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# Constraints on Agricultural Production in the Northern Uplands of Vietnam

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The Northern Uplands of Vietnam form one of the largest ecological regions in the country, characterized by complex biophysical conditions and a high diversity in ethnic minorities, cultures, and farming systems. The Doi moi

("renovation") program has, since the early 1980s, resulted in significant changes in agriculture production and related economic trends. However, poverty, low agricultural productivity, and land degradation are still major problems. This article illustrates the factors that drive these problems by analyzing agricultural land use in Suoi Con, a small agroforestry watershed in the Northern Uplands. We first identified the current land-use systems and analyzed constraints on agricultural production. The results indicate

that although low soil fertility and land degradation are considerable problems, availability of household capital, low technology levels, and land fragmentation are major constraints on agricultural development. These constraints were analyzed from different points of view to identify mismatches between the implementation of top-down government policies and specific conditions that may explain why actual land-use change in the Northern Uplands deviates from the government's development plans. Results of land-use analysis in the Suoi Con watershed suggest that participatory and bottom-up approaches are needed to better understand problems and opportunities in household agricultural production in order to develop appropriate land-use plans and policies.

**Keywords:** Northern Uplands; land-use constraints; land evaluation; resource use efficiency; Vietnam.

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## Introduction

The Northern Uplands of Vietnam (NUV), also called the Northern Midlands and Mountain Areas, constitute one of the largest ecological regions of Vietnam. The region covers 29% of the national land area and has 11 million inhabitants (GSO 2009). It is characterized by a hilly and mountainous topography and a high diversity in ethnic groups, cultures, and farming systems (Castella and Quang 2002; Wezel et al 2002; Vien 2003). Influenced by the *Doi moi* (renovation) and agricultural decollectivization policies (from the early 1980s to the mid-1990s), significant economic and societal changes have taken place in the NUV (GSO 1996; Castella et al 2005; GSO 2011). One of the major changes involves land-use rights, which have been taken from large agricultural cooperatives and given to households. Consequently, the household has become the smallest unit in the land-use decision-making process.

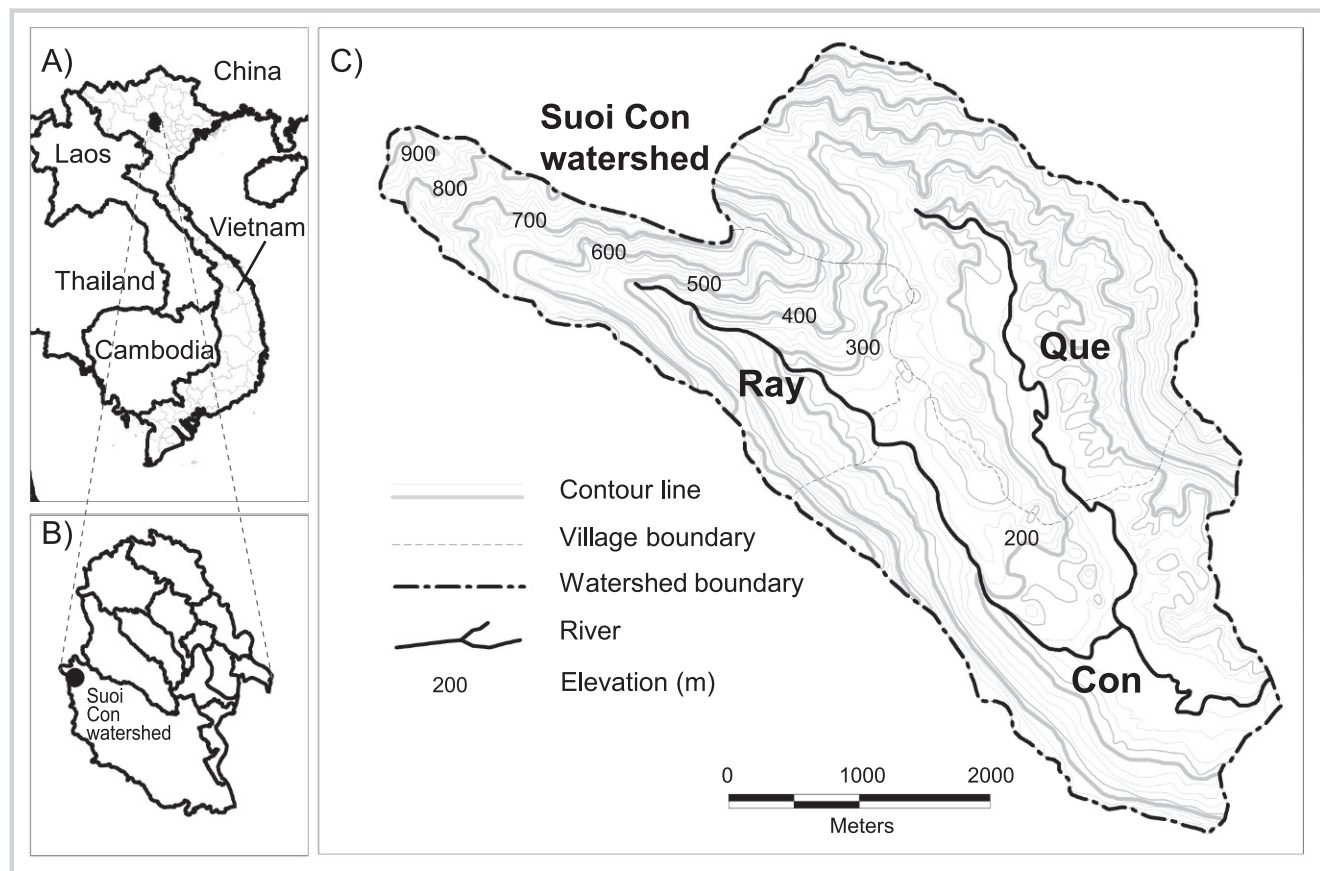
Top-down government policies have led to a number of political and social conflicts (Akram-Lodhi 2002; Thanh and Sikor 2006). As observed during this case study, household land-use decisions are not in line with

the market-oriented strategy of the government, and the family-based agricultural systems together with ineffective implementation of government policies have created several negative impacts on resources. For example, the establishment of new reclamation areas for agriculture from the 1960s to 1980s has led to a serious decline in natural forest and an increase in land degradation (Vien et al 2005). Stricter conservation enforcement in Vietnam has led to increased opportunity costs for local communities (McElwee 2010).

Despite efforts by government, poverty is still a major problem in the NUV. With an annual per capita income of less than US\$ 500 per year, the NUV is the poorest region in Vietnam. In 2008, 32% of its population lived under the poverty line (GSO 2009). Farmers face uncertainties in relation to weather, markets, and policies. Steep sloping land, scarcity of arable land, water shortages, lack of information on new technology, and cultural isolation hold back agricultural development (MARD 2006; Sekhar 2007).

In order to develop rational agricultural land-use plans, there is a need to assess the potentials and limitations of land. The method that uses physical, social,

**FIGURE 1** The Suoi Con watershed (A) location in Vietnam; (B) location in Phu Tho Province; (C) map of the watershed itself. (Map by the authors)



and economic information to assess the potential use of land is commonly known as land evaluation (LE). Following the basic method introduced by the Food and Agriculture Organization of the United Nations (FAO) (FAO 1976), several LE approaches, ranging from empirical and qualitative to mechanistic and quantitative, have been developed with the support of computing technologies and geographic information systems software (Sanchez et al 1982; Janssen et al 1990; Littleboy et al 1996; Cools et al 2003; Van Keulen 2007; Recatalá Boix and Zinck 2008; Sonneveld et al 2010). In general, more complex LE methods provide more accurate descriptions of land potentials but also require a higher quantity and quality of inputs and cost more (Rossiter 1996; Manna et al 2009). Although the old FAO LE framework has limitations in characterizing the dynamics and spatial variability of biophysical factors such as soil properties, climate, and crop requirements (Kam et al 2002; Manna et al 2009), it has been adopted worldwide to support land-use planning because it is based on simple qualitative procedures that require only basic knowledge of land resources. The revised version of the framework (FAO 2007) is appropriate not only for regional scales

(nation or agro-ecological zone) (Manna et al 2009) but also for local (watershed, village, community, and household) scales. The FAO framework for land evaluation is still useful and appropriate for resource management studies, especially in developing countries.

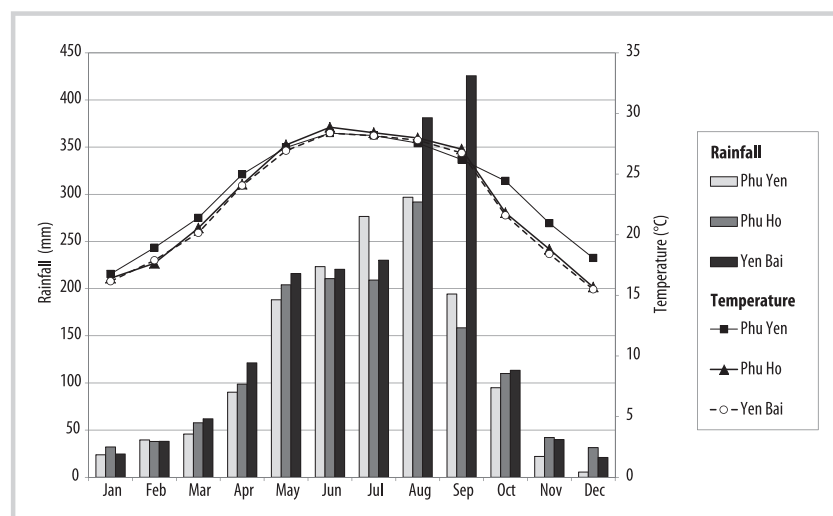
This article uses results obtained from FAO's 2007 LE, a literature review, stakeholder meetings, and a household survey, all conducted in 2008 in Suoi Con, a small watershed in the NUV, to analyze limitations in agricultural development from different points of view. It also explores the mismatches between the land-use objectives of the government and those of households in the NUV, which prevent land-use change from aligning with the government's long-term development plans.

## Materials and methods

### Study site

Suoi Con (Figure 1) is a small agroforestry watershed in Thu Cuc Commune, Tan Son District, Phu Tho Province, in northern Vietnam ( $104^{\circ}49'42''\text{E}$  to  $104^{\circ}53'41''\text{E}$  and  $21^{\circ}16'1''\text{N}$  to  $21^{\circ}19'17''\text{N}$ ) with a total area of 1760 ha. Only 21% of the area is used for agriculture. The

**FIGURE 2** Average monthly rainfall and air temperature measured at 3 climate stations around the Suoi Con watershed, Vietnam.



remaining 79% is used for forestry, settlements, and infrastructure or is unused. Irrigation systems cover only 17% of the agricultural lands.

The annual rainfall is high, around 1600 mm per year, but it is distributed unequally over the year, forming two distinct seasons (Figure 2). The rainy season, from mid-April to the end of September, contributes up to 76% of the annual rainfall. Water shortages for agriculture often occur in the dry season. The average monthly air temperature ranges from 15°C to 28°C, but it can reach 33°C in summer and 10°C in winter. The variations of rainfall and temperature create three main cultivation seasons: spring (February–June), summer (July–October), and winter (November–January).

The lands of the Suoi Con watershed are shared by three villages—Con, Que, and Ray—with a total of 399 households. The two main ethnic groups in these villages are the Muong and Dao. According to Dang et al (1993), the Muong split from the Viet-Muong community around the first century AD. Their language is very similar to that of the Kinh, the dominant ethnic group in Vietnam. They traditionally live in the mountains and developed their own culture independently. In the Suoi Con watershed, Muong people are the original settlers and own most of the fertile land. Their two villages (Con and Que) have 355 households located close to the lowland part of the watershed (Figure 1). They traditionally cultivate irrigated crops (rice, maize, groundnut, sweet potato, and vegetables) in the irrigated and flat land and perennial crops (tea and fruit trees) on upland fields around the village.

According to Phuc (2007), the Dao in Vietnam originally came from China in the 13th to 20th centuries. Ray village in Suoi Con was formally established in the 1960s by a small group of Dao people who migrated from a northern province. In the past, most of the households in Ray village maintained swidden fields on the sloping land in the highest part of the watershed and subsisted on forest and rain-fed agriculture.

Their fields are often remote from their village, difficult to access, and infertile. Since the agricultural land and forest land allocation policies were issued in 1981 and 1992, respectively, slash-and-burn cultivation has been prohibited. The Dao people were forced to change from shifting cultivation to settled land-use systems. They constructed paddy terraces and also grow rain-fed rice, cash crops (maize, cassava, and soybean), and fruit trees and raise livestock.

Although Muong and Dao people have different cultures, languages, and cultivation habits, they are similar in their perceptions on livelihood improvement and their land-use decisions. These similarities are the result of the long-term cultural adaptations of the two ethnic groups and regular interactions between villages in the watershed.

#### Identification of biophysical constraints

A field survey was conducted to capture characteristics of agricultural land in the study area. Twenty-four primary (soil pits) and 32 secondary (auger holes) soil profiles (0–120 cm) were collected in the watershed (about one profile per 30 ha), following the *Handbook for Soil Survey and Land Evaluation* (Chieu et al 1999). Surface soil samples (0–20 cm), taken at 5 positions within a radius of 100 m around each primary soil profile, were used to determine soil properties. The morphological, physical, and chemical properties of soils, together with information from a 1:50,000 soil map of Phu Tho Province (NIAPP 2006), were used to build a detailed soil map of the Suoi Con watershed, following the FAO's guidelines for distinguishing soil subunits (FAO 1990).

Other data required for analyzing biophysical constraints were obtained from various sources: monthly climate data from the Vietnam Institute of Meteorology, Hydrology and Environment; satellite images from the Vietnam Remote Sensing Center; a land-use map of Thu Cuc commune from the Forest Inventory and Planning

**TABLE 1** Suitability of main annual crops for land in the Suoi Con watershed.

Crop	Crop season	Percentage of agricultural land			
		Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Irrigated rice	Spring	12	5	81	2
	Summer	12	49	37	2
Rain-fed rice	Summer	43	55	2	–
Maize	Spring	33	63	4	–
	Summer	13	83	4	–
	Winter	13	2	2	83
Groundnut	Spring	3	74	23	–
	Summer	5	72	23	–
Soybean	Spring	55	45	–	–
	Summer	–	100	–	–
	Winter	15	2	–	83
Vegetables	Spring	13	78	9	–
	Summer	–	91	9	–
	Winter	2	15	–	83
Sweet potato	Spring	–	87	13	–
	Summer	–	87	13	–
	Winter	–	87	13	–
Cassava <sup>a)</sup>		17	46	29	8

<sup>a)</sup>Due to long growth duration, only one cassava crop is possible per year. In Suoi Con, cassava is often sown in mid-February and harvested in late October.

Institute; and a digital elevation model (resolution of  $30 \times 30$  m) from the Earth Remote Sensing Data Analysis Center.

After the decollectivization of agriculture, the household became the basic unit of land-use decisions. Farmers can freely choose their cropping system. Besides traditional and inbred crop varieties, several imported and hybrid varieties have been introduced and applied in the watershed. For instance, up to 8 varieties of rice and 7 varieties of maize are being used in a cultivation season. To simplify the land evaluation, the latest FAO framework (FAO 2007) was applied to determine land suitability for only 8 crops (Table 1) without distinction of varieties: irrigated rice, rain-fed rice, maize, groundnut, soybean, vegetables, sweet potato, and cassava.

In the first step of this land evaluation, only static land variables such as slope, soil, irrigation, drainage, and village borders were used to distinguish land units. In order to retain spatial variability of continuous variables like slope and to reduce homogeneity in land unit delineation, land characteristics were represented in georegistered gridded maps (Kam et al 2002) with a resolution of  $30 \times 30$  m. In the next step, dynamic

variables (rainfall and temperature), properties of the top soil horizon (0–20 cm), and land requirements for crops given by Sys et al (1993) were used to determine suitability classes for the selected crops. Crop requirements and land characteristics were matched for each possible crop–season combination. The weighting-rating method (Rossiter 1996) and the maximum limitation method (Sys et al 1991; Rossiter 1996) were then applied to determine overall suitability for crop–season combinations. For each land unit, possible crop rotations could be identified based on suitability and duration of combinations of crops and seasons. For example, if a land unit is suitable for rice in summer and for maize in spring and summer, then possible rotations include spring maize and summer rice, spring maize and summer maize, spring fallow and summer rice, and spring fallow and summer fallow. Current cropping systems preferred by farmers reflect well the suitability classes generated by the land evaluation. After land evaluation, crop varieties dominantly used in the watershed were taken into consideration in the analysis of input/output levels and land-use decisions by farmers (Table 2).



**TABLE 2** Current (C) and recommended (R) investments in annual crops in the Suoi Con watershed.

Crop	Season	Labor		Costs <sup>b)</sup>		Crop yields		Revenue	
		(d ha <sup>-1</sup> )		(US\$ ha <sup>-1</sup> )		(t ha <sup>-1</sup> )		(US\$ ha <sup>-1</sup> )	
		C	R	C	R	C	R	C	R
Inbred rice variety supplied by seed companies	Spring	209	272	150.0	356.3	3.8	5.5	1175.0	1687.5
	Summer	195	272	143.8	337.5	3.6	5.0	1125.0	1562.5
Inbred rice variety produced by household	Spring	209	272	168.8		3.9		1218.8	
	Summer	195	272	143.8		3.7		1156.3	
Hybrid rice variety supplied by seed companies	Spring	209	272	212.5	443.8	4.1	6.5	1275.0	2031.3
	Summer	195	272	193.8	381.3	3.6	6.0	1106.3	1881.3
Upland rain-fed rice	Summer	333	354	112.5	231.3	1.6	2.3	487.5	718.8
Hybrid maize	Spring	216	328	137.5	450.0	3.9	6.0	862.5	1312.5
	Summer	216	328	143.8	450.0	3.9	6.0	862.5	1312.5
	Winter		328		450.0		6.0		1312.5
Groundnut	Spring	334	397	100.0	412.5	2.0	4.5	1375.0	3068.8
	Summer	306	369	93.8	375.0	1.4	4.5	937.5	3075.0
Soybean	Spring	244	314	112.5	375.0	1.4	4.0	1043.8	3000.0
	Summer	244	314	150.0	375.0	2.8	4.0	2087.5	3006.3
	Summer		314		393.8		4.0		3006.3
Cabbage	Winter	460	467	318.8	943.8	6.9	30.0	1737.5	7500.0
Sweet potato for root	Spring		265		437.5		16.7		3131.3
	Summer		265		437.5		16.0		3000.0
	Winter		265		437.5		16.0		3000.0
Sweet potato for leaves	Spring	322	334		412.5	8.5	27.0	187.5	700.0
	Summer	322	334		412.5	8.5	27.0	187.5	718.8
	Winter	322	334		412.5	8.5	27.0	187.5	718.8
Cassava <sup>a)</sup>		333	431	62.5	306.3	13.9	40.0	312.5	875.0

C = under current farming practices; R = with recommended technology.

<sup>a)</sup>Due to long growth duration, only one cassava crop is possible in per year. In Suoi Con, cassava is often sown in mid-February and harvested in late October.

<sup>b)</sup>Only expenses for seeds and fertilizers were used in calculation of cost.

### Identification of socioeconomic constraints

A household survey in the Suoi Con watershed was conducted in 2008 by Vietnamese researchers without the presence of local officials to collect socioeconomic data on land use under traditional practices. The survey was implemented through face-to-face interviews in individual households. All households were listed by village chiefs based on levels of agricultural investment

(land area, fertilizer use, cropping techniques, and labor), and then 100 households (25% of the total) were randomly selected for the survey. Land-use information on each plot of each household was split into 3 periods (1995–2000, 2000–2005, and 2005–2008), corresponding to the government's land-use planning schedule (updated every 5 years). In addition, farmers were asked what they would be planting in the future. Socioeconomic

constraints were mentioned by respondents during the household survey and verified by the analysis of survey results. Averages of values provided by households were used to describe farmers' current practices. Recommended technology levels were identified by the level of inputs and outputs to reach attainable yield under similar soil and climate conditions given in cultivation guidelines (Siem and Phien 1999; VAAS 2008; Vien and Nga 2008).

To evaluate biophysical and socioeconomic constraints from other points of view, various sources of information such as government documents, research articles, project reports, and local newspaper articles were consulted. In addition, stakeholder meetings with the participation of local authorities, the commune's agricultural department, the Women's Social Union, the Youth Union, and farmers were conducted to discuss constraints on agricultural production based on information collected from the household survey and the literature review. The constraints were then ranked by participants.

## Results

### Land characteristics

The field survey identified a number of limitations on agriculture related to soil, topography, and water availability in the Suoi Con watershed. Up to 92% of the watershed is covered by acrisols, which have low fertility, high acidity, and degradation problems. The remaining 8% is overlain with fluvisols, luvisols, and regosols. The steep slopes and the heterogeneous topography are major limitations for agricultural production. Nearly 40% of the 366 ha of agricultural land has a slope that exceeds 15 degrees, which is considered marginally suitable for many crops (Sys et al 1993). However, local farmers do not consider that slope level a limitation in cultivation.

Table 1 presents the area of suitable land for the main annual crops in the three growing seasons. Most land can be classified as suitable or marginally suitable. Rainfall and temperature are more suitable for crops in the summer than in other seasons. As a result, many fields that are classified as marginally suitable or not suitable in spring and winter seasons (for example, for irrigated rice, maize, soybean, and vegetables) become suitable in summer.

### Household characteristics

Table 3 presents characteristics of households in Con, Que, and Ray villages. Of 100 survey respondents, 29% were women. Women often described agricultural activities more clearly and provided more details than men. However, there was no distinction between men and women in implementing agricultural activities. In general, the age of householders, household size, and number of laborers in households were similar in the three villages. However, the education level of Muong householders in Con and Que villages (intermediate school) was higher

than that of the Dao people in Ray village (primary school). Total land area of individual households varied from 1.2 ha to 3.9 ha, but the average area of household agricultural land was around 0.6 ha. For both Muong and Dao people, agricultural production contributed 83–87% of annual household income. More than 50% of agricultural income was from annual crops. The standard deviation and coefficient of variation demonstrated a large difference between households in each village in terms of land area, annual income, and share of income sources—thus, variation occurred not only between villages and ethnic groups but also within them.

### Land use

Total area of land for cultivation (rain fed and irrigated) was 366 ha, including 60 ha of irrigated rice and 306 ha of rain-fed crops (rice, maize, soybean, groundnut, and cassava). Figure 3 shows the land use of 461 plots (49 ha) in 3 periods (1995–2000, 2000–2005, and 2005–2008), and in the future as projected by farmers, based on the results of the household survey. Overall, agricultural lands expanded between 1995 and 2008, especially in the area with single and double cropping. The expansion of agricultural land has resulted in the reduction of forest and fallow land. Between 2000 and 2005, various fallow and forest lands were reassigned to agriculture and agroforestry. Correspondingly, a number of shrub and fallow plots in 1989 (Figure 4A) disappeared with the establishment of large agricultural areas in 2008 (Figure 4B). In addition, dense forests have been degraded and converted to young planted forests or other land uses.

### Current agricultural production

In general, investments for crops under current farming practices are much lower than recommended (Table 2). For example, current rice yield in this watershed varies from 3 t to 4 t ha<sup>-1</sup>, while the average attainable yield under similar conditions (such as climate and soil) is above 5 t ha<sup>-1</sup> (Siem and Phien 1999; VAAS 2008; Vien and Nga 2008). To reduce costs, farmers prefer producing their own seeds than purchasing them. For example, many farmers grow their own inbred rice varieties instead of using inbred and hybrid rice varieties supplied by seed companies.

The watershed has 22 ha under perennial crops, but these crops currently contribute only a small proportion of household income. For example, most tea fields are in the first or second year of development, and so tea production is not considerable. Other perennial crops (longan, litchi, and citrus) are often grown scattered in household gardens, mainly for home consumption.

Since the 1980s decollectivization of agriculture, fish ponds and livestock (buffalo, native cows, pigs, and poultry) have been managed by individual households. Most costs relate to the purchase of young animals. Only a

**TABLE 3** Characteristics of households in 3 villages in the Suoi Con watershed. (Table extended on next page.)

	Age of householder	Education of householder <sup>a)</sup>	Number of household members	Number of laborers	Land area (ha)	
					Agricultural land	Forest lanzd
Con village—Ethnic group = Muong; number of respondents = 34 (19 men and 15 women)						
Min	27.0	3.0	3.0	2.0	0.1	–
Mean	42.4	6.1	5.2	3.0	0.6	0.6
Max	61.0	10.0	7.0	6.0	2.8	7.0
SD	7.6	1.5	1.1	1.1	0.6	1.4
CV%	18.0	24.1	22.0	37.5	89.1	223.7
Que village—Ethnic group = Muong; number of respondents = 47 (40 men and 7 women)						
Min	20.0	0.0	3.0	1.0	0.1	–
Mean	38.1	5.8	5.0	3.1	0.5	3.4
Max	60.0	9.0	10.0	6.0	1.4	30.5
SD	9.5	2.2	1.7	1.1	0.3	6.5
CV%	24.9	37.3	33.1	33.8	71.9	189.5
Ray village—Ethnic group = Dao; number of respondents = 19 (12 men and 7 women)						
Min	24.0	0.0	4.0	2.0	0.3	–
Mean	42.2	3.9	5.9	3.3	0.8	2.1
Max	66.0	9.0	10.0	7.0	2.4	17.1
SD	10.9	2.6	1.7	1.6	0.6	4.2
CV%	25.9	67.6	29.3	47.2	72.4	199.1

<sup>a)</sup>There are 12 years of basic education in Vietnam: 5 years of primary school, 4 years of intermediate school, and 3 years of secondary school. CV% = coefficient of variation; SD = standard deviation.

few households buy feed from the market. Although total production is low, livestock contributes up to 47% of households' agricultural income.

### Agricultural constraints

In the Suoi Con watershed, rice is the staple food for both Muong and Dao people. Maize, cassava, sweet potato, and other annual crops are considered cash crops or are grown as animal feed. To satisfy food demand based on the national targets (GoV 2011) for about 2000 people in 2015, the watershed needs to provide at least 424 t per year of rice. In addition, to rise above the national poverty line, annual income for the watershed as a whole needs to increase from US\$ 225,000 per year in 2008 to US\$ 375,000 per year by 2015. In stakeholder meetings, local authorities indicated that traditional techniques, limited land area, shortage of water, and lack of market information are the most serious constraints on the ability of farmers in the watershed to reach land-use targets. However, solutions

to these problems were not defined in the local government's land-use strategy.

Local authorities listed constraints in the following order of importance: techniques, land, irrigation, markets, capital, and labor. However, in the household survey, limited household capital was mentioned by 90% of respondents, followed by limited land area and quality (45%), lack of agricultural techniques (40%), labor shortage (38%), lack of irrigation water (18%), low-yielding crop varieties (14%), pests and diseases (10%), and lack of market access (8%). From the farmers' perspective, lack of capital is the major constraint. About half of the interviewed households said that they are using loans from formal and informal credit sources (such as government banks, private credit services, relatives, and neighbors) to maintain production. This does not mean that the other half have sufficient capital without having to borrow. Rather, they have little access to credit and therefore have to continue using limited production techniques. Many households do not have a land tenure



**TABLE 3** Extended. (First part of Table 3 on previous page.)

	Annual income (US\$)		Income sources (US\$)			
	Per capita	Per household	Annual crops	Perennial crops	Aquaculture and livestock raising	Other
<b>Con village—Ethnic group = Muong; number of respondents = 34 (19 men and 15 women)</b>						
<b>Min</b>	53	277	184	–	–	–
<b>Mean</b>	374	1881	750	47	768	316
<b>Max</b>	1046	5230	1890	822	3125	2500
<b>SD</b>	258	1236	354	151	880	622
<b>CV%</b>	69	66	47	320	115	197
<b>Que village—Ethnic group = Muong; number of respondents = 47 (40 men and 7 women)</b>						
<b>Min</b>	43	214	152	–	–	–
<b>Mean</b>	216	1104	507	4	411	182
<b>Max</b>	564	4514	1294	93	2793	1500
<b>SD</b>	118	839	267	16	567	344
<b>CV%</b>	54	76	53	410	138	189
<b>Ray village—Ethnic group = Dao; number of respondents = 19 (12 men and 7 women)</b>						
<b>Min</b>	68	341	196	–	–	–
<b>Mean</b>	223	1419	683	–	549	187
<b>Max</b>	499	4992	1435	–	3556	1800
<b>SD</b>	120	1136	340	–	900	467
<b>CV%</b>	54	80	50	–	164	250

document (“red card”) or valuable property to mortgage for agricultural loans. Asked what they would do if the policy was changed so that every household had sufficient access to credit, 57% of respondents said they would use such loans to invest in livestock, 14% in cultivation only, and the remaining 29% in both livestock and cultivation.

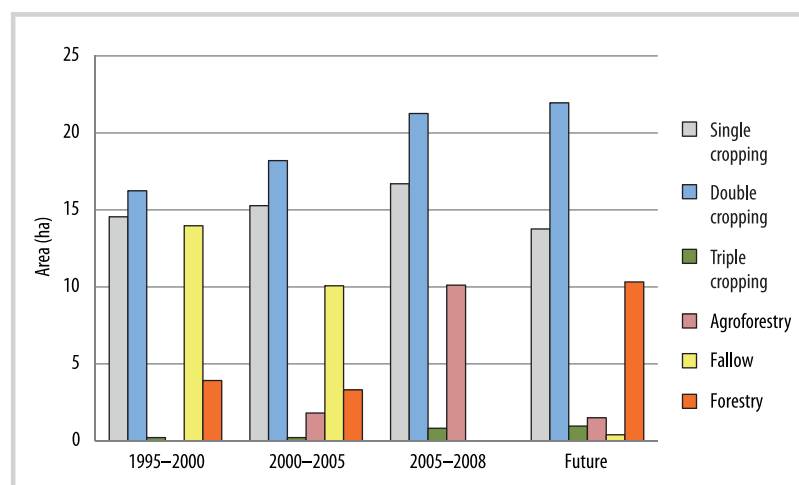
#### Alternative land-use options

A plot of land is often suitable for various crop types in different seasons. Therefore, farmers have several alternatives in using the plot. Based on conditions (eg rainfall, market price, and availability of capital and labor), farmers may choose an appropriate alternative to alleviate their biophysical and socioeconomic constraints. Farmers have replaced the spring rice crop on terraces, grown mainly for self-sufficiency, with cash crops such as spring maize, groundnut, or soybean to adapt to water shortages. Results of the household survey showed that availability of labor and household capital at the end of a crop season also influence the choice of crop and the level of investment in the next season.

Figure 5 illustrates two land-use options corresponding to two possible production targets. The wide range of land suitability and crop–season combinations provides an opportunity for farmers to quickly change their cropping systems to adapt to changes in biophysical and socioeconomic conditions.

#### Discussion

As Table 2 indicates, traditional technology results in low crop yields (about 40–75% of yields expected under the recommended technology levels). Thus, low soil fertility, steep slope, and low land suitability are not the main constraints in agriculture production in the region. Various experimental studies (Phien et al 1998; Siem and Phien 1999; Bo et al 2003) have proved that such land constraints can be overcome by improving cultivation techniques. According to an agricultural extension officer in the watershed, farmers can access modern technologies without language and gender barriers. However, it is very difficult to convince farmers to apply the recommended techniques because of their shortage of capital and

**FIGURE 3** Land use in the Suoi Con watershed.

difficulty in accessing credit. That is why only 14% of interviewed households expressed dissatisfaction with existing crop varieties. The technology constraint should be described as a low rate of adoption of improved technology. As a result, crop production and economic returns for the households have not improved.

Despite efforts of the government since 1998 to reallocate agricultural land (GoV 1998), land fragmentation is still a serious problem for agricultural production, especially in mountainous areas (Lan 2001; MARD 2006; Hung et al 2007). The main causes of land fragmentation are both population growth, with the division of land among inheriting children, and the equal division of cooperative land to individual households during decollectivization in 1980s and 1990s, when each household received many plots of different quality levels (Markussen et al 2012). In the Suoi Con watershed, the average farm size is 0.58 ha. Each household typically owns 4–7 separate parcels with different soil types, terrain, and/or irrigation conditions. At present, land fragmentation limits the large-scale implementation of agricultural mechanization, a basic condition for market-oriented agriculture (Markussen et al 2012) and national rural development targets. Thus, land fragmentation is another major constraint on agricultural production, but it was not mentioned by farmers during the household survey.

Although 90% of surveyed households reported a shortage of capital, local authorities argued that capital availability is not really a constraint because there are various credit services in the region, and possibilities for extending household capital are available, although farmers still find the procedures complex. They emphasized that farmers' adoption of agricultural techniques is more important than extending capital. However, a report of the central government indicated that without enough capital, farmers have less chance to apply new technologies and varieties (GoV 2003).

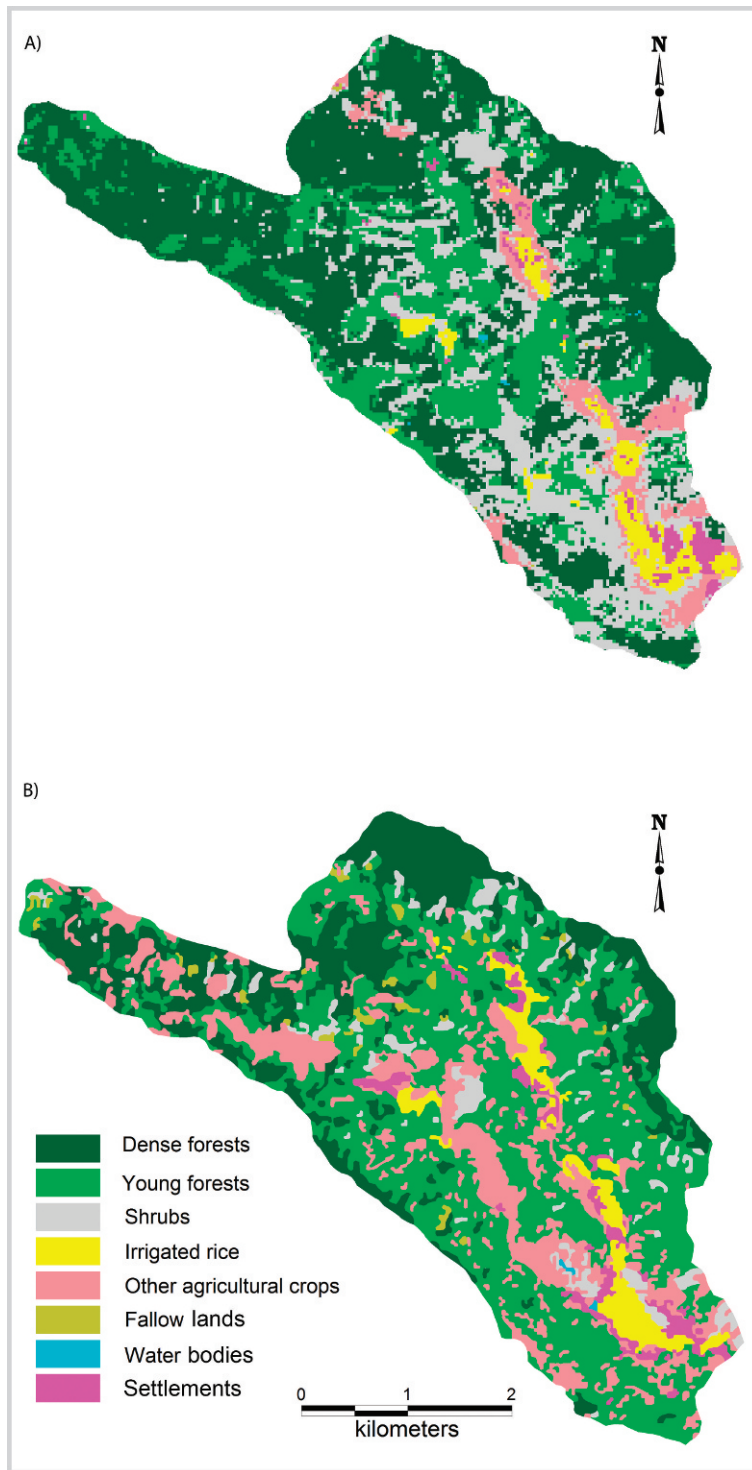
According to Hao (2005), nearly 30% of Vietnam rural households in 2001 were unable to access formal or semiformal credit. Dower (2004) identified high interest rates and strict mortgage requirements as the main reasons for this. In the NUV, most small and poor households do not have much collateral such as the “red card,” so they often rely on small loans from informal sources such as neighbors, relatives, and private financial services.

We agreed with local authorities that labor is not a constraint. A labor shortage occurs at the beginning and the end of crop seasons, but the problem appears to be manageable within the labor exchange groups established by relatives or neighboring households. Moreover, limitations on household capital prevent farmers from expanding their agricultural activities, and therefore, the need for extra laborers is not high with current cultivation practices.

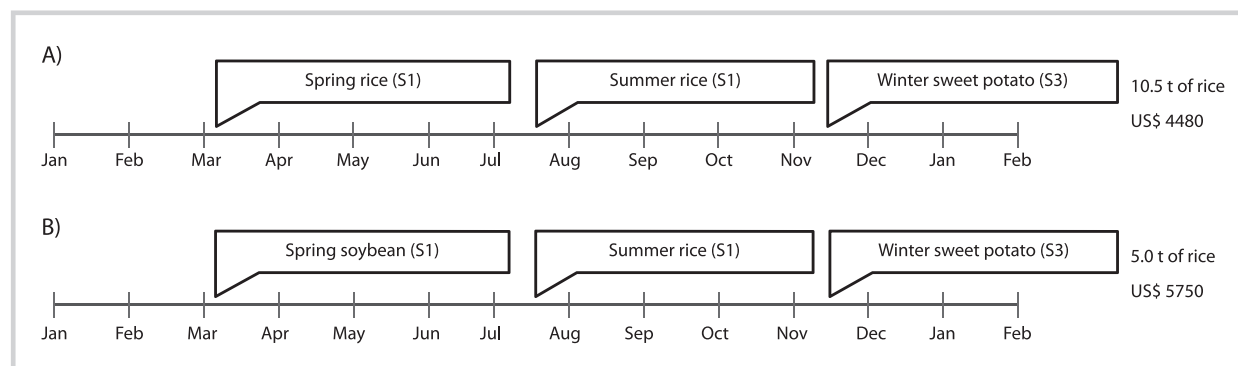
While irrigation water and a market for agricultural products are not of urgent concern to farmers, these are considered important factors for agricultural development by the People's Committee of Thu Cuc Commune, an even higher priority than availability of capital and labor. From their point of view, when agriculture in the region shifts to a higher level of production (market-oriented or mechanized agriculture), better infrastructure and market access will be required.

As mentioned earlier, local authorities prioritize techniques, followed by land, irrigation, markets, capital, and labor; while farmers' highest priority is capital, followed by land, techniques, labor, irrigation, crop varieties, pest control, and markets. This mismatch in defining core problems leads to mistakes in determining cause-and-effect relations and establishing action plans. Therefore, in land-use planning at the community level, land users need to properly define constraints in order to identify suitable interventions.

**FIGURE 4** Vegetation cover of the Suoi Con watershed (A) in 1989; (B) in 2008.



**FIGURE 5** Two alternative land-use options based on crop suitability: (A) maximizing rice production by growing rice in both spring and summer seasons; (B) alternative crop rotation applied to maximize income while maintaining enough rice production for food self-sufficiency. Land suitability classes: S1 = highly suitable; S3 = marginally suitable. Rice production and total revenues are estimated for 1 ha.



According to Rerkasem and Rerkasem (1998), soil erosion alleviation has never been an objective of farmers in the upland regions of Southeast Asia. The household survey in the Suoi Con watershed showed that although households in the study site can recognize the appearance of surface crusts, gullies, and stoniness in their fields, they have not applied conservation measures. The increase in agroforestry and forest land (Figure 3) was not for the purpose of land conservation but rather reflects the flexibility in land-use decisions made by households to adapt to changes in natural and economic conditions. Considering the diversity in biophysical conditions and availability of alternative land-use options, using cropping systems that satisfy both economic and land conservation targets could be a viable approach for sustainable land-use in the upland regions.

## Conclusions

The study in the Suoi Con watershed demonstrates common livelihood problems in the NUV, where rural households rely on agricultural production for food and income. Considering the limitations of the land

resources, an integrated management technique is needed to improve crop production, economic returns, and land conservation. Agricultural techniques, household capital, and land fragmentation are the most important factors holding back agricultural development in the mountainous regions. On the other hand, the wide range of suitable crops and the number of alternative land-use options are great advantages for the region. The study also found different points of view on land-use constraints and a gap between the land-use plan prepared by the government and decisions by farmers in the region. Therefore, participatory and bottom-up approaches are needed to better understand problems and opportunities in household agricultural production in order to develop appropriate land-use plans and policies. Participatory meetings between farmers and local authorities should be organized to define constraints on land use and to identify suitable interventions. At the meetings, farmers should be informed about the land-use plan prepared by the government and discuss the possible constraints on implementation. Then, these constraints should be ranked and agreed on by all participants. This process is commonly required for watersheds in upland areas.

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