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THE SUSTAINABILITY OF TRADITIONAL AND MODERN AGRICULTURAL LAND USE IN VIETNAM

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Introduction

The production of food and fibre in Vietnam has increased steadily over the last few decades. This is mainly due to the increased use of external inputs, such as chemical fertilizers and pesticides, and through the intensification of land use, mainly by mechanization and irrigation. But these newly adopted agricultural practices also adversely affect the environment. Land degradation has increased and soils show a significant decline in fertility and organic matter content. Also water resources are degraded, both in quality and quantity (Conway, 1990). The agricultural sector in Vietnam is challenged at two ends: to secure the requirements of food and fibre for a growing population and at the same time to arrest land degradation and its detrimental effects on land productivity. Agriculture is the predominant sector of the economy of Vietnam, with more than 70 percent of the people living in rural areas and depending on agriculture for their livelihood.

The total area of cultivable land is about 11.7 million ha. The high population growth, i.e. around 1.75 percent annually (FAO, 1999), further leads to a reduction in available land for cultivation by diverting land for homestead construction, industrial development, the expansion of cities (urbanization), and other non-agricultural purposes. The average land-holding size will decrease and inevitably lead to an increase of landless farmers and an increased demand on the land's productivity. However, recent experience in the country has shown that any increase in production through intensification of land use by irrigation, the introduction of high yielding varieties, chemical fertilizers, and pesticides has had adverse effects on the land. This applies in particular to unsuitable cropping patterns and lack of appropriate rotations, inappropriate soil management practices, and unbalanced use of chemical fertilizers and pesticides. In the remote areas of the country, food self-sufficiency is mainly dependent on local food production, but the farmers cannot produce adequate quantities of food due to limited land for cultivation and low crop yields under the unproductive traditional cultivation practices. Strong emphasis on cereal production and high yielding varieties has led to monocropping and a dependency on irrigation, chemical fertilizers, and pesticides. Due to excessive and unbalanced use of chemical fertilizers, the soil quality is gradually deteriorating. Also, fish populations in the rivers and other water bodies have drastically decreased due to water pollution by chemicals, including fertilizers and pesticides (Rahman, 1998). Farmers handling pesticides and fertilizers inappropriately often suffer from heart and skin diseases. Also, livestock that consume grasses and fodder crops treated with pesticides and herbicides suffer from diseases (Rahman, 1998*)*. There is a large gap between crop yields in Dien Bien District and other districts in the mountains. This study has focused on two types of smallholder farming systems in the northern highlands of Vietnam: (i) the traditional (indigenous) farming system with a low external input level and (ii) the modern farming system with increased external input levels. So, the overall objective of the study is to assess and compare the traditional and modern farming systems in terms of their contribution to sustainability.

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Profile of Lai Chau Province

Lai Chau Province borders China in the north, Lao Cai Province in the northeast, Son La Province in the southeast, and Lao PDR in the west. The province is divided into eight districts and two towns. In the past, Lai Chau town was the administrative centre of the province. Dien Bien Phu town was established in 1994 and is the administrative centre of Lai Chau Province. Unlike other provinces, Lai Chau Province has a deep depression of 3 700 ha, and it is surrounded by mountains. There are 175 communes in the province, of which 85 are listed among the 2 135 of the poorest mountainous communes.

The total area of the province is 1 700 000 ha, of which 70 percent comprises mountains and high plateau. In Lai Chau Province, there are three main types of soils. Alluvial soil is found mainly along rivers and streams, creating paddy areas. The mountainous areas in Lai Chau Province are part of the catchments of the Red River and Da River and runoff contributes to water reserves in the Hoa Binh lakes (the Hoa Binh lakes are important for controlling floods in the lowland regions of Vietnam).

In the winter, Lai Chau and Dien Bien Phu experience high humidity. Annual rainfall varies from 1 500 to 2 000 mm. The western mountains are drier than the other mountains areas. The annual average temperature is 25°C.

Lai Chau Province has a population of 505 655 people and an average population density of 250 persons/km^2. The population growth rate is 1.9 percent. The number of people of working age is 207 824 accounting for 41.1 percent of the population. The four main ethnic groups are the Tay, Thai, Kho Mu, and H'Mong (called Mong) accounting for 17.5, 7.2, 9.3, and 8.1 percent respectively. There are 26 other ethnic groups such as the Cao Lan, Muong, Xa, and Lao.

The predominant land use in the province is forestry, accounting for 33.2 percent of the total area. Most of the unused land accounts for 50.3 percent (Figure 1). This land is suitable for forestry and it has potential for economic development.

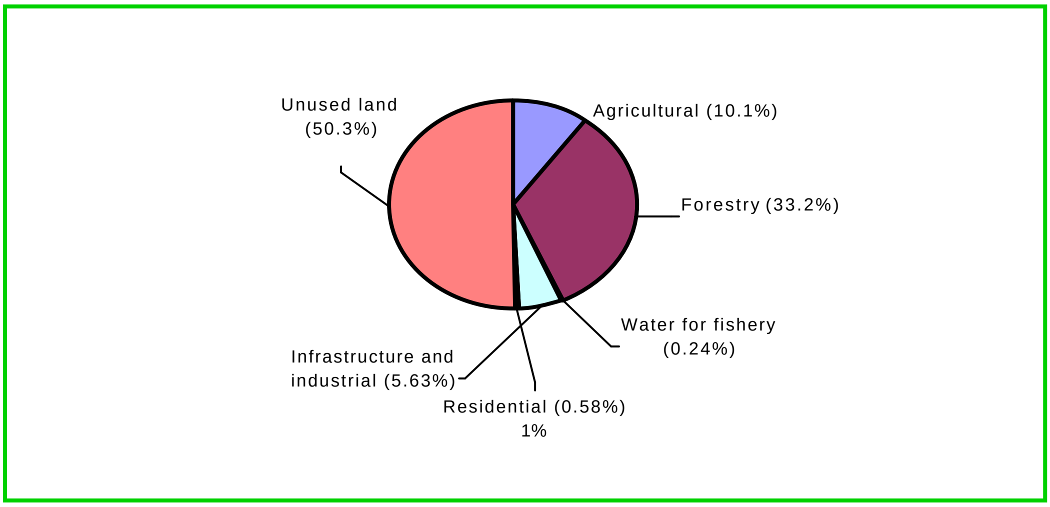

Figure 1. Land use in Lai Chau Province, Vietnam

Profile of Dien Bien District

Dien Bien District is located in the south of Lai Chau Province. It borders Muong Lay District in the north, Tuan Giao and Dien Bien Dong districts in the east, Son La Province in the south, and Lao PDR in the west. In general, Dien Bien District is influenced by a wet, tropical climate.

Dien Bien has 47 000 people belonging to about 8 600 households; 19 646 of the people are of working age, accounting for 41.8 percent of the population. The distribution of labour by sectors is 83.1 percent in agriculture; 2.26 percent in industry and construction; 1.76 percent in services; and 12.88 percent in local administration. The population growth rate of Dien Bien District is 1.9 percent. Fifty-three percent of the population is ethnic Thai; 25 percent is H'Mong; 12 percent is Kho Mu; 5 percent is Kinh and 3 percent is Tay. Four communes lying in the deep depression and Dien Bien town have been integrated into the national electricity network. The local farmers living in these communes obtain electricity from small-scale hydropower plants. The district has an area of 160 000 ha, of which 12 000 ha are agricultural lands accounting for 7.5 percent of the land area; 69.5 percent of the area is forest land or 111 200 ha. Unused land occupies 28 640 ha or 17.9 percent; the residential area is only 1 percent or 1 600 ha and 4.1 percent or 6 560 ha of the land is government reserve.

The Thanh Nua commune consists of 34 villages. Thanh Nua commune administers each village. There are five ethnic groups living in the community: Thai (73 percent), H'Mong (11 percent), Kho Mu (4 percent), Tay (2 percent), and Kinh (10 percent).

Thanh Nua commune is located west of Dien Bien town and has an arable area of 10 350 ha, of which 626.21 ha are agricultural land. The agricultural land use is characterized by poor cultivation, low fertilizer application, and the use of local varieties. The cassava yield never exceeds 4.6 t/ha. With low input levels and the need for more fertile land, shifting cultivation is unavoidable. Moreover, the slash-and-burn practices also deplete soil fertility. The average number of family members in the traditional household is 5.56. The largest household has 15 people and the smallest household has three members. In the modern households, the average number of family members is 5.96. The largest household has 13 people and the smallest household has four members.

Table 1. Educational levels in the study area

Type of household	No education	Primary	Secondary	Higher secondary	Graduation
Traditional	7 (21.88%)	16 (50.0%)	6 (18.75%)	3 (9.37%)	0
Modern	2 (6.26%)	19 (59.36%)	11 (34.38%)	0	0

For both traditional and modern households, the predominant educational level of the adults is primary school (Table 1). In Vietnam the primary level consists of grade 1 to grade 5. In practice, all illiterate people belong to the ethnic minority category. This applies to both traditional and modern households.

One hundred percent of the households are involved in agriculture and forestry. In other areas, especially in the lowlands, the people participate in small handicraft businesses or other occupations. But in the study area the majority of the respondents' households do not have additional occupations.

Soil fertility and current fertilization status

In Dien Bien District, the degree of cultivated slopes is 10–100 percent, commonly 45 to 70 percent. These slopes are difficult to cultivate and should, if possible, be under permanent cover. Three main types of soils are found in the area: light yellow and humus-rich soils on the high mountains (i.e. 1 700 to 2 800 metres above sea level); yellowish red and humus rich soils on clay or weathered rock; and yellowish red and humus-rich soils on acid volcanic rock. The land is divided into two land units: (a) sloping land (slopes) and (b) terraced fields (terraces). It is not known exactly when these parcels of land were first used for cultivation after clearing of the original forest by slash and burn. Most of the terraced fields were established some decades ago and now no virgin forest is left. Twenty soil samples were sampled for each land unit (slopes and terraces) to determine five soil properties: available N, available P, organic matter, Cation Exchange Capacity (CEC), and base saturation.

Available N

On the terraced fields, the traditional farming practices were higher in available N than the modern farming practices. However, the difference is not significant. The reason for this may be that on the modern terraces more N is being taking up by the higher yields of hybrid rice varieties. Therefore after harvesting, some elements in this soil such as N may become scarce. Only about 10 percent of the fields on traditional slopes were at the medium level, whereas on the terraces a higher proportion of fields were at the medium level. Generally, N in this soil is low, in both traditional and modern farming.

Available P

Only limited soil P is actually available to crops in the course of one growth cycle. Some is lost or tied up in minerals or in stable organic and organo-mineral compounds. It becomes available to the plants only after weathering or biochemical decomposition of the organic structure. Approximately 60 to 70 percent of the fields with traditional and modern arrangements on the slopes have very low to medium available P levels. This might be because in modern farming practices more higher yield crops are cultivated than in traditional farming and therefore the crops take up more P from the soil.

Organic matter

The organic matter (OM) content of the soil in the study area varied between the two farming systems on both the slopes and terraces. The soil organic matter index (OMI) is calculated as follows:

$$OMI = \{(OM_{vl} *1) + (OM_{l} *2) + (OM_{m} *3)\}/N$$

where: $OM_{vl,}$ OM_{l} and $OM_{m,}$ are frequencies of very low, low, and medium OM. N is the sample size.

Table 2. Distribution of OM in the soil

Ranges % (*)	Interpretation (*)	Traditional		Modern	
		% of fields (slopes)	% of field (terraces)	% of field (slopes)	% of field (terraces)
2.1–4.2	Medium	10	10	60	10
1.0–2.0	Low	80	80	40	50
< 1.0	Very low	10	10	0	40
	Total	**100**	**100**	**100**	**100**
OMI		2.0	2.0	2.6	1.7

Source: Field survey
(*) Bouma and de Meester (1989)

Table 2 shows a medium level of soil OM content on traditional slopes and a higher level on the modern slopes. This might be because the level of crop residues was higher on modern slopes than on traditional slopes, because of the higher biomass and crop yield. Generally, OM in the terraced fields was lower than that in the upland slopes for both types of management. This might be because the farmers burn the rice straw or remove the crop residues after harvesting. Cattle foraging in the fields cleared any growth of rice or grass during the dry season. In Table 2, the low and very low ranges of OM had the largest share and the low ranges were dominant (from 40 to 80 percent on the upland slopes and from 50 to 80 percent in the terraced fields) compared with forest land. It is also obvious that OM was much higher in forest soil than in the upland slopes and in the terraced fields for both farming systems.

Cation Exchange Capacity

The CEC reflects the capacity of a soil to exchange and retain nutrients for plant growth. The general levels of CEC for both traditional and modern farming on the upland slopes and on the terraced fields were low and very low. Overall, the CEC was low or very low. The frequencies observed on the upland slopes for both traditional and modern farming are similar.

Base saturation

Base saturation was significant between traditional and modern management on the upland slopes (Table 3).

Table 3. Distribution of base saturation in the soil

Ranges, % (*)	Interpretation	Traditional		Modern	
		% of field (slopes)	% of field (terraces)	% of field (slopes)	% of field (terraces)
>75	Very high	0	0	0	0
60.0-75	High	0	0	0	0
41.0–60.0	Medium	0	10	10	40
21.0–40.0	Low	90	90	90	60
<20.0	Very low	10	0	0	0
	Total	**100**	**100**	**100**	**100**

Source: Field survey (2001)
(*) According to ILACO (1981)

Most fields had very low values in traditional upland slopes. Medium values were only found in modern upland slopes. Table 3 shows no significant difference between traditional and modern terraced fields.

Relationship between soil fertility and crop yield

The relationship between soil fertility and crop yields is established with linear multiple regression models (Tables 4 and 5). The general equation is:

$$Y = a^*X_1 + b^* X_2 + c^* X_3 + d^* X_4 + e^* X_5 + f$$

where: Y = crop yield, kg/ha; a, b, c, d, e, f = constants; X_1 = nitrogen %; X_2 = available phosphorus %; X_3 = OM %; X_4 = CEC cmol kg/ha soil; X_5 = base saturation %.

Traditional maize

Table 4. Multiple regression summary relationship between soil fertility and traditional maize yield

	Model	Constant	AN(*)	AP(*)	OM(*)	CEC(*)	BS(*)	R	R^2
Sig.	0.003	0.000	0.079	0.034	0.006	0.007	0.001	0.99	0.97
C		808.61	-11.139	28.85	24.85	43.93	7.75		

Source: Field survey (2001)
Sig.: Significant
C: Coefficient
(*) Are: AN: Available Nitrogen; AP: Available Phosphorus; OM: Organic Matter; CEC: Cation Exchange Capacity; BS: Base Saturation

$Y_{ma1} = 28.85X2 + 24.848\ X_3 + 43.932\ X_4 + 7.752\ X_5 + 808.61$

Modern maize

Table 5. Multiple regression summary relationship between soil fertility and modern maize yield

	Model	Constant	AN (*)	AP (*)	OM (*)	CEC(*)	BS (*)	R	R^2
Sig.	0.015	0.001	0.150	0.049	0.031	0.020	0.005	0.997	0.994
C		995.04	-8.43	41.55	25.36	42.75	7.37		

Source: Field survey (2001)
Sig.: Significant
C: Coefficient
(*) = AN: Available Nitrogen; AP: Available Phosphorus; OM: Organic Matter; CEC: Cation Exchange Capacity; BS: Base Saturation

$Y_{ma2} = 41.55X_2 + 25.36\ X_3 + 42.75\ X_4 + 7.37\ X_5 +995.04$

Thus, both Y_{ma1} and Y_{ma2} show that N does not have a close relationship with maize yield. These results indicate that local maize is less responsive to N than modern varieties. Therefore, there is a need to change to new maize varieties. Maize yields were higher with modern management as opposed to traditional management with local maize.

Traditional cassava

Table 6. Multiple regression summary relationship between soil fertility and traditional cassava yield

	Model	Constant	AN (*)	AP (*)	OM (*)	CEC (*)	BS (*)	R	R^2
Sig.	0.003	0.000	0.251	0.060	0.003	0.002	0.002	0.999	0.999
C		3353.9	1.05	-4.93	36.36	18.04	1.75		

Source: Field survey (2001)
Sig.: Significant
C: Coefficient
(*) = AN: Available Nitrogen; AP: Available Phosphorus; OM: Organic Matter; CEC: Cation Exchange Capacity; BS: Base Saturation

$$Ycas1 = 36.36^* X_3 + 18.04^* X_4 + 1.75^* X_5 + 3353.90$$

Modern cassava

Table 7. Multiple regression summary relationship between soil fertility and modern cassava yield

	Model	Constant	AN (*)	AP(*)	OM (*)	CEC(*)	BS(*)	R	R^2
Sig.	0.039	0.000	0.042	0.231	0.087	0.050	0.017	0.992	0.984
C		2983.18	34.23	31.86	28.33	51.41	7.84		

Source: Field survey (2001)
Sig.: Significant
C: Coefficient
(*) = AN: Available Nitrogen; AP: Available Phosphorus; OM: Organic Matter; CEC: Cation Exchange Capacity; BS: Base Saturation

$$Ycas2 = 34.23^* X_1 + 51.41 X_4 + 7.84 X_5 + 2983.18$$

Tables 6 and 7 show that N and available P do not seem to be critical for traditional cassava yields. However, OM content, CEC, and base saturation were closely related to the yield (high significance level). However, N is more closely related with modern cassava yield and is an element to promote increased cassava yield.

Current fertilization status

Nutrients are applied to compensate for nutrient uptake by plants and nutrient losses by leaching. At harvest the farmers aim for high crop yields and high residual soil fertility. This study focused on three major kinds of fertilizer application in the region: mineral fertilizer, animal manure, and green manure. Fertilizer use in the region is a serious problem. From 1991 to 2000, the total amount of chemical fertilizer used was approximately 27 103 t. In general, the amount of nutrients applied per hectare increased significantly. The major reason for this increase was the increase of hybrid crop varieties. However, the general level of fertilizer application for traditional crop varieties in an extensive traditional farming system was low. In poor living conditions with low income, farmers cannot afford fertilizer at the quantities required. Most of the household members wanted and could increase yields of crops if they could afford fertilizer. The different fertilizer application rates and crop yields are described in Table 8.

Table 8. Fertilizer application for crops

Crops	Type of HH	Number of HH	Average rates of fertilizer application Animal manure (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Average yield (kg/ha)
Spring rice	T	25(32)	4 935.4	84.5	57.5	2.1	3 894
	M	31 (32)	3 813.1	102.8	75.9	4.6	4 955
Summer rice	T	25 (32)	0.00	77.2	51.3	4.8	3 518
	M	31 (32)	4 218.9	90.0	64.1	11.7	4 361
Maize	T	32	0.0	33.9	31.5	0	1 228
	M	27 (32)	0	56.7	72.7	0	2 272
Cassava	T	27 (32)	0	0	0	0	3 334
	M	27 (32)	0	25.7	0	03518	4 322

Source: Field survey (2001); HH: household; T: traditional; M: modern

Animal manure was an essential fertilizer for rice and there was a difference between traditional and modern farmers. In the traditional system, all farmers used animal manure for the spring rice, while in the modern farming system, it was used by both traditional and modern farmers. Application rates of N and P for maize were also higher in modern farming systems. For cassava, no fertilizer was applied in traditional farming. In the modern farming system, only N was applied.

This led to higher yields in the modern farming system. With the limited data any estimation of fertilizer responses is preliminary. But with more experimental data becoming available, more exact fertilizer requirements can be determined. However, for this remote region, the problem might be solved based on a rather simple approach, as suggested by ILACO (1981). This shows that based on the nutrient uptake by crops through the yield, the rate of fertilizer application could be calculated.

Animal manure use

As mentioned already, local farmers use animal manure for crop nutrient supply. In the study area, although the natural land area is large, the grazing land is limited and a large portion is bare land. The grassland available for grazing was 670 ha in 1999; this belonged to the government and enterprises (Tuyet, 1999). This area was not enough for the number of animals (i.e. about 17 200 head in 1999). Therefore, the animals mainly live on by-products and whatever they find when they forage. Very few households have animal stables where animals can produce manure.

Table 9. Animal manure production in farming households

Type of annimal	Traditional			Modern		
	Average number of animals (head)	Number ofHH	Animal manure (kg)	Average number of animals (head)	Number ofHH	Animal manure (kg)
Cattle	1.81	12(32)	592	1.95	23(32)	3 120
Pigs	2.00			2.20		
Others	0	0	0	0	0	0

Source: Field survey (2001)
f. HH: Frequency of household

Table 9 shows the amount of animal manure available in the households, both traditional and modern. The quantities produced from their animals are very small — approximately 592 kg per traditional household and 3 120 kg per modern household. This is only sufficient for 0.06 ha (traditional farming) and 0.31 ha (modern farming). In general, manure availability for both traditional and modern farming is not sufficient. However, in some modern households, the amount of animal manure applied has reached 7-10 t/ha. This raises concerns on how to convince local farmers who practise traditional animal grazing to set up a new system of animal management to raise the potential of animal resources to increase crop yields. Another difficulty is the feasibility of transporting animal manure to the uplands as well as the terraced fields. In practice, the farmers have to carry the animal manure on their backs to the fields, and not by cart or tractor. Therefore, effectiveness is often limited, especially when manure has to be carried along small paths that go up or down steep slopes. Usually, manure is transported when farmers have other reasons to go to their fields.

Green manure resources

The potential for nutrient supplementation via green manure is high in the lowland area (Delta region). In the study area no household planted legume crops that could benefit the cultivation of a second crop. Only green residual parts of plants were applied to the soil.

The leaves and stems of maize and cassava were used as residues in the soil after harvest in the traditional and modern farming systems. In the terraced fields only 50 percent of crop residues, mainly rice, were left in the field. Local farmers do not use other organic resources such as legumes for increasing soil fertility. This is why soil OM content is higher on upland slopes than in terraced fields.

Cropping pattern and sustainability of agricultural land use

The cropping pattern in the study area is determined by physical factors (e.g. climate, soil types, water supply) and socio-economic conditions. The study tried to identify the existing cropping patterns in the area and their opportunities and limitations so that they can be improved.

Effects of climate on food crops

Climate cannot be altered to make it more suitable for crop production. Dien Bien District has a typical tropical climate. The lowest average temperature is 13.9°C in January and the highest is

23.4°C in May. There are nine months with an average temperature of more than 20°C. Therefore, a diversity of tropical and subtropical food crops grow well in the region. But at present, only food crops such as cassava and maize that have adapted to the temperature in the rainy season from April to November are grown.

There are some constraints for the cultivation of major food crops such as rice, maize, and cassava. It is difficult for farmers to select a suitable temperature range to grow two crops of rice per year, since in the second season (October to December), the average temperature is less than 20°C. This is unsuitable for the flowering and filling stages of rice. From January to the beginning of March, the average temperature ranges from 17-20°C. This is unsafe for transplanting the rice seedlings.

Double cropping of spring and summer rice has been tested in the terraced fields. To cope with the cold temperature at the beginning of spring-rice cultivation (end of December and January), the rice seedlings are protected and tended in rice-seedling nurseries with nylon roofs that not only keep the inside air warm (compared to outside) but also prevent the seedlings from damage by frost or dew.

In the study area maize is also planted as a monocrop. It occupies the upland slopes from April to October. In the past, there were some attempts to modernize maize cultivation. The local government provided farmers with short-term and high yielding varieties to encourage a change from one maize crop to two maize crops per year. This worked very well. Dien Bien District has rather high rainfall throughout the year over two seasons: the minor (dry) season from October to April with monthly rainfall of about 100 mm and the major rainy season from May to August with monthly rainfall ranging from 200-400 mm (see Figure 2).

These two seasons are connected by a month with an average rainfall of less than 250 mm (September). Unlike temperature, rainfall is highly variable. For the months in the

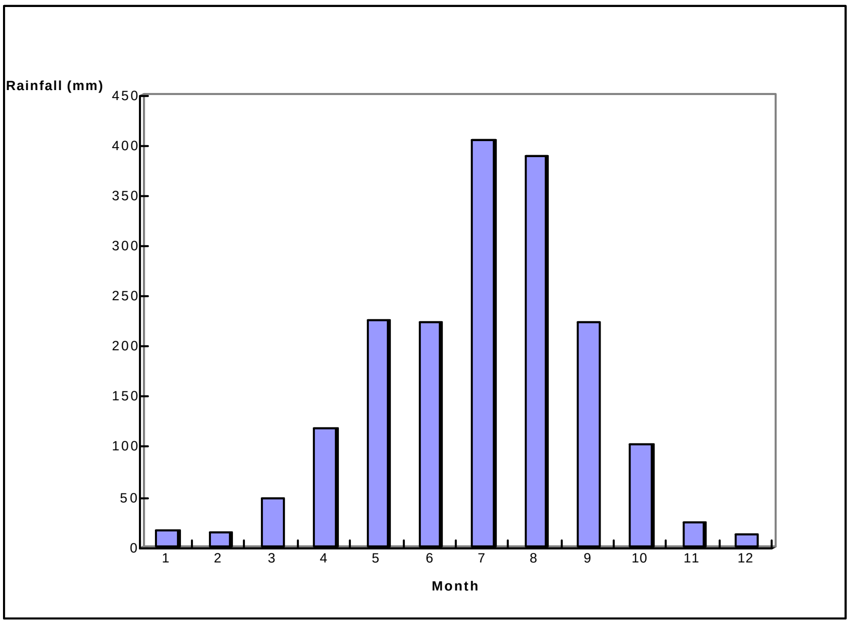

Figure 2. Average monthly rainfall in Dien Bien district (1991-2000)

drier season, the rainfall is low and it is not concentrated. Therefore if a crop that has a high moisture requirement is planted during this season, the likelihood of moisture from rainfall will be low. With four months of average rainfall exceeding 200 mm, the farmers can plant rain-fed rice in their terraced fields as well as maize and cassava on the upland slopes.

Effect of land types and multiple choice of crop

The types of soil and land as well as water supply have strong effects on crop distribution and crop productivity. It is obvious that the farmers know that it is better to plant cassava on upland slopes and paddy rice in the terrace fields, because cassava is sensitive to flooding and paddy rice needs more moisture than other crops. Studies of maize cultivation in terraced fields indicate that maize grows better and that it gives higher yields than on upland slopes due to better moisture, more applied fertilizer, and better weed control. Problems occur if the cropping is carried out continuously year-by-year at the current status of low fertilizer application, especially for the traditional households. Then the soil fertility becomes quickly depleted. Therefore this pattern should only be promoted if the supply of fertilizer, manure, and green manure, more suitable crop varieties, and better water supply can be provided.

On the upland slopes, two crops per year could be grown to increase land productivity and farmers' income, i.e. maize and soybean. The maize could be planted in spring (February, March) and harvested in summer (July), directly followed by soybean, which would be planted after maize (August) and harvested in autumn (November). A benefit of this system would be an increase in crop residues returned to the soil and the N left in the soil by the N-fixing soybean plants. For both upland slopes and terraced fields, these patterns will only be successful if the local government becomes involved and develops trials and demonstrations in the farmers' fields.

Cropping pattern on upland slopes

Only two crops are cultivated on the upland slopes, i.e. maize and cassava in both traditional and modern farming (Table 10). These crops are grown as single crops, covering the land for only part of the year, followed by fallow.

Table 10. Average crop yields (kg/ha)

	Traditional		Modern	
	Maize	Cassava	Maize	Cassava
Study area (*)	1 228	3 334	2 272	4 322
Province (**)			3 900	4 500

(*) Source: Field survey

(**): Provincial Statistic Department

All traditional households planted maize and 84.37 percent of the modern households planted maize. The yield level for modern households was higher than traditional households. For cassava the number of households that planted this crop was similar. Also the yield was higher in modern than in traditional households. However, they are lower than the average yields reported from the province. For fertilizer application, no traditional household used fertilizer for cassava. Modern households used only a little N. For maize, the farmers only used N and P, more in modern than in traditional management. On the upland slopes, crop yields were low and obtained by exploiting the actual inherent soil fertility.

Cropping pattern in the terraced fields

There are two planted crops in the cropping year, i.e. from December to October, in the terraced fields. Seventy-eight of the traditional households planted spring rice, while 97 percent of the modern households planted spring rice. No household practices crop rotation. The growing period is from December to June for spring rice and from June to October for summer rice. Both traditional and modern households practised monoculture of paddy rice.

Table 11. Average yields of spring and summer rice (kg/ha)

	Traditional		Modern	
	Spring rice	**Summer rice**	**Spring rice**	**Summer rice**
Study area (*)	3 894	3 518	4 955	4 361
Province (**)			3 700	3 500

(*) Source: Field survey

(**) Provincial Statistic Department

Table 11 shows that yields are higher for spring rice than for summer rice. The yields are also higher for modern than for traditional management in both systems. In modern households, higher levels of inputs are applied than in traditional households.

The data show that in the study area the yields are higher than at the provincial level. Productivity of the terraced fields could be increased if a rotation was implemented with rice and legumes. Then soil fertility would also increase. It is clear that in the study area rice is important to local farmers for food security. There is also potential to increase yields with new rice varieties and to improve soil-fertility management. From 1991-2000 the ratio of rice production to total food production within the district showed a general increase from 51 to 67 percent.

Relationship between soil fertility and crop yield

The relationship between soil fertility and crop yields is established with linear multiple regression models. The general equation is:

$$Y = Q + A^{*}input1 + B^{*}\ input2 + C^{*}\ input3 + D^{*}\ input4 + E^{*}\ input5 +$$
$$+ F^{*}\ input6 + G^{*}\ input7 + H^{*}\ input8$$

where:
Y = Crop yield, kg/ha
A, B, C, D, E, F, G, H = constants from input1 – input8
Input1 = Urea, kg/ha
Input2 = Superphosphate, kg/ha
Input3 = Potassium, kg/ha
Input4 = Animal manure, kg/ha
Input5 = Seed, kg/ha
Input6 = Pesticide, kg/ha
Input7 = Herbicide, kg/ha
Input8 = Labour, workday/ha

However, in the study area there are differences between households for each crop. Therefore the establishment of the relationship between crop yield and input factors through linear multiple regression is difficult.

Maize

In practice, the modern households used higher rates of inputs than traditional households. Moreover, new varieties of maize are also grown in some modern households.

The equation for describing the influence of inputs on maize yield in the modern households is:

$$Y = 9651.97 + 16.1*input1 - 8.54* input2 + 186.09* input5 + 2.02* input8$$

where: Input 1 = Urea, Input 2 = Phosphorus, Input 5 = Seed, Input 8 = Labour

Cassava

For the traditional households the model is highly significant and very significant for the modern households. This difference may be explained by the fact that modern households used fertilizer (urea) and higher investment in labour than the traditional households.

The equation for the cassava model in the modern household is:

$$Y = 2528.79 - 1.50*input\ 1 + 1.44*input\ 5 + 2.44*\ input\ 8$$

where: Input 1 = Urea, Input 5 = Seeds, Input 8 = Labour

Spring rice

For spring rice, both traditional and modern households show non-significant or low significant regression of yield with P, K, and seed input. Labour is highly significant for the modern households but not significant for the traditional households. Because most of the traditional households use local varieties, there is overall low yield potential. The local farmers cannot invest enough capital in rice cultivation, such as N, new varieties, and K. Seeds were not significant for yield production in the traditional household. Without input investment and new rice varieties, spring rice yield will not increase — indeed sometimes it is decreasing for both traditional and modern households. However, in modern households local farmers have been using hybrid rice varieties such as Khang Dan, Tap Giao, but only in some households.

An increase in pesticide could lead to decreasing yield, especially in the modern households. This may be explained by the fact that local varieties have a high resistance to pests and diseases. Therefore pesticides may lead to crop poisoning and also to decreasing crop capacity for nutrient uptake from the soil. Labour investment is important for increasing the spring-rice yield; labour input is not significant for the traditional households but highly significant for the modern households. Yields with modern farming practices are higher than yields with traditional farming; changing to improved spring-rice varieties and improving soil fertility will increase the yields of traditional households to the level of modern households.

Summer rice

The equation for the summer-rice model in the traditional household is:

$$Y_{\text{Summer rice 1}} = 2515.5 + 4.98*\text{input 2} - 0.66*\text{ input 5} – 272.8*\text{input6} + 1.5*\text{input 8}$$

where:

$Y_{\text{Summer rice}}$ = summer rice yield in the traditional households
2515.5 = Model constant
Input 2 = Superphosphate
Input 5 = Seed
Input 6 = Pesticide
Input 8 = Labour

The equation for the summer-rice model in the modern household is:

$$Y_{\text{Summer rice 2}} = 6309.8 – 4.9 * \text{input 1} + 1.9 * \text{input 2} – 690 * \text{input 4} – 5.7 * \text{input 5} – 203.2 * \text{input 6} + 0.72 * \text{input 7} + 9.4 * \text{input 8}$$

where:

$Y_{\text{Summer rice 2}}$ = Summer rice yield in the modern households
6309.8 = Model constant
Input 1 = Urea, kgN/ha
Input 2 = Superphosphate, kgP/ha
Input 4 = Manure, kg/ha
Input 5 = Seed, kg/ha
Input 6 = Pesticide, kg/ha (Padans, Validacine)
Input 7 = Herbicide, kg/ha
Input 8 = Labour, workday/ha

Nitrogen is not significant for the summer rice yield in the traditional households, but highly significant in the modern households. However, the equation shows that increased N applications have a negative effect on yields in the modern households. The quantity of N applied for traditional summer rice has to increase significantly in order to have an effect on the yield. There are some modern households that use new varieties, but in general the modern household uses N at a sufficiently high level to increase the yields of the current varieties. Superphosphate has a positive effect on summer-rice yield for both traditional and modern households.

Physical and socio-economic factors affecting the sustainability of agricultural land use

Water resources for crop growth and management

Dien Bien District has a cool, dry, and sunny climate. Most of the terraced fields are planted with rice. They are either rainfed or irrigated with water from the mountains. Maize and cassava on the upland slopes are only rainfed. Over the past years the rainfall in the region has been high (Figure 3). Therefore, it is not difficult to grow paddy rice as well as maize and cassava.

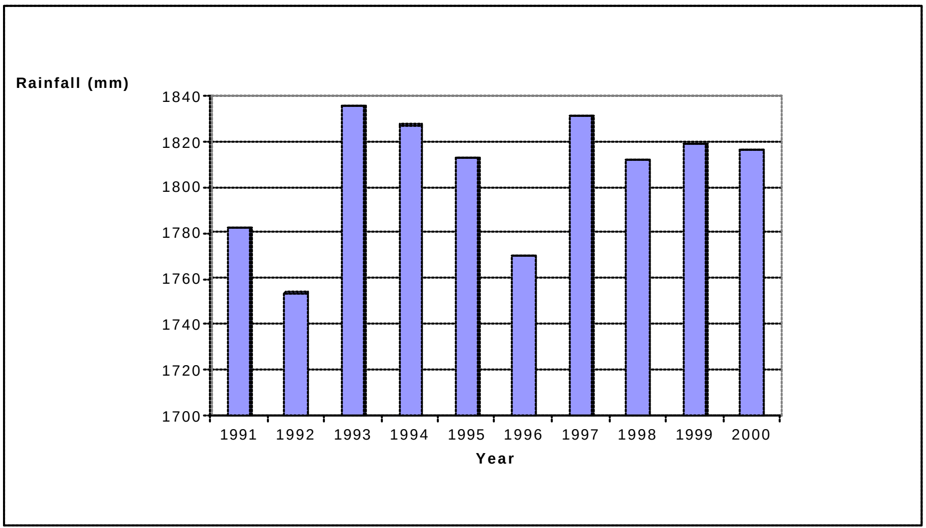

Figure 3. Average annual rainfall in Dien Bien District (1991-2000)

Livestock husbandry

In Dien Bien District, livestock production has a direct influence on soil fertility and crop yields. Livestock production in general can contribute to an increase or a decrease in food security. Sometimes the grazing animals damage the crops. Table 12 gives an overview of the animal numbers kept by the farmers. The mean number of cattle per household was 1.81 for the traditional farmers and 1.95 for modern farmers. In practice one animal can plough 300–500 m^2 of land per day.

Table 12. Animal ownership of households

Items	Traditional households		Modern households	
	Cattle	Pigs	Cattle	Pigs
Number of HH	16 (50%)	18 (56%)	22 (69)	29 (91)
Average no of animals per household	1.81	2.0	1.95	2.20

Source: Field survey (2001); HH: households

Half of the traditional households did not have any livestock while the majority of the modern households did have livestock. In practice, they could borrow cattle for ploughing from cousins or other relatives. If a second crop per year was planted, the cattle that foraged freely and unattended in the fields would also damage this crop by eating and trampling. For example, during the summer-autumn period in 1998, soybeans were planted in a small field to test its suitability for the soil and climate. To protect the crop, the farmers fenced the soybean plots. But the animals still broke into the parcels and destroyed the crop although their owner had been asked to keep the cattle away during the cropping season (Tuyet, 2000). Therefore, when a second crop is promoted the problem of freely grazing cattle has to be addressed effectively.

Family labour

In the region labour for crop production is all family labour. From the interview of 62 households it was clear that no household hired labour for crop cultivation. The reason was that the cultivated land area per person is low, about 0.11 ha/person in the traditional households and 0.19 ha/person in the modern households. The survey also showed that there were no rich households, which had accumulated enough capital to expand crop production with hired labour.

Labour input is generally highly significant for all crop yields, for both traditional and modern farming practices and in both terraced fields and sloping areas. The amount of labour invested for the crops was higher in the modern than in the traditional households. However, with the available labour force, there was no labour constraint during the cropping season. After the main crop, the farmers had plenty of time to do other work, such as preparing for festivals, visiting people, repairing the house, and preparing for their family members' wedding parties. In practice, all of these activities took place after the crop harvest in November and lasted until April of the upcoming cropping year. This was typical for both the traditional and modern households.

Farmers' equipment, transportation of fertilizers

High levels of crop production require improved equipment and also transportation facilities as well as improved means for food processing. The farm equipment in the study region was mostly old traditional equipment, such as hoes, ploughs, knives, harrows, reaping hooks, and back-baskets. No modern electrical equipment such as threshing or winnowing machines, or even irrigation pumps was available. For transporting material, normally farmers used back-baskets. For food processing, most farmers had traditional pedal mortars; some had water mortars that used waterpower for husking rice or other cereals.

Household income

The survey showed that most of the local household's incomes were obtained from crop cultivation. This applies to both traditional and modern households. However, the gross margin for each crop cultivation is different between traditional and modern households. For each crop, the total gross margin is higher for modern than traditional farming. The last total gross margin in traditional farming was VND9 399 200 and for modern farming this was VND14 475 200, a difference of about VND5 million/ha. This is shown in Table 13.

Table 13. Average household income from crop cultivation

Type of management	Income from crops (VND1 1 000)	Average number of persons/HH	Income/person/year (VND1 000)
Traditional	1 391.20	5.56	250.21
Modern	4 334.73	5.96	727.30

Source: Field survey

VND14 000 = US$1.00 (July, 2001)

The local farmers did not have any other income. Therefore the income per capita per year was very low, especially in the traditional households (VND250 200). The minimum government-approved wage for the mountainous regions is VND80 000 per person per month. This is equivalent to an annual per capita income of VND960 000. The study area therefore suffers from extreme poverty. In Vietnam about 2 135 extremely poor communities have been identified.

Effects of government supporting policies

In general, economic and social factors determine the success of agricultural production in a region. There are many factors and combined they can have a counterproductive influence on production and agricultural land use. The best way would be to subsidize the cost of production inputs for crop production to encourage farmers to improve the productivity through more intensive farming. In the past, attempts were made in the district to subsidize the transportation cost of chemical fertilizers for farmers in remote areas. To stimulate the use of high yielding varieties, the local government released several tons of a new hybrid variety of rice (Khang man) free of charge. This was expensive, because the seed cost US$2.00/kg (price in 1999). This new variety of rice was first used in Dien Bien in 1996. It was estimated to have twice the yield or more of local varieties. There were similar conditions for hybrid maize, but compared to hybrid rice, its cultivation was less effective due to the difficulty of proper fertilization under sloping land conditions.

Effects of government extension services

The involvement of the government to improve crop productivity was reflected through improved extension services to the farmers. The extension services helped the farmers to shift from unproductive extensive crop cultivation to a higher level of intensive farming. First, new varieties were tested and demonstrated in the farmers' fields. The supply of seeds gave farmers a chance to follow the new recommended techniques. There were some primary successes with new varieties of food and fruit crops, and with the introduction of a second crop of rice per year. All this was due to the considerable attempts by the local government to reduce the farmers' constraints. However, the lack of useful and applicable scientific information, crop response estimates, and feasible solutions that are suited to the local infrastructure have been a major limitation to the adoption of new technologies.

Local market

In the rainy season, landslides often block roads. This hampers the transportation of fertilizer from the lowland areas and the circulation of agricultural products within the location. Almost all agricultural products are for local consumption. This discourages production.

The need for the enhancement of sustainable agricultural land use

In the past, growth has often been achieved by degrading the natural resource base. Increasingly, it is being realized that land is a major factor for global life-support systems and that it also has an intrinsic value beyond agricultural production. There is increasing evidence that this is not a utopian dream, but indicators of land quality and sustainable land management are needed as guidelines (Dumanski, 1998).

Soil-fertility degradation

Decreased soil fertility is a major cause of unsustainable crop production. The soil-fertility status was compared with the original soil fertility under natural forest.

Table 14. Selected soil-fertility properties in the study area compared to forest soils

Soil-fertility properties	Under natural forest *	Traditional management **		Modern management **	
		Sloping land	Terraced land	Sloping land	Terraced land
Available N (%)	3.05	1.79	2.5	2.37	2.00
Available P (%)	6.1	2.65	3.7	3.19	4.76
OM (%)	4.2	1.72	1.92	2.46	1.55
CEC (cmol kg/ha soil)	8.7	3.73	3.34	3.53	4.29
Base saturation (%)	56.0	17.8	38.22	30.29	39.91

Source: * Phien (1991)
** Field survey (2001)

Table 14 shows the differences in some major soil-fertility parameters between natural forest soil and agricultural soils:

Available N

On the traditional upland slopes, N was reduced by nearly 50 percent compared to the forest soil. On upland slopes with modern management the reduction was lower. On the terraced fields, for both traditional and modern management, the losses were about 25-30 percent compared to the forest soils.

OM

OM was also reduced by about 50 percent on traditional and modern upland slopes compared to the forest soil.

CEC

The CEC was significantly reduced by about 50 percent in both traditional and modern management systems (steep land and terraced land).

Base saturation

Compared with the forest soil, there was a reduction of 40-60 percent compared with the forest soils.

As the original forest was cleared for cropping, the land use alternated between cultivation and fallow. The losses in soil fertility were mainly caused by crop uptake and removal and losses due to erosion, runoff, and mineralization.

Soil erosion

The annual rainfall in the region is high, about 1 750-1 850 mm, with a rainy season of 4-5 months with monthly rainfall of 200-400 mm.

Crop cover is poor affording little protection to the soil and soil OM content is low due to poor crop and soil management.

All these factors generate serious soil erosion. Nutrients are lost via crop uptake and soil erosion has created a large area of degraded land; uncultivated bare land comprises about 30 percent of the total land area.

Decline of forest land

Table 15. Forest land cleared in Lai Chau Province and in the northern mountainous region of Vietnam (1991–1998)

Year	1991	1992	1993	1994	1995	1996	1997	1998
Lai Chau Province (ha)	109	758	-	256	1 784	1 200	201	782
Northern mountainous region (ha)	3 286	5 947	2 963	3 137	2 094	4 726	8 837	37 883
% of forest land cleared in Lai Chau Province compared with the whole of the northern mountainous region	3.31	12.74	-	8.16	85.19	12.34	2.27	2.06

Source: Statistical Officer (1999)

In 1995, 2 094 ha of forest land were cleared in the northern mountainous region of which 1 784 ha were cleared in Lai Chau Province. This was 85.19 percent of the total forest land cleared in the northern mountainous region (Table 15).

Requirements for productive resources and environmental protection

One purpose of sustainable agriculture is to secure food security for local farmers. This study is mainly concerned with soil fertility and water conservation as well as forest protection.

Soil-fertility conservation

To address the current problem of soil-fertility decline, new cropping systems should be promoted to overcome some of the constraining factors of crop cultivation. To cope with soil erosion, increasing the crop canopy, planting cover crops, and alley cropping systems are useful. Rainfed crops should be planted at a reasonable density. Information from a previous study showed that, for instance, the local maize was planted at a density of about 25 000 plants/ha. Intercropping with a legume crop can be beneficial for soil fertility. This system may be promoted on upland slopes; especially advocated are leguminous trees planted in hedgerows and alley crops along the contour lines. These hedgerows intercept and shorten the length of slopes. Reducing ploughing and harrowing on the slopes during the rainy season contributes to soil conservation. Mulching the soil with crop residues, grass, and rice straw contributes to retaining soil moisture and increasing soil fertility.

Forest conservation and agroforestry

The orientation of increasing the cultivated area through an increase in cropping intensity may help to reduce deforestation because it reduces the need for more land. If the land is more productive, the need for more land will be reduced, and the forest will be protected. Now, as they have land and forest use certificates, the local farmers have reduced massive exploitation of forest for both cropland

and fuelwood. Aside from cropping benefits, agroforestry will also better protect the land and the environment.

Conclusion

1. Very low soil fertility requires local farmers to develop more effective farming systems, especially in traditional households. The major constraints in soil fertility are the low contents of N, available P, and K. Other soil properties (i.e. OM, CEC, base saturation) are also at a low level. These conditions lead to low crop yields.
2. Fertilizer needs to be applied at higher levels, especially in the traditional households. An increase in fertilizer input can significantly increase crop yields. Improving animal management and introducing leguminous crops as green manure and for N fixation will also improve soil fertility and reduce the susceptibility of the soils to soil erosion.
3. The current land use for crop production in the study area needs to be changed. Fertilizer use is very low and unbalanced for the crops grown. This not only leads to low soil fertility but also to an increase in land degradation. This is especially serious in the traditional households. On the upland slopes, single cropping patterns with short periods of land cover also lead to high soil-fertility losses.
4. The cropping systems in the traditional households have a very low productivity level. The district has large agricultural areas but only a small portion is being used for crop cultivation. In this area, cropping systems are characterized by low input and low output levels, especially in the traditional households. These households are also constrained by low income and lack of capital for production and investment. Poor infrastructure has also prevented the local farmers from changing to more intensive and effective crop production. Therefore, the annual crops produced are insufficient for the local people's consumption needs; poverty remains a problem.
5. For both traditional and modern households, there is a labour surplus that should be utilized. Large areas of arable land are unused. These areas can be reclaimed to expand crop production. In the traditional households, the great resource of animal manure has not been sufficiently exploited. Thus, manure and fertilizers are still serious constraints for crop growers. The tropical and subtropical climate of the region allows the farmers to diversify crops. The proper exploitation of climate has enormous potential for crop productivity improvement.
6. Productive and sustainable agricultural land use requires high levels of investment and management. The immediate aims are to increase soil fertility and crop yield. This can be achieved with a more intensive farming system, and appropriate assistance to the farmers by the local and central government.
7. Soil conservation needs to be addressed in the context of soil-fertility conservation and maintenance.

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