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Does Land Fragmentation Affect Household Livelihood Choice in Rural Vietnam?***

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Abstract

This paper examines how cropland fragmentation affects livelihood choice among households in Vietnam's 12 provinces over the 2008–2016 period. Using cluster analysis techniques, we first classify households into various livelihood clusters. Then, employing multinomial logit regression analysis, we quantify how land fragmentation affects livelihood choice. The current research shows that land fragmentation has a positive impact on nonfarm diversification. Households with a higher intensity of fragmentation have a higher likelihood of pursuing a wide range of strategies based on nonfarm self-employment, wage-earning, or remittance sources rather than specialize in cultivation. Our findings suggest that households actively diversify away from agriculture in response to the disadvantages of land fragmentation. Notably, we discover that such coping strategies provide higher incomes than a cultivation-based livelihood.

Keywords: Land fragmentation; Livelihood choice; Multinomial logit; Income; Rural Vietnam

JEL: D31, D63, Q12, Q18

1. Introduction

Land fragmentation is a common agricultural issue in many countries, where a single farm contains many separate land parcels (Knippenberg, Jolliffe, & Hoddinott, 2020). While agricultural land is a rural household's most valuable asset in Vietnam, it has higher levels of fragmentation and the parcels are small in size (Nguyen, 2014; Pham, MacAulay, & Marsh, 2007; Tran & Vu, 2019). The median farm size in the northern plains, for example, is less than a quarter of a hectare, and arable land is divided into 5.5 different plots on average (Markussen, Tarp, Thiep, & Tuan, 2016). Also, the degree of fragmentation is much higher in Vietnam than in other South Asian countries, such as Cambodia, Myanmar, and the Philippines (World Bank [WB], 2016).

In several countries, land fragmentation has been shown to be an obstacle to profitable crop cultivation and agricultural mechanization (Ali, Deininger, & Ronchi, 2019; Markussen

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et al., 2016; Niroula & Thapa, 2005). For rural households, a number of studies have illustrated the negative consequences of land fragmentation, for instance its effect on crop productivity in some provinces of North Vietnam (Pham et al., 2007), and in rural Vietnam generally, lower farm efficiency and a greater need for labor (Nguyen, 2014). Other recent studies reveal that land fragmentation reduces crop and total income for rural households (Tran & Vu, 2019) and increases food insecurity for ethnic minorities in the North Central provinces (Tran & Vu, 2021). To the best of our understanding, nevertheless, no research has analyzed the influence of land fragmentation on the choice of rural household livelihood in Vietnam. A comprehensive understanding of how land fragmentation affects livelihood choice is necessary when designing and implementing policies to help rural households improve their living standards. The research gap and the importance of the topic inspired us to implement the current study.

In this piece of research, we analyze the impact of cropland fragmentation on livelihood choice among rural households in Vietnam's 12 provinces over the 2008–2016 period. First, we classify households into various livelihood clusters employing cluster analysis techniques. Using a multinomial logit regression analysis, next we quantify how land fragmentation affects livelihood choice. We provide the first result that land fragmentation increases the likelihood of choosing non-farming livelihoods. Specifically, households with higher levels of fragmentation have a higher probability of adopting various other livelihoods relied on nonfarm, wage-earning, or remittance sources rather than specializing in cultivation. Our finding suggests that households have responded to the disadvantage of land fragmentation by diversifying towards non-farming activities. In particular, we find that such coping strategies offer higher incomes than livelihoods based on farming.

The rest of the research is organized into five sections. Theoretical and empirical evidence is given in Section 2, while data and methods are reported in Section 3. Section 4 provides results and discussion, followed by Section 5 that gives conclusions and offers some useful policy recommendations.

2. Theoretical and empirical evidence

There are several channels through which land fragmentation results in negative effects for agricultural production. For instance, farms that are fragmented are likely to entail higher transportation costs. If parcels are far from home as well as from each other, farmers waste time traveling between the parcels and home (Ciaian, Guri, Rajcaniova, Drabik, & y Paloma, 2018; Kompas, Che, Nguyen, & Nguyen, 2012). It is also more difficult, time-consuming, and expensive to manage, supervise, and secure scattered plots. Not only do irrigation costs tend to be higher for fragmented farms (H. Nguyen, 2014; Pham et al., 2007), but small, dispersed plots often demand a larger labor force, waste land, and require even more land as well as fixed costs for fencing, border construction, paths, and roads (Ciaian et al., 2018; Demetriou, Stillwell, & See, 2013). In particular, land fragmentation hinders farmers from using modern, mechanized equipment, such as tractors and harvesters, and discourages farmers from planting highly profitable crops that can only be grown on a large scale (Manjunatha, Anik, Speelman, & Nuppenau, 2013). Consequently, land fragmentation has reduced the growth and productivity of agricultural production in

Bulgaria (Di Falco, Penov, Aleksiev, & Van Rensburg, 2010), China (Nguyen, Cheng, & Findlay, 1996), India (Manjunatha et al., 2013), France (Latruffe & Piet, 2014), Japan (Kawasaki, 2010), South Asia (Niroula & Thapa, 2005) and Vietnam (Kompas et al., 2012). Therefore, land consolidation programs have been implemented in many countries (Jin, Xu, Xiang, Bai, & Zhou, 2016; Niroula & Thapa, 2005; Oldenburg, 1990; Wu, Liu, & Davis, 2005).

While empirical evidence frequently points out the disadvantages of fragmentation, there are arguments that fragmentation is not always bad, and in some cases may even benefit farmers in several ways. Fragmented farms may offer a variety of soils and planting conditions that allow farmers to diversify their plants, optimize expenses, and lower market risk (Ciaian et al., 2018; Di Falco et al., 2010; Kawasaki, 2010; Pham et al., 2007). Furthermore, by growing crops in distinct parcels in different places, farmers can mitigate fluctuations in output caused by events like floods, droughts, and disease (Markussen et al., 2016). For example, land fragmentation in rural Albania had a significant effect on agricultural diversification, lowering food insecurity, with the influences being larger for small farm households than for large farm households (Ciaian et al., 2018). The same result was discovered in Rwandan farm households, where land fragmentation improved food quality, food security and food sustainability (Ntihinyurwa, de Vries, Chigbu, & Dukwiyimpuhwe, 2019). Land fragmentation was found to mitigate crop yield loss when households suffered rainfall fluctuations in Africa (Veljanoska, 2018).

The literature suggests that fragmentation has both advantages and disadvantages and depending on the specific case, can be beneficial or harmful. In Vietnam, fragmentation has been found to reduce farm efficiency and increase labor costs (Nguyen, 2014; Pham et al., 2007). Nguyen and Warr (2020) similarly find that a lower level of land fragmentation promotes rice productivity, encourages the use of mechanized equipment and reduces the amount of farm labor needed, which in turn provides more labor for nonfarm activities.

In Vietnam, other studies reveal that fragmentation makes food security worse for ethnic minorities (Tran & Vu, 2021) and reduces rural households' income (Tran & Vu, 2019). While the literature on Vietnam and other countries has often investigated how fragmentation affects crop productivity or household well being (income or food security), no study has investigated how fragmentation affects livelihood choice among rural households in Vietnam. The current research is the first to fill this research gap. We hypothesize that land fragmentation increases the likelihood of households diversifying their livelihoods toward non-farming activities as a coping strategy. If such strategies offer higher incomes than those dependent on farming, we can draw the assumption that households have effectively coped with this disadvantage of land fragmentation.

3. Data and methods

3.1. Data

In our study, household data from 2008 to 2016 were taken from the Viet Nam Access to Resources Household Surveys (VARHS). The surveys were carried out every two years in 12 Vietnamese provinces, namely Lao Cai, Phu Tho, Lai Chau, Dien Bien, Hanoi (Ha Tay), Nghe An, Quang Nam, Khanh Hoa, Dak Lac, Dak Nong, Lam Dong and Long

An. While the VARHS is not a nationally representative survey, they are representative at the provincial level and give a wealth of rich information on household demography, education, occupation, assets and income-generating activities for individuals and households. The surveys were carried out in cooperation with the Institute for Economic Management (CIEM) and Social Affairs of Vietnam's Institute of Labor, Science, and Social Affairs (ILSSA). After selecting relevant variables for our analysis, we made use of households included in VARHSs from 2008, 2010, 2012, 2014, and 2016, consisting of 1751, 1709,1862, 2004 and 2012 samples, respectively.

3.2. Theoretical framework

In terms of the conceptual framework, our study is based on the sustainable rural livelihood (SRL) framework (Ellis, 2000; Scoones, 1998). We classified households into income livelihood typologies, based on the share of household income from various sources (Ellis, 2000). In particular, we consider sources of household income earned from various activities as livelihood strategies to utilize household resources and manage any negative effects on livelihood outcomes caused by land scarcity and fragmentation, adverse climate shocks, uncertain agricultural activities, unpredictable market conditions, and land scarcity (Asfaw, Scognamillo, Di Caprera, Sitko, & Ignaciuk, 2019; Barrett, Reardon, & Webb, 2001; Gautam & Andersen, 2016; Nguyen, Tran, & Van, forthcoming; Tran & Vu, 2020). In this sense, the current study investigates the role of land, especially land fragmentation, among other factors, in their choice of livelihood strategies.

3.3. Classification of livelihood strategies

The data from the 2008-2016 VARHS reveal that each family individual participated in one or more income-generating activities, and that each family commonly engaged in multiple activities. As a result, livelihood strategies adopted by local households should not be determined solely by separate activities. Accordingly, our research utilizes cluster analysis methods to categorize households based on their income sources. This methodology enables us to group a sizable number of households into an exhaustive set of mutually exclusive clusters, so that households in one livelihood group have similar characteristics while those in other groups have dissimilar characteristics (Everitt, Landau, Leese, & Stahl, 2011; Romesburg, 2004).

Following previous studies on rural Vietnam (Hoang, Tran, Nguyen, & Nguyen, 2019; Tran, Lim, Cameron, & Vu, 2014), we select proportion of income by source as a clustering variable. Given that incomes are directly comparable, the income share approach has been widely used because it provides a straightforward and easy interpretation for quantitative studies (Soltani, Angelsen, Eid, Naieni, & Shamekhi, 2012). Six income sources were used as clustering variables, namely (1) income from cultivation (crops and forest); (2) income from animal husbandry (poultry, cattle, aquaculture); (3) income from wage-earning work (both in the private and public sectors); (5) income from public transfers (pensions and social welfare) and (6) other income from remittances, interest, rentals and gifts.

Cluster analysis techniques can be used in several ways. In our study, a two-step cluster analysis approach is used, as described by

Punj and Stewart (1983) and Halpin (2016). First, we used the Duda stopping rule to obtain the suitable number of clusters employing average-linkage cluster analysis (Halpin, 2016). The large value of the Duda is 0.7124 while the pseudo-T squared is 565.70, which corresponds to the suitable number of six clusters (see Appendix 1). K-mean clustering is then used to perform cluster analysis with six clusters. Finally, we define and name the clusters discovered, and interpret them by analyzing the differences in the mean share of income sources among clusters. Tables 1, 2, and 3 show the household income structure and characteristics for each of the six livelihood groups identified.

3.4. Modeling factors affecting livelihood choice

We employ a multinomial logit model (MLM) to quantify the effect of land fragmentation on livelihood choice since this choice is a response variable with five categories. Because of its ease of estimation and interpretation, the MLM is probably the most popularly used estimator for nominal response variables (Cheng & Long, 2007). Let L_{ij} (j = 1, 2, 3, 4, 5, 6) and express the likelihood of a household adopting a specific livelihood, with j = 1 indicating that the household has chosen a non-farming livelihood, j=2 showing that the household has adopted a wage-earning livelihood, j=3 for households choosing a cultivation livelihood, j=4 for households taking up a wage-earning and farming livelihood, j=5 for households pursuing a public transfer and husbandry livelihood, and j=6 for households adopting some other income and cultivation livelihood. Specifically, the MLM was created by:

$$L_{ij}(j = k|X_i) = = \frac{\exp(\beta_k X_i)}{\sum_{j=1}^{6} \exp(\beta_j X_i)} (j = 1,2,3,4,5,6) \quad (1)$$

In Equation (1), the model is only identified if β_j is defined as zero for one of the livelihood clusters and the interpretation of coefficients can be done comparison with that cluster, called the base or reference group (Train, 2003). In the current study, the cultivation livelihood is selected as the reference category. In Equation (2), L_{ij} denotes the livelihood strategy of a household *i*, β_i is the parameter to be calculated, X_{ij} is a vector of household features, Z_i represents various sorts of land, C_i is the commune-level variable, and u_i is an error term.

$$L_{ij} = \beta_{0+} \beta_1 X_i + \beta_2 \text{Land fragmentations}_i + \beta_3 Z_i + \beta_4 C_i + u_i \quad (2)$$

Land fragmentation is measured by the Simpson index. The Simpson index for each household can be given as:

$$S = 1 - \sum_{i=1}^{N} a_i^2 / \left(\sum_{i=1}^{N} a_i \right)^2$$

Where a_i shows the size of a plot i owned by a household, and N indicates the total number of plots. The value of the index lies between zero and one, with a greater value showing higher levels of fragmentation (Ciaian et al., 2018).

4. Results and discussion

4.1. Household characteristics by livelihood

Table 1 compares the income proportion of six livelihood clusters. The first cluster is the "nonfarm livelihood", where income from nonfarm self-employment accounts for about 72% of total income. The second cluster can be called the "wage-earning livelihood"

because households in this group earned about 82% of their total income from wage-paying employment. The third cluster is made up of those who derive about 68% of their total income from farming, which can be labeled a "cultivation livelihood." The fourth cluster comprises the "wages/cultivation livelihood" because wage-earning work and cultivation contribute on average about 49% and 21% respectively of the total income for households in this group. The fifth cluster is the "public transfers/husbandry livelihood", where the total income of households in this group is received from public transfers (about 33%) and animal husbandry (approximately 30%). Finally, the sixth cluster is the "other income/cultivation livelihood." Other income, including remittances, rental income, interest, and gifts make up about 63% of total income for households in this group.

Table 1. Income shares by livelihood cluster

Livelihood clusters/ Proportion of income	Nonfarm livelihood	Wage-earning livelihood	Cultivation livelihood	Wages/ cultivation livelihood	Public transfers /husbandry livelihood	Other income/ cultivation livelihood	Total
Wages	7.56%	81.83%	6.80%	48.75%	6.25%	7.66%	34.03%
Cultivation	8.80%	8.55%	68.10%	21.26%	17.22%	13.77%	23.91%
Animal husbandry	4.14%	2.59%	10.64%	10.89%	29.83%	6.27%	10.03%
Nonfarm	72.04%	1.24%	1.93%	5.52%	3.68%	2.73%	12.05%
Public transfers	2.25%	1.76%	3.59%	4.79%	32.66%	6.54%	7.36%
Remittances/ gifts/rents	5.21%	4.04%	8.94%	8.79%	10.36%	63.03%	12.61%
Observations	1224	2236	1711	2039	1234	894	9338
%	13%	24%	18%	22%	13%	10%	100%

Source: Authors' estimation from the 2008-2016 VHARSS.

Table 2 shows how the number of households by livelihood cluster changed over time. Between 2008 and 2016, the number of households specializing in nonfarm self-employment grew by one percentage point, from 12.70% to about 13.10%. At the same period, the number of households with a wage-earning livelihood grew significantly, from about 16% to roughly 24%. There was a substantial decline in the number of households specializing in cultivation, falling from about 32% to approximately 18%. The number of households with a wage-earning/ cultivation livelihood declined slightly from about 24% to 22%, while the number of those with a public transfers/husbandry livelihood increased from around 12% to 13.2%. The number of households pursuing a livelihood based on other income or cultivation also rose from about 6.2% to 9.6%. In general, the data shows a shift of households from cultivation to other livelihood strategies over the period 2008–2016.

Table 2. Livelihood clusters by year

Livelihood clusters by year	2008	2010	2012	2014	2016	Total
Nonfarm livelihood						
Obs	222	232	228	264	278	1,224
%	12.68	13.58	12.24	13.17	13.82	13.11
Wage-earning livelihood						
Obs	264	320	458	548	646	2,236
%	15.08	18.72	24.6	27.35	32.11	23.95
Cultivation livelihood						
Obs	546	315	317	270	263	1,711
%	31.18	18.43	17.02	13.47	13.07	18.32
Wages/cultivation livelihood						
Obs	404	393	432	430	380	2,039
%	23.07	23	23.2	21.46	18.89	21.84
Public transfers/husbandry livelihood						
Obs	207	256	230	289	252	1,234
%	11.82	14.98	12.35	14.42	12.52	13.21
Other income/cultivation livelihood						
Obs	108	193	197	203	193	894
%	6.17	11.29	10.58	10.13	9.59	9.57
Total						
Obs	1,751	1,709	1,862	2,004	2,012	9,338
%	100	100	100	100	100	100

Source: Authors' calculation from the 2008-2016 VHARSS.

Table 3 shows the level of real household income per person by livelihood cluster over time. Between 2008 and 2016, the income level for the whole sample increased from roughly 1.27 million VND to about 8 million thousand VND. In 2008, households specializing in cultivation earned least (887 thousand VND), while those in the nonfarm group earned the most (2116 thousand VND). Based on mean per capita income by livelihood, it can be reported that the high-income group includes households with a nonfarm livelihood and those with a cultivation/other income livelihood, while the middle-income group is represented by those with public transfers/ husbandry and wage-earning livelihoods. The poorest group includes those specializing in cultivation or both wage-earning employment and cultivation. This trend is similar to that observed in 2016 and indicates that cultivation offers the lowest return. It also suggests that shifting out of this sector may be an effective solution of improving incomes for rural households.

Table 3. Monthly income per capita by livelihood cluster, 2008-2018
(Real income, 1000 Vietnamese dong (VND))

Livelihood cluster over year	2008	2010	2012	2014	2016	ALL
Nonfarm livelihood						
Mean	2116	3039	2737	2937	3945	2999
Sd	2855	5882	3947	2902	3082	3901
Wage-earning livelihood						
Mean	1344	1658	1648	2024	2299	1894
Sd	891	1207	889	1475	1460	1311
Cultivation livelihood						
Mean	887	1130	1424	1468	1503	1218
Sd	883	1689	1578	1475	1564	1420
Wage-earning/cultivation livelihood						
Mean	1123	1299	1449	1713	1931	1501
Sd	782	917	992	1228	1400	1119
Public transfers/husbandry livelihood						
Mean	1307	1590	1650	1810	1934	1675
Sd	928	1284	1560	2053	2499	1799
Other income/cultivation livelihood						
Mean	1745	1604	1867	2550	1840	1945
Sd	1899	1882	1868	2699	1477	2048
Whole sample						
Mean	1269	1650	1721	2025	2263	1805
Sd	1418	2580	1891	1965	2046	2038

Source: Authors' calculation from the 2008-2016 VHARSS.

One of the most useful tools for comparing well-being over groups is a Pen's Parade, which takes the form of a quantile graph (Haughton & Khandker, 2009). Thus, we also employ the quantile graph to compare income levels across livelihood clusters. In Figure 1, the horizontal axis denotes every household ranked by real income per capita, from poorest to richest, while the amount of real income per capita is given on the vertical axis (Haughton & Khandker, 2009). The figure clearly shows that at every quantile considered in 2008, the income level is largest for those specializing in nonfarm self-employment, and those specializing in cultivation are the poorest. In general, the same trend was also observed in 2016, confirming that the nonfarm livelihood offers the highest return, whereas the lowest derives from cultivation. The data in 2016 also reveals that households in the wage-earning livelihood had the second-highest income level. Both years show a large income gap between nonfarm and other livelihoods in all quantiles considered. In particular, the data from both years implies that switching from cultivation to other livelihoods can help local household significantly enhance their living standards.

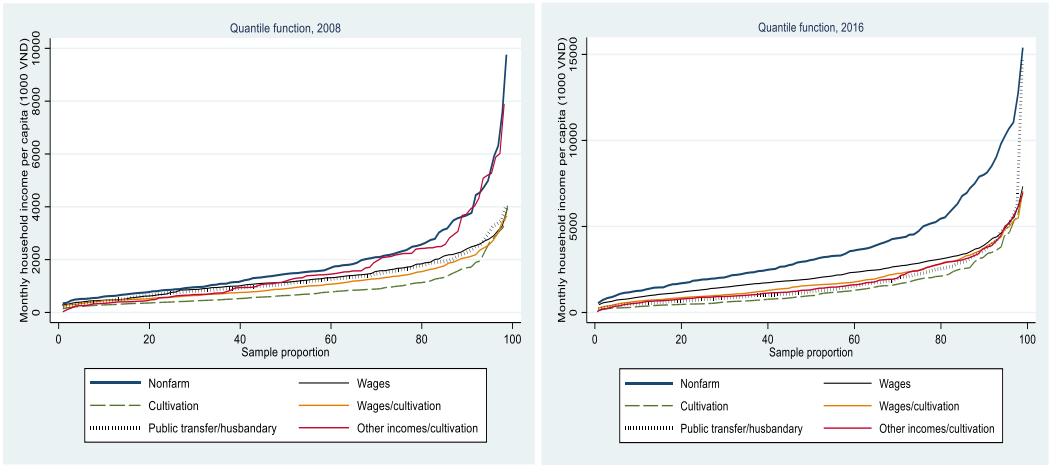

Figure 1. Income quantiles by livelihood cluster, 2008-2016.
Source: Authors' estimation from the 2008-2016 VHARSS.

Table 4 describes household features by livelihood cluster and shows that the number of household heads belonging to the Kinh/Hoa (majority) population is much lower for those engaged in cultivation than for those in other livelihoods. This implies that most ethnic minority households pursue a livelihood based on cultivation. The average age of household heads tends to be higher for those earning from public transfers and husbandry than for those in the cultivation and other income livelihoods. Individuals in these groups also tend to have larger families and more dependent members. Households specializing in cultivation are characterized by lower levels of education than those with nonfarm or wage-earning livelihoods. As expected, the former also had more land than the latter. In particular, the level of land fragmentation is higher for those with cultivation and cultivation/wage-earning livelihoods (about 56%) than for those engaged in wage-earning and nonfarm livelihoods (about 48%–51%). The proportion of households affected by health and economic shocks is significantly higher than for those with other income/cultivation livelihoods. The proportion of households experiencing natural disasters is also much higher for those living from cultivation than it is for those with other livelihoods.

4.2. The influence of land fragmentation on livelihood choice

The results from the MNL are given in Table 5. The results can be transformed and interpreted in terms of the relative risk ratio (RRR). The RRR is the exponential of the coefficients, which can be calculated as one probability divided by another. In the current study, this is the likelihood of a household adopting a particular livelihood (e.g., a wage-earning livelihood) divided by the likelihood of the household pursuing a cultivation livelihood. (Long & Freese, 2006). With changes in explanatory variables, the RRR of a coefficient indicates how the probability of a household pursuing a given livelihood can be compared to the probability of that household taking up a cultivation livelihood (the reference livelihood). For example, a RRR > 1 indicates that as land fragmentation increases, the risk of a household taking up

Table 4. Household characteristics by livelihood cluster

Household characteristics	Nonfarm		Wages		Cultivation		Wages/cultivation		Public transfers/ husbandry		Other incomes/ cultivation		All	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Ethnicity (1=Kinh/Hoa; 0=ethnic minorities)	0.95	0.22	0.88	0.33	0.52	0.50	0.75	0.43	0.69	0.46	0.84	0.37	0.77	0.42
Gender (1=male; 0=female)	0.83	0.37	0.77	0.42	0.87	0.33	0.82	0.39	0.81	0.39	0.67	0.47	0.80	0.40
Marital status (1=married; 0=single)	0.86	0.35	0.80	0.40	0.87	0.33	0.84	0.36	0.82	0.38	0.68	0.47	0.82	0.38
Age (years)	50.56	12.47	51.35	12.59	50.04	12.91	51.45	12.75	57.99	14.65	59.19	14.64	52.66	13.55
Household size (members)	4.42	1.58	4.50	1.45	4.74	1.90	4.61	1.56	4.05	1.92	3.22	1.76	4.37	1.73
Dependency ratio	0.34	0.27	0.30	0.23	0.36	0.27	0.31	0.24	0.50	0.34	0.50	0.38	0.36	0.29
No education (1=yes; 0=no)	0.04	0.21	0.06	0.24	0.21	0.41	0.09	0.29	0.13	0.33	0.12	0.32	0.11	0.31
Primary education (1=yes; 0=no)	0.15	0.36	0.19	0.39	0.28	0.45	0.22	0.41	0.26	0.44	0.26	0.44	0.22	0.42
Lower secondary (1=yes; 0=no)	0.54	0.50	0.52	0.50	0.41	0.49	0.50	0.50	0.41	0.49	0.45	0.50	0.48	0.50
Upper secondary (1=yes; 0=no)	0.26	0.44	0.23	0.42	0.10	0.30	0.19	0.39	0.21	0.41	0.17	0.38	0.19	0.40
No vocation (1=yes; 0=no)	0.76	0.43	0.73	0.45	0.94	0.24	0.82	0.38	0.84	0.36	0.86	0.34	0.82	0.39
Short-term vocation (1=yes; 0=no)	0.15	0.35	0.17	0.38	0.04	0.19	0.12	0.32	0.05	0.22	0.08	0.27	0.11	0.31
Long-term vocation (1=yes; 0=no)	0.04	0.19	0.02	0.14	0.01	0.08	0.01	0.10	0.01	0.09	0.02	0.14	0.02	0.13
Professional education (1=yes; 0=no)	0.05	0.21	0.04	0.20	0.02	0.12	0.03	0.18	0.05	0.22	0.03	0.17	0.04	0.19
College/university (1=yes; 0=no)	0.01	0.11	0.04	0.20	0.00	0.05	0.02	0.13	0.05	0.21	0.01	0.09	0.02	0.15
Land fragmentation (1=yes; 0=no)	0.51	0.29	0.48	0.30	0.56	0.28	0.57	0.28	0.56	0.27	0.53	0.29	0.54	0.29
Annual land (m2)	12972	32742	11264	23044	58207	183537	20839	39193	20115	39171	17178	39415	23916	86030
Perennial land (m2)	1737	13240	899	10642	6654	22369	1398	8218	1153	7402	1650	15169	2278	13787
Forestland (m2)	608	7826	303	4931	1760	21776	1102	12844	1839	17273	652	6493	1021	13434
Horticultural land (m2)	494	1912	405	961	1077	3187	684	1520	795	2285	513	937	663	1973
Health shocks (1=yes; 0=no)	0.09	0.28	0.08	0.28	0.05	0.22	0.11	0.32	0.13	0.33	0.19	0.40	0.10	0.30
Economic shocks (1=yes; 0=no)	0.16	0.36	0.13	0.33	0.12	0.33	0.19	0.39	0.19	0.39	0.24	0.43	0.16	0.37
Natural disasters (1=yes; 0=no)	0.23	0.42	0.26	0.44	0.47	0.50	0.41	0.49	0.42	0.49	0.32	0.47	0.35	0.48
People's committee (Km)	1.55	3.13	1.91	3.38	3.10	8.82	2.31	5.30	2.21	4.46	1.90	1.82	2.21	5.25
Car road (Km)	1.99	8.01	1.74	5.93	4.36	11.56	2.20	6.47	2.80	9.92	1.60	2.97	2.48	8.07
Hospital (Km)	8.24	8.71	9.27	10.23	17.00	32.96	11.44	12.32	12.81	13.23	10.31	9.49	11.59	17.53
Observations	1124		2236		1711		2039		1234		894		9338	

a wage-earning livelihood relative to that of adopting a cultivation livelihood increases. ARRR < 1 reveals that the risk of a household undertaking a wage-earning livelihood decreases as land fragmentation increases.

Table 5 shows that the coefficient of land fragmentation is positive and statistically highly significant (p-value 0.01), which indicates that fragmentation has a positive effect on the choice of non-cultivation livelihoods. Keeping all other variables constant in the model[1], a 10 percentage point increase in land fragmentation increases the likelihood of a household taking up a nonfarm livelihood by about 16%. Similarly, the effect of pursuing a wage-earning livelihood is approximately 13.4%. Same but smaller effects were found for the choice of other livelihoods. Our research is the first to show that households with higher levels of land fragmentation are more likely to choose strategies that are less dependent on farming. In particular, as already discussed in the previous sub-section, such non-cultivation livelihood strategies offer higher income than one dependent on cultivation. Combined, these findings suggest that households cope effectively with the disadvantage of land fragmentation by diversifying their livelihoods towards non-farming activities. This coping strategy not only allows them to earn higher incomes, but also reduces their reliance on natural resources. The findings here partly support previous evidence that land fragmentation should not be viewed as an absolute phenomenon. This adverse condition may induce rural households to actively change their livelihoods toward nonfarm activities as a method of enhancing their income in rural societies.

Table 5. The effect of land fragmentation on livelihood choice

	Nonfarm		Wages		Wages/cultivation		Public transfers / husbandry		Other income/ cultivation	
VARIABLES	Coeff	Se	Coeff	Se	Coeff	Se	Coeff	Se	Coeff	Se
Ethnicity	2.12***	(0.340)	1.17***	(0.217)	0.59***	(0.144)	-0.23	(0.160)	0.33**	(0.161)
Gender	-0.13	(0.175)	-0.46**	(0.182)	-0.42**	(0.176)	-0.33	(0.243)	-0.48*	(0.269)
Marital status	-0.24	(0.185)	-0.41*	(0.218)	-0.06	(0.181)	0.39	(0.244)	-0.06	(0.197)
Age	-0.00	(0.005)	0.00	(0.004)	0.01*	(0.004)	0.03***	(0.004)	0.03***	(0.005)
Household size	0.31***	(0.043)	0.35***	(0.037)	0.23***	(0.025)	0.02	(0.028)	-0.25***	(0.044)
Dependency ratio	-1.26***	(0.271)	-2.13***	(0.237)	-1.41***	(0.187)	0.39*	(0.210)	-0.14	(0.254)
Primary education	0.40*	(0.240)	0.58***	(0.135)	0.44***	(0.153)	0.35**	(0.148)	0.31	(0.195)
Lower secondary	0.81***	(0.266)	0.81***	(0.151)	0.66***	(0.141)	0.56***	(0.145)	0.59***	(0.214)
Upper secondary	0.98***	(0.329)	0.73***	(0.178)	0.75***	(0.186)	0.76***	(0.158)	0.76***	(0.215)
Short-term vocation	0.71***	(0.219)	1.02***	(0.182)	0.81***	(0.174)	0.20	(0.207)	0.54***	(0.184)
Long-term vocation	1.28***	(0.479)	1.00**	(0.433)	0.34	(0.455)	-0.04	(0.474)	0.86**	(0.409)
Professional training	0.88**	(0.391)	1.13***	(0.345)	0.78**	(0.307)	0.81**	(0.350)	0.44	(0.454)
College/university	0.72	(0.715)	2.30***	(0.621)	1.62***	(0.539)	2.46***	(0.655)	0.61	(0.590)
Land fragmentation	1.46***	(0.325)	1.26***	(0.268)	1.18***	(0.217)	1.39***	(0.267)	1.22***	(0.261)
Log of annual land	-0.98***	(0.082)	-1.00***	(0.049)	-0.65***	(0.039)	-0.69***	(0.054)	-0.64***	(0.077)
Log of perennial land	-0.19***	(0.036)	-0.22***	(0.027)	-0.15***	(0.021)	-0.16***	(0.021)	-0.16***	(0.023)
Log of forestland	0.04	(0.031)	-0.01	(0.026)	0.02	(0.022)	0.07**	(0.027)	0.01	(0.029)
Log of horticultural land	-0.10***	(0.016)	-0.09***	(0.017)	-0.02	(0.015)	-0.02	(0.017)	-0.06***	(0.016)

[1] This can be calculated as: exp (1.46*0.1)-1 =.15719619=0.16.

	Nonfarm		Wages		Wages/cultivation		Public transfers / husbandry		Other income/ cultivation	
VARIABLES	Coeff	Se	Coeff	Se	Coeff	Se	Coeff	Se	Coeff	Se
Health shocks	0.29	(0.241)	0.54**	(0.225)	0.54**	(0.232)	0.62***	(0.232)	1.19***	(0.191)
Economic shocks	0.14	(0.226)	-0.14	(0.164)	0.28*	(0.170)	0.31**	(0.150)	0.18	(0.174)
Natural disasters	-0.35***	(0.127)	-0.12	(0.083)	0.09	(0.082)	0.26**	(0.110)	0.04	(0.101)
People's committee	-0.07	(0.055)	-0.01	(0.009)	0.00	(0.004)	-0.01	(0.011)	-0.01	(0.014)
Car road	0.00	(0.005)	-0.01	(0.006)	-0.01**	(0.006)	0.00	(0.004)	-0.04***	(0.009)
Hospital	-0.01*	(0.007)	-0.01*	(0.005)	-0.01**	(0.002)	0.00	(0.002)	-0.00	(0.004)
2010	0.93***	(0.112)	1.02***	(0.141)	0.74***	(0.112)	0.95***	(0.145)	1.31***	(0.175)
2012	0.92***	(0.146)	1.38***	(0.146)	0.90***	(0.137)	0.97***	(0.159)	1.43***	(0.199)
2014	1.07***	(0.123)	1.59***	(0.131)	1.06***	(0.127)	1.26***	(0.142)	1.40***	(0.195)
2016	1.23***	(0.100)	1.90***	(0.124)	1.04***	(0.126)	1.08***	(0.149)	1.25***	(0.191)
Constant	8.53***	(0.687)	7.39***	(0.439)	5.05***	(0.411)	3.20***	(0.619)	-12.40***	(1.226)
Pseudo R2	0.18									
Prob > chi2	0.000									
Observations	9,338									

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
The cultivation livelihood is the reference group.

Other factors are found to affect livelihood choice. The relative risk ratios of choosing a non-farming livelihood are about 8.3 times higher for the Kinh/Hoa group than for the minor ethnicities. The choice of a wage-earning, wage-earning/cultivation, or other income livelihood has similar, smaller effects. This conclusion supports previous findings in Vietnam that show that the smaller ethnicities are much less likely to diversify into non-farming pursuits in rural Vietnam. The coefficient of household size is statistically positive while that of dependency is negative in the choice of some livelihood strategies, revealing that the likelihood of choosing a livelihood dependent on non-farm or wage-earning employment is higher for larger households but lower for those with a higher dependency ratio. This suggests that nonfarm diversification entails labor-intensive activities.

As in previous findings in Vietnam (Tran, Tran, & Nguyen, 2020) and other developing countries (Corral & Reardon, 2001; Escobal, 2001; Micevska & Rahut, 2008; Rahut, Jena, Ali, Behera, & Chhetri, 2015), our study shows that households with better educated members have higher chances of choosing livelihood strategies that are less dependent on agriculture but offer higher income. Specifically, relative to a household whose head lacks formal education, the likelihood of choosing a non-farm livelihood is about 2.7 times greater for a household whose head has completed upper secondary education[2]. Similarly, the corresponding effect is about 2.07 times for the choice of a wage-earning livelihood. In particular, we find that the effect on the pursuit of non-farm and wage-earning livelihoods is greater for households whose heads have completed some level of vocational training. Unsurprisingly, households owning more croplands were less likely to specialize in something other than cultivation as their livelihood strategy. For example, a 10%

[2] This is calculated as exp (0.98*1) = 2.6644562=2.7

increase in the area of annual cropland would reduce the risk of a household taking up a nonfarm livelihood by about 9%[3]. The finding is consistent with that in several developing countries, showing that households holding more land have less motivation to diversify towards non-farm activities (Escobal, 2001; Rigg, 2006; Tran, 2014).

Various shocks also exert significant effects on livelihood choice. Specifically, health shocks were found to increase the likelihood of choosing any livelihood other than cultivation, except for a non-farm livelihood. For example, the likelihood of undertaking a wage-earning livelihood (rather than a cultivation livelihood) is about 1.7 times greater for a household experiencing a health shock. Economic shocks were also found to increase the likelihood of pursuing wage-earning/cultivation and public transfers/husbandry livelihoods. In general, the findings accord with those in several other studies (Chuang, 2019; Ersado, 2005; Kijima, Matsumoto, & Yamano, 2006), which show that households pursue non-farm diversification as their active strategy for coping with various shocks. Finally, the coefficient of the year dummy variables is positive and statistically highly significant. This suggests that the likelihood of choosing a non-cultivation livelihood is greater for the years 2010, 2012, 2014, and 2016 than for 2008.

5. Conclusion and policy implications

There are currently two opposing viewpoints on land fragmentation. On the one hand, fragmentation is seen as a negative issue because it raises cultivation costs or lowers productivity. In several developing societies, furthermore, fragmentation results in lower incomes, greater poverty, and food insecurity. The opposing viewpoint, on the other hand, contends that plot fragmentation is not always negative because it may mitigate risk or variation in crop incomes by dispersing plots spatially. Other empirical evidence shows no negative effect or even evidence of the positive effect of fragmentation on food security and non-farm diversification in some countries. However, empirical research into the link between fragmentation and livelihood choice is limited and currently no empirical evidence has been adduced for Vietnam.

Our study fills the research gap by investigating the effect of annual cropland fragmentation on livelihood choice among rural households. We employ pooled household data over the 2008–2016 period in combination with a micro-econometric analysis that accounts for several household and commune characteristics. Our study shows fresh evidence that land fragmentation has a positive effect on non-farm diversification. Specifically, households with higher degrees of fragmentation tend to adopt any of five livelihood strategies that were less dependent on cultivation. These strategies include (i) non-farm, (ii) wage-earning, (iii) wage-earning/cultivation, (iv) public transfers/husbandry, and (v) cultivation/other income livelihoods, which all provide a higher income than cultivation. The findings here suggest that rural households have been actively diversifying their income sources as a way to deal with land fragmentation.

Although promoting land consolidation would help boost agricultural productivity (Nguyen & Warr, 2020), our research findings

[3] Given a 10% increase in the are of annual cropland, the corresponding change in logarithm for annual cropland size is log (1.01) = 0.09531, and the relative risk of taking up a nonfarm livelihood vs choosing a cultivation livelihood can be reported in terms of the exponential function as exp (-0.98*0.09531) = .91082563≈0.91

imply that effective policies for expanding rural non-farm activities should be strongly promoted because they encourage rural households, especially those whose land is fragmented, to change their livelihoods by adopting profitable non-farm strategies. We also identify various other factors associated with livelihood choice, particularly the choice of profitable livelihood strategies. Among other factors, better education emerges as the key factor in the choice of nonfarm or wage-earning livelihoods, which offer profitable strategies. Thus, policies for improving the level of education, both general and vocational, for rural households, especially ethnic minorities, should be further implemented.

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Appendix 1

Number of clusters	Duda/Hart	
	Je(2)/Je(1)	pseudo T-squared
1	0.7968	2540.16
2	0.6474	4661.88
3	0.6574	1959.02
4	0.4745	1792.97
5	0.5408	1815.17
6	0.7124	565.70
7	0.6133	3024.63
8	0.5525	218.70
9	0.6802	515.83
10	0.6149	325.73
11	0.6410	249.22
12	0.6556	808.37
13	0.6594	408.55
14	0.7293	1208.55
15	0.6403	949.79