days less for a household whose head was from the Kinh/Hoa group than for one whose head was from an ethnic minority.

We also found that better education and non-farm self-employment help reduce food insecurity for local households. For instance, the number of days without protein-rich food would be 1.99 days less (−1.99 days) for a household whose head attained upper secondary education than for one without education. The corresponding effect is −0.99 days and −1.81 days for the ethnic minority and Kinh/Hoa groups, respectively. In addition, the number of days without protein-rich food would be 1.07 days less for a household with non-farm self-employment than for one without. A similar effect was found for both ethnic minority and Kinh/Hoa households. Owning water pumps, motorbikes and living in a larger housing area and closer to a fresh water source reduce the number of days without protein-rich food among ethnic minority households. However, a similar effect from owning motorbikes and living in a larger housing area is only observed among Kinh/Hoa households.

6 | CONCLUSION AND POLICY IMPLICATIONS

It is generally recognised that the land reform of the early 1990s was one of the most important causes of land fragmentation in Vietnam. While the effect of land fragmentation on farm efficiency and the diversification of production has been well established in the literature, there is limited econometric evidence for its effect on food security in Vietnam. Using a micro-econometric approach with household survey data, our study is the first to investigate the effect of land fragmentation on food security in the poorest districts of Vietnam's North Central Coast.

The main findings of our research are as follows. First, land fragmentation, as measured by the Simpson index, was found to increase the likelihood of a household suffering from food insecurity (i.e., hunger) during the year, and more days without protein-rich food within a week. Such negative effects were found only for ethnic minority households, not for Kinh/Hoa

households. The finding is robust to various model specifications, even after controlling for income and other socio-economic characteristics of households. Thus, our findings indicate that land fragmentation has a negative effect on food security at the household level. Consequently, our research finding implies that policies for promoting land consolidation (or reducing land fragmentation) would help reduce food insecurity among ethnic minorities in the study area. A similar policy implication is also suggested in Ethiopia, where combining multiple small plots into larger heterogeneous plot clusters could improve food security (Cholo et al., 2019).

Second, we find that the level of education of household heads plays a major role in ensuring food security, reducing both hunger and the number of meals without protein-rich food for local households. In addition, it was found that non-farm self-employment enabled households to reduce food insecurity. Overall, our research findings are consistent with previous studies, which confirm the positive role of education and non-farm self-employment in improving food security at the household level.

Third, the current study found that EM households were much more vulnerable to food insecurity than were Kinh/Hoa households. A useful implication here is that it should be of practical use in the region to implement policies expanding opportunities for local households to gain access to better education and local non-farm activities. Also, food security for ethnic minorities should be given the highest priority on the rural development agenda in Vietnam.

Our study has certain shortcomings. Since we used cross-sectional data, we were unable to investigate the effect of land fragmentation on food security over time. Also, the use of panel data to examine the effect of fragmentation would reduce bias, as this method allows researchers to remove time-invariant unobservable household characteristics that might affect household well-being. This implies that given the availability of panel data, further research should address this issue. In addition, with detailed information on food consumption, future research should measure food security using both objective and subjective indicators.

CONFLICT OF INTEREST

The authors declare that they received no funding for this research and there is no conflict of interest in this research.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the Vietnam General Statistics Office upon reasonable request.

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APPENDIX 1

TABLE A1 Odd ratio estimates for the impact of land fragmentation on hunger

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Land fragmentation	1.63*	2.37***	1.09
	(0.421)	(0.583)	(0.559)
Ethnicity	0.56**		
	(0.149)		

(Continues)

TABLE A1 (Continued)

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Age	1.01	1.00	1.01
	(0.011)	(0.010)	(0.017)
Gender	0.77	0.60*	0.94
	(0.158)	(0.169)	(0.281)
Primary education	1.03	1.02	0.85
	(0.218)	(0.176)	(0.364)
Lower secondary education	0.98	0.91	0.90
	(0.212)	(0.171)	(0.342)
Upper secondary education	0.21***	0.28***	0.10***
	(0.055)	(0.095)	(0.061)
Above upper secondary	0.22***	0.21***	0.15*
	(0.101)	(0.087)	(0.166)
Household size	1.31***	1.18***	1.58***
	(0.081)	(0.051)	(0.190)
Dependency ratio	0.83	0.94	0.73
	(0.116)	(0.093)	(0.189)
Annual cropland	0.82***	0.78***	0.92
	(0.050)	(0.059)	(0.058)
Perennial cropland	0.96	1.00	0.95
	(0.025)	(0.024)	(0.046)
Forestland	0.96*	0.97*	0.94
	(0.023)	(0.016)	(0.044)
Wage employment	1.01	1.10	0.75
	(0.150)	(0.212)	(0.215)
Self-employment	0.57**	0.64**	0.47
	(0.151)	(0.132)	(0.237)
Water pump	1.14	1.20	0.99
	(0.183)	(0.227)	(0.295)
Motorbike	0.45*** (0.092)	0.43*** (0.057)	0.40 (0.225)
Housing area	0.27***	0.36***	0.19***
	(0.077)	(0.061)	(0.106)
Closest distance to a fresh water source	1.12***	1.13***	1.09
	(0.040)	(0.042)	(0.114)

TABLE A1 (Continued)

Explanatory variables	Whole sample Model 1	Ethnic minorities Model 2	Kinh/Hoa Model 3
Constant	342.84***	5.73***	385.13**
	(395.172)	(0.871)	(1041.114)
Pseudo R^2	0.25	0.23	0.18
Observations	2447	1845	602

Note: Robust standard errors in parentheses. Estimates were accounted for by sampling weights and clustered at the commune level. Response variable: food hunger (1 = yes; 0 = no).

Source: Authors' calculations using data from the Quantitative Socio-Economic Survey for Emission Reduction-Program Provinces Areas (QSESERPA) survey.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.