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Effects of Land Quality on Land Use: Farm-level Panel-data Evidence from Viet Nam

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Abstract

The sustainable livelihoods framework (SLF) is a comprehensive way to study agricultural issues. So far, to our best knowledge, no study has applied the SLF to examine the influence of land quality on land use intensively. The current research examines the effects of land quality on farmers' decision-making on land use in Vietnam by modifying the sustainable livelihoods framework and using the fixed effects regression model. The method controlled the household and commune-level unobserved invariant characteristics and resulted in more robust estimates than pooled Ordinary Least Squares (OLS) estimation. The sample is a five-wave panel dataset of 2008-2016 with 1,534 farm households. The results reveal that land quality affects land-use choices through several aspects of land quality. More specifically, regarding topography, plot fertility level, plot locations, and soil and water conservation, results show that their effects reflect the cultivating practices for each land-use type in the sample. Findings also show that the irrigation system positively affects rice production in Vietnam. Policymakers should consider various aspects of land quality when designing policies and programs relating to land use, irrigation distribution, and especially the master plan for agricultural production and rural development. Flexible guidance for land uses of each type is closely connected with land quality in each region that may be most suitable for sustainable agriculture development.

Keywords

Farming household, fixed-effects model, land quality, land use, panel data, Vietnam.

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Introduction

Land-use changes significantly contribute to agriculture production in the world (Rabbinge and Van Latesteijn, 1992; Li and Wang, 2003; Yan et al., 2009; Yan et al., 2009; Hamblin, 2009; Angus et al., 2009; Tanrivermis, 2003; Zander and Kächele, 1999). Evidence shows that land-use changes increase the intensity of agriculture production (Li and Wang, 2003), land productivity (Yan et al., 2009), and poverty (Apata et al., 2021; Kotykova and Babych, 2021). Using land with strict agricultural land effectively mobilizes industrialization and urbanization in Turkey (Tanrivermis, 2003).

Small farm households in developing countries live in various physical and socio-economic conditions beyond the farm's decision-making. These conditions include climate variability (Thulstrup, 2015), local governance (Miratori and Brooks, 2015; Kyeyune and Turner, 2016), law (Nguyen and Tran, 2018; De Janvry et al., 2015), local institution (Marschke et al., 2014), and land quality (Bouma, 2002; Hardie and Parks, 1997; Eckhardt and Stackelberg, 1995).

Land quality is a crucial determinant of land use in developed and developing countries. Various pieces of evidence came from Podmanicky et al. (2011) in Europe, Salvati (2010) in Southern

Europe, Zambon et al. (2017) in Italy, Eckhardt and Stackelberg (1995), Hardie and Parks (1997), and Tong and Chen (2002) in the United States, Honisch et al. (2002) in Germany, Woli et al. (2004) in Japan, Xu et al. (2002) in China, Witcover et al. (2006) in the Amazon Basin, and Teshome et al. (2014) in Ethiopia.

While many studies have examined factors affecting land use, especially recently, those have considered climate change and extreme weather events in their research (Lambin et al., 2001; McCord et al., 2015; Lehmann, Briner, and Finger, 2013), little has been done to understand the effects of land quality on land-use choices in recent decades in the context of developing countries, especially countries in transition. The current study, thus, aims to fill this gap.

Consequently, the objective of this study is to examine whether the land quality may favor land-use choices in Vietnam. We use commune fixed-effects regression and five-wave panel data from Vietnam Access to Resources Household Surveys (VARHS) with 1,534 farm households, resulting in 8679 representative observations. In addition, we modify the sustainable livelihoods framework to incorporate land quality in land-use decision-making. Our key research question is: how does land quality drive farmers' choices, given several land-use alternatives.

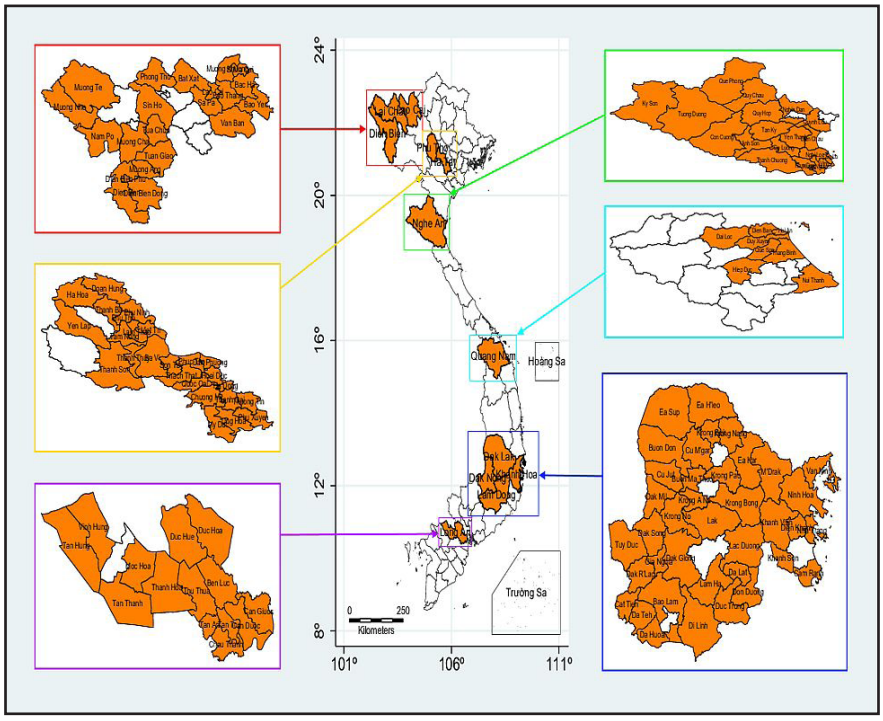
The study makes both empirical and methodological contributions to the literature on land use and sustainable livelihood in two ways: (i) enhancing the SLF by covering a more comprehensive range of land use choices such as rice land, land for other annual crops, land for perennial crops, forestry, and aquaculture area thanks to the availability of a unique dataset and (ii) paying more attention to land quality in examining land-use choices.

Materials and methods

Data

We used data from VARHS from 2008 to 2016. The VARHS was designed to cover the characteristics and living conditions of rural households in twelve provinces in Vietnam every two years, namely: Dak Lak, Dak Nong, Dien Bien, Ha Tay, Khanh Hoa, Lai Chau, Lam Dong, Lao Cai, Long An, Nghe An, Phu Tho and Quang Nam (Figure 1). There were 2,131 households interviewed in all survey rounds. The final number of panel households comes to 1,534 because of missing data. The VARHS has been used intensively in the works of Nguyen et al. (2018), Ngo et al. (2020), Markussen and Ngo (2019), and Markussen et al. (2011).

The VARHS also included a commune-level survey. Interviews with the commune administrators were performed in all communes where the VARHS



Source: Authors' creation

Figure 1: VARHS Site surveys.

households reside. Although families were spread over 465 communes, the commune balanced-panel data between the 2008 and 2016 surveyed round was 418.

The household questionnaire consists of several sections: (a) general characteristics of household members and housing; (b) agriculture activities; (c) employment, occupation, time use, and other sources of income; (d) expenditures, savings, durable assets; (e) credit; (f) shock and risk copping; (g) social capital and network; (h) trust, political connections, and (i) rural society.

Concerning land quality surveyed in the household questionnaire, some dimensions include (a) topography, (b) land with irrigation, (c) plot slop, (d) plot fertility level, (e) plot problem, (f) plot location, and (g) Soil and water conservation infrastructure.

The commune questionnaire consists of several sections: (a) demographic information; (b) migration; (c) development programs; (d) agriculture and land; (e) income and employment; (f) infrastructure; (g) shocks; (8) irrigation management; (h) credit and saving; (e) commune problems; and (k) access to services.

Methods

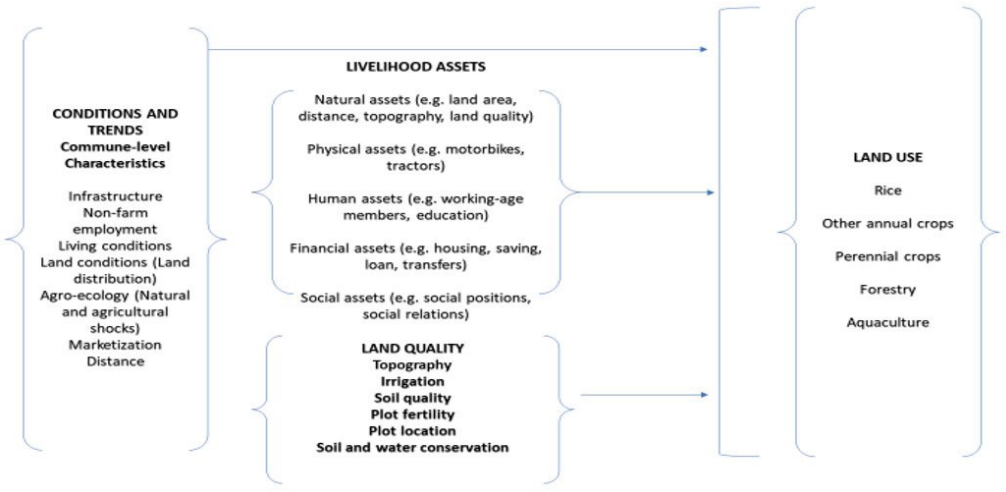
Conceptual framework

Land use is a persistently important issue in agriculture development. The driving forces of the various land-use decisions are not easy to generalize. There have been many types of research on land-use decisions under different approaches, such as the deforestation-based approach (Angelsen and Kaimowitz, 2000; Eakin et al., 2014; Liu et al., 2013) and the livelihoods approach (Nguyen et al., 2015; Baird and Gray, 2014). Hettig et al. (2016) conducted a meta-analysis of 91 recent empirical and theoretical studies on land-use changes at the farm-household level. They concluded that many studies rely on small samples and face problems of internal validity. Most recent research by Nguyen et al. (2017) examined determinants of farmers' land-use decision-making by extending the sustainable livelihoods framework (SLF), including factors belonging to the livelihood platforms, weather-shocked experiences and expectations, and physical-economic conditions of the local communities. So far, to our best knowledge, no study has applied the SLF to examine the influence of land quality on land use intensively. In this paper, we fill that gap by modifying the framework developed by Scoones (1998) and extended by Nguyen et al. (2017), focusing on land quality and using a sample of 1,534 farm households in 5 waves of surveys.

Livelihood includes five types of capital (assets): natural capital, physical capital, human capital, financial capital, and social capital (Scoones, 1998), as illustrated in Figure 2. These livelihood platforms clarify the factors featuring land-use choices by farmers. Accordingly, land-use choices are a function of various factors representing the endowments and constraints (Nguyen et al., 2017).

Specification of the econometric model

We use a fixed-effects regression model to investigate the effects of land quality on land-



Source: Authors' modification from Scoones (1998)

Figure 2: Land quality and farmers' decision-making of land use.

use choices, exploring a balanced panel dataset of five rounds from 2008 to 2016. The method is appropriate for controlling the household and commune unobserved invariant characteristics, resulting in more robust estimates than pooled Ordinary Least Squares (OLS) estimation (Damon, 2010). The model has the following general form:

$$Y_{itz} = f(X_{it,} V_{vt}) + \beta_{iz} + \mu_{itz}, \quad (1)$$

Where i, t, and z denote household i, in year t, and commune v; z is the types of land use, taking value from 1 till 5: (1) rice, (2) other annual crops, (3) perennial crops, (4) forestry and (5) aquaculture. Y is the shares of land use; X is a vector of the explanatory variables at the household level, V is a vector controlling for the commune characteristics, β is the invariant-unobserved, and μ is the variant-unobserved characteristics of the household.

The identification of independent variables is based on the SLM in Figure 2. At the household level, the following variables are used: First, in the current research, the natural assets are proxied by the farmland area (in ha). Since farmland area might be an essential factor in agriculture production, the share of land with land-using certificate (LUC) (in %) as land property rights strongly influence choices of land allocation by farmers (for example, through investment (Rigg et al., 2012), and the average distance from the living location to plots owned by the rural household (in km) (Nguyen et al., 2017).

Second, the human assets are examined through several variables: demographic characteristics (the dependency ratio (in %) (Nguyen et al., 2017), the age average of working-age members (in years) (Nguyen et al., 2017), the percentage of female-head share (in %) (Nguyen et al., 2017), working forces (the share of the household member at working ages (between 16 and 65 years old, in %) (Nguyen et al., 2017), and education levels (the educational levels as measured by the percentage of household members with the highest certificate, in %) (Nguyen et al., 2017).

Third, the physical assets are analyzed through the transportation assets (the number of tractors and motorbikes) and the production assets (the number of pesticide sprayers) (Nguyen et al., 2017).

Fourth, the financial assets are exhibited by housing (the area of the living house, in m2) (Nguyen et al., 2017), the saving (the total saving in a million Vietnamese currency (VND)), the borrowing (the total of the loan, in a million VND) (Menkhoff and Rungruxsirivorn, 2011), the private transfer and the public transfer (both in a million VND) (Nguyen et al., 2017).

Fifth, social assets are typified by trust relations and social connectedness (Pretty & Ward, 2001; Nguyen et al., 2017). The trust relations are signified by the sources of obtaining money by households when needing money (for example, they can choose to borrow from a relative, friend, neighbor, or other sources, in dummies). Social connectedness is measured by the membership of a household member in a socio-political organization (in a dummy variable) (Baird and Gray, 2014; Forsyth and Evans, 2013), such as: being an office head having a membership of the Communist Party of Vietnam (CPV), and being a member of the Women Union.

Local socio-economic conditions constrain farming households in rural areas. At the commune level, the following variables are used: First, non-farm employment: the number of firms or factories with at least ten employees in the commune (Bezu et al., 2012), firms with at least ten employees in the neighboring commune where people can work and come back within the day.

Second, the distance (in km) from the commune center to the nearest bus station, from the commune center to the main road.

Third, natural and agricultural shocks are measured by whether a commune has faced any problem of the flood, drought, typhoon, landslide, animal or livestock epidemics, plant disease, insects, or rats in the last two years (Povel, 2015; Doss et al., 2008).

Several alternative measures of land quality at the household level are used. Details are: (i) The shares of land measure the topography with different slopes (in %), namely: flat, slight slope, moderate slope, steep slope; (ii) Irrigation is exhibited by the percentage of irrigated land (in %); the shares of land measure (iii) Soil quality with various possible problems (in %) such as land with gullies, low-lying land, sedimentation land, stony soils/clay, land with no problem, and (iv) The plot fertility level is measure by the shares of land with different fertility levels compared with other plots in the village (in %), namely: less than average, average, and above average. Land quality also includes (v) the location of plots in the irrigation canal is measured by the shares of land in the head end, middle,

and tail end (in %), and (vi) the condition of soil and water conservation infrastructure is measure by the shares of land with soil and water conservation infrastructure (in any terms of rock bunds, soil bunds, terraces, grass lines) and that of with none of soil and water conservation infrastructure (in %).

Estimation strategy

Since our key research question is how to land quality drive farmers' choices of land uses, we follow several estimation steps as follows:

Step 1 (Panel A1): Models are estimated with all household-level variables related to capital in the livelihood framework at the household level. In addition, commune-level variables, namely: (i) distance, (ii) non-farm employment, and (iii) natural and agricultural shocks, are included in the models.

Step 2 (Panel A2): Additions of household-level variables related to land quality into the models will be estimated. Specifically, Panel A2.1 deals with the topography, Panel A2.2 examines the role of irrigation, Panel A2.3 reveals various possible problems with soil, Panel A2.4 analyses the plot fertility level, and Panel A2.5 measures the effects of plot location in the commune irrigation canal. Panel A2.6 seeks the influence of soil and water conservation infrastructure.

Results and discussion

Statistical description

The descriptive statistics presented in Appendix 1 illustrate the livelihood conditions of rural households in Vietnam. Regarding natural assets, the land area per farm decreases over the period. Similarly, the share of irrigated land falls. The land value increased between 2008 and 2016, and it was at its highest in 2014 - the share of land with LUC increased between 2008 and 2016. The average distance from the living place to the plots more or less is unchanged during the period.

For human assets, the dependency ratio decreased between 2008 and 2016. Farm heads' percentage increases and farm households are older and less in terms of working-age member percentage. In addition, farm heads are more educated.

Regarding physical assets, farmers have higher numbers of motorbikes but fewer pesticide sprayers and tractors in 2016 compared to 2008. This is reasonable because, in general, economic growth in Vietnam. Regarding financial assets, farmers are better-off in 2016 compared to 2008, as they have more housing areas, higher saving volume, and higher annual public and private transfers. This is also partly because of the achievement in economic development in Vietnam during the decade from 2008 to 2016. More social trust is found when farmers in Vietnam rely more on relatives or friends regarding social assets. In addition, in terms of the social network, more farmers in Vietnam are observed to be members of socio-political organizations such as party members or members of the Women Union during the period.

Land quality statistics are presented in Appendix 2. Regarding topography, the land is more in unfavorable conditions in 2016 than in 2008. However, the land is improved over the mentioned period in irrigation. Concerning soil problems, it is shown that land is improved over the period, whereas the fertility level and plot location seem to be stable. Soil and water conservation infrastructure have not improved much during the period.

The descriptive statistics of the commune characteristics are presented in Appendix 3. As mentioned in the previous section, commune characteristics include (i) distance, (ii) non-farm employment, and (iii) natural and agricultural shocks. The opportunities for off-farm employment in the communes (proxied by the number of firms with more than ten workers) are better in 2016 compared to 2008. For variability, farmers in Vietnam experienced fewer weather shocks between 2008 and 2016.

Appendix 4 presents the farmland allocation in Vietnam. Observations can be made: (a) rice is still the dominant crop in Vietnam; (b) the land percentage of other annual crops grows up in the sample period; (c) the land proportion of perennial crops also increases in the studying period, (d) the land portion of forestry crops decreases in the study period, and (e) the land share of aquaculture tend to stand still in the period.

The basic model

Table 1 shows that the models explain 2-6% of the variation in the dependent variables (as shown in the third line from the bottom of Table 1). Firstly, regarding natural assets, the farmland positively affects the land for perennial crops (This is in line with Nguyen et al. (2017) for the case of Thailand), forestry, and aquaculture, whereas it negatively affects the rice land. Farmers may explore other crops or activities with higher income with more land.

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Household-level characteristics					
Natural capital					
Land size (ha), log	-0.2700*** (0.0174)	0.0233 (0.0175)	0.0990*** (0.0116)	0.1260*** (0.0081)	0.0230*** (0.0054)
Land with LUC (%)				-0.0115** (0.0052)	
Distance to plot (km)	-0.0014* (0.0008)		0.0028*** (0.0005)		-0.0008*** (0.0002)
Human capital					
Dependency ratio (%)					-0.0119** (0.0052)
Female head (yes=1)	-0.0770** (0.0366)				
% of the household member at working ages			0.0005** (0.0003)		
% of "Cannot read and write"	-0.0864** (0.0431)	0.0500 (0.0437)			
% of "Completed Primary"	-0.109*** (0.0414)	0.0585 (0.0419)			
% of "Completed Lower Secondary"	-0.0789* (0.0423)	0.0309 (0.0428)			
% of "Completed Upper Secondary"	-0.0474 (0.0443)	-0.0003 (0.0448)			
Physical capital					
Number of motorbikes	0.0320*** (0.0095)	-0.0237** (0.0096)			
Number of tractors			-0.0459*** (0.0141)		
Financial capital					
Loan size (mill. VND), log			0.0011* (0.0006)		
Private transfer (mill. VND), log	-0.0035*** (0.0009)	0.0019** (0.0009)			
Social capital					
In case of needing money: ask a friend (yes=1)					0.0045* (0.0026)
Being an officer (yes=1)	0.0300* (0.0164)				
Commune-level characteristics					
Distance from the commune center					
To the main road (km)					8.19 x 10-5* (4.84 x 10-5)
To the extension shop (km)		-1.70 x 10-5** (8.56 x 10-6)			
Non-farm employment					
Non-farm employment type 1 (Numbers)			-0.0109** (0.0047)	0.0091*** (0.003)	0.0050** (0.0023)
Non-farm employment type 2 (dummy)					-2.75 x 10-5* (1.62 x 10-5)

Note: Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1; HH: Household; Non-farm employment type 1: Number of enterprises with the size of 10 or more employees in the commune; non-farm employment type 2: Having enterprises with the size of 10 or more employees in the neighboring communes where people can work there and come back within the day (dummy).
Source: Authors' estimation from VARHS08-16.

Table 1: Determining factors of land-use choices (Panel A1) (To be continued).

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Natural and agricultural shocks					
The flood last year (yes=1)				-0.0082**	
				(0.0040)	
Landslide last year (yes=1)			-0.0233**		
			(0.0092)		
Plant disease last year (yes=1)			-0.0133**		
			(0.0064)		
Flood two years ago (yes=1)				0.0112***	
				(0.0038)	
Drought two years ago (year=1)				-0.0082**	
				(0.0033)	
Typhoon two years ago (yes=1)	0.0157**			-0.0085**	
	(0.0074)			(0.0035)	
Landslide two years ago (yes=1)			0.0285***		
			(0.0094)		
Plant disease two years ago (yes=1)			0.0167***		
			(0.0064)		
Insects/rats two years ago (yes=1)	-0.0216***	0.0186**			
	(0.0074)	(0.0074)			
Year dummies	Yes	Yes	Yes	Yes	Yes
Constant	0.8020***	0.1800***	0.1180***	-0.0166**	0.0180***
	(0.0445)	(0.0422)	(0.0443)	(0.0066)	(0.0044)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	19.09	6.194	13.90	33.84	6.221
F for u (i)=0	8.833	5.750	11.22	2.819	8.160
R^2 within model	0.064	0.015	0.036	0.058	0.007
R^2 between model	0.125	0.0002	0.150	0.081	0.0003
R^2 overall model	0.139	0.006	0.133	0.060	1.79 x 10-5

Note: Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1; HH: Household; Non-farm employment type 1: Number of enterprises with the size of 10 or more employees in the commune; non-farm employment type 2: Having enterprises with the size of 10 or more employees in the neighboring communes where people can work there and come back within the day (dummy).
Source: Authors' estimation from VARHS08-16.

Table 1: Determining factors of land-use choices (Panel A1) (Continuation).

While we find no effect on most land with LUC, the negative impact is seen on the land for forestry. The negative sign may be explained by the fact that Vietnam has achieved a high LUC coverage for rice and other annual crops. Forestry land, on the other hand, in principle, mostly belongs to state ownership. In addition, once farmers receive forestry with LUC, they may change the initial using purpose to other ones such as non-agricultural activities (such as relaxing areas or residential areas).

The distance from the living house to the farming plots is negatively associated with the rice land (This is in line with Nguyen et al. (2017) for the case of Thailand) and land for forestry but positively correlated with the land for perennial crops.

Second, for human assets, the dependency ratio negatively affects the opportunity to explore the aquaculture area, whereas a negative effect accompanies the female-head household on the rice land. More labor forces in terms of the percentage of household members of the working ages tend to promote more land for perennial trees. This is because perennial crops are usually cultivated in slope areas, and thus mechanization is bounded. The result is in line with Nguyen et al. (2017) for the cases of Thailand and Vietnam. Besides, the more the level of education of the household members, the less possibility that they will be involved in rice cultivation. This may be because the higher educated farmers tend to focus on off-farm or self-employment.

Third, regarding physical assets, the number of motorbikes positively correlates with rice land but is negatively associated with the land for other

annual crops. This is because motorbikes are the main transportation means of rice in sampled provinces in Vietnam. The number of tractors negatively influences perennial land (This is in line with Nguyen et al. (2017). The adverse effect may reflect that tractors are not suitable for perennial crops (for example, due to the area's slope).

Fourth, regarding financial assets, loan size positively influences the land proportion of perennial crops. The positive effect might be because such activities require much investment. Concerning the private transfer, it negatively affects rice but has a positive one on other annual crops.

Fifth, regarding social assets, a close relationship with friends is positively associated with exploring the aquaculture area, whereas being in an office positively influences rice land. In Vietnam, as a rice (and aquaculture) exporting country, such social relationships support farmers in business.

Regarding the commune-level characteristics, firstly, households living in the commune with a longer distance to the main road would increase the aquaculture area. In contrast, the distance to the extension shop would decrease the land for other annual crops as farmers would regularly need technical support. The off-farm employment possibilities outside the commune might reduce the surface area for aquaculture. This is quite in line with Nguyen et al. (2017), who found that the off-farm wage employment opportunities would reduce the land share of rice. In addition, the off-farm employment opportunities inside the commune would decrease the probability of cultivating perennial crops and increase the chances for forestry and aquaculture.

Secondly, the commune that experienced a flood last year would designate less land for forestry. This is in line with Nguyen et al. (2017). The situation can explain the income shock prevented farmers from investing in forestry. In addition, forestry requires a high level of initial and continual investments and a long period to get back the returns. Similarly, households in communes face landslides, and plant disease also reduces land for perennial crops.

With the more prolonged time of shocks, namely two years, households in the commune where flood two occurred would allocate more land to forestry. Families in the commune that endured typhoons would give less land to forestry but more to rice land. Farmers in the commune that encounter landslides and plant disease would allocate more land to perennial crops. Farming households in the commune that observed animal/livestock epidemics would give less land to rice but more to other annual crops.

Effects of land quality

The results of estimating the influence of land quality on land use are shown in Table 2. All models include variables related to farming household characteristics, commune characteristics, and year-fixed effects. Model A2.1 deals with the topography, Model A2.2 examines the role of irrigation, Model A2.3 reveals various possible problems with soil, Model A2.4 analyses the plot fertility level, and Model A2.5 measures the effects of plot location in the commune irrigation canal. Model A2.6 seeks the influence of soil and water conservation infrastructure.

In general, the empirical results add evidence to the existing literature on the effects of land quality on land-use decisions in developing countries recently, such as Xu et al. (2002) for the Yellow River Delta in China, Woli et al. (2004) for in eastern Hokkaido (Japan), Witcover et al. (2006) for the Amazon Basin, and Teshome et al. (2014) for the North-Western Ethiopian Highlands.

First, regarding the topography in Model A2.1, farmers who own more percentage of flat land would apportion more land to rice, other annual crops, and perennial crops but less to aquaculture. In addition, farmers who experience more land percentage with a slight slope, a moderate slope, or a steep slope would allocate less land to rice since it is not favorable for rice cultivation. Moreover, farmers who process more land percentage with a slight incline, moderate slope, or steep slope would give more land to other annual crops, perennial crops, and forestry. In most cases, farmers appropriate less land for aquaculture, which can be explained that farmers may allocate land to aquaculture if sufficient water surface is available. Our results align with Teshome et al. (2014), who found that land quality (e.g., slope and soil fertility status) influences farmers' sustainable land management practices and investments.

Second, regarding the role of irrigation, the proportion of irrigated land has a positive influence on the rice area and a negative effect on other annual crops, perennial crops, forestry, and aquaculture. This finding makes sense since the irrigation system mainly serves rice production in Vietnam. Different types of crops also need water and mostly depend on water pumping.

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Household-level characteristics	Yes	Yes	Yes	Yes	Yes
Commune-level characteristics	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Panel A2.1 - Topography					
Land share with flat (%)	0.0566**	0.1760***	0.0374**	0.0151	-0.2820***
	(0.0246)	(0.0251)	(0.0166)	(0.0116)	(0.0068)
Land share with slight slope (%)	-0.0286	0.2140***	0.0672***	0.0295**	-0.277***
	(0.0261)	(0.0266)	(0.0175)	(0.0123)	(0.0072)
Land share with moderate slope (%)	-0.1020***	0.2170***	0.0795***	0.0863***	-0.2750***
	(0.0290)	(0.0296)	(0.0195)	(0.0136)	(0.0079)
Land share with steep slope (%)	-0.1650***	0.1730***	0.1390***	0.1260***	-0.2660***
	(0.0454)	(0.0463)	(0.0306)	(0.0211)	(0.0124)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	20.76	8.472	12.98	32.17	160.7
F for u (i) =0	7.988	5.708	10.31	2.639	5.330
R^2 within model	0.081	0.028	0.042	0.074	0.212
R^2 between model	0.170	0.006	0.182	0.112	0.535
R^2 overall model	0.187	0.0167	0.161	0.084	0.394
Panel A2.2 - Irrigation					
Land with irrigation (%)	0.1920***	-0.0837***	-0.0040	-0.0505***	-0.0540***
	(0.0123)	(0.0127)	(0.0084)	(0.0058)	(0.0038)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	30.19	8.573	13.10	37.73	31.43
F for u (i) =0	8.218	5.311	11.18	2.621	7.901
R^2 within model	0.101	0.023	0.036	0.070	0.037
R^2 between model	0.206	0.040	0.148	0.116	0.043
R^2 overall model	0.206	0.044	0.131	0.084	0.037
Panel A2.3 - Problems with soil					
Land share with gullies (%)	-0.0632***	0.0553***	-0.0177	0.0283***	-0.0060
	(0.0168)	(0.0170)	(0.0112)	(0.0078)	(0.0052)
Dry land share (%)	-0.0230**	0.0319***	-0.0047	0.0039	-0.0079***
	(0.0097)	(0.0098)	(0.0065)	(0.0045)	(0.0030)
Low-lying land share (%)	-0.0113	0.0259	0.0053	-0.0084	-0.0133**
	(0.0179)	(0.0182)	(0.0120)	(0.0084)	(0.0056)
Sedimentation land share (%)	0.0091	-0.0164	0.0010	0.0021	-0.0102
	(0.0231)	(0.0235)	(0.0155)	(0.0109)	(0.0072)
Share of land with landslide (%)	-0.0493	0.00919	-0.0156	0.0583***	-0.0049
	(0.0473)	(0.0481)	(0.0317)	(0.0222)	(0.0140)
Land share with stony soils/clay (%)	-0.1030***	0.0678**	-0.0053	0.0509***	-0.0119
	(0.0279)	(0.0284)	(0.0187)	(0.0129)	(0.0086)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	15.94	5.558	10.27	23.92	4.423
F for u (i) =0	8.312	5.647	10.93	2.750	8.053
R^2 within model	0.068	0.019	0.037	0.063	0.009
R^2 between model	0.138	0.003	0.142	0.090	0.0002
R^2 overall model	0.152	0.013	0.126	0.067	0.001

Note: Standard errors in parentheses; *, **, and ***: p < 10%, 5%, and 1%, respectively
Source: Authors' estimation from VARHS08-16.

Table 2: Effects of land quality on land-use choices (Panel A2) (To be continued).

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Panel A2.4 - Fertility level					
Less than average	0.0181**	0.0169**	-0.0300***	0.0229***	-0.0255***
	(0.0077)	(0.0078)	(0.0052)	(0.0036)	(0.0025)
Average	0.0171***	0.0130**	-0.0207***	0.0160***	-0.0231***
	(0.0061)	(0.0062)	(0.0040)	(0.0029)	(0.0019)
Above average	0.0303***	0.0129	-0.0249***	0.0073*	-0.0221***
	(0.0089)	(0.0090)	(0.0059)	(0.0042)	(0.0028)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	17.26	5.456	13.70	30.14	19.36
F for u (i) =0	8.637	5.753	10.88	2.780	8.147
R^2 within model	0.066	0.016	0.042	0.065	0.029
R^2 between model	0.133	0.0003	0.180	0.090	0.009
R^2 overall model	0.148	0.005	0.161	0.069	0.013
Panel A2.5 - Plot location					
Head end	0.0291***	0.0098	-0.0150***	-0.0161***	-0.0062**
	(0.0080)	(0.0081)	(0.0053)	(0.0038)	(0.0025)
Middle	0.0311***	0.0086	-0.0169***	-0.0174***	-0.0042**
	(0.0058)	(0.0059)	(0.0039)	(0.0028)	(0.0019)
Tail end	0.0114	0.0125	0.0150*	-0.0320***	-0.0060
	(0.0133)	(0.0136)	(0.0089)	(0.0063)	(0.0040)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	18.04	5.321	13.15	30.93	5.211
F for u (i) =0	7.888	5.742	10.12	2.789	8.156
R^2 within model	0.068	0.016	0.041	0.067	0.008
R^2 between model	0.158	3.20 x 10-7	0.190	0.091	5.44 x 10-5
R^2 overall model	0.170	0.004	0.163	0.069	0.0002
Panel A2.6 - Soil and water conservation					
Land with soil and water conservation infrastructure	-0.0091 (0.0059)	0.0139** (0.0061)	-0.0123*** (0.0039)	0.0165*** (0.0028)	-0.0033* (0.0018)
None of soil and water conservation infrastructure	0.0125*** (0.0038)	0.0129*** (0.0039)	-0.0194*** (0.0026)	0.0004 (0.0018)	-0.0054*** (0.0012)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	18.10	6.320	15.94	31.54	7.206
F for u (i) =0	8.183	5.767	10.22	2.780	8.148
R^2 within model	0.066	0.018	0.046	0.064	0.010
R^2 between model	0.141	0.0001	0.213	0.087	3.77 x 10-5
R^2 overall model	0.154	0.005	0.185	0.065	0.001

Note: Standard errors in parentheses; *, **, and ***: p < 10%, 5%, and 1%, respectively
Source: Authors' estimation from VARHS08-16.

Table 2: Effects of land quality on land-use choices (Panel A2) (Continuation).

Another possible: when the irrigated land share increases, farmers in Vietnam would switch from the other annual crops to rice. Xu et al. (2002) also found similar results when discovering that vegetation cover has expanded in the Yellow River Delta, China, with improved irrigation networks. Improvements in irrigation will strengthen the rice area, supporting food security in Vietnam.

Third, concerning possible problems with soil, farmers who witness more land with gullies, dry land, or land with stony soils/clay would allocate less to rice but more to other annual crops and forestry. Interestingly, farmers who have

experienced more share of dry land or low-lying land would give less aquaculture. Xu et al. (2002) indicated that in the areas of increased salinization, cultivation on lands that are not suitable for farming has decreased. Witcover et al. (2006) found that soil quality matters for land use. For example, good-soil farms had higher forestry land rates than their medium-soil counterparts. Policies regarding rice land should reflect the land quality in the concerned area. Current strict rice-security guidelines may need to be revised now. Mechanisms for adaptation vary by soil quality level and may need to be guided. The master plan of national land use needs to change the land quality and land degradation in recent years of vast agriculture development and industrialization.

Fourth, referring to the plot fertility level, farmers allow more land for rice, other annual crops, and forestry regardless of the fertility levels, whereas farmers designate less land for perennial crops and aquaculture irrespective of the fertility levels

Fifth, regarding possible problems with plot locations, farmers who have explored plots at the head end or middle would allocate more to rice. However, they tend to apportion less land for perennial crops, forestry, and aquaculture.

Finally, concerning plot soil and water conservation, farmers who have had plots with soil and water conservation infrastructure would designate more to other annual crops and forestry but less to perennial crops. Given land plots without soil and water conservation infrastructure, farmers cultivate rice, other annual crops, but not forestry, and perennial crops. Woli et al. (2004) showed that river water quality affects intensive livestock farming areas, mixed agriculture, livestock farming, and grassland-based dairy cattle and horse farming areas. Infrastructure investment in the rural area may need to take land use and cultivation characteristics.

Conclusion

Land quality plays an important role in land-use choices. With a unique panel dataset of five-wave surveys from 2008 to 2016 with 8679 observations, the current study examines the effects of land quality on farmers' land uses among rural households in Vietnam. The fixed effects regression models that control the household and commune unobserved invariant characteristics are estimated. The current paper enhances the sustainable livelihoods framework by covering a more comprehensive range of land-use choices: rice land, land for other annual crops, perennial crops, forestry, and aquaculture. In addition, several new alternative measures of land quality at the household level are used, namely: (i) the topography, (ii) irrigation, (iii) soil quality, (iv) the plot fertility level, (v) the location of plots in the irrigation canal, and (vi) the condition of soil and water conservation infrastructure.

The results reveal that land quality also affects land-use choices through several aspects of land quality. More specifically, regarding topography, plot fertility level, plot locations, and soil and water conservation, results show that their effects reflect the cultivating practices for each land-use type in the sample. Findings also show that the irrigation system positively affects rice production in Vietnam. The framework in this study can be employed and expanded to examine similar topic in developing or transition countries.

The results confirm the critical role of land quality on land uses in a developing country. Thus, policymakers should consider various aspects of land quality when designing policies and programs relating to land use, irrigation distribution, and especially the master plan for agriculture production and rural development. Flexible guidance for land uses of each type is closely connected with land quality in various regions with different ecological conditions that may be most suitable for sustainable agriculture development.

This study has some limitations. First, land quality at the plot level has not been explored to bring into the analysis due to its handling complexity. Secondly, the sustainable livelihood framework has not addressed the relationship between land use and livelihood strategy. Third, the land quality that may be more specific in quantitative measurement is not available, and thus it does not allow us to give objective assessments. Future work can reply to more detailed surveys and go further in these research directions.

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Appendix

Variable	2008	2010	2012	2014	2016
Natural capital					
Land size (ha)	0.882	0.850	0.836	0.798	0.777
Land value (mill. VND)	152,496.11	314,564.42	470,638.82	1,271,661.85	559,216.49
Land with LUC (%)	0.761	0.731	0.807	0.807	0.795
Distance to plot (km)	1.050	0.970	1.083	0.958	0.978
Human capital					
Dependency ratio (%)	0.646	0.646	0.645	0.630*	0.599
Female head (yes=1)	0.075	0.082	0.090	0.101	0.108
Age average of working-age members (years)	33.356	34.423	38.350	40.892	36.068
% of household member at working ages	0.646	0.646	0.645	0.594	0.599
% of "Cannot read and write"	0.087	0.081	0.077	0.077	0.063
% of "Completed Primary"	0.258	0.245	0.233	0.187	0.161
% of "Completed Lower Secondary"	0.395	0.394	0.396	0.396	0.396
% of "Completed Upper Secondary"	0.236	0.266	0.276	0.318	0.360
% of "Can read and write but never went to school or did not finish primary school"	0.023	0.014	0.018	0.022	0.020
Physical capital					
Number of motorbikes	0.720	0.770	0.813	0.869	0.832
Number of pesticide sprayers	0.349	0.373	0.299	0.312	0.292
Number of tractors	0.032	0.019	0.020	0.016	0.016
Number of machines of all kinds	0.127	0.116	0.077	0.067	0.064
Financial capital					
Housing area (m2)	67.851	72.300	79.619	84.932	85.889
Saving volume (mill. VND)	12,996.47	29,813.06	44,730.87	40,065.39	39,918.89
Loan size (mill. VND)	11,984.93	14,048.06	13,920.12	17,448.83	12,037.33
Private transfer (mill. VND)	3,288.15	3,891.48	6,502.14	7,809.25	7,432.95
Public transfer (mill. VND)	3,127.77	3,856.01	4,836.24	6,834.55	7,405.69
Social capital					
In case of needing money:					
ask relative (yes=1)	0.724	0.801	0.797	0.806	0.766
ask friend (yes=1)	0.117	0.109	0.196	0.171	0.22
ask neighbor (yes=1)	0.292	0.235	0.229	0.172	0.195
ask other (yes=1)	0.063	0.032	0.019	0.024	0.037
Being an officer (yes=1)	0.056	0.059	0.045	0.056	0.058
Party membership of head (yes=1)	0.057	0.069	0.065	0.077	0.078
Member of Women Union (yes=1)	0	0.090	0.082	0.078	0.069

Note: Total observations in each year: 2,131.
Source: Authors' estimation from VARHS08-16.

Appendix 1. Statistical summary of the household-level characteristics, 2008-2016

Variable	2008	2010	2012	2014	2016
1. Topography					
Land share with flat (%)	0.438	0.396	0.385	0.061	0.027
Land share with slight slope (%)	0.240	0.254	0.258	0.142	0.243
Land share with moderate slope (%)	0.137	0.151	0.123	0.021	0.019
Land share with steep slope (%)	0.025	0.010	0.009	0.026	0.054
2. Irrigation					
Land with irrigation (%)	0.573	0.613	0.62	0.437	0.420
3. Problems with soil					
Land share with gullies (%)	0.070	0.073	0.062	0.052	0.050
Dry land share (%)	0.140	0.214	0.138	0.637	0.647
Low-lying land share (%)	0.100	0.078	0.037	0.038	0.034
Sedimentation land share (%)	0.041	0.056	0.023	0	0
Share of land with landslide (%)	0.015	0.012	0.013	0	0
Land share with stony soils/clay (%)	0.052	0.019	0.032	0	0
Land share with no any problem (%)	0.415	0.347	0.466	0	0
4. Fertility level					
Less than average (yes=1)	0.115	0.135	0.082	0.052	0.050
Average (yes=1)	0.660	0.642	0.646	0.637	0.647
Above average (yes=1)	0.065	0.034	0.047	0.038	0.034
5. Plot location					
Head end (yes=1)	0.065	0.046	0.055	0.070	0.020
Middle (yes=1)	0.144	0.172	0.115	0.120	0.196
Tail end (yes=1)	0.043	0.030	0.037	0.027	0.028
6. Soil and water conservation					
Land with soil and water conservation infrastructure (yes=1)	0.325	0.008	0.001	0	0.002
None of soil and water conservation infrastructure (yes=1)	0.515	0.447	0.376	0.361	0.327

Note: Total observations in each year: 2,131.
Source: Authors' estimation from VARHS08-16.

Appendix 2. Statistical description of variables related to land quality, 2008-2016.

Variable	2008	2010	2012	2014	2016
Distance					
Distance 1 (km)	9.978	9.927	10.898	9.939	11.196
Distance 2 (km)	2.745	3.412	2.529	2.025	7.067
Distance 3 (km)	12.453	11.482	42.522	11.493	11.225
Distance 4 (km)	5.932	6.358	75.989	7.397	5.440
Non-farm employment					
Non-farm employment type 1	8.458	19.23	17.028	21.466	27.711
Non-farm employment type 2 (dummy)	0.337	0.207	0.258	0.243	0.251
Natural and agricultural shocks					
Flood last year (yes=1)	0.437	0.396	0.319	0.322	0.202
Drought last year (year=1)	0.412	0.499	0.331	0.349	0.407
Typhoon last year (yes=1)	0.293	0.365	0.250	0.336	0.163
Land slide last year (yes=1)	0.188	0.175	0.128	0.080	0.068
Animal/livestock epidemics last year (yes=1)	0.389	0.420	0.400	0.358	0.243
Plant disease last year (yes=1)	0.410	0.480	0.392	0.348	0.241
Insects/rats last year (yes=1)	0.298	0.283	0.260	0.190	0.118
Flood two years ago (yes=1)	0.383	0.584	0.358	0.331	0.211
Drought two years ago (year=1)	0.410	0.415	0.328	0.335	0.362
Typhoon two years ago (yes=1)	0.289	0.335	0.291	0.306	0.174
Land slide two years ago (yes=1)	0.145	0.187	0.130	0.087	0.076
Animal/livestock epidemics two years ago (yes=1)	0.348	0.344	0.426	0.408	0.246
Plant disease two years ago (yes=1)	0.449	0.432	0.439	0.322	0.213
Insects/rats two years ago (yes=1)	0.269	0.292	0.272	0.14	0.130

Note: : Distance 1: Distance from the commune center to the nearest bus station (km); Distance 2: Distance from the commune center to the main road (km); Distance 3: Distance from the commune center to the extension center; Distance 4: Distance from the commune center to the extension shop (km). Non-farm employment type 1: Number of enterprises with ten or more employees in the commune; non-farm employment type 2: Having enterprises with ten or more employees in the neighboring communes where people can work there and come back within the day (dummy).
Source: Authors' estimation from VARHS08-16.

Appendix 3: Statistical summary of the commune-level characteristics, 2008-2016.

Variable	2008	2010	2012	2014	2016
Land size (ha)	0.882	0.850	0.836	0.798	0.777
% of rice	0.603	0.595	0.596	0.597	0.549
% of other annual crops	0.219	0.236	0.238	0.223	0.246
% of perennial crops	0.116	0.117	0.123	0.140	0.166
% of forestry	0.039	0.032	0.019	0.017	0.016
% of aquaculture	0.024	0.021	0.024	0.024	0.023

Source: Authors' estimation from VARHS08-16.

Appendix 4: Land and the share of land-use types, 2008-2016.