On-Site Costs and Benefits of Soil Conservation in the Mountainous Regions of Northern Vietnam

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October, 2001

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EEPSEA is supported by the International Development Research Centre (IDRC); the Danish Ministry of Foreign Affairs (DANIDA); the Swedish International Development Cooperation Agency (Sida); the Ministry of Foreign Affairs, the Netherlands; the Canadian International Development Agency (CIDA); the MacArthur Foundation; and the Norwegian Agency for Development Cooperation (NORAD).

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ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude to the following organisations and persons for their invaluable support, help and encouragement in the study:

The Economy and Environment Program for Southeast Asia (EEPSEA) for giving him the opportunity to improve his knowledge on environmental economics and for granting him the funds to conduct this study.

Dr. Herminia Francisco, Deputy Director of EEPSEA, for her invaluable advice and guidance throughout the study period.

Consultants of EEPSEA for their suggestions and comments for the improvement of the study.

Dr. David Glover, Director and Ms Catherine Ndiaye, Program Assistant of EEPSEA for their encouragement and help.

Dr. Vu Dinh Hoa, Mr. Nguyen The Phuong, and the study team, for their contribution during the conducted period of the study.

Hanoi Agricultural University for giving him the time and encouragement to carry out the study.

The National Institute of Soil and Fertilisers and Thainguyen University for providing the required data for the study.

Staff of the Faculty of Economics and Rural Development, Hanoi Agricultural University for their assistance in data collection.

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ON-SITE COSTS AND BENEFITS OF SOIL CONSERVATION IN THE MOUNTAINOUS REGIONS OF NORTHERN VIETNAM

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ABSTRACT

Soil erosion is a serious problem in the mountainous regions of northern Vietnam. A study was carried out to measure the on-site costs of soil erosion and the benefits of soil conservation practices in this area.

The data for the study analysis included time series data collected from experiments on soil erosion during the period 1992 to 1998 and cross-section data from surveys on farm households. The function for the relationship between productivity loss and soil loss and the function for productivity gain from soil conservation practices and financial analysis were used to estimate the on-site costs of soil erosion and the benefits of soil conservation practices. The function for expenditure on soil conservation was also applied to determine factors affecting a farmer's adoption of soil conservation practices.

The findings of the study highlighted a significant difference in crop yields between farming practices with and without soil conservation measures. Soil conservation technology of *Tephrosia candida* hedgerow yields a high net present value (NPV) and is a suitable technique for farmers to use.

The results of the production function analysis showed that soil conservation practices facilitated intensive and improved crop productivity. For maize production, a 1% increase in material and labour costs for soil conservation practices would increase the yield of maize by 0.04% and 0.0512% respectively. For cassava production, the yield would increase by 0.0035% and 0.0064% respectively.

Expenditure on soil conservation is affected by farm characteristics, farm incomes, labour resources and the education level of the head of the household as well as by rural credit availability. To promote areas of soil conservation practices in the region, the top priority policies should be on land, training on crop production and soil conservation technology, technical support for farmers, and the development of diverse economic activities in the region.

1.0 INTRODUCTION

Land is an essential resource for purposes such as agriculture, forestry, human habitation, industrial use and mining. With 80% of its population depending on agriculture for their livelihood, Vietnam's cultivated land per capita is, however, limited to only 0.1 hectare. Therefore, the prevention of land degradation is of great importance.

The mountainous regions of northern Vietnam are spread over 16 provinces covering a land area of 102,961 km^2 with a population of 12.39 million people. This watershed, characterised by its sloping lands, is made up of mountains, hills and small valleys. Any land use changes in these regions affect not only the people, natural species and biological environments on-site, but also influence a large area of the Red River Delta. Such changes therefore have an impact on the economic development and the environment of northern Vietnam.

Soil erosion resulting from bad farming practices on sloping lands, without attention to soil conservation, has been known to be a serious problem in the northern mountainous areas.

Soil erosion causes loss of productivity at all levels in northern Vietnam. At farm level alone, decline in crop yields due to soil erosion results in low income. This condition particularly affects the poor and leads to increased unchecked migration to urban areas and other regions. Off-site consequences of soil erosion place pressure on the environment in terms of sedimentation and silt that can clog up irrigation channels and lower the water storage capacity of dams. This decreases water supply and hydropower productivity and increases government expenditure on infrastructure and conservation measures. In Vietnam, soil conservation has recently been given attention, but no evaluation has been made concerning the economic cost of soil erosion. The economic evaluation of soil erosion is, therefore, urgently needed.

This study aims to measure and concentrate on the on-site costs of soil erosion and productivity gains from soil conservation at farm level in the mountainous areas of northern Vietnam. Off-site costs are therefore not included. The study deals also with factors that influence a farmer's adoption of soil conservation practices.

Results of this study will help farmers and the government become more aware of the on-site costs of soil erosion and the benefits of soil conservation. The importance of this study lies in identifying ways to enhance soil conservation practices, and assist policy-makers in selecting optimal soil conservation strategies for mountainous areas.

2.0 OBJECTIVES OF STUDY

- To estimate the on-site costs of soil erosion using a production function analysis.
- To measure the impact of soil conservation practices on crop productivity.
- To undertake a cost-benefit analysis of soil conservation measures for maize and cassava farming systems.
- To assess the extent of the adoption of soil conservation practices by farmers and to analyse determinants of soil conservation expenditure.
- To offer policy recommendations on soil conservation practices in the mountainous regions of northern Vietnam.

3.0 REVIEW OF RELATED LITERATURE

3.1 Costs of Soil Erosion

Soil erosion is a physical process and refers to the wearing-away of the land surface by water and/or wind as well as to the reduction in soil productivity due to physical loss of topsoil, removal of plant nutrients, and loss of water. Soil erosion is a flow concept and is measured as a rate: x tonnes/ha/year.

Soil erosion includes a range of phenomena such as sheet erosion (the removal of thin layers of topsoil from an eroded site), gully erosion (the formation of incised gullies in a hillside) and mass wasting (the structural failure of part of a hillside as in the case of a landslide). Although all of these types of erosion do occur naturally, man's use of watershed lands, particularly steep areas, can greatly increase the extent and rate of erosion. Activities such as agriculture, logging, and construction can lead to increased soil erosion. Soil erosion is therefore a complex phenomenon influenced by natural and socio-economic factors.

According to Seckler, (1987) the soil loss function can be written as:

$$E = f(C, S, T, L)$$

where

E is the average annual erosion

C is the climatic factor (rainfall, wind, et cetera)

S is the soil factor (soil erodibility of a specific soil type)

T is the topography factor (slope and length of the field)

L is the land utilisation factor (cropping management and erosion control practices).

Soil erosion is particularly problematic in tropical countries. It threatens developing tropical countries where agriculture is primary to development and the majority of the rural population depend on it for their livelihood (Enters, 1998). Soil erosion affects both upstream and downstream areas. Upstream, soil erosion leads to loss of productivity and loss of water storage capacity on eroded sites. Downstream sedimentation results in damage to downstream fields, river channels, and capital infrastructure such as dams, water system and irrigation channels, thereby imposing costs to downstream water users. In Vietnam, due to serious soil erosion, almost all the rivers are highly charged with silt load. The Red River transports 0.6 billion m^3 of silt and the Mekong river 1.5 billion m^3 of sediment per year (Thai Phien and Nguyen Tu Xiem, 1995).

From the farmer’s perspective, the on-site costs of soil erosion include cost to the farmer's investment in terms of fertilisers, pesticides, equipment, labour, and loss of crop output.

Alternatively, the on-site cost of soil erosion can be described as the loss in current income to the farmer resulting from soil erosion.

To estimate the economic significance of soil erosion, it is necessary to develop models of the physical dimensions of erosion, to link these to the changes in crop production and farming systems, and finally, to evaluate these changes. Research on the relationship between soil erosion and crop productivity has been recently conducted in developing countries. In El Salvador, Wiggins and Palma (1980) estimated a 2% yield decline for each centimetre of topsoil lost. In Java, Indonesia, the annual productivity loss ranged from 0% to 12% (Magrath and Arens, 1989).

Soil erosion and the depletion of soil resources are serious problems for countries whose economies depend heavily on the agricultural sector. However, farmers are unlikely to invest in soil conservation unless they can see the benefits of soil erosion control. The benefit that a farmer receives from soil conservation would derive from soil being a potential income yield asset. The ‘stock’ of soil available to a farmer is essentially an economic asset that can be exploited through cultivation to yield a stream of present and future income (Barbier, 1995). The benefits of soil conservation come from the gain in current and future production. The optimal level of soil conservation is the level at which the present value of the additional income derived from soil conservation equals the additional cost of such soil conservation.

3.2 Approach to Measuring the On-Site Costs of Soil Erosion

Three methods have been commonly used to estimate the on-site costs of soil erosion and benefit of soil conservation:

1. Replacement Cost Approach
2. Cost-Benefit Analysis (CBA)
3. Productivity Change Approach.

3.2.1 The Replacement Cost Approach

The replacement cost approach calculates the cost that would be incurred in order to replace a damaged asset (Grohs, 1994). There are often nutrient and herbicide losses associated with soil erosion. Therefore, the on-site cost is sometimes measured in terms of the loss in marginal productivity of crop output from incremental changes in inputs, multiplied by the unit price of the crop and less the costs of foregone inputs (Barbier, 1995).

Many researchers, like Cruz, Francisco and Conway (1988) in Magat, Philippines, have used this method to measure the on-site costs of soil erosion. They concluded that the estimated on-site cost of soil erosion was around Peso 1,068 per hectare (USD 50.1 per hectare) at financial prices and Peso 2,716 per hectare (USD 127 per hectare) at shadow prices. Norse and Arens (1989) also used the replacement cost method to measure the on-site cost of soil erosion in Zimbabwe. Although the replacement cost approach is appealing, the link between the loss of nutrients and loss of production has not been established (Norse and Saigal, 1992).

3.2.2 Cost-Benefit Analysis (CBA)

The cost-benefit analysis method has been used in more recent studies (Enters, 1998). This method analyses the cost and benefit of soil erosion and its control. The CBA framework compares cost and benefit figures over the life-span of the project and then computes the present value of the net benefit stream at the prevailing discount rate (Francisco, 1998). In general, the following criteria are used in evaluating a project on soil conservation:

Benefit-Cost Ratio (BCR)

BCR is the ratio of benefits to costs of a project. A soil conservation project will be deemed acceptable if the BCR is greater than one.

Net Present Value (NPV)

The NPV measures the present value of the stream of net benefits over the life span of the project. For a soil conservation project to be economically viable, the NPV must be positive.

The Internal Rate of Return (IRR)

The IRR gives the rate of return of the project at the point where the NPV equals zero (NPV = 0). If the IRR is greater than the opportunity cost of capital, then the project will be acceptable.

This approach is of interest, but the collection of economic data for it can be time-consuming and arduous. Choosing the right discount rate is also very important.

Using the CBA method, Curent and Scherr (1995) analysed the financial and economic benefit of 56 agro-forestry systems in Central America and the Caribbean. They found that 75% of the agro-forestry systems analysed had positive NPV at a 20% real discount rate.

Francisco (1998) used the CBA framework to analyse the profitability of soil conservation technology in Malaysia, Thailand and the Philippines. The soil conservation treatment in the Philippines involving banana and sapodilla as hedgerows with maize and peanut receiving high level of fertilisers, proved to be most profitable with a BCR of 1.93. The annual income from this system was estimated at Peso 53,424.62 per hectare using a 10% rate of discount or Peso 41,506.17 per hectare at a 12% rate of discount. In Thailand, a comparison of the NPV realisable from the 'with' and 'without' fertiliser treatment systems revealed that in general, fertiliser played a key role in enhancing profitability of the farm enterprise. The analysis of return to labour from all treatments in Chiang Mai revealed that annual returns to labour were highest in the agro-forestry system in both the 'with' (Baht 55,395.00 per hectare) and 'without' (Baht 22,328.00 per hectare) fertiliser treatments.

Foltz et al. (1995) also estimated the economic returns of 72 alternative land use systems under agriculture in the Eastern Corn Belt. It was found in this study that groups of farmers who appeared to have different ranking of preferences could find alternatives that simultaneously satisfied their goals.

3.2.3 Productivity Change Approach

In recent years, the productivity change approach has been used by the majority of analysts (Enters, 1998). Following this approach, the cost of erosion damage equals the value of lost crop production valued at market price (Grohs, 1994). Alternatively, it is the difference in crop yields with and without erosion, multiplied by the unit price of crop, less the costs of production (Barbier, 1995).

Francisco (1998) used an exponential regression analysis to measure the relationship between crop yield and cumulative soil loss in the Philippines, Thailand and Malaysia. Results from Thailand showed that for the maize yield function, the only significant relationship was obtained for treatment with contour grass strips, but only at a 15% level of confidence. All coefficients had negative signs, depicting the inverse relationship between the yield of maize and cumulative soil loss. Findings of the Philippines' studies also showed that maize yield declined with rising cumulative soil loss under the farmer's practice of alley-cropping with low input. For the production function of peanut, the coefficient relating cumulative soil loss and yield was negative and significant.

Magrath and Arens (1989) applied this method to analyse the on-site costs of soil erosion in Java, Indonesia. The study showed that an annual 1% productivity decline was estimated at Rp 2,686 per hectare. Grohs (1994) and Nelson et al. (1996) also used this method. The productivity change approach is straightforward in application but may lead to over-estimation of the on-site costs of soil erosion if not carefully applied (Barbier, 1995).

3.3 Adoption of Soil Conservation Practices

Some recent studies on the economics of soil conservation are concerned with incentives for farmers to adopt soil conservation practices. It has been generally indicated that land tenure arrangements, soil characteristics, input and output prices, availability of off-farm employment, farm size, household size, discount rates and government policies collectively influence the acceptance or refusal of soil conservation measures by farmers.

Rerkasem (1996) identified three key elements that played a significant role in sustainable land use management. These are:

1. The presence of appropriate and cost-effective technological solutions
2. Social organisation and communal resource management
3. The ability of local people to participate in making crucial decisions related to land management.

Young (1987) maintained that the three main constraints to the application of a land use system were:

1. Type of land
2. Size of land
3. Supply problems.

In the case of tree planting on low-income farms in the Philippines, Shivelly (1997) used a stochastic dynamic model to examine tree planting decisions by low income farmers. The analysis demonstrated that changes in relative prices and relative risks were important determinants in a tree planting decision.

In the uplands of Java, Barbier (1990) indicated that the relationship between the erodibility and profitability of different farming systems on different soils and slopes was an important determinant in whether upland farmers adopted a soil conservation strategy. He also suggested that access to certain subsidised inputs such as fertilisers and seeds by upland farmers might prove to be a disincentive in controlling long-term damage of soil erosion, in that removal of such subsidies may lead to a reduction in or termination of investment in soil conservation measures.

Land use decisions are also affected by the security of land ownership. The possession of a legal title has been found to contribute to capital formation and land improvement (Feder and Onchan, 1997). Most analyses of agro-forestry adoption emphasise the significant importance of technical, social and cultural factors in shaping land use decisions of farmers (Kerkhoff, 1990).

The decision by farmers to adopt soil conservation practices also depends on conservation technology. Erosion prevention often involves the integration of vegetative and agronomic technology with suitable farming systems. By the early 1980s, hedgerow inter-cropping was widely advocated as a technology to better sustain permanent cereal cropping with minimal or no fertiliser input, and as a soil erosion control measure for sloping land (Garrity, 1993). According to Francisco (1998), the soil conservation technology introduced in countries like China, Malaysia, Laos and Thailand consists of variations of the alley-cropping system and agro-forestry. The use of legumes as cover crops is more common in smallholder plantations where the use of bare land with natural grass growth is popular.

For this study, it became necessary to understand why farmers do or do not invest in soil conservation, the extent of their investment, if any, and which technology farmers would apply to reduce soil erosion.

4.0 METHODOLOGY

4.1 Measurement of On-Site Costs Using Experimental Data

Soil is not homogenous. Compared to sub-soil, topsoil is more productive due to its richness in organic matter content. Soil loss and crop loss are related to each other. If soil erosion results in the exposure of the sub-soil, cultivation on this normally results in decreased productivity and increased costs. Soil erosion is a major environmental problem in the northern mountainous regions of Vietnam, especially on slope lands. To measure the on-site costs of soil erosion in these regions, one must estimate the value of crops lost due to soil erosion. The analytical methods used are the linear regression function and cost-benefit analysis (CBA). Data used for the analysis came from the experimental treatments set up by the National Institute of Soil and Fertilisers in three villages.

4.1.1 Experimental Data for Analysis

Soil erosion is a cumulative process and crop yield normally declines over time following soil loss. Therefore, the data for analysis is time series data. This data was collected from available sources and from studies conducted by the National Institute of Soil and Fertilisers of Vietnam and Thainguyen University.

The studies covered four treatments for soil erosion:

- Baseline treatment (T1): Growing maize and cassava without soil conservation practices.
- Alley-cropping treatment (T2): Tea as hedgerows in addition to growing maize and cassava.
- Hedgerow treatment (T3): Tephrosia candida on the boundaries in addition to growing maize and cassava.
- Hedgerow treatment (T4): Tea and grass as hedgerow in addition to growing maize and cassava.

Individual plots were 30*7m, making a total area of 210m^2. Each treatment was carried out in three replications.

The studies were undertaken over seven years from 1992 to 1998. Information obtained from each treatment covered:

- Soil loss: Average soil loss per year and cumulative soil loss in tonnes per hectare from 1992 to 1998 under different treatments.
- Yields in kilogram per hectare of maize and cassava crops under treatment during the seven-year period.
- Fertilisers and other inputs applied.
- Market prices of inputs and outputs during the study period.

4.1.2 Linear Regression Function

Linear regression is used to measure the relationship between productivity loss and soil loss. The function takes the following form:

$$Y = f(X_i) \qquad (1)$$

where

Y is the yield of crop (kg/ha)

X_i is the cumulative soil loss (tonnes/ha)

The function will be applied for two crops: maize and cassava.

Equation (1) was applied for each separate treatment in each village.

Linear Regression Function for the Baseline Treatment

There were 21 observations on the baseline treatment. The following function directly measures the on-site costs of soil erosion for practices without soil conservation:

$$Y_n = f(X_{in}) \tag{2}$$

where

Y_n is the yield of crops under the baseline treatment

X_n is the soil loss in the baseline treatment.

Linear Regression Function for Treatments with Soil Conservation Practices

Based on the observations of T_2, T_3 and T_4, the function for soil conservation practices is:

$$Y_w = f(X_{iw}) \tag{3}$$

where

Y_w is the yield of crops under treatments using soil conservation practices

X_{iw} is the cumulative soil loss in treatments using soil conservation practices.

From equations (2) and (3), the following function is derived:

$$Y_n - Y_w = f(X_{in} - X_{iw}) \tag{4}$$

Equation (4) reflects the difference in productivity loss between treatments with and without soil conservation measures. It enables the analysis of the benefits of soil conservation under different methods of soil erosion control.

4.1.3 Financial Analysis

Analysing the differences in net income between different methods of soil erosion control is very important in finding the best method for application in agricultural practices. Some studies have used the cost-benefit analysis (CBA) for assessing the optimal control of soil erosion to determine how cultivation and input use influence soil conservation.

In our study, a financial analysis is used for comparing the costs and benefits between different treatments of soil erosion control. The main steps in this analysis are:

- Identifying the costs and benefits of each treatment.
- Evaluating the costs and benefits of each treatment.
- Comparing the costs and benefits between soil erosion control treatments.

There are four common evaluation criteria used in comparing the costs and benefits of investment or alternative actions. These include the internal rate of return (IRR), the benefit-cost ratio (BCR), the net present value (NPV) and the net benefit-investment rate (Gittinger, 1982).

In our study, the NPVand BCR are used to compare the benefits of soil conservation between different treatments.

The basic technique for calculating the NPV is to discount costs and benefits occurring in different periods and express them all at a common value at any one point of time. The formula of the NPV is as follows:

$$\text{NPV} = \frac{\sum^{t}\left(B_t - C_t\right)}{\left(1+i\right)^t} \quad (5)$$

where

B_t is the gross value of crops under each treatment

C_t is the cost of crops under each treatment
(includes expenditure for soil erosion control)

i is the discount rate

t is the time horizon

Definition

Discount rate: The calculation of the NPV requires the determination of an appropriate discount rate. In this study, the discount rate was the borrowing rate given by the State Bank at 1.0% per month. This interest rate remained almost unchanged during the period 1994-1998.

The estimation equation for the BCR is given below:

$$\text{BCR} = \frac{\sum B_t /(1+r)^t}{\sum C_t /(1+r)^t} \quad (6)$$

A BCR of greater than 1 is preferred. A BCR value of less than 1 would mean that the soil conservation project is not profitable.

The results of a cost-benefit analysis would be a sound basis for discussions on soil conservation policies and in determining optimal methods of soil conservation practices to be adopted by farmers.

4.2 Soil Conservation Analysis Using Survey Data

4.2.1 Survey Data for Analysis

The production function analysis will use cross-section data from a survey on farming households.

Questionnaire Design

Primary data was collected through personal interviews with the farmers on the production of rice, maize, cassava and other crops. The interviews were conducted using a questionnaire seeking the following information:

1. General farming information: farm size, farm location, land utilisation, land property, soil type, and class of soil.

2. Farm household characteristics: age, sex, education and occupation of the head of the household, household size and other household characteristics.

3. Total asset value of machinery, tools and equipment, livestock and draft animals (buffaloes and cattle used in land preparation activities) owned by the farmer.

4. Variable inputs used in crop production:

    - Labour input i.e. headcount and man-days of family labour and hired labour; payment to hired labour both in cash and in kind.

    - Quantity of seeds, fertilisers, pesticides, other material inputs and cost in cash and in kind.

5. Output and income: Yield of crops and income of farmers. Income includes total income; on-farm income and non-farm and off-farm incomes.

6. Market and credit information: Farm gate price and market price of crop output, credit available for the farm, amount borrowed, and interest rates.

7. Land tax and land tenure.

8. Farmer's knowledge of and experience in soil conservation.

9. Soil conservation information: Soil conservation expenditure such as labour and fertilisers required for soil conservation, methods of soil conservation, motivation and behaviour of farmers with regard to soil conservation, and response of farmers to government-issued policies on land conservation.

4.2.2 Measurement of Productivity Gain

Farmers in uplands understand that soil erosion results in loss of crop productivity, but they are only likely to practise soil conservation when they can see economic advantages in doing so. Higher productivity and returns will mean that farmers can afford to invest in soil conservation. Therefore analysing productivity gain from soil conservation practices would be a useful means to convince farmers to invest in soil conservation.

In this study, the production function analysis was chosen to measure how the level of investment in soil conservation practices influences crop productivity.

A production function is defined as a quantitative relationship between input and output of production. Analysis of a production function can provide information on the production efficiency of inputs (Heady and Dillon, 1978).

In this study, the Cobb-Douglas production function was employed. This is an appropriate function when many input variables are included. Its advantages are as follows:

- It has been proven to be a highly appropriate statistical function to measure agricultural productivity.
- It is linear in its logarithmic form and thus is easy to compute.
- The estimated parameter represents the elasticity of outputs with respect to the inputs.
- In the case of this study, the Cobb-Douglas production function allows the effect of soil conservation practices on crop output to be isolated from other factors. The variable of expenditure on soil conservation can be used as the measure of the extent of the adoption of soil conservation practices.
- It enables the computation of the marginal products of crops from the coefficient of the variable expenditure on soil conservation practices.

The special Cobb-Douglas production function form is:

$$Y = A X_1^{\alpha 1} X_2^{\alpha 2} X_3^{\alpha 3} X_4^{\alpha 4} X_5^{\alpha 5} X_6^{\alpha 6} X_7^{\alpha 7} e^{\Sigma\gamma Di + ui} \qquad (7)$$

where

A is the intercept

Y is the value of crop output (in VND thousands)

X_1 is the labour used for crop cultivation (in man-days)

X_2 is the organic manure for crop cultivation (in tonnes)

X_3 is nitrogen for crop cultivation (in kg)

X_4 is phosphorus for crop cultivation (in kg)

X_5 is potassium for crop cultivation (in kg)

X_6 is the material expenditure for soil conservation (in VND thousands)

X_7 is the labour required for soil conservation practices (in man-days)

D_i represents the location ‘dummy’.

Definitions

Crop output: The yield of crops used as a measure of the product in the production function. The total value of products per hectare expressed in Vietnam Dong (VND thousands) is calculated by multiplying the local market price by the yield.

Labour used for crop cultivation: This is the labour required mainly for farm operations, namely land preparation, planting, hand-weeding, fertiliser and pesticide application, and so on, expressed in man-days per hectare. The labour man-day is computed on an eight-hour workday spent on a particular farm operation. It includes both hired and family labour.

Chemical fertiliser is used in three forms: urea, superphosphate and potassium. The quantity of each kind is computed based on the type and formula to get nutrient fertiliser.

Labour requirements for soil conservation includes family labour and hired labour for planting trees and grass on the boundaries, making terraced plots and maintaining terraced plots, tied ridging and trash lines.

Expenditure on soil conservation includes cash investments for fertilisers, including fertilisers used in grass strips, grass seeds, tree seedlings, and trees grown on the boundaries.

Location of village: $D_i = 1$ if the village is located in the southeast of the region. Otherwise, $D_i = 0$.

From the Cobb-Douglas production function, the value of marginal products with respect to expenditure on soil conservation was derived as follows:

$$VMP_{xi} = \frac{\partial Y}{\partial Xi} \quad \text{or} \quad VMP_{xi} = \alpha_i * AP_{xi} \qquad (8)$$

where

α_i is the coefficient of variables (labour and expenditure requirements for soil conservation practices)

AP_{xi} is the average value of products.

The estimated result indicates the effect of soil conservation expenditure on crop output and measures the extent of soil erosion control. The value of marginal products with respect to soil conservation expenditure measures productivity gains from soil conservation practices.

4.2.3 Analysis of Soil Conservation Adoption

The production function analysis also provides a measure of the benefit of the farmer's adoption of soil conservation practices. Understanding what factors influence a farmer's decisions on soil conservation and how economic incentives affect soil erosion control are helpful in forming environment-friendly agricultural policies. There are many factors that affect soil conservation adoption. This study concentrates on:

- Human factors
- Physical factors
- Socio-economic factors.

The main technique used to analyse the adoption behaviour of farmers was to review their opinions on soil conservation.

The analysis aimed to provide answers to the following questions:

- How do low-income farmers respond to the need to adopt soil conservation practices?

- How do off-farm incomes affect soil conservation practices?

- What are the characteristics of farmers adopting soil erosion control?
- How do physical factors affect soil erosion control by farmers?
- How do changes in the market price of inputs and outputs and the interest rate of credit affect farmers' decisions to invest in soil erosion control?
- How does credit, agricultural extension and training on land conservation techniques affect soil erosion control?

To analyse the impact of factors on soil conservation investment, the following function was estimated:

$$\mathrm{Ln}(Y) = \alpha_0 + \alpha_1 \mathrm{Ln}(X_1) + \alpha_2 \mathrm{Ln}(X_2) + \alpha_3 \mathrm{Ln}(X_3) + \alpha_4 \mathrm{Ln}(X_4) + \alpha_5 \mathrm{Ln}(X_5) + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \gamma_4 D_4 + u_i \quad (9)$$

where

Y is the farm's expenditure for soil conservation (in VND thousands)

X_1 is the farm size (in hectares)

X_2 is the labour headcount

X_3 is the family income (in VND thousands)

X_4 is credit (in VND thousands)

X_5 is the education level of the head of the household

D_1 is the slope of the land ($D_1 = 1$ if the slope of the land $\leq 20^{\circ}$. Otherwise $D_1 = 0$)

D_2 is the distance from the farmer's house to the field ($D_2 = 1$ if the field is located near to the farmer's house. Otherwise $D_2 = 0$)

D_3 is the ethnic minority group ($D_3 = 1$ if farmer is from the Kinh group. Otherwise $D_3 = 0$)

D_4 is the time of land use in years.

The result of the above estimated function reflects the relationship between factors such as farm size, family size, income of farm, and expenditure on soil conservation.

Based on the results of the above analysis, farmers and policymakers can select the best strategy for improving land conservation in the region.

5.0 DESCRIPTION OF THE STUDY AREA

This study was conducted in the mountainous regions of northern Vietnam. The major characteristics of the study sites are as follows:

5.1 General Description of the Mountainous Regions of Northern Vietnam

Climatic Conditions

Tropical climate with high humidity. Average temperature: 21°C to 27°C. Average rainfall: 1800 mm per year but unevenly distributed. In general, rainfall is heaviest from May to September, during which time the soil is prone to serious erosion.

Soil and Land

This is an upland region with red and yellow soil (ferralic acrisol) having a light structure. The soil is characterised by a low pH of about 4.0 - 5.5, poor fertility, and low organic matter.

Socio-Economic Conditions

The majority of the inhabitants come from ethnic minority groups such as the Tay, the Nung, and the Thai. The main socio-economic problems are poverty (30% of households are poor), high birth rate (2.5% per year), and migration. Over a period of five years from 1993 to 1998, 7,0677 households migrated to other areas. The agricultural productivity level is low.

5.2 Description of the Study Sites

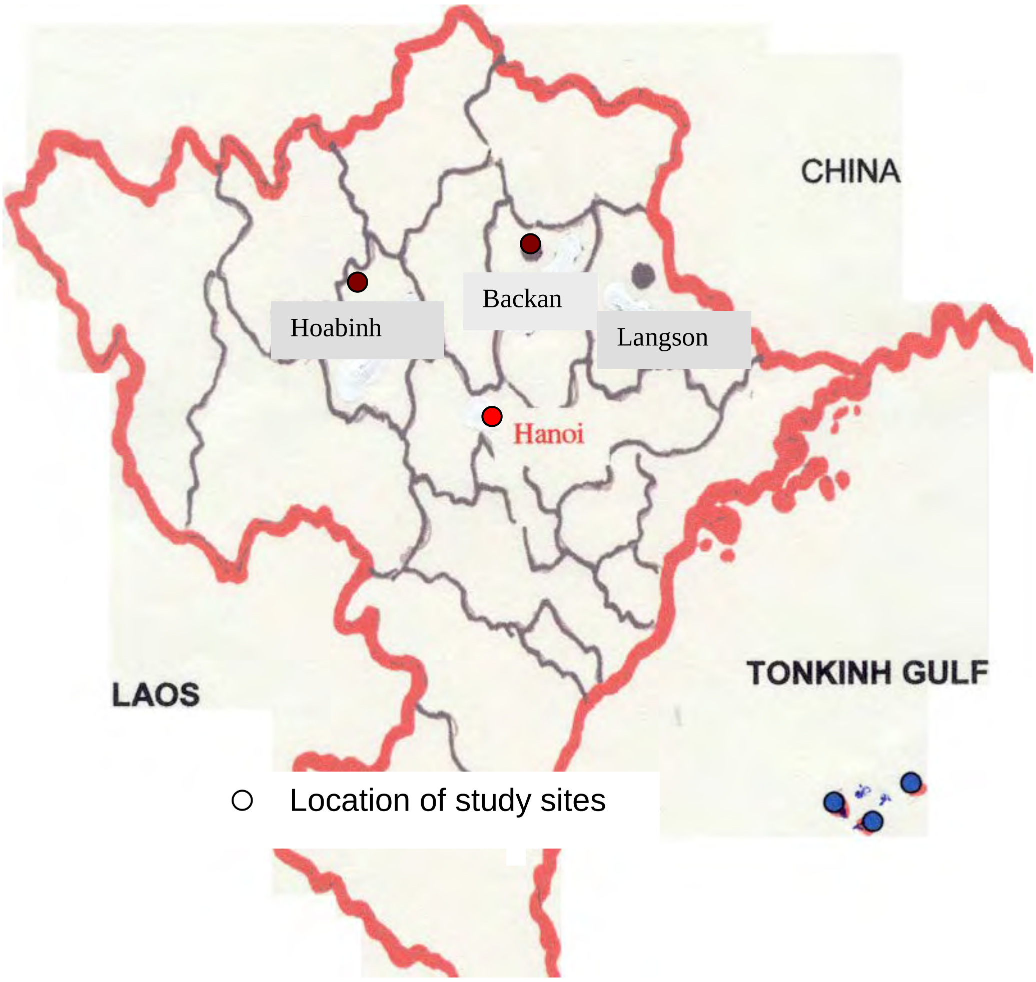
The three villages chosen as sites for both the experimental treatments and the village surveys are as follows:

Hoason Village: The village, located in the Hoabinh province, is a typical village in the north-west mountainous region. It has lower slopes than the other study sites. Maize and cassava are the dominant crops in the village.

Dongdang Village: The village, located in the Langson province, is a typical village in the south-east area of the northern mountainous region. Land is highly sloping and the average rainfall is higher than that of the west and the centre of the region. Cassava and maize are the dominant crops.

Ngocphai Village: The village, located in Backan province, is a typical village in the central area of the region. The village has agro-ecological and socio-economic conditions characteristic of the central part of the northern mountainous region. With medium sloping lands, upland rice and cassava are the dominant crops.

MAP OF NORTHERN VIETNAM



6.0 RESULTS AND DISCUSSION

To measure the on-site costs of soil erosion and the benefits of soil conservation, the study used experimental data and survey data for analysis and the results of both are presented in this section in two parts.

6.1. Analysis of On-Site Costs and Benefits of Soil Conservation Using Experimental Data

6.1.1 Soil Loss – Productivity Analysis

The northern mountainous regions of Vietnam cover 10 million hectares of mainly slope lands. Land used for agriculture is estimated about 1.2 million hectares, of which 1 million hectares are used for annual crops.

Since 1992, the National Institute of Soil and Fertilisers and Thainguyen University have carried out research studies on soil conservation in this region. The studies have consisted of four treatments with three replications on two crops: maize and cassava. Objectives of the research have been to measure the quantity of soil loss and productivity of crops over several years. Details of treatments and data collection have been presented in Section 4 under 'Methodology'.

In this section, the results of the treatments on soil conservation practices are used to analyse the impact of cumulative soil loss on the yield of crops. Linear regression functions relating yield to cumulative soil loss used time series data on sets of treatments from 1992 to 1998. The analyses were aimed at examining how cumulative soil loss affected the productivity of maize and cassava.

First, focus was placed on the relationship between soil loss and the yield of crops under treatments with and without soil conservation practices.

Soil Loss and Yield Relationship

Soil Loss

Results obtained from the treatment of soil erosion in the mountainous regions of northern Vietnam showed that gross erosion varied according to the type of crop grown, soil conservation practice and rainfall. Table 1 presents the amount of soil loss under different treatments with and without soil conservation practices.

Table 1 shows that soil loss was highest in 1996 with a rainfall of 1,943 mm and lowest in 1998 with a rainfall of 684 mm. In general, cassava is planted on higher slope lands, so soil loss in cassava production areas is higher than in maize production.

Table 1. Comparison of Soil Loss per Hectare Between Treatments With and Without Soil Conservation Practices

Year	*Rainfall (mm)*	*Maize production (tonnes/ha)*			*Cassava production (tonnes/ha)*		
		With	*Without*	*Difference*	*With*	*Without*	*Difference*
1992	773.5	4.47	6.73	-2.26**	11.25	12.21	-0.96 NS
1993	1,025.5	7.47	17.5	-10.03 ***	17.81	20.72	-2.91 **
1994	2,011.1	17.57	19.03	-11.46 ***	20.91	25.86	-4.95 ***
1995	1,173.6	11.42	20.76	-9.34 ***	16.47	24.09	-7.62 ***
1996	1,943.2	17.51	30.03	-12.52***	21.91	37.85	-15.86 ***
1997	1,612.8	12.41	20.98	-8.57 ***	19.32	27.12	-7.8 ***
1998	684.0	5.93	16.12	-10.19 ***	10.28	19.04	-8.76 ***

NS: Not significant *** Significant at 1% ** Significant at 5%

Comparison of soil loss per hectare between the baseline treatment (without soil conservation) and treatments with soil conservation practices showed that the average soil loss in the baseline treatment was higher both in maize production as well as in cassava production. The difference in soil loss between treatments was statistically significant at 1% level from 1994 to 1998.

Comparison of soil loss between treatments with hedgerow showed that the lowest quantity of soil loss was in the contour line of *Tephrosia candida*, it being only 84.2% of that of the contour line of tea, and 50% compared with the case without soil conservation practice.

Maize Yield

The data on maize production treatments is based on observations from 1992 to 1998. To measure productivity change, a comparison of maize yields between treatments with and without soil conservation was carried out; other factors that affected maize yield such as variety, fertiliser and labour, being kept constant in treatment over time.

Observations showed that maize yields, both with and without soil conservation practices, were decreasing from 1992 to 1998. Inputs were constant over time. However, the yields of maize decreased slowly under treatments with soil conservation practices, while for the treatment without soil conservation practices, maize yields decreased very fast.

Table 2. Comparison of Maize Yields Between Treatments With and Without Soil Conservation Practices

Year	*With (kg/ha)*	*Without (kg/ha)*	*Difference (kg/ha)*
1992	1,595.0	1,578.6	17 NS
1993	1,545.0	1,268.3	267.7 ***
1994	1,440.0	917.6	552.4 ***
1995	1,525.0	989.6	535.4 ***
1996	1,290.0	663.6	626.0 ***
1997	1,117.6	488.0	629.6 ***
1998	1,164.3	503.0	661.3 ***

NS: Not significant *** Significant at 1%

In 1998, treatment with soil conservation practices gave a maize yield of 1,164.3 kg per hectare, being equal to 73% of the maize yield in 1992 for treatments with soil conservation practices. On an average, the yield of maize decreased by 5% per year.

Under the baseline treatment, the yield of maize per hectare was 503 kg in 1998. It was equal to only 31.86% of the maize yield in 1992. On an average, the yield of maize under the baseline treatment decreased by 17.4 % per year.

Comparison of the maize yields between treatments with and without soil conservation practices showed that the maize yields under treatments with contour hedgerow were significantly higher than those under the baseline (without soil conservation) treatment. This difference increased in the period from 1992 to 1998.

These results revealed that without soil conservation practices, the yield of maize decreased. After seven years, the soil loss under the baseline treatment reduced the yield of maize by as much as 2.2 times of that under the contour hedgerow treatment.

For maize production treatments, maize cropping is followed by peanut cropping. The gross value of production of both maize and peanut crops is given below.

Table 3. Comparison of Gross Value of Production Between Treatments With and Without Soil Conservation Practices

Unit: VND thousand

Year	*With soil conservation*			*Without soil conservation*			*Difference (1-2)*
	Maize	Peanut	Total (1)	Maize	Peanut	Total (2)	
1992	3,987.5	1,443.0	5,430.5	3,946.5	1,335.0	5,281.5	149.0 **
1993	3,862.5	1,281.0	5,143.5	3,170.7	1,350.0	4,520.7	622.7 ***
1994	3,600.0	1,539.0	5,139.5	2,294.0	1,155.0	3,449.0	1,690.0***
1995	3,812.5	1,692.0	5,504.5	2,474.0	1,269.0	3,743.0	1,761.5 ***
1996	3,225.0	1,398.0	4,623.0	1,659.0	1,182.0	2,841.0	1,782.0***
1997	2,792.5	1,125.0	3,917.5	1,220.0	1,023.0	2,243.0	1,674.5 ***
1998	2,910.0	1,245.0	4,155.0	1,257.5	1,065.0	2,322.5	1,832.5 ***

NS: Not significant *** Significant at 1% ** Significant at 5%

Table 3 shows that the difference in gross value of production per hectare between treatments with and without soil conservation practices is of high statistical significance. The gross value of production for treatments without soil conservation practices decreased by 2.7% in 1992 compared with treatments with soil conservation practices, and by VND 1,832.5 thousand per hectare or 44.1% in 1998.

Cassava Yield

The same trend was found in cassava production. The difference in cassava yields between the baseline treatment and treatments with hedgerow was not significant in 1992 and 1993, but became highly significant in the 1994-1998 period. This difference in yield increased over time (Table 4).

Under the baseline treatment, the yield of cassava was 7,134 kg per hectare in 1998, less by 49.5% compared with the yield of cassava in 1992. On an average, the yield of cassava was reduced by 11.5% per year under the baseline treatment. Under treatments with soil conservation practices, the yield of cassava was 11,271 kg per hectare in 1998, being 81.7% of the cassava yield in 1992. On an average, the yield of cassava was reduced by only 4.2% annually.

These results imply that a high rate of soil loss results in low yields of cassava.

Table 4. Comparison of Cassava Yields Between Treatments With and Without Soil Conservation Practices.

Year	*With (kg/ha)*	*Without (kg/ha)*	*Difference (kg/ha)*
1992	13,796	13,851	-55 NS
1993	13,605	13,162	443NS
1994	13,278	9,950	3,328***
1995	13,998	10,208	3,790***
1996	11,580	9,595	1,985***
1997	11,251	8,567	2,664***
1998	11,271	7,134	4,137***

NS: Not significant *** Significant at 1%

Impact of Cumulative Soil Loss on Yield of Crops

In order to determine the impact of cumulative soil loss on crop yield, a linear regression function was chosen. The rationale for fitting cumulative soil loss to yield was based on the hypothesis that the productivity of a crop is influenced by the amount of soil that is removed over the time.

Data used in the linear regression function was time series data, which was collected from 1992 to 1998. The function included two variables: yield of crop in kilograms per hectare and cumulative soil loss in tonnes per hectare.

Maize Production

Four estimation functions were run separately for 4 treatments:

T1: Baseline treatment without soil conservation practices.

T2: Treatment with tea contour hedgerows as soil conservation practice.

T3: Treatment with *Tephrosia candida* hedgerows as soil conservation practice.

T4 : Treatment with tea and grass hedgerows as soil conservation practice.

Fertiliser application for maize production was unchanged over time with N: 60 kg, P_2O_5: 60 kg and K_2O: 60 kg per hectare.

The results are presented in Table 5.

Relationship between the Yield of Maize and Cumulative Soil Loss

Table 5. Relationship Between Maize Yield and Cumulative Soil Loss

Parameters	*T1*	*T3*	*T2*	*T4*
Intercept	1,421	1,629.7	1,631	1,604
	(28.39) ***	(38.3) ***	(112)***	(28.60)***
Cumulative soil loss	-7.56	-6.26	-7.4	-7.0549
	(- 11.9) ***	(-6.2) ***	(-21.02) ***	(-5.2) ***
R^2	0.833	0.863	0.823	0.814
F	143	38.9	88.79	27.28
N	21	21	21	21

NS: Not significant *** Significant at 1%

The results showed that control of soil loss was an important factor in maize production. The sign of the coefficient was negative and highly significant in both treatments. The coefficient of cumulative soil loss was largest (-7.56) for the baseline treatment and lowest (-6.26) for treatment with *Tephrosia candida* hedgerows. It implied that on an average, other factors being constant, with one increased tonne of cumulative soil loss, the maize yield decreased by 7.56 kg and 6.26 kg under treatment without soil conservation and treatment with *Tephrosia candida* hedgerows, respectively.

The R^2 of the model ranged from 0.814 to 0.863. This high value indicates that the estimation regression function used adequately explains the relationship between cumulative soil loss and maize yield being modelled.

To measure the impact of cumulative soil loss on the total value of crops in the plot, the following function was used:

$$Y = \delta_0 + \delta_1 X_i + u_i \qquad (10)$$

where

Y is total value of crops in the plot and

X_i is cumulative soil loss.

The result of estimation function is indicated in Table 6.

It shows that with two crops in a plot per year, if the cumulative soil loss increased one tonne per hectare, total value of crops would decrease VND 21.269 thousand for treatments with soil conservation practices and by VND 23.48 thousand for the baseline treatment.

Table 6. Relationship Between Value of Crops and Cumulative Soil Loss

Parameters	*With soil conservation*	*Without soil conservation*
Intercept	5,557.58 (25.3)***	4,935.10 (15.1)***
Cumulative soil loss	-21.269 (-3.98)***	-23.48 (-5.35)***
R^2	0.76	0.85
F	15.85	28.65
N	21	21

NS: Not significant *** Significant at 1%

Comparison Functions

To determine the difference in productivity losses between treatments with and without soil conservation practices, three comparison functions were run.

Function for comparing yield and cumulative soil loss between T2 and T1:

$$Ln(Y_{T2} - Y_{T1}) = \beta_0 + \beta_1 Ln(X_{T2} - X_{T1}) + U_i \quad (11)$$

Function for comparing yield and cumulative soil loss between T3 and T1:

$$Ln(Y_{T3} - Y_{T1}) = \beta_0 + \beta_1 Ln(X_{T3} - X_{T1}) + U_i \quad (12)$$

Function for comparing yield and cumulative soil loss between T4 and T1:

$$Ln(Y_{T4} - Y_{T1}) = \beta_0 + \beta_1 Ln (X_{T4} - X_{T1}) + U_i \quad (13)$$

The results of the estimation functions are presented in Table 7.

Table 7. Comparison Functions on the Differences in Cumulative Soil Loss and Maize Yields Between Treatments With and Without Soil Conservation Practices

Parameters	*T3 and T1*	*T2 and T1*	*T4 and T1*
Intercept	4.21 (17.99)***	4.42 (14.09)***	4.23 (8.75)***
Difference in cumulative soil loss	0.37 (8.24) ***	0.294 (5.54) ***	0.326 (3.97) ***
R^2	0.78	0.473	0.75
F	68.0	4.58	15.78
N	21	21	21

NS: Not significant *** Significant at 1%

In Table 7, the coefficient of difference in soil loss in the three functions is positive. This means that if the difference in soil loss between treatments with soil conservation practices and the baseline treatment is increased, the difference in maize yields between treatments with soil conservation practices and the baseline treatment would also increase.

R^2 was of high value and statistical significance, indicating that changes in the differences in both soil loss and maize yields between treatments with and without soil conservation practices were closely related.

Cassava Production

Table 8 reports regression functions for cassava production.

Table 8. Relationship Between Cassava Yield and Cumulative Soil Loss

Parameters	*T1*	*T2*	*T3*	*T4*
Intercept	13,820.5*** (10.33)	14,473*** (15.8)	14,817.8*** (49.5)	14,971.0 *** (29)
Cumulative soil loss	-39.8*** (- 5.6)	-30.09*** (-3.7)	-28.05*** (-7.9)	-28.66*** (- 4.3)
R^2	0.888	0.762	76.8	0.793
F (1,19)	160	16.08	62.9	19.2
N	21	21	21	21

NS : Not significant *** Significant at 1%

Fertiliser application rates in cassava production were unchanged over time with N: 60 kg, P_2O_5: 60 kg and K_2O: 20 kg per hectare.

The analysis of the estimation functions showed that the coefficients of soil loss were negative and of high statistical significance. It meant that one tonne of soil loss per hectare resulted in a decrease of 39.8 kg, 30.09 kg, 28.05 kg and 28.66 kg in cassava yield under treatments T1, T2, T3 and T4, respectively.

Comparison Functions

Table 9. Comparison Functions on the Differences in Cumulative Soil Loss and Cassava Yields Between Treatments With and Without Soil Conservation Practices

Parameters	*T3 and T1*	*T2 and T1*	*T4 and T1*
Intercept	0.897 (0.488) ^{NS}	1.69 (0.85)^{NS}	-1.035 (-0.287)^{NS}
Difference of cumulative soil loss	0.65 (3.28)***	0.589 (2.9)**	0.88 (2.1)*
R^2	0.46	0.629	0.478
F	10.7	8.48	4.58
N	21	21	21

NS: Not significant *** Significant at 1% ** Significant at 5% * Significant at 10%

Comparison functions on the differences in cassava yield and soil loss between treatments T3, T2, T4 and treatment T1 showed that if the difference in cumulative soil loss between T3, T2, T4 and T1 increased by 1%, the difference in cassava yields (Y_{T3}-Y_{T1}), (Y_{T2}-Y_{T1}) and (Y_{T4}-Y_{T1}) increased by 0.65%, 0.589% and 0.88 %, respectively.

These results clearly show that soil loss leads to low productivity in maize and cassava production.

6.1.2 Financial Analysis of Soil Conservation

To determine the best technology for soil conservation in a sloping land region, a financial cost-benefit analysis was carried out on technological treatments of soil conservation. This was based on the hypothesis that in the long run, farmers with soil conservation practices would receive higher net incomes compared with farmers without soil conservation practices.

The financial analysis was based on current prices of outputs and inputs. The results were expressed in the present value (PV) and net present value (NPV) using a 12% rate of discount. The life-span for calculating NPV was the seven years that corresponds to the experimental period.

Financial Analysis for Maize Production

The NPV was computed and compared between the different treatments for maize production. See Table 10 below.

Table 10. Financial Analysis for Maize Production

Item	*T1*	*T2*	*T3*	*T4*
1. Gross value (VND thousand)	8,749.8	13,762.9	13,600.0	13,852.0
2. Cost (VND thousand)	9,965.8	11,467.6	10,757.6	11,007.7
3. NPV (12%)	-1,216.0	2,295.3	2,843.5	2,844.4
4. B/C	0.878	1.200	1.264	1.258

- Under the baseline treatment (T1), profitability was low. The yield of maize was low due to high soil loss. The labour cost was higher than that for the other treatments because the labour requirement for land preparation and weed control was high for this treatment. Therefore, the net benefit was positive only in 1992 and 1993, and negative in the following years. These results indicate that farming systems without soil conservation practices on slope lands will not be financially viable in the long run.

- Under the treatment with *Tephrosia candida* hedgerows (T3), the yield of maize was highest, and the material and labour costs lowest compared with the other treatments. The soil became more fertile and spongy because the green matter from the hedgerows was used as organic manure for maize production. The net benefit was positive during the experimental period. The present value of net benefit (NPV) was VND 2,843.5 thousand per hectare with a life-span of seven years. These results suggest that growing hedgerows of *Tephrosia candida* is a suitable form of soil conservation technology for farmers.

- Under the treatment with tea and grass hedgerows (T4), the returns from tea hedgerows were higher than that under the treatment with *Tephrosia candida* hedgerows, but the NPV of VND 2,844.4 thousand per hectare was the same. Under this treatment, material and labour costs were higher compared with the other soil conservation technologies, especially in the first year. Therefore, this technology is not so good for poor farmers.

Financial Analysis for Cassava Production

The same trend was found in the cost-benefit analysis of cassava production.

Table 11. Financial Analysis for Cassava Production

Item	*T1*	*T2*	*T3*	*T4*
1. Gross value (VND thousand)	17,814.0	22,428.4	22,018.0	22,232.8
2. Cost (VND thousand)	12,726.6	13,290.0	13,006.0	13,420.8
3. NPV (12%)	5,088.3	9,138.0	9,012.1	8,811.2
4. B/C	1.399	1.690	1.690	1.656

Table 11 shows that treatment with *Tephrosia candida* hedgerows had a high NPV of VND 9,012.1 thousand per hectare, while the NPV of the baseline treatment was VND 5,088.3 thousand per hectare. The net benefit of cassava production was negative after five years of cultivation.

Based on the results of the financial analysis, it can be concluded that the best methodology for soil conservation is *Tephrosia candida* hedgerows for both maize and cassava production, because the NPV and yield per hectare in this treatment were highest.

6.2 Measurement of Productivity Gain Using Survey Data

6.2.1 Descriptive Statistics of Samples

It was necessary to conduct an analysis of the advantages of soil conservation in farms. A total of 297 upland farms from three villages; 120 in Hoason, 82 in Dongdang and 95 in Ngocphai, were selected for the analysis. The characteristics of the farms are laid out in Table 12.

Hoason Village

The village is located in the Luongson district of Hoabinh province. It is 70 km west of Hanoi. 62% of the population belongs to the Muong ethnic minority group. In this village, farmers own their lands. The average land area is 12,959 m^2 of which sloping land is 10,828 m^2, occupying 83.5% of the total cultivated area. The main cropping system in the village is rice in the lowlands, or maize, cassava, soyabean and peanut on the slopes. The major sources of technical information are from the district Extension Centre, the Hanoi Agricultural University and the Institute of Soil and Fertilisers. The Extension Centre and extension programmes of the Institute and the University educate and guide farmers on soil conservation technology and improved crop cultivation techniques such as designing contour lines, planting hedgerows, choosing good varieties to plant, and applying pesticides and fertilisers.

Ngocphai Village

The village is located in the Chodon district of Backan province. It is far from the district centre and from main roads. The road conditions of the village are more difficult compared with those in Hoason. The majority of the population is of the Tay and Dao ethnic minority groups. The average education level of the head of the household is low at four years. The average household size is bigger, as compared with the household size in Hoason, but its farm size is smaller. The average cultivated land area is 9,242 m^2 of which sloping lands occupy 95.6%. In comparison with Hoason, the slopes of this village are steeper, but the soil is more fertile. Land use titles have been issued here. Everywhere in the village, gardens are unproductive with low value species of fruit trees.

The major income sources come from upland rice, maize and forest products. The level of income is low. In fact, poverty is one of the major problems in the village, the percentage of poor farmers is more than 35%. Recently, some agricultural extension programmes by non-governmental organisations and universities have been conducted in this village, such as slope land management funded by the French government and fertiliser application for upland rice production funded by the International Rice Research Institute (IRRI). Fifty per cent of the farmers were invited to participate in these training courses for one to two weeks. This has created a good platform for the application of soil conservation techniques in this village.

Dongdang Village

It is located far from the centre of Langson province, but near a main road. About 82% of the population belongs to the Nung ethnic minority group. Of the farms, 52% use soil conservation technology. Compared with Hoason and Ngocphai, the area of sloping lands in this village is less, occupying only 68%. The main crops on sloping lands are cassava and fruit trees.

The selected farms were separated into two groups: farms with soil conservation practices and farms without soil conservation practices.

The former made up about 60.6% of the total. Characteristics of the group were as follows:

- All farms were cultivated settlement farms.
- Cultivated farm land was clearly allocated by the village committee.
- Farmers had long-term rights to land use.
- Farmlands were located around the village.

There were 117 farms without soil conservation practices making up 39.4% of the total number of sample farms. Cultivated lands were situated far from the village. Some of the farmers practised shifting cultivation.

In the group of farms with soil conservation technology, the practices included:

- *Traditional technology:* Farmers made terraced plots and used stones to make branches to prevent soil erosion. However, these methods are only applicable to less-steep farmlands and they require more labour compared with other methods.

- *Making hedgerow lines:* Almost all farmers grew *Tephrosia candida* hedgerows. This technology is easy to apply and the cost is low. Furthermore, it is a very suitable soil conservation practice for sloping lands. Some of the farmers (28% of selected farms in Hoason) grew tea hedgerows. This method enables farmers to earn income from the tea, but the cost of soil conservation incurred is high. Farmers in the three villages mentioned are expanding their adoption of hedgerow practices.

- *Inter-cropping technology:* Universities and district extension centres have promoted this technique in Hoason and Dongdang since 1996. The inter-cropping system includes maize mixed with soyabean or maize mixed with peanut or cassava mixed with green bean. It has the effect of increasing the fertility of the land and increasing returns per hectare. However only 15.5% of selected farms applied this technique. Almost all the farmers said that they encountered problems with investment capital and pesticide control.

Table 12. Characteristics of the Farms and Villages

Characteristics	*Unit*	*Hoason village*	*Dongdang village*	*Ngocphai village*
1. Distribution of samples	Farm	120	82	95
• Farms with soil conservation	Farm	78	51	51
- Percentage of total	%	65.0	62.2	53.7
• Farms without soil conservation	Farm	42	31	44
- Percentage of total	%	35.0	37.8	46.3
2. Minority ethnic group	% of total	62.0	82.0	100.0
3. Farm size	M^2	12,959.0	9,593.0	9,242.0
- Sloping land	%	83.5	71.8	95.6
4. Household size	Person	5.6	6	6.5
5. Number of labourers	Person	3.0	2.9	2.8
6. Average age of household head	Years	41.4	42.6	40.3
7. Education level of household head	Years	6.5	6.3	4.0
8. Farmers taking training courses on soil conservation	%	35.0	14.0	50.0

6.2.2 Production Functions

To measure productivity gains in soil conservation farms, an analysis of the output and input of maize and cassava production was conducted.

Maize Production

Comparison of Output and Input

Comparison of output and input per hectare between areas with soil conservation and areas without soil conservation is shown in the following Table 13.

Table 13. Comparison of Output and Input per Hectare of Maize Production

Item	*Unit*	*With soil conservation*	*Without soil conservation*	*Difference*
1. Yield of maize	kg	2,520.5	1,455.2	1,065.3
2. Major inputs				
- Organic manure	tonnes	2.56	0.83	1.73
- Nitrogen (urea)	kg	85.6	42.8	42.8
- Phosphorus (21% of P_2O_5)	kg	189.3	81.0	108.3
- Potassium (45% of K_2O)	kg	37.6	15.8	21.8
- Labour	man-day	191.0	184.8	6.2
3. Soil conservation expenditure				
- Materials	VND ’000	67.0	0.0	67.0
- Labour	man-day	31.0	0.0	31.0

On average, the yield of maize production was found to be higher in areas with soil conservation practices compared to areas without such practices. This could be attributed to the more intensive use of fertilisers and labour facilitated by soil conservation conditions.

Most farmers with soil conservation practices used more organic manure than those without such practices.

In general, the amounts of nitrogen, phosphorus and potassium used in areas with soil conservation practices in the three villages of Hoason, Dongdang and Ngocphai, were respectively 42.8 kg, 108.3 kg and 21.8 kg per hectare higher compared with areas without soil conservation practices. In the survey, most farmers stated that chemical fertiliser application was inefficient in areas without soil conservation practices. Survey data showed that 16%, 36% and 50% of maize production areas were not treated with nitrogen, phosphorus and potassium respectively. Most of them were in areas without soil conservation practices.

The difference in labour requirements for maize production between soil conservation and non-soil conservation areas was 6.2 man-days per hectare, which was not statistically significant. In soil conservation areas, the labour requirement for fertiliser application was higher than that in areas without soil conservation, while the labour requirement for land preparation and hand weeding was higher in areas without soil conservation.

Almost none of the farms had been sprayed with pesticides during maize production.

Soil conservation reduced the level of soil loss and facilitated intensive use of fertiliser. Sixty two per cent of the farmers invested capital for soil conservation practices in maize production.

To prevent soil erosion, most of the farmers planted trees along the contours of sloping fields as hedgerows. In Hoason, 28% of the surveyed farmers applied hedgerows of tea. These farmers also wanted to earn income from tea production. All of the farmers in Dongdang and Ngocphai grew hedgerows of *Tephrosia candida* as they found that labour and materials required for this technology were lower compared with growing hedgerows of tea, and in addition, this technique was easier to apply.

The results of the survey also showed that fields located far from the farmer's house were not convenient for soil conservation activities.

Production Function for Maize Production

In order to determine the impact of soil conservation activities on maize production, the production function was chosen to estimate the parameters of inputs related to maize yields. The variables included the yield of maize, quantity of major input elements such as labour, organic manure, nitrogen, phosphorus, potassium, and soil conservation expenditure for labour and materials. It also included a 'dummy village', D_1, which referred to Hoason Village.

In the logistic form, the production function is as below:

$$\text{Ln } Y = \alpha_o + \alpha_1 \text{Ln}X_1 + \alpha_2 \text{Ln}X_2 + \alpha_3 \text{Ln}X_3 + \alpha_4 \text{Ln}X_4 + \alpha_5 \text{Ln}X_5 + \alpha_6 \text{Ln}X_6 + \alpha_7 \ln X_7 + \gamma D_1 + u_i \quad (14)$$

This function is run using the ordinary least square (OLS) method. To test the significance of the estimation model and the significance of individual coefficients of the model, the *F* test and *T* test were applied respectively.

The results of the estimation model are presented in Table 14.

Table 14. Estimation Function for Maize Production

Variable	*Coefficient*	*T stat.*
Intercept (α_o)	5.5843 ***	4.857
Organic manure (X_1)	0.1387 ***	3.428
Nitrogen (X_2)	0.0050 NS	0.532
Phosphorus (X_3)	0.0318 ***	3.904
Potassium (X_4)	0.0164 **	2.038
Labour (X_5)	0.4075 *	1.888
Material for soil conservation (X_6)	0.0390 *	1.749
Labour for soil conservation (X_7)	0.0512 *	1.688
Dummy of Hoason Village (D_1)	0.1043 NS	1.495
Number of sample	159	
R^2	0.5333	
Adjusted R^2	0.4711	
Value of F	8.571	

NS: Not significant *** Significant at 1% ** Significant at 5% * Significant at 10%

As can be seen from the results, organic manure, phosphorus and potassium used by farmers were important factors affecting maize production. The signs of these coefficients were positive and significant with a high level of confidence. The elasticity of these three variables implies that on an average, a 1% increase in organic manure, phosphorus and potassium will result in an increase in the yield of maize by 0.1387%, 0.0318% and 0.0164%, respectively.

The elasticity of the labour variable was the largest at 0.4075 and significant at a 10% confidence level. It suggests that an increase in labour will lead to increased maize production. In maize production, pre-harvest labour, especially for weeding, plays an important role in determining the yield. Of the farmers interviewed, 67.5% answered that the yield of maize was low due to damage caused by weeds.

The coefficients of both the labour and material variables in soil conservation expenditure were positive and significant at a 10% statistical level. This shows the importance of soil conservation expenditure to improved maize production.

The coefficient of nitrogen was the smallest at 0.005 and not statistically significant. It may be explained by the fact that nitrogen is easily run off sloping lands.

The R^2 of the maize production model was 0.5333, indicating that 53.33% of the maize production yield was determined by the independent variables included in the model.

Based on the results of the estimated production function, the optimal level of soil conservation expenditure was calculated as follows:

$$X^* = (P_y * Y_i * \alpha_i)/P_{xi} \quad (15)$$

where

P_y is the price of output and

P_{xi} is the price of input.

From this, the optimal level of soil conservation expenditure for maize production was determined at 40 man-days of labour and VND 105 thousand of material expenditure per hectare.

Cassava Production

Comparison of Output and Input

The difference in the yields and major input factors for cassava production are given in Table 15.

In general, the levels of major input elements such as organic manure, nitrogen, phosphorus and potassium applied in cassava production were lower compared with those in maize production, for example, the level of phosphorus applied for cassava production was only 41.2% of that used for maize production.

As for maize production, farmers used more fertilisers in soil conservation areas. The results of the survey also showed that 49.5% of surveyed farmers did not use organic manure for cassava production. For nitrogen, phosphorus and potassium, the figures were 52.5%, 33.3% and 47.4% respectively.

The labour used for cassava production was lower in areas with soil conservation practices in comparison with non-soil conservation areas, which required more labour for land preparation, hand-weeding and harvesting.

For soil conservation, 100% of the farmers planted *Tephrosia candida* as hedgerows. Soil conservation expenditure was low at VND 31.3 thousand for materials and 16 man-days of labour. Farmers apparently put less importance on soil conservation for cassava production as only 55% of them employed soil conservation practices in cassava production areas.

Table 15. Comparison of Output and Input per Hectare of Cassava Production

Item	*Unit*	*With soil conservation*	*Without soil conservation*	*Difference*
1. Yield of cassava	tonnes	14.80	12.36	2.44
2. Major inputs				
- Organic manure	tonnes	1.7	0.7	1.0
- Nitrogen	kg	20.5	8.6	11.9
- Phosphorus	kg	78.6	36.6	42.0
- Potassium	kg	27.3	11.6	15.7
- Labour	man-day	264.5	301.0	36.5
3. Soil conservation expenditure				
- Materials	VND '000	31.3	0.0	31.3
- Labour	man-day	16.0	0.0	16.0

Production Function for Cassava Production

To measure the productivity of cassava production, the yield was estimated by a production function. The function included the following variables: yield, organic manure, nitrogen, phosphorus, potassium, labour for cassava production, soil conservation expenditure and 'dummy' villages: D_1 for Hoason Village and D_2 for Ngocphai Village. The form of the function is as follows:

$$\text{Ln } Y = \alpha_o + \alpha_1 \text{Ln}X_1 + \alpha_2 \text{Ln}X_2 + \alpha_3 \text{Ln}X_3 + \alpha_4 \text{Ln}X_4 + \alpha_5 \text{Ln}X_5 + \alpha_6 \text{Ln}X_6 + \alpha_7 \text{ln}X_7 + \gamma_1 D_1 + \gamma_2 D_2 + u_i \quad (16)$$

The results of this estimation function are shown in Table 16. All coefficients of variables were positive, indicating a direct relationship between the variables and cassava yield. The coefficients of the labour and phosphorus variables were significant at a 10% statistical level. The coefficient of the organic manure variable was highly significant at 1%, while coefficients of the nitrogen and potassium variables were not statistically significant. These results suggest that farmers can maximise cassava production if they increase their input of manure, phosphorus and labour.

The ratio of marginal product to input was 0.8, 6.6, and 8.7, respectively for manure, labour and phosphorus.

Table 16. Estimation Function for Cassava Production

Variable	*Coefficient*	*T stat.*
Intercept (α_o)	8.320 ***	20.578
Organic manure (X_1)	0.079 ***	6.729
Nitrogen (X_2)	0.027 NS	0.747
Phosphorus (X_3)	0.0042 *	1.682
Potassium (X_4)	0.0092 NS	1.187
Labour (X_5)	0.1354 *	1.901
Material for soil conservation (X_6)	0.0035 NS	0.080
Labour for soil conservation (X_7)	0.0064 *	1.674
Dummy: Hoason Village (D_1)	0.192 *	1.674
Dummy: Ngocphai Village (D_2)	0.0285 *	1.957
Number of samples	199	
R^2	0.4761	
Adjusted R^2	0.409	
Value of F	4.57	

NS: Not significant *** Significant at 1% ** Significant at 5% * Significant at 10%

The coefficient of the variable for labour used for soil conservation activities was positive and statistically significant at 10%. The coefficient of the material expenditure variable was also positive, but not significant. This implies that labour investment for soil conservation practices is important in improving the yield of cassava. The optimal level of soil conservation expenditure was at 35 man-days of labour per hectare.

Summary

From the above results, it can be concluded that input efficiency is affected by soil conservation practices. If farmers want to increase maize and cassava productivity, they should invest in soil conservation practices on sloping lands.

In summary, soil conservation practices will facilitate intensive production and contribute to the improved productivity of crops.

6.3 Soil Conservation Expenditure Determinant

The benefits of soil conservation practices are obvious, but in the mountainous areas of northern Vietnam, application of soil erosion control methods is still limited. We need to understand the factors affecting the individual farmer's decision whether or not to adopt soil conservation practices and if having done so, whether or not to expand such areas of conservation.

The following factors may influence a farmer's decision to invest in soil conservation expenditure:

- *The farmer's understanding of soil erosion and his perception of the benefits of soil conservation practices:* This is an important factor. It is expected that farmers will invest in soil erosion control when they understand that soil erosion is a serious problem that causes loss of productivity, and that investment in soil conservation practices will bring about higher income.

- *Land conditions:* These include land-related factors such as farm size (cultivated area of the farm), type of land, slope of land, right and duration of land ownership, and distance from the farmer's house to the field.

- *The size of the farm:* This is expected to influence the adoption of soil conservation practices negatively, because if farmers have a large land area of sloping lands, they tend to practise shifting cultivation and not bother with soil erosion control.

- *The slope of the land:* This factor may positively or negatively affect soil conservation decisions. High sloping lands may be difficult for soil conservation activities. On the other hand, if soil erosion is serious, farmers may apply soil erosion control measures to safeguard their income. On low sloping lands, farmers generally seek to improve crop yields by employing the soil conservation technique of making terraced fields.

- *The duration of land usage:* The period of time during which the land is farmed is an important factor. Generally, after some years of land use, the fertility of the soil becomes poorer due to run-off of topsoil, and thus crop yields decrease rapidly, so farmers must be concerned about soil conservation practices to protect crop yields over time.

- *The distance of the field from the farmer's house:* It has been noted that if the field is located near the house, it is more convenient for the farmer to employ soil conservation practices.

- *The educational level of the head of the household:* The higher this is, the more positive the expected influence on the adoption of soil conservation practices as highly educated farmers tend to adopt new technology more readily.

- *Labour resources:* Availability of labour is expected to influence the adoption of soil conservation practices positively, as labour is required for planting hedgerows, making terraced plots and so on.

- *Age of the head of the household:* The farmer's age could be a positive or negative factor. Young farmers are more likely to be interested in adopting new technology to improve yields, although limited funds may be a constraint. Older farmers are less likely to be able to adopt new technology, especially if extra labour output is required, but they have the advantage of long-term experience in farming the land and may be financially stronger with capital to invest.

- *Income sources:* High incomes from on-farm and off-farm activities are expected to positively affect soil conservation expenditure, as high-income farmers have more available money and so are more likely to invest in soil conservation practices than low-income farmers.

- *Ethnic group:* Ethnic minorities such as the Dao, the Muong and the Hmong may be less likely to invest in soil conservation practices because they follow a tradition of shifting cultivation and are in a low-income situation. The traditions and living conditions of an ethnic group may therefore negatively affect soil conservation expenditure.

- *Training and extension activities:* This factor is expected to positively influence the adoption of soil conservation practices. Training and extension activities will help farmers gain a better understanding of the effects of soil erosion and the benefits of soil conservation, as well as facilitate the application of soil conservation technology on sloping lands.

To test the above assumptions, information was gathered on the various factors.

Table 17 provides full sample data on adopter and non-adopter factors influencing soil conservation expenditure. The average adopter farm applied VND 31.3 thousand and 16 man-days per hectare for soil conservation in cassava production and VND 67.0 thousand and 31 man-days in maize production.

Table 17. Comparison of Characteristics of Farmers With and Without Soil Conservation Practices

Variables	*With soil conservation*	*Without soil conservation*	*Difference*
- Cultivated area (ha)	1.102	1.030	0.072^{NS}
- Family income (VND thousands)	10,293.0	8,216.0	2,077**
- Labour resource (persons)	3.1	2.5	0.6***
- Educational level (years)	5.8	5.0	0.8*
- Age of household head (years)	41.1	40.9	0.2^{NS}
- Credit (VND thousands)	228.0	29.0	199.0***

NS: Not significant *** Significant at 1% ** Significant at 5% * Significant at 10%

- The average cultivated area of farmers with soil conservation practices was 1.102 ha, while that of farmers without soil conservation practices was 1.03 ha. The difference in the cultivated areas was 0.072 ha, which was not statistically significant.

- On an average, the family income of farms with soil conservation practice was VND 2,077.0 thousand higher than that of farms without soil conservation practice. The difference was significant at a 5% level.

- Labour resource: The number of labourers was 3.1 persons per farm with soil.

- conservation practices. The difference in labour between the two groups was 0.6 persons, which was statistically significant at a 1% level.

- The difference in the educational levels of the heads of the households of the two groups was 0.8 years, which was significant at a 10% level, while the difference between them in age was 0.2 years, which was not statistically significant.

- The difference in credit utilised between the two groups was large. Although none of the farmers used credit for soil conservation directly, credit utilisation affected the farmers' behaviour.

Besides analysis of the above factors, understanding the farmers' opinions on soil conservation is also important. The farmers' responses to soil erosion control are summarised as follows:

Farmers' Perceptions of Soil Erosion

At Hoason Village: Most farmers understood that soil erosion was a serious problem that would reduce the soil fertility of sloping lands. However, only 25% of the farmers interviewed understood that soil erosion caused damage downstream areas. Most farmers agreed that soil erosion control brought about benefits in the long run. At the time of the survey, 23.3% of farmers had not yet invested in soil conservation practices, but confirmed that they would implement soil conservation methods introduced by the Institute of Soil and Fertilisers in the following year.

At Ngocphai Village: 82% of the farmers interviewed agreed that soil erosion caused damage at farm level, while 18% of them were indifferent to soil erosion problems. Some were shifting cultivation farmers. Most of the soil conservation adopters in the village understood that soil conservation practices would lengthen the productive life of land. They confirmed that crop yields were very low in the areas without soil conservation practices after four years of farming. Only 68% of these farmers, however, answered that farms with soil conservation practices would give them more income compared with farms without soil conservation.

Land Conditions

Recognition of soil erosion as a serious problem does not guarantee the use of soil erosion control practices. Land conditions of the farm play an important role in the farmer's decision-making on soil conservation expenditure. Of the farmers interviewed, 38.5% stated that they did not want to invest in soil conservation activities in areas far from their houses because it was difficult to maintain hedgerow lines when the main crops were harvested. (Hedgerow lines were normally destroyed by the buffalo and cattle grazing). 27.3% of the farmers answered that soil conservation practices were not efficient on high sloping lands because they required too much labour to make contour lines, and farmers had to re-plant hedgerow lines every year, making the expenditure on soil conservation higher than that for lesser sloping lands. Farming methods also affected soil conservation decisions. Of the farmers interviewed in Ngocphai, 18.8% answered that they did not want to plant hedgerows because hedgerow lines caused problems for land preparation. Farmers could not burn them to clear wild grass in field-making and the labour requirement for hand-weeding was too high. Some members of the Management Committee of Ngocphai expressed the view that if the borders between agricultural and forestlands were clearly demarcated, farmers would not deforest land for agriculture.

Training and Extension Activities

Most farmers wanted to be supported with soil conservation techniques from extension centres and extension programmes of institutes, universities and non-governmental organisations. 15.6% of the farmers expressed interest in soil conservation but did not know how to implement such practices. Of the farmers in Ngocphai, 25% wanted to visit demonstration plots to observe how soil conservation methods were carried out. 62% of the farmers in Hoason and Dongdang confirmed interest in learning from demonstration plots prepared by the Institute of Soil and Fertilisers. Most of the respondents said that they had benefited from training courses. However, 50% of them felt that the training courses were too short. (A course lasted an average of 3 to 5 days.) 42% of the respondents wanted to receive more extension visits. Farmers would be better equipped to apply soil conservation and technical practices in crop production if they were given more extension visits.

Other Factors

37% of the farmers in Hoason, 41% of the farmers in Dongdang and 61% of the farmers in Ngocphai said that they were short of capital to invest in crop production and soil conservation. All of the farmers applying soil conservation wanted to receive subsidies from extension programmes on soil conservation. Some of them requested that the local government support them with *Tephrosia candida* seeds for planting hedgerows.

45% of the farmers said they had problems with insufficient labour for soil conservation activities. 65% of the farmers who did not practise soil conservation answered that they did not want to do so because soil conservation practices would create pesticide and weeding control problems. (Farmers would not be able to burn wild grass before planting, resulting in insects and wild-grass growth thriving.)

Most farmers in the three villages wanted to borrow money for expanding their economic activities. They said that if their economic conditions were improved, they would be more concerned about soil conservation.

6.3.1 Function of Soil Conservation Expenditure

To assess the level of expenditure on soil conservation, the following soil conservation expenditure function was estimated:

$$\mathrm{Ln}\,(Y) = \alpha_0 + \alpha_1 \mathrm{Ln}(X_1) + \alpha_2 \mathrm{Ln}(X_2) + \alpha_3 \mathrm{Ln}(X_3) + \alpha_4 \mathrm{Ln}(X_4) + \alpha_5 \mathrm{Ln}(X_5) + \alpha_6 \mathrm{Ln}(X_6) + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \gamma_4 D_4 + u_i \qquad (17)$$

where

Y is the farm's expenditure of soil conservation in VND thousands.

The results of the estimation are shown in Table 18.

The results show that farm size had a significant negative influence on expenditure on soil conservation, at a 10% level, suggesting that if the cultivated farm area was too large, the farmer would not be concerned about soil conservation practices.

Table 18. Estimated Results of Soil Conservation Expenditure Function

Variables	*Coefficient*	*T stat.*
Intercept	- 10.68 ^{NS}	-1.194
Cultivated area (X_1)	- 0.298*	-1.65
Labour resource (X_2)	1.042*	1.837
Family income (X_3)	0.0393*	1.853
Credit (X_4)	0.04^{NS}	0.518
Education level of household head (X_5)	0.06*	1.672
Age of household head (X_6)	-0.77^{NS}	-0.949
Slope of land (D_1)	1.088^{NS}	1.228
Distance (D_2)	0.66***	4.089
Minority ethnic group (D_3)	1.31^{NS}	1.387
Time of land used (D_4)	0.79*	1.912
R^2	0.373	
F	5.99	
N	218	

NS: Not significant *** Significant at 1% ** Significant at 5% * Significant at 10%

As expected, the education level of the head of the household and training courses were shown to be important factors in determining soil conservation expenditure. The education level coefficient showed a positive influence on the expenditure of soil conservation, significant at a 10% level, meaning that with each additional year of education, soil conservation expenditure of farmers would increase by 6%.

The coefficient of labour resource was significant and positive, suggesting that the number of workers was also an important factor in a farmer's decision to invest in soil conservation expenditure.

The coefficient of family income was positive and significant at a 10% level, meaning that with an increase in family income, expenditure on soil conservation would also increase. This also suggests that expanding production and improving the income from on-farm and off-farm activities would contribute to soil conservation investment.

The coefficients of slope of land and minority ethnic group were also positive but non-significant, while the coefficients of distance and time of land use were positive and significant at 1% and 10% level respectively, suggesting that land allocation and rural transport conditions were important considerations in increasing expenditure on soil conservation.

7.0 CONCLUSIONS AND POLICY RECOMMENDATIONS

7.1 Conclusions

The following conclusions can be drawn from all the results obtained in this study:

1. Soil erosion problems were of high significance in the mountainous regions of northern Vietnam. The major causes of soil erosion were high rainfall levels and bad farming practices on slope lands.

2. Soil conservation technology can reduce soil loss on sloping lands. The difference in soil loss between farming practices with and without soil erosion control was highly significant.

3. Crop productivity and cumulative soil loss were closely related. Estimation functions showed that the lower the cumulative soil loss, the higher the crop productivity.

4. The soil conservation technology of hedgerows of *Tephrosia candida* is a suitable technique for farmers. The advantages of this technology are low soil loss, low soil conservation costs and high NPV.

5. Farms with soil conservation practices used more fertilisers in crop production compared with farms without soil conservation practices.

6. Soil conservation practices will facilitate intensive production and contribute to improved productivity of crops on farms.

7. Decisions on soil conservation expenditure are affected by the characteristics of the farms, the income of the farmers and the resources they own. Improving the condition, as well as the family income of the farms will increase soil conservation expenditure by farmers.

8. Extension programmes, training courses and the education levels of the farmers are important factors affecting farmers’ decisions on soil conservation expenditure. This underscores the importance of human capital development in increasing expenditure on soil conservation.

7.2 Policy Recommendations

Soil conservation is very important in mountainous regions. If soil conservation technology is applied by farmers, crop yields will increase and degrees of poverty and shifting cultivation habits will be reduced. This study has clearly shown that soil conservation practices would greatly benefit these regions. Therefore, in order to expand the areas of soil conservation practices in these regions, government policies should give top priority to the following recommendations:

- The Government should provide education and training to farmers to improve their knowledge of soil conservation practices. Training courses should focus on the technology of soil conservation practices, crop management on slope lands and sustainable development of agriculture.

- The Government should design a master plan of land use in the region, clearly identifying borders between forestry and agricultural lands and issue farmers with long-term rights to land use, taking into consideration land tax, farm size (average cultivated land per farm) and management of agricultural land resources.

- The Government should support soil conservation technology by expanding the activities of extension centres in the region and supplying farmers with tea and *Tephrosia candida* seeds for soil conservation practices.

- The Government and the Agricultural Bank should expand credit facilities in the region. Rural credit will encourage farmers to expand their economic activities in order to earn higher incomes, and this in turn will encourage farmers to purchase agricultural and other materials for soil conservation practices.

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APPENDIX 1

Table A. Financial Analysis for the Baseline Treatment of Maize Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of corn product	2,367.9	1,902.4	1,743.4	2,375.0	1,791.7	1,366.4	1,458.7
- Return from hedgerow	0	0	0	0	0	0	0
2. Cost							
- Material cost of corn production	494.0	520.0	614.0	728.0	838.0	939.0	929.0
- Labour cost of corn production	1,025.0	1,170.0	1,365.0	1,710.0	1,900.0	1,920.0	1,950.0
- Material cost of soil conservation	0	0	0	0	0	0	0
- Labour cost of soil conservation	0	0	0	0	0	0	0
3. Net benefit	848.9	212.4	-235.5	-62.96	-946.3	-1,492.6	-1,420.3
4. NPV (12%)	- 1,216.0						
5. Benefit-Cost Ratio	0.878						

APPENDIX 2

Table B. Financial Analysis for *Tephrosia Candida* Hedgerow Treatment of Maize Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of corn product	2,413.5	2,325.0	2,869.0	3,672.0	3,591.0	3,178.0	3,468.0
- Return from hedgerow	0	0	0	0	0	0	0
2. Cost							
- Material cost of corn production	599.0	625.0	734.0	863.0	988.0	1,104.0	1,081.0
- Labour cost of corn production	1,050.0	1,080.0	1,400.0	1,665.0	1,575.0	1,900.0	1,850.0
- Material cost of soil conservation	35.0	0	0	50.0	0	0	70.0
- Labour cost of soil conservation	90.0	48.0	64.0	144.0	70.0	70.0	160.0
3. Net benefit	639.5	572.0	671.0	950.0	958.0	104.0	307.0
4. NPV (12%)	2,843.5						
5. Benefit-Cost Ratio	1.264						

APPENDIX 3

Table C. Financial Analysis for Tea Hedgerow Treatment of Maize Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of corn product	2,370.0	2,302.5	2,622.0	3,648.0	3,375.0	3,088.4	3,303.1
- Return from hedgerow	0	0	125.0	185.0	240.0	300.0	350.0
2. Cost							
- Material cost of corn production	599	625.0	734.0	863.0	988.0	1,104.0	1,081.0
- Labour cost of corn production	1,050.0	1,170.0	1,640.0	1,755.0	1,620.0	1,990.0	1,995.0
- Material cost of soil conservation	120.0	15.0	18.0	15.0	26.0	28.0	28.0
- Labour cost of soil conservation	250.0	42.0	120.0	105.0	120.0	110.0	125.0
3. Net benefit	351.0	450.5	235.0	1,095.0	861.0	156.4	424.1
4. NPV (12%)	2,295.3						
5. Benefit-Cost Ratio	1.20						

APPENDIX 4

Table D. Financial Analysis for Tea and Grass Hedgerow Treatment of Maize Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of corn product	2,394.0	2,325.0	2,897.5	3,432.0	3,483.0	3,242.4	3,291.5
- Return from hedgerow	0	0	105.0	150.0	185.0	240.0	250.0
2. Cost							
- Material cost of corn production	599.0	625.0	734.0	863.0	988.0	1,104.0	1,081.0
- Labour cost of corn production	1,070.0	1,100.0	1,350.0	1,600.0	1,675.0	1,650.0	1,850.0
- Material cost of soil conservation	220.0	15.0	18.0	15.0	26.0	28.0	28.0
- Labour cost of soil conservation	250.0	42.0	120.0	105.0	120.0	110.0	125.0
3. Net benefit	255.0	543.0	780.5	999.0	859.0	590.4	457.5
4. NPV (12%)	2,844.4						
5. Benefit-Cost Ratio	1.258						

APPENDIX 5

Table E. Financial Analysis for Baseline Treatment of Cassava Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of cassava product	4,155.3	3,948.6	3,980.0	4,593.6	3,838.0	3,426.8	2,853.6
- Return from hedgerow	0	0	0	0	0	0	0
2. Cost							
- Material cost of cassava production	494.0	520.0	614.0	728.0	838.0	939.0	929.0
- Labour cost of cassava production	1,315.0	1,560.0	2,072.0	2,385.0	2,580.0	2,620.0	2,620.0
- Material cost of soil conservation	0	0	0	0	0	0	0
- Labour cost of soil conservation	0	0	0	0	0	0	0
3. Net benefit	2,346.3	1,868.6	1,294.0	1,480.6	420.0	-132.2	-695.4
4. NPV (12%)	5,088.3						
5. Benefit-Cost Ratio	1.399						

APPENDIX 6

Table F. Financial Analysis for *Tephrosia Candida* Hedgerow Treatment of Cassava Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of cassava product	4,162.8	4,096.8	5,645.2	6,120.0	4,845.2	4,488.8	4,528.8
- Return from hedgerow	0	30.0	0	0	65.0	0	55.0
2. Cost							
- Material cost of cassava production	494.0	520.0	614.0	728.0	838.0	939.0	929.0
- Labour cost of cassava production	1,315.0	1,560.0	2,072.0	2,385.0	2,580.0	2,620.0	2,620.0
- Material cost of soil conservation	35.0	0	50.0	0	0	70.0	0
- Labour cost of soil conservation	85.0	42.0	160.0	72.0	80.0	150.0	70.0
3. Net benefit	2,233.8	2,004.8	2,749.2	2,935.0	1,412.2	709.8	964.8
4. NPV (12%)	9,012.1						
5. Benefit-Cost Ratio	1.69						

APPENDIX 7

Table G. Financial Analysis for Tea Hedgerow Treatment of Cassava Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of cassava product	4,111.8	4,060.8	5,154.0	6,253.6	4,508.0	4,569.6	4,494.8
- Return from hedgerow	0	0	198.0	165.0	360.0	600.0	480.0
2. Cost							
- Material cost of cassava production	494.0	520.0	614.0	728.0	838.0	939.0	929.0
- Labour cost of cassava production	1,315.0	1,560.0	2,072.0	2,385.0	2,580.0	2,620.0	2,620.0
- Material cost of soil conservation	120.0	15.0	18.0	21.0	26.0	28.0	28.0
- Labour cost of soil conservation	250.0	42.0	120.0	105.0	120.0	120.0	120.0
3. Net benefit	1,932.8	1,923.8	2,528.0	3,179.6	1,304.0	1,462.6	1,277.8
4. NPV (12%)	9,138.0						
5. Benefit-Cost Ratio	1.697						

APPENDIX 8

Table H. Financial Analysis for Tea and Grass Hedgerow Treatment of Cassava Production

Unit: VND thousand

Cost and benefit	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
1. Benefit							
- Gross value of cassava product	4,141.8	4,087.5	5,340.4	6,293.7	4,543.6	4,435.6	4,502.0
- Return from hedgerow	0	0	120.0	165.0	240.0	315.0	280.0
2. Cost							
- Material cost of cassava production	494.0	520.0	614.0	728.0	838.0	939.0	929.0
- Labour cost of cassava production	1,315.0	1,560.0	2,072.0	2,506.6	2,580.0	2,620.0	2,520.0
- Material cost of soil conservation	150.0	15.0	18.0	41.0	26.0	28.0	58.0
- Labour cost of soil conservation	250.0	42.0	120.0	105.0	120.0	120.0	120.0
3. Net benefit	1,932.8	1,950.0	2,636.4	3,078.7	1,219.6	1,043.6	1,055.0
4. NPV (12%)	8,811.2						
5. Benefit-Cost Ratio	1.656						