Ministry of Education and Training   Ministry of Agriculture and Rural Development

FORESTRY UNIVERSITY OF VIETNAM

Nguyen Van Chung

Title of the research topic

" Research in economic and environmental impacts of some agroforestry models in the northern mountainous regions of Vietnam"

Master Thesis in Forestry

Granted by SIDA/SEANAFE

Speciality: **Management of forest resources**

Code: **60 62 68**

Scientific supervisor: Dr. Le Quoc Doanh

Ha Noi, 2009

CONTENTS

LIST OF TABLE

INTRODUCTION

1. Rational

Sloping lands occupy 3/4 of the total 32.929 million hectares of Vietnamese natural inland territory. These are diverse ecosystems, rich in potential but also very vulnerable. The use of sloping land is facing a series of obstacles such as soil erosion, surface run-off, vertical leakage, lack of soil moisture, acid soil, poor nutrition and low available nutrition. These obstacles are related to the most important factor that is the organic circle including vegetation cover and humus content and soil texture.

Mountainous Vietnam occupies nearly 1/3 of the country's population (> 24 million), of which nearly 9 million are of ethnic minority groups population mostly with lower education level, out of date cultivation habit, poor economy, low livelihood and unsustainable ecosystem caused by human. Most of lands are strongly dissected with steep slopes and cragginess. Because of lack of production lands, the farmer in mountainous areas have to cultivate on the highly sloping lands, even higher than 45 degrees. With such slopes, erosion occures quickly that leads to serious land degradation and lands become bare hills. The desertification is taking place in many localities. Especially, when the population increases faster the pressure on the sloping becomes havier, so the diversity of ecosystems with development potentials will become much more sensitive and vulnerable. By the increasing unsuatainable exploitation and use of sloping lands, the risk of erosion is also increasing, that results in the faster increase of degraded land, reduced crop yield, and degraded environment that cause bad impacts directly and in the long term to the natural resources and human life. It has become a great necessity to pay attention not only to research, testing and transfer good techniques of land use, intensive cultivation, but also to protection and enrichment of the land resources; it means that we have to build and transfer of suitable cultivation models that bring about high economic efficiency, maintaining natural resources and environmental protecting in order to improve the efficiency of land use and increase the production sustainably.

Northern mountainous region with over 90% sloping lands is one of the most difficult areas, 51% of which have high slopes and 38.4% have thin soil layer with less than 50cm depth. Therefore, the introduction of agro-forestry models in practices plays an important role to improve livelihoods for farmers in mountainous areas. Many agro-forestry models have been applied such as Indigofera teyismanii) + tea + Teprosia candida (Phu Tho, Yen Bai), grass + cattle raising + fruit (Son La, Yen Bai), upland rice + cassava + Mangletia glauca (Yen Bai, Tuyen Quang, Ha Giang ...), models of intercropping with peannut, soybean in fruit orcharts in Phu Tho, Yen Bai, etc. The above agro-forestry models have proven to be of effectiveness and sustainability. However, there is still no comprehensive research to evaluate the most potential and appropriate systems to recommend for up scaling. Therefore, I propose to implement a resarch project entitled "***Research on economic efficiency and environmental impacts of some agro-forestry models in the Northern mountainous region***".

2. Objectives

- Evaluate the economic efficiency and environmental impacts of some popular agro-forestry models in the Northern mountainous region of Vietnam.
- Analyze the causes influencing the effectiveness of the models.
- Suggest solutions to improve efficiency and expand the model.

3. Scientific and Practical values

3.1. Scientific values

- From the results of the project to contribute to practical and theoretical basis to develop agro-forestry models in the Northern mountainous region.
- Serve as the scientific basis for orientation to sustainable exploitation, use and protection of natural resources in the mountainous regions.

3.2. Practical values

- Farmers are advised to use measures and models that are economically effecive and environmental friendly.
- Improve income and livelihood of farmers in mountainous regions.

4. Objects and study areas

4.1. Objects

- Objects: popular agro-forestry models in Northern mountainous regions of Vietnam,

- Main crops: Acasia, Eucaliptus, litchi, mango, …

- Intercropping species: fodder grasses, short term crops (Peanuts, Soybean,…)

- Animals: Buffalo, cows, goats, sheeps, chickens…

4.2. Study areas.

- Research will be implemented in:

+ Phu Tho town – Phu Tho province.

+ Van Chan District – Yen Bai province.

+ Hoang Su Phi District – Ha Giang province.

CHAPTER I

LITERATURE REVIEW AND SCIENTIFIC BASIS OF THE PROJECT

1. General information about sloping lands

1.1. Definition of sloping land:

Definition of sloping land: Sloping land is the land with incline surface, rough or wavy. The angle created by the inclining surface and the horizontal surface of the ground is the slope of the land surface.

Based on the status of sloping land, farmers can follow suitable orientations and use suitable measures for cultivation [12].

- Gentle slope: below 15^0 (make terraces, home gardens).

- Medium slope $16\text{-}25^0$ (make terraces, home gardens and forest gardens).

- Strong sloping land $25\text{-}35^0$ (make permanent cultivation fields orforest gardens).

- Strong sloping land $>35^0$ (projection for forest nursing and protection).

1.2. Constraints to enlargement of cultivation on sloping land

+ Soil erosion and land degradation.

The leading research topic in sloping land is that in control of erosion, rehabilitation and improvement of soil fertility, particularly in the degraded areas. In the tropics, due to the characteristics of climate such as annual rainfall and distribution, the nature of land as well as the great pressure of exploitation of sloping land, the soil erosion has become one of factors that impacts strongly on all aspects, need, so the soil erosion need to be paid more attention to.

The level of erosion depends on many factors such as soil structure, the porosity of the surface layer, the length of clope, etc.. especially the vegetation cover. Cropping systems have great impacts on the level of soil erosion and run off. In 1978, W. Wischemeier H. and D. Smith D built a popular formula for calculation of soil loss due to erosion as follows:

$$A = R.\ K.\ L.\ S.\ C.\ P$$

In which: A: The amount of soil loss due to erosion.

R: The coefficient of erosion due to rain.

K: The coefficient of erosion due to soil types.

L: The length of slope.

S: The degree of slope.

C: The coefficient of the coverage of plants.

P: The coefficient of methods of soil protection.

Every year, there is a large amount of eroded soil (25 billion tons) drifting into river, sea and about 5-7 million hectares of land becoming uncultivable (BG Rozanov, 1990) because of the impact of soil erosion. Only in Asia, there are about 440 million hectares of land affected from erosion by rain water, of which 322 million hectares are located in Southeast Asia (LR Oldeman, 1994).

According to Thomas Fairhurst and Erst Mutert (1999), due cultivation habits of highland swellers, as well as due to increasing food demands, a lot of the forest lands have been replaced by upland rice, maize field by slash-and-burn cultivation without soil protection measures. This has gradually been losing the rever head forest resources, reducing penetration ability to keep water by the soil surface, increasing the frequency of flash floods, soil erosion and landslides.

The statistics show that the rivers are transporting a large number of eroded soils (sandy and mud) that sediment at the estuaries and seaports: in China, Hoang Ha river is carrying 1.6 billion m^3 tons of soil to Bengan Bay and the Brahmaputea River in India is carrying 726 million m^3 tonnes, the Indus river is carrying 435 million m^3 tons of soil to the sea (FAO, 1995).

According to FAO (1995), Southeast Asia is considered as the greatest erorion region in the world. In 17 countries in Southeast Asia, Vietnam is one of the 5 countries that have the amount of soil eroded by water from the medium to extremely serious levels). At present, more than 3 billion tons of eroded soils are sedimented along the sea shore regions annually, accelerating the process ecosystems destruction in the coastal areas that are most valuable and diverse in the world (Ernst Muter; Thomas Fairhurst, 1999).

Soil erosion leading to reduction of soil quality through the reduction of pH, organic substances, absorption capacity, bufferring capacity, worsening soil structure, reduction of surface moisture, increasing siltation and phosphorus fixing ability... ... is one of the causes to reduce production capacity and output of crops on slope lands.

Because of the unique climate: hot and humid, more rains, heavy rainfall and rain intensity that leads to strong erosion and run off, causing the loss of clay minerals and the organic matters, reducing the absorption ability of lands that in turn become poor in nutrients. The run off also increases iron and aluminum accumulation, acidification of lands and phosphorus fixing, resulting in higher content of phosphorus in the soil but reducing the available phosphorus (Thai Phien, Nguyen Tu Siem, 1998).

In Viet Nam, the average annual rainfall is from 1500-2500 mm, 80% of which is in rainy season and 61% of which cause surface flow leading to critical erosion over the area of 4.3 million ha (Thai Phien, Nguyen Tu Siem, 1993). The erosion impacts on social-economic situation and environment strongly, reducing the productivity of lands.

Sloping land in Vietnam occupies about 75% of the total natural area and is an important part of national land asset. Slopings are associated with diversity of the forest, industrial plants, fruits and grasslands, food crops, rare medical plants, etc… However, due to many reasons, out of 14.2 million hectares of unused lands, 10.4 million ha are of hills and mountains, accounting for 73% of the total unused land area in the country (Le Thai Bat, 2000).

According to data on the level of land degradation of Asia - Pacific Ocean from FAO (Nguyen Trong Ha, 1996), in Vietnam the rate of land degradation rankes first, occupying 48.9% of the total area of the country and is equal to India.

Through many studies, Thai Phien (1997) showed that the nutrients lost annually due to erosion is equivalent to 100,000 tons of urea, 220,000 tons of Super phosphates, 50,000 tons of potassium fertilizer (K_2SO_4) and about 5 million tons of (farm yard manure – FYM), not accounting the loss of other elements like Ca^{+2}, Mg^{+2} with other micro-elements.

The erosion strongly impacts on the rapid degradation of land. According to calculations of the scientists, in the favorable conditions 30 years is needed to form

2.54 cm surface soil layer (FAO, 1995). It is not simple and easy to recover the surface soil loss, so all cultivation techniques on sloping land related to the erosion prevention, keeping the resource base for long cultivation need to be applied and extended.

According to the statistics of the General Department Hydro-meteorology, in the Central Highlands in 1995, 25 thousand hectares of coffee were killed by drought, thousands of other hectares were affected by the lack of irrigation, the underground water level dropped by more than 10 - 20 m after 10 years.

According to Bui Huy Hien (2003) the erosion risk in 7 ecological regions of the country is very high. Due to traditions, Vietnamese farmers have much experience in paddy rice production, but little experience in cultivation of sloping land.

In the North East Region, the area of sloping land below 15^0 occupies a significant rate 17.7%. In Viet Bac - Hoang Lien Son and the North West, slopes at level I occupy only 4 to 8% of the total hilly and mountainous area, so the risk of soil in the region is high; 2/3 area of the Northeast has become deforested. In the Southcentral coastline 14% of lands are of high erosion and 70% are of very high erosion. The most threated with soil erosion area that is located in the transition from the mountains and hills to coastal plains are being intensively exploited for growing short-term crops. In the Central Highlands, only 7.8% of sloping land below 3^0 is under the low rish of erosion, and the rest is under the high and very high rish of erosion.

Constraints related to soil toxicity: the erosion causes the reduction alkaline metals in the soil and parallel accumulation of aluminum and iron leading to the increase of the soil acidity, that in many cases is also a toxic factor in the soil. Low moisture holding capacity, low percentage of stable soil agregates, low level of alkaline saturation, high rate of phosphorus fixing, fast run off of ions NH_4^+, K, Na, Ca, Mg, Si are general characteristics of soil toxicity on sloping lands. Cultivation of food crops on sloping lands such as cassava, rice reduces the soil fertility seriously. Also, after planting Eucaliptus for 10 years, the soil becomes heavily degraded. This shows the seriousness of the erosion's impacts on the environment ecology when transferring from tropical forest ecosystems to agricultural ecosystems. While erosion in forest lands is diminished to minimum, the soil erosion on sloping fields without erosion prevention measures can reach up to 200 or more than 200 tons/ha/year which significantly reduces the nutrients in the soil.

+ *Drought in dry season*

It's difficult to keep water on sloping land. Therfore, the cultivation depends on the rainfall. In some areas, there is not enough water for people and animals. Drought is one of the main difficulties of sloping lands. It is obvious that the crop will fail if it rains one month later than expected. According to Le Quoc Doanh, Ha Dinh Tuan, Andre Chabanne (2004), drought in the dry season is a result of the loss of forests as well as of the uncontrolled cultivation on sloping lands.

+ *Reduction of forest cover*

Large areas of lands have become bare hills and lands because of decreased forest area, backward cultivation methods. In Asia, once the forest has been destroyed to grow food crops, the soil will become acidic and infected by alang grass (Imperata cylindrica). Then, farmers will fallow this area and continue to destroy forests to open new lands for food crop cultivation.

The loss of forest vegetation cover will badly affect the environment, causing natural calamities such as drought, floods, flash flood in the uplands.

+ ***The status of isolation***

Many localities in mountainous provinces are isolated from developed centers, the infrastructure is extremely poor to allow access to public services. This slows down the process of advanced technology transfer to farmers and causes bad affects to the economic development in the region.

+ *The rate of poverty and low literacy*

Residents living in sloping lands are mainly of ethnic minorities with high poverty rates and lower education level than the average level of the whole country. The application of effective and sustainable cultivation techniques, soil erosion control measures, water resources reservation and higher economic efficiency crops requires certain investments in economy and technology.

All the above are the main constraints in the uplands that require more effective and environment friendly orientation for sustainable economic and social development.

1.3. Potentials of sloping lands

According to FAO, there are about 1,434 million ha of agricultural lands throughout the world (accounting for 10.6% of natural land), in which sloping lands occupy 973 million hectares (about 65.9%) (Hudson, N., 1988) [44]. In total of sloping land, over 10^0 slope lands amounat to 377 million hectares (about 25.5%) (Hudson, N., 1988 [44], Dent, I., 1989 [41]). In Southeast Asian, about 91 million ha (accounting for 21% of total area) is agricultural land, in which 58 million hectares (about 52.8%) are sloping lands (Dierolf Thomas et al, 2001) [55]. According to Dudal (1978) [40], in 20 years from 1957 to 1977, the world-wide agricultural land increased by 150 million ha, equal to 10% of the lands that could be reclaimed for agriculture and 9% of cultivation land at that time. But in 20 years, the world population increased by 40% and food produced from the new area feeds only 1/3 of the increased population. It is clear that the increase in yield and production to meet the food demand of people is a big challenge, especially in the context of curent climate change and the green house effects. If the sea level increases, it is easy to lose large plains in coastal areas.

Therefore, the exploitation and use of natural resources in the uplands is essential. Thought, there are many difficulties and limitations, Le Quoc Doanh, Nguyen Van Bo and Ha Dinh Tuan (2005) [5] showed that there are still large development potentials in sloping land areas, such as:

- *Expanding cultivation area:*

Sloping land is an important part in agricultural production accounting for 973 million ha (66%) out of 1,500 million hectares of agricultural land in the world. In Vietnam, sloping land occupies about 76% of natural land. Out of 9.4 million hectares of agricultural land, only 4.06 million hectares of paddy rice land, and over 5 million ha are of sloping land, of which 640 thousand hectares for rice and the rest are forest land and unused lands. As flat lands have been cultivated very intensively and the agricultural lands are reduced by about 0.4%/year, in which the area of rice cultivation is decreased by about 1%/year (Source: vnMedia.vn, day: 25/05/2007), so the sloping lands areas are the only source for expansion of cultivation areas.

- *Cash crop cultivation and diversified products*

Crop structure in mountainous areas is very diverse. While most of crops cultivated in the lowland are food crops, the mountainous areas have great potential for fruits, high-value industrial plants, specialty and temperate crops/vegetables, etc.

- *Livestock development:*

The farms for livestock development at large scale require space without causing environmental pollution affecting human health. This can be met only in the mountainous areas. This strength is only for the mountains and cannot be be found in the lowlands, expecially in North Vietnam. It is necessary to exploit the potential of lands for development of fodder soecies for animal husbandry in mountainous areas.

- *Forestry development:*

Forests have many extremely precious natural resources for socio-economic, development and play an important role in production and environmental protection: water saving, providing oxigen and climate regulation. In Vietnam, forests only exist in slope land areas and there are great potetials in mountainous areas to develop forestry and directly or indirectly related products.

According to Le Van Khoa, Tran Thi Lanh (1997) [16], sloping lands have a number of strengths such as:

- Large and good (bazan soil, red brown soil on limestone, black soil accumulated at the foot of slope lands, ...).

- Cool climate and humidity, allowing temperate crop cultivation,

- Mountainous farmers have much cultivation experience on sloping lands,

- Less wind storm, less spread of disease, plentiful organic source.

In summary, although there are many difficulties/obstacles, there are also many potentials for development in mountainous areas. There are many advantages that do not exist in the lowlands such as large land area, bio-diversity, potential for commercial goods' development, cool and humid climate... Therefore, it is necessary to promote the agricultural production to meet nutritional needs of farmers, while protecting the environment for existence and long-term development of the nation.

2. Overview on status of agro-forestry research and development

2.1. Situation of research in the world

Cultivation of timber sopecies with agricultural crops in the same area has been a long-term habit of farmers in many places in the world. According to King (1987), the habit of "*slash and burn - SAB*" was very polpular in Europe in medieval ages and then growing timber trees with agricultural crops or after harvesting the last. This farming system still existed in Finland until the end of the 19th century and still in some areas of Germany up to to 1920s. In Asia, China is considered as one of the *"cradles"* of Oriental agriculture. When looking at the beginning of agriculture, it is realized that cultivation of timber trees with agricultural crops has existed a long time ago. In the Han dynasty (from 206 BC. to 220 AC.), the development of timber trees with livestock and agricultural cultivation were encouraged (Zhu Zhaohua, and Fu Maoyi C.B. Sastry, 2001). Chinese ancient history has recorded and described details of intercropping techniques. In the late Minh dynasty, a famous book "Nongzheng Quanshu" (A completed debate on agricultural cultivation) writen by Kunangchhi Hsu (1640) described a kind of cultivation of soyabean and *Castanopsis* sp. and both grew well (the first had straight trunk and soyabean had high yield).

In American tropical regions, during cultivation period, farmers imitated conditions of forests in order to create the beneficial influence of forest ecology. They grew coconut as the tallest level plants, then orange and mandarine as the lower tall level and then coffee or cacao; the seasonal short-term plants intercropped were maize, peanut ... and creeping crops such as pumpkin ... This is a system combining many species, each level has its own structure; the appearance of the second level crops looks like a mixed tropical forest.

Shifting cultivation is considered as the oldest cultivation method. The Hunnunoo in Philipin are experiened in using it. In areas of destroyed forest for agricultural cultivation, they considered carefully to leave certain trees which protect the soil and crops from extreme sun shine. Woody trees are an important component of Hunnunoo cultivation system and they can be planted or left from old forest, and also supply wood for construction or heating (Conklin, 1957). These cultivaion systems are very popular in Asian tropical regions. In Western Nigeria of Africa, people plant potato, corn and soybean (Forde, 1937). In Western Nigeria, the Yoruba used mixed systems of herbal plants, bushy plants and woody plants. It is said that their system is a means of conserving human energy by using the maximum available space, protecting soil fertility as well as anti-erosion and prevent the soil from degradation (Ojo, 1966).

Following shifting cultivation systems is the Taungya system. Its origin is associated with a local word of Myanmar which means mountainous cultivation. The formation of the Taungya system in the tropics is seen as a sign for later agro-forestry methods (Nair, PKR, 1987). In 1806, when Myanmar was a part of India, colony of

Britain, Mr. U. Pankle let people to plant Teak forests and food crops while the forest canopy was not full to meet the annual food demands. This method is called Taungya, then he transferred this technique to Dictrich Brandis - the UK governor in India. Since then, the technique has become popular and widely applied in India and South Africa. According to Vonhesmer (1966 and 1970) and King (1979) most of people in the tropics started their cultivation with this method. Taungya is said to be the start of the transition from shifting cultivation to agro-forestry cultivation, and the Taungya has been developed into current diversity agro-forestry methods.

So what is agro-forestry? There are many definitions such as: Benn (1977), King and Chandler (1978), PCARD (1979), Lundgreen (1983) ... But the current definition of Lundgreen and Raintree (1983) is considered complete and recognized widely. According to this definition: "*Agro-forestry is the a collective name for land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agro-forestry systems there are both ecological and economical interactions between different components).* From the above definition, some features of the system can be drawn as following:

- Including two or more than two species (may be both trees and animals) one of them must be perennial.

- At least two or more products from the system.

- Production cycle is usually longer than one year.

- More diversity in ecology and economy than monoculture.

- Requires a compatible relationship between perennials and other components.

In the process of agro-forestry formation and development, one recognizes that agro-forestry plays important role in resolving the problems of food, reduction of the declining of forest resources, protection and improvement of soil fertility. That was why since early meetings in 1967 and 1969, FAO has paid attention to this issue and come up with the accord that "Applying agro-forestry methods is the best way to use tropical forest land reasonably to solve the food problems and jobs for excess labour and also reestablish the ecological balance of environment".

In 5th May 1990, an International Conference on Agro-forestry in Asia and the Pacific was held in Bangkok (Thailand) with 12 member countries including Vietnam. The conference put foreward a number of reasons why one should expand and develop agro-forestry models in the region. One of them is that the Asia and the Pacific account for 69% of the population in the world, while having only 28% of the world agricultural lands. Due to the conflict between population pressure and land, about 2 million hectares of forests are being destroyed annually.

In front of the policy to expand and develop agro-forestry in all countries in the world, each country has its own forms and ways to develop agroforestry with definite differences to suit their natural and eco-society conditions in each country.

Thailand has developed agro-forestry method to hold water, maintain moisture, improve the ecological environment, improve the living standards of people. The successful models in maize farms + pineapple creating several levels of mixed forests including forest trees + legumes + corn + pineapple ... Thailand has studied more than 20 intercropping agricultural species in the forests and the most popular one is the forest with bands of fruit trees and crops: peanut, beans, litchi, mango, coffee, black pepper, etc.

The agro-forestry method in India is very famous for their "green revolution". Thanks to the revolution’s results, India as a country with big population country can produce not only enough food to overcome hungry but also have excess rice for export. In India, coconut is one of the most popular species. It plays an important role in the economy, especially in Kerala State where coconut accounts for 70% of area and coconut products in India. Cocoa is a very successful intercropping species with coconut, especially where irrigation is easily available. Coffee is grown in high elevation places and often combined with pepper, jack fruit and other fruits, and a typical food crop grown in family gardens is cassava.

Alley Cropping is an agro-forestry cultivation technique in which fast growing nitrogen fixing legumes are grown in hedge rows with agricultural crops grown in between the two hedgerows. This technique was studied in Ibanda International Tropical Agricultural Institute (Wilson and Kang, 1980). This cultivation provides wood, feed for animals and green manure source to enhance soil fertility and crop productivity. This technique is suitable for cultivation on sloping lands because of its capacity to control soil erosion and run off. In addition, the root systems of the legumes fix the nitrigen in the soil leading to the increase in soil fertility.

In many agro-forestry models built in countries around the world, the system of Sloping Agricultural Land Technology (SALT) in order to use sustainably sloping land has been completed and developed by Bapstit Mandanao Rural Life Center of the Philippines since the mid 1970s. There are 4 recognized systems of Sloping Agicultural Land Technology since 1992:

- Model SALT 1 (Sloping Agricultural Land Technology): This is a comprehensive model based on measures of soil protection for food production. SALT 1 comprises of 25% of forest trees + 25% of perennial plants + and 50% of annual crops.

- Model SALT 2 (Simple Agro - Livestock Technology): This technique is based on SALT1 with a part of lands set aside for planting fodder grasses for livestock. Design the cultivation area for SALT2 is as the following: 40% for agricultural production + 20% for forest +20% for grasses + 20% for building animal stalls.

- Model SALT 3 (Sustainable Agro - Forest Land Technology). This technique is based on the combination between small scale forest production and food production. In model SALT3 farmers spend the low parts of lands at the foot of slopes for planting food crops in between hedgerows made of nitrogen fixing legumes. In the higher parts of lands up to the top, they grow forest trees or let the forest to regenerate naturally. The structure of land use is as follows: 40% for agriculture + 60% for forestry. This model requires high investment in labour sources and capital as well as suitable knowledge.

- Salt Model 4 (Small Agro-fruit Livelihood Technology): This is a model of small fruit livelihood agro-technology and structure of land use is: 60% of forestry + 15% of agricultural crops + and 25% of fruits. This model requires high investment of capital, human and cultivation techniques.

2.2. Situation of in-country research and development

The land use by agro-forestry method has been formed a long time ago with different forms. Applied models changed from easy to complex depending on local customs and habits. It is difficult to determine accurately the point when the agro-forestry system was formed. However, it is commonly recognized that agroforestry formation and development is associated with the development of agriculture & forestry sciences and human awareness of land use and economic needs. At the beginning, shifting cultivation is considered as the oldest method; then technology revolution in livestock, crop cultivation, and after shifting cultivation, the appearance and existence of Taungya systems (cultivation in the mountains) in the tropics is a signal for the development of agro-forestry systems in the future.

In Vietnam, agro-forestry cultivation methods have been applied a long time ago, such as traditional farming systems of ethnic minorities, garden ecosystem in many ecological regions of the country. Consider the technical aspects of AF models and techniques, Vietnamese models have been developed consistently. Since the 1960s, the models of garden-fish pond- animal stall (VAC) were developed and spreaded throughout the country with many different improvements to suit different ecological regions. Then the system of forest-garden-fish pond-animal stall (RVAC) and hilly garden developed strongly in mountainous areas.

With the research program in agro-forestry (1981- 1985), it was the first time in Vietnam that the study in AF was reviewed and implemented on the scientific basis ensuring the consistency in terms of theoretical, practical aspects based on natural and socio-economic conditions. Agro-forestry is considered as a production project mainly focused on the development of social forestry models in the whole country, such as:

According to Nguyen Xuan Dau (1986), agro-forestry cultivation structure and method in the Northern mountainous area, cultivation models on sloping land such as forest crops and tea often give high economic effectiveness.

Besides the efforts of Vietnam itself, other international organizations such as FAO has helped Vietnam build agro-forestry program (1987 - 1989) implemented in the coastal sandy region. Especially since 1991, the Vietnam-Sweden program has studied the problems of land use and development of farming systems in the North and South Vietnam. The research project led by Vuong Van Quynh (1994) delt with some measures to protect land and develop good methods of cultivation in Yen Phu Commune - Ham Yen District - Tuyen Quang Province. In September 1992, thanks to the support of the Organizations of Agriculture, Forestry and Timber/Wood in Asia and the Pacific (Project GCT/RAS - 131-NET), a national workshop on agro-forestry in the mountainous area of Vietnam was held at the Vietnam Forestry University. One of the main workshop's contents was to deal with agro-forestry models in ecological economic areas of North West, North East, coastal and Central Highlands. In addition, the workshop also discussed some issues related to agro-forestry.

Since 1996, Vietnam and Finland cooperated to develop agro-forestry systems in Cho Don District of Bac Kan Province. Many models have been constructed in the region and highly appreciated by experts. Information, knowledge of agro-forestry have been summazied under different view points by a number of scientists. Typically, the publication of Le Trong Cuc and colleagues (1990) on review and analysis of agricultural ecosystems in the Northern mountainous areas based on ecological and human culture approach. Some typical agro-forestry systems have been summarized by FAO and IIRR (1995) and described in publications of Agricultural Extension Department under models of sustainable land use. Mittelman (1997) had a very good study on the status of agro-forestry and social-forestry in Vietnam, especially the policy factors affecting the development of agro-forestry

International Center for Research in Agro-forestry (ICRAF) supported with a project entitled "Agro-forestry Capacity Building in Vietnam". This project was implemented from 1998 to 2003. Dr. Le Quoc Doanh, Deputy Director General of Vietnam Agricultural Science Institute (VASI) was the country coordinator of the project. The *Project objectives were:*

- Create linkage between Vietnam and ICRAF's programs in the South-East Asia to support the development of alternatives to slash-and-burn;
- Enhance capacity for Vietnam in research and agro-forestry education;
- Help Vietnam develop and enlarge systems to replace slash-and-burn systems.

The main project activities:

Project created a nationwide network with some 10 members such as Vietnam Agricultural Science Institute (VASI) (the nodal institution), Hanoi Agricultural University, Thai Nguyen Agro-forestry University, Forestry Science Institute of Vietnam, Vietnam Forestry University - Xuan Mai, Hue Agro-Forestry University, Tay Nguyen University, Ho Chi Minh Agro-forestry University - Thu Duc.

Beside organizing training courses for trainers (TOT), the project recommended many successful agro-forestry models such as integration of livestock in agricultural cultivation, forestry planting and agro-forestry systems.

Vietnamese Network for Agro-forestry Education (VNAFE) was established in 2002. It is a national network belonging to Southeast Asian Network for Agro-forestry Education (SEANAFE) coordinated by ICRAF. The objective of the network is to enhance the education capacity in management of natural resources and agro-forestry in Vietnam in particular and Southeast Asia in general. The greatest success of the network is the establishment of close relationship among partners and strengthening the training capacity of the network members. In addition to the development of agro-forestry curriculum, the network also makes a number of important researchs such as "agro-forestry landscape", "Marketing for agro-forestry products", "Environmental policies", etc.

Vietnam Agricultural Science Institute cooperated with the Center for International Cooperation in Agricultural Research for Development (CIRAD) to implement the project "Agricultural Systems in Northern Mountainous Regions of Vietnam" (SAM project). This was a project specially studying ecological agriculture, focusing mainly on research and recommended sustainable cultivation techniques on sloping lands. It recommended direct sowing mulch-based cultivation systems (DMC) both for increasing land productivity and preventing soil erosion, keeping soil moisture, increasing soil fertility for long term cultivation, toward reducing and stopping slash-and-burn shifting cultivation.

According to a report of professor Hoang Hoe at the Asia-Pacific Agro-forestry Conferrence in 1990, the Vietnamese AF systems include:

* Shifting cultivation:

- The Gia Rai and E De people in the Central Highland slash and burn the vegetation covers where soil is rich in fertility. After 1-2 years cultivation they move to another places and then return to the fallow plots to produce food crop after 10-15 years.

- The Muong people in Hoa Binh and Thanh Hoa are used to clear the forest then they sow the seeds of Chinese berry (*Melia azedarach*), then they burn the cleared vegetal layers to stimulate the germination of the seeds, then grow rice. After 3 crops, the Chinese berry grow well, farmers do not cultivate rice but bamboo. After 10 years they return to exploit Chinese berry, bamboo and start a new cultivation cycle.

- The Dao people in Thanh Hoa, Lao Cai, Yen Bai .... are used to cultivate upland rice, cassava and cinnamon in the first 3 years. Rice and cassava not only meet the demand for food, but also protect the land when the cinnamon canopy has not been full.

* Agro-forestry models in the plain: Farmers plant a number of forest bands for protection of their fields from storms, while supplying significant amount of wood for the local consumption. VAC economic model plays important role in improving and gradually increasing the standards of living for each family and is the complete non-waste cycle of the production process & products consumption, making most use of idle labor and agricultural by-products... This has been a popular model in our country in the last few recent decades and thanks to the encouraging policies of the Party and the Government it has been developing in large scale. VAC model also shows clearly the agro-forestry characteristics in the mountains through the relationship between the development of forest - livestock - fish pond models. That relationship through the 3 components of the same system improves its own productivity and stability.

* Agro-forestry models on sloping lands: Models of intercropping of agricultural crops and forest trees in the early stages of forests. These models are very common throughout mountainous provinces.

Farmers grow maize, potatoes, beans, peanut in the young forests. These models help the forest increase effectiveness and protect the land resources. The forests are protected carefully through the care and protection of agricultural crops. Farmers also increase their income through agricultural products annually. Models of upland rice, cassava with *Mangletia glauca, Styrax tonkinensis* in Tuyen Quang, Yen Bai, Phu Tho; models of peanut, beans, cassava with Eucaliptus in Vinh Phu, Ha Tay; The agro-forestry models of forest and industrial trees are very popular in the central and the highlands. In these models, forest trees act as shadow trees, break the wind, protecting and improving the grow conditions for long-term industrial plants. Thanks to intercropped forest trees, industrial plants grow better, their productivity is increased, and ecological environment is improved. Forest trees also provide a source of wood, fuel, fruits, food, medicine ... Some popular models in Phu Tho, Thai Nguyen are *Indigofera teysmanii* + tea + *Tephrosia candida*. Farmers also plant fruits with industrial trees and annual crops like litchi, tea, mango, bean, peanut with orange, mandarine, pomelo ...

According to Vu Van Me - Forestry Science Institute of Vietnam - summarized that there are many models in the North West such as models of forest trees + pasture lands + cows raising + fruits. AF Model in Moc Chau is composed of forest + crop field + upland rice + jujuba in Na Kan Village - Chieng Sinh Commune - Son La Province...

* Forestry-Aquiculture method in the salt-marsh: This model is common in the coastal areas, estuaries where there are natural salt-marsh or planted forests combined with shrimp and fish or honey-bee raising. Timber trees in the salty-marsh play a protective role, both provide wood, fuel and provide a source of feed for fish and shrimp.

* Forestry-Aquiculture method in the alkaline lands: this model is concentrated in the South in the areas contiguous to mangroves. During 6 rainy months, people can raise fish, shrimp under cajuput forest and bee raising. They also plant Eucaliptus + cashiew nut + pineapple and other fruits in free spaces.

In summary, agro-forestry production has been existing since a long time ago and its role is more and more important in the current social-economic conditions especially in the context of climate change. To be in the line of international development, Vietnam has made important steps in AF research and development. Many agro-forestry models have been recommended to use, however, it is necessary to research and evaluate them for identification and recommendation of the most potential models for production.

CHAPTER II

RESEARCH MATERIALS, CONTENTS AND METHODS

2.1. Materials

Study objects are popular agro-forestry models in Northern mountainous area of Vietnam with following plants:

- Main plants: Acasia, Mangletia glauca, pomelo, mango…

- Intercrops: Cassava, Guatemala grass, Guine grass *(P. maximum)*, *arachis pintoi…*

- Other grasses and animals: Chicken, pick, buffalos, beef, goat...

2.2. Study contents

- Investigate natural, economic and social conditions in the study areas.

- Study biological characteristics of crops in the models.

- Estimate economic effect of the models.

- Evaluate environmental impacts.

+ Estimate the capacity of soil protection, effective usage and sustainable model.

+ Estimate competence of keeping soil moisture, water resources protection and the relationship between model and water stability (drinking water and water for irrigation).

+ Capacity to prevent environment from pollution (soil, water, atmosphere…)

- Evaluate the comprehensive effects of the models.

- Propose solutions to increase the effects of the models.

2.3. Study methods

2.3.1. Collect and document information

- Collect from domestic and overseas documents.

- Collect through management and professional offices,

- Previous researches in agro-forestry

- Investigate by question sheets and interview: Investigate and interview related households, 10 household/study area.

2.3.2. Investigation of standard plots

- Identify soil holding capacity

Method 1: Digging trenches for harvesting eroded soil from the certain plot area of some agro-forestry models and compare with that amount from the same plot area but without AF models (the dimensions are 80 cm wide x 80 em deep x 50 cm wide at the bottom. The amount of eroded soil after rains is trapped in the trench. In the period of the experiments, this amount is harvested and dried up and weighted. When the weight become constant (not changing), that weight is the value of soil loss due to erosion.

Method 2: Set 3 standard plots with the area of $4m^2$ in each model and in the places without the models. Then put erosion sticks in such a way that the uppper end of the cticks be at the same level of soil surface (5 sticks in 5 representative positions per plot). After a rain, more or less amount of soil will be eroded, the upper parts of the sticks go out of the ground surface with certain length. At the end of the rainy season, the upper parts of the sticks exposed above the soil surface are measured, then take the average height values and multiply by the plot area and bulk density to estimate the amount of the soil loss.

2.3.3. Analysis of different parameters

- Economic efficiency

We determine the input costs and income of each year through collected data, then calculate the total cost and income until the time of investigation. The profit is calculated by formula:

$LN = \sum Bt - \sum Ct$

Where:

LN: Benefit from model

$\sum Bt$: Income from model

$\sum Ct$: Input for model

- Social effect

- Job creation: This is expressed through the number of working days in each model per year. Those models that require great number of working days for both permanent and seasonal workers are more efficient in this aspect.

Table for recording job creation ability

No	Total number of labor days	Number of ussual workers	Number of seasonal workers

- Soil conservation ability: Determining the amount of soil loss using the following formula:

$$D = \frac{P}{S} . 10.000$$

Where:

D : Amount of soil loss in a model (ton/ha).

P : Amount of eroded soil from an experimental plot (kg).

S : Area of the experimental plot (m^2).

Table for recording eroded soil loss

No	Model	Amount of soil loss (Ton/ha)	Compared to control	
			Ton/ha	%
1	Control plot			
2				

- Soil moisture conservation ability: Determining soil moisture content:

Relative moisture content is the % rate between the amount of water in soil and the weight of fresh soil sample.

$$A\% = \frac{(W_1 + W_2) - W_3}{W_2} .100$$

where:

W_1 : Weight of aluminum box (g).

W_2 : Weight of fresh soil before drying (g)

W_3 : Weight of aluminum box and dried soil after drying(g).

Results are included into the following table:

Table for soil moisture maintain capacity by different models

No	Model	Soil moisture	
		%	% compared to C
1	Control		
2			

- Overall effectiveness.

Investigation and interviews of households about their income, costs, strengths and weaknesses of each model, comparing different models help to select the best one in all three economic, social and ecological aspects.

2.3.4. Data analysis.

- All data were analysed by MS Excel

CHAPTER III

RESULTS AND DISCUSSIONS

3.1. Natural, social-economic conditions in the Northern mountainous region

3.1.1. General characteristics:

The Northern mountainous region includes 15 provinces with the area of nearly 102 thousand km^2 and 11.6 million people belonging to more than 30 ethnic minorities, 84% of which are living in rural areas. There are 1.8 million households participating in agriculture and forestry production and aquaculture, exploiting and using about 1.35 million ha of agricultural land (accounting for 13.4% of natural area)

- The region is classified into 3 sub-ecological regions as follows:

+ The North West sub-region: including Hoa Binh, Son La, Lai Chau and Dien Bien provinces.

+ The Central sub-region of North VN (Viet Bac – Hoang Lien Son): including Ha Giang, Lao Cai, Yen Bai, Tuyen Quang and Phu Tho provinces.

+ The North East Sub-region: including Cao Bang, Lang Son, Bac Kan, Thai Nguyen, Quang Ninh and Bac Giang provinces.

3.1.2. Natural features and relationship with production agriculture-forestry.

3.1.2.1. Location

The Northern mountainous provinces are located in 3 eco-forestry regions: North West, Northern Center and the North East, with geographic coordinates as follows:

From $20^o57'44"$ to $23^o23'12"$ North,

From $102^o08'30"$ to $108^o04'06"$ East.

Administrative border is as follows:

- The North borders with China.
- The West borders with Laos.
- The Eastern and Southeast is adjacent to South Sea.
- The Southwest borders with Cambodia.

3.1.2.2. Topographical features.

General features of the area are complicated, strongly dissected with high mountains, river systems with valleys and plateaux.

Topographical features of each sub-area are as follow:

- The North West: This is large area with hills and mountains, complicated terrain which are dissected with many high mountains and valleys.

- The Northern Center (Viet Bac - Hoang Lien Son): This is an area of mountains and highlands dissected by valleys, large rivers running along the length of cracks and brocken areas formed through out the land formation process.

- North East Sub-region: main features are hills, mountains, low highlands and wide valleys.

- Topographical features of the whole region:

+ In general, the terrains are hilly and mountainous with high slope, strongly dissected, limited development of infrastructure systems (transport, electricity, information access, communication, etc....) as well as organization of economic and production activities.

+ Some areas are of wide and flat pleataux, valleys where can agricultural production systems be developed at concentrated scale with diverse structures.

+ In 3 sub-region, the North East region has the highest rate of valley and flat land (8.14% natural area), the respective ratios of the Central and North West are 2.06% and 1.28%. These topographical features show that the region has great potential for agro-forestry development but there is a need to wisely exploit and use of natural resources and develop sustainable agriculture and forestry on sloping lands with attention to adaption to ecological characteristics of the region like high terrain, problem soils and limestone mountains.

3.1.2.3. Soil characteristics

- Soil characteristics of the Northern mountainous region:

+ In 3 ecological agricultural sub-regions in the Northern mountainous region, the North West has the largest ratio of sloping land (94.41%), followed by the Northern Center (87.15%) and the North East (the lowest) (81.88%). Concerning steep sloping land group of over 25^0 slopes, the highest ratio is also in the North East (87.45%), in the Northern Center (80.70%), the North East (68.77%). High ratio of steep slope land is a great limiting factor for agriculture and living standard development for local residents.

+ Flat lands are concentrated only in valleys, sedimented lands and swampy lands, … Flat lands occpy only a small part in the region. So, the agriculture on sloping lands is still palying a very important role, hence being very popular at large scales.

+ Land features of of the region show that the most favourable group and soil for the development of agricultural production is the group of alluvium, valley, erode gray soils, red brown soil on neutral macma bazal, limestone, and red yellow soil develpoed on clay basis. Based on the appropriate standards, lands for agricultural production only account for about 10% of the region's area (appropriately 1 million hectares).

3.1.2.4. Climatic features.

The Northern mountainous regions is influenced by the tropical monsoon climate with cold, dry winter and hot, humid summer. However, due to the terrain differentiation in terms of altitude,… and the formation of the closed valleys etc., there are abundant micro-climatic niches in the regions. General climate characteristics by agro-ecological sub-region are as following:

- The climate is affected by the terrain and differentiation in altitude: the temperature basis in winter is gradually increased from the North East to North West. The change depends on elevation rather than on latitude. It can be said that the differentiation of the tempareture base has created a diversity of the climatic conditions in the region, in general, as well as in each sub-region, in particular. At the height of 300 - 900m, 900 - 1.700m and over 1.700m, the different tempareture levels makes niches of cool tropical, sub-tropical and temperate climatic niches. This is an advantage of climate resources, allowing the region develop diversity of agro-forestry products originated tropical, sub-tropical and temperate conditions. This is an important factor contributing to improve the competitiveness of the region's agricultural products.

- The region's humidity meets basic requirements for short-term crops through 6 months of rainfed and dry period. Lack of water in dry season, especially in limestone mountains always requires proactive and effective solutions to improve production and living standards of the people.

- The low temperature is a disadvantage for crop's productivity (especially for tropical crops) and the capacity to increase crop season for short-term plans in many areas in the region, especially at the elevation of higher than 900m. In addition, a number of disadvantage factors such as hoarfrost, whirlwind, tornado, storm, hail, hot-dry wind, heavy rain ... also requires suitable production systems in order to minimize the harm and protect ecological environment.

3.1.2.5. Hydrographic features and water resources.

Assessment on water resources of the region:

- Although the surface water sources are quite rich, the exploitation for use in agricultural production is limited because most of river systems are distributed in the high section, high slope, strong flow and water surface is lower than cultivation fields; this makes lot of difficulties in water use for production. On the other hand, as the low cover forest makes the flows of rivers increase that causes floods, land slides, while in dry season the flow is much lower and in many small rivers and streams (accounting for more than 90% of river systems in the region) the water resources are almost exhausted. These factors have impacted significantly to the production, people living standard, particularly in upland areas.

- Farmers have not exploited underground water for production because the underground water is distributed too deeply, especially in the rocky mountain areas.

- In general, the water resources of the region is appropriate for dry land crops, especially for perennial crops. However, there is a great need to improve production efficiency in the irrigated areas by sustainable intensification of land use.

3.1.2.6. Evaluation of natural factor impacts, from geographical - ecological point of view, on agro-forestry production systems in the Northern mountainous region

- Advantages and disadvantages of geographical & ecological conditions.

- The characteristics of geographical & ecological conditions in the Northern mountainous have created typical advantages and disadvantages that are quite basic to the development of systems of agricultural production in the region.

+ Ability to develop the most diversified agro-forestry products as compared with other ecological regions in the country.

+ There are conditions to form agro-forestry production areas focused on commercial production at large scale.

+ There are rich and uniques structures of agro-forestry products, specialities, that is the basis to create attractive and highly competitive trademarks in the market for both immediate and long terms.

- Limitations and challenges of geo - ecological conditions:

1 / Limited by the complexity of the terrain:

- The differentiation of the terrain in the elevation is considered as the most complicated in the region which governed by the factors: strong dissection, difficult access and steep slopes. The complexity of the terrain makes the agricultural production system in the region influenced and limited.

- Dissected topography by the craggy mountain systems limits the conversion process of the production in the region, particularly in rural areas.

- High terrain slopes limit to the ability to exploit land for agricultural production, particularly to apply advanced intensive cultivation systems: nearly 80% of land in the area located on the 25^{O} slopes and the rate of flat land is only about 3.6%. Beside steep slopes, there are significant areas of rocky mountains which are almost unable to be exploited for agricultural and forestry production in the region. Stone mountain areas without forest is accounting for nearly over 431 thousand ha (4.3% of the region's total natural area). The provinces with large area of rocky mountain are Cao Bang (21%), Ha Giang (8%), Lang Son (6%) and Son La (5%).

2 / Climate and water factors

- There is a period of drought because of the extreme and seasonal rainfall distribution. So most of cultivation area, especially in the mountainous regions, the short-term crop farming systems are mainly based on the rain water in the rainy season. This factor limits the capacity of increasing the number of cropping seasons, expansion of cultivation area and increasing production, especially with long duration crops. This constraint is clearly expressed through the fact that about 76% of annual crop area is planted with dry land crops or with only one crop season.

- The long period of drought not only limits the cultivation activities, but also limits to the development of animal husbandry due to the lack of green feed and drinking water for animals.

- The lower temperature by high terrain of the mountainous areas is an advantage to the temperate crops, but minimises the accumulated temperature needed for growth requirements of short-term crops.

- A number of climate factors such as hoarfrost, hot-dry wind, hail, flood ... are disadvantages that harm agricultural production in the region. Some coffee crops, fruits, vegetables ... were lost due to hoarfrost and hail. These climate disadvantages require careful consideration in production organization.

3.1.3. Evaluation of social-economic factors.

3.1.3.1. Positive factors favorable influencing the effective and sustainable evelopment of agriculture-forestry production in the region.

- Northern mountainous region is famous for its multi-minorities with rich traditions, cultures and production experience. Most communities have attached to the agro-ecological conditions for along time. In local production systems, there are many advanced, adapted cultivation experience and practices between people and natural conditions.

- Cultivation habits of H'Mong group are associated with the residence characteristics in high altitude, where shifting cultivation, burning forests for farming are prevalent. However, many of them have setled with permanent cultivation production systems. Typically in Sa Pa (Lao Cai), Phong Tho (Lai Chau), Mu Cang Chai (Yen Bai) ... the H'Mong people have made large areas of upland terraces which are exploited effectively sustainably.

- On the rocky mountains in Ha Giang, the H'Mong have for along time setled with stable life and organized permanent cultivation production systems with creative but also hardworking technical solutions. This can be seen with the system of fields in the rock holes and peaces of terraces made of stone walls in rocky mountains.

- Thus, much local production experience and indigenous knowledge have been screened and accumulated in specific ecological conditions to select the most effective and suitable systems. Therefore, this knowledge system is becoming richer and richer, being preseved sustainably, and constantly added, enhanced through many generations in communities in this very diverse agro-ecological region with a lot of potentials and also difficulties. Access, inheritance and application of the basic local knowledge system contributes actively to the effective and sustainable development of production systems in the region, making most use of the advantage in human and natural resources in the region. The education level in the region has been improved significantly. These are important factors contributing to raising awareness of the ethnic groups about economy, culture and society, creating favorable conditions for the application of new techniques, production methods, improving access to the market. These are positive factors favor the integration both in width and depth between local communities in the region, as well as between the region with the whole country in the socio-economic development process, towards industrialization and modernization of the country. Commercial production development has contributed to creation of driving forces for improving ecenomic and production capacity in the region.

3.1.3.2. Constraints in social and transport conditions influencing agriculture and forestry production systems in the region.

- Most of more developed socio-economic areas are concentrated in low lands or in areas that have relatively favorable conditions of production and good infrastructure such as: along the main roads, dense population, lowland rice fields, flat plateaux, communities with relatively high education level. These areas meet all factors to attract investment for social-economic development. In contrast, in some areas (mainly in the upland and remote rural areas) the infrastructure developes slowly, causing constraints to the flow of agricultural products, limiting the integration of the mountain communities with the general social-economic development in the region and the whole country.
- The limitation in transportation conditions and socio-economic integration also limit the ability to disseminate and adopt advanced technologies to production that leads to slow development of production, low yield and efficiency. With the existence of extensive farming systems, self-sufficient economy are the declines in land, forest, and water resources. The income and living standards of the local people are at low level, and the rate of poverty and hunger is quite high. In order to solve the disparity among areas in the region, it requires comprehensive solutions and development pathways in due time. This is one of the factors that influence long-term socio-economic development in general and market-oriented agricultural development in particular.

3.1.4. General assessment of natural, economic and social factors that have relationship with agro-forestry production systems in the region.

3.1.4.1. Basic advantages:

- Northern midland and mountainous regions are important parts in terms of geographical and economic means for socio-economic development strategy and maintaining social security and defense of the country. The region is the gateway of the North and Northwest, bordering China and Laos, and in the Southest is the economic zone of the Red River Delta. This is a great advantage in terms of social-economic development opportunities for the regions.

- The regions have great potential of natural conditions that are favorable for agriculture and forestry production with diverse products including crops and animals originated in tropical, sub-tropical and teperate zones. This is a great competitive advantage of the region in terms of market oriented product development.

- The regions have favorable potential for development of a integrated economic structure of industry - service - agriculture - forestry with a large system of national and international border gates; systems of main national highway is being upgraded and developed, domestic airports, seaports; hydroelectric potential and richest mineral resource reserves of the country, with beautiful natural scenery and diverse culture, rich history and plentiful labor force which are attracting for tourism and investment.

3.1.4.2. Constraints and challenges

- Sloping, complicated and dissected topography, diasdvantageous features of water resources and climate conditions, especially the extremism of rainfall in the region that causes long period of drought. The land is mainly sloping land that requires large investment for exploitation.

- The social economy base is low compared with other regions in the country and the infrastructure is also poor. The economic structure is unbalanced, still predominantly an agricultural economy. The economy occumulation of the region is not sufficient that limits the ability to develop production, particularly market oriented production. Living economic and spiritual conditions of the majority population are low. People's intelligence level is not high, the labor force is also limited in terms of intensive farming production and many production techniques are backward but still popular.

- Agro-forestry production is being changed positively towards market but some weakness is still existing and facing with challenges of the market requirement, such as low quality, limitations in storage and processing both in scale and technology that leads to the low market competiveness, especially for export markets.

3.2. Research results and discussion about some popular agro-forestry models in the Northern mountainous region

3.2.1. Classification of some agro-forestry models

Go through the survey, investigation interview 30 households in the area of research we conducted an assessment models combine agro - forestry is a broad and highly effective in the area:

- Model 1: Passport Mr. Giang A Sung in Suoi Giang - Van Chan district - Yen Bai province

- Model 2: NOMAFSI - Phu Ho - Phu Tho Town - Phu Tho province.

- Model 3: Passport Mr. Ha Van Dung - in Ban Nhung - district Hoang Su Phi - Ha Giang.

- Model 4: Passport Mr. Nguyen Van Hung - Phu Ho - Phu Tho Town - Phu Tho province.

Table 1. Agro-forestry models in the studied areas

No	Model	Study area
1	*Acacia mangium* Wild + Cassava + livestocks	Yen Bai
2	Pomelo + Mango + Arachis pintoi	Phu Tho
3	Mangletia glauca + Guatemala grass + livestocks	Ha Giang
4	Acacia only (Control)	Phu Tho

3.2.2. Biological characteristics, planting and caring techniques in each model.

3.2.2.1. Model 01: Acacia + Cassava + livestocks

➢ Acacia mangium wild.

- **Biological characteristics**: Light loving, fast growing and very well performing in alluvial deposits, deep occumulated soil at the foots of slopes, moist and fertile. However, it can also grow on thin erosion soil with drought and poor fertility, acidic (pH = 4 - 5) but not very well. It is suitable to tropical humid climate with annual average temperature 29 - 30^{o}C, the average temperature in hottest months 31 - 34^{o}C, the average temperature in coldest months 12 - 16^{o}C, withstanding light frost,and the rainfall of 1.000 4.500mm/year and without long dried season.

- Crops management:

Treatment of vegetal cover: Instead of completely cutting or burning all crops residues, the burning can be done along contour line where planting is to be made and keep vegetal mulch in the rest areas to prevent soil from erosion. Trees should be planted in rows perpendicular to the slopes., .

Land preparation: In places where the slope is lass than 15^0, soil can be prepared in whole area by disk tractors, after that use other tractor to make furrows at 40cm deep, then dig holes with the dimension of 30x30x30cm along the furrows. In places with slope higher than 15^0, it is impossible to make mechanical land preparation, holes could be made by hands with the dimension of 40x40x40cm.

Hole filling up and applying basal fertilizers: For bare lands and hills, whole filling should be made 7-10 days before planting. Wholes should be filled up, firstly by the surface soil rich in humus content, then up to the soil level by the rest soild.

Basal fertilizer application is made mainly of mineral and microbiological fertilizers, the recommended dose is from 100 to 150g/hole or 200-300g microbiological fertilizers per hole. It is possible to apply mixed 50g NPK + 100-150g microbiological fertilizers per hole. Where soil is acidic (pH<4.5) one can apply additional lime powder or termo-phosphate.

Planting density: Intensive tree planting to supply raw woods for fiber and paper industry could be made at 1660 - 2000 plants/ha, but the most appropriate density is 1660 plants/ha at spacing 3mx2m.

Planting season: The best planting time is at the beginning of vegetation seasons. In the Northern provinces, there are two good planting times that are spring-summer (March-May) and autumn (July-August), however the main season is spring-summer.

Trees: When the weather begins with rain and make soil moist, select the shady and fresh days with small rain to plant small trees. Before placing the trees into the holes, it is necessary to break the soil in the hole, thoroughly mix fertilizers and fill up the holes with soil, the dig small holes with 10 cm - 15cm dimension in the centers of the holes, using knife to cut and remove the bags from the pot before planting, place the tree into the holes vertically in such a way that the upper face of the pot is 1 - 2cm lower than the soil surface, use hand to press the soil aroud the plants and use the hoes to earth them up.

- Caring for the planted forests

During 2-3 years after planting, the care for trees should be conducted 2 times per year at the beginning of the rainy season and dry season. The care activities include: replacing dead plants by new ones 15 days after planting, weeding and softening the soil around the trees. In the second year 2, apply fertilizers, clear the vegetation around the trees.

After 3-5 years, the forest canopy will cover all space, the first thining will be made at 6-7 years of age, and the thining intensity is up to 30-50%. As the raw material for paper pulp, the forest can be logged at 9-10 years old.

- Techniques of cassava (*Manihot esculenta)* intensive cultivation

Biological characteristics

- Cassava plant is originated from the tropics, it is well adapted to the wide range of the temperature from 10 - 35^{0}C.

- During its growth and development, the plant requires intensive light to produce high yield.

- Cassava is a drought tolerance crop, but in the process of growth and development it also requires a certain amount of water, especially at the initial period (shoot initiation from cuttings and young plants). In the lack of water, the plant grows and developes poorly.

- Cassava can be grown on many different types of soils, but to achieve high productivity, the soils selected should folowing standards: thick soil layer, soft, rich in nutrients, pH levels: 6-7, with slope of <15^0.

- *Planting techniques:*

Farming season: Spring season: from the end of January to March

Autumn season: from September to October

Preparing soil: Depend on terrain to design plots.

< 4^{0}slope:	Planting with long bands.
5 - 10^0 slope:	Planting as contour rows.
10 - 15^0 slope:	Making terraces and planting cassava.

Plough deeply and harrow carefully, clear weeds, make beds at right dimension and plant cassava at certain density, depending on soil types.

Fertilizer application: For 1 ha cassava: 8-10 tons of farm yard manure + 120-150kg Urea + 200-240 kg phosphate + 100-1120 kg kali clorua.

Density: In flat land: Make beds, planting space 1.2m, x 0.7-0,8m; Ensure the density of 12.500-14.000 plants/ha.

Method: Cassava can be planted by two following methods:

- Put the cuttings at an angle of 15-30^0, cover by soil at about 3⁄4 of the cuttings.
- Put the cuttings vertically, cover with soil at 1⁄3 of the cuttings.

3.2.2.2. Model 2: Pomelo** (Citrus grandis) **+ Mango (Mangiferum indica) + Arachis pintoi

➢ **Pomelo** *(Citrus grandis)*

- Biological characteristics:

Temperature: Pomelo originates in tropical, sub-tropical regions, can be planted in from 40^0 N and 40^0 S, suitable temperature is from 23- 29°C.

Light: Suitable light intensity 10.000- 15.000 lux (equivalent to the light at 8 a.m or 16 p.m).

Water: Pomelo need much water in the period of young plants, blosooming and fruiting, but it is easy to be killed by flooding. Suitable humidity is 70- 80%, rainfall is about 1000- 2000mm/year. It is necessary to be watered in dry season, but the water must not be salty over 3%.

Soil: The soil layer needs to be at least 0, 6m deep, light or medium texture, aerated, well drained, high organic matter >3%, pH from 5, 5- 7, salt content shall not be over 3‰, with ground water table below 0,8m.

- Variety choice

The pomelo varieties can be multiplied by vegetative propagation (grafting, cutting). The selected mother tree must have at least three seasons with stable yield and quality, uniform fruit size and attractive color.

Layering: Suitable age of mother tree for layering is from 16-18 moths. Diameter of the layering branch is 1.5 - 2.0 cm; select medium height of branches with no evident pest damage; do not choose the branches nearby the gound, or on the top of mother trees.

Grafting: grafting eyes should be taken from good variety with vigourous growth; height of grating point is of 30-40 cm from the top.

- Plating season:

Spring: from Feb to Apr, for pomelo. Spring season is most suitable season for planting

- Soil selection and preparation:

For Pomelo

Pomalo is suitable to old alluvial soils, annually added with alluvia, meeting requirements like good drainage, thick soil layer (more than 1m), underground water table lower than 1.5m, good nutrition contents (humus of 1.5 - 2% or higher), enough water for irrigation in dry season.

The fruit garden must be arranged into blocks. The area of each block is about 1.000m^2. Around the block, plant wind break trees like Acacia, Cassia siamea, not plant other citrus species.

About 2 before planting, plough and harrow thw soil properly, clear weeds and roots of other wild species, treat the soil with lime powder (500 kg/ha), Benlate (20 kg/ha), Basudin, Vibasu 10H (15 - 20 kg/ha).

- *Hole digging:*

Hole demension: 0,6m x 0,6m x 0,6m in flat lands; 0,8m x 0,8m x 0,8m in hilly lands. Density: 6m x 5 m, 335 plants/ha.

Planting method: Dig the planting hole with 30 cm x 30 cm at the center of the big hole, remove the plastic bag of the pot at put the plant into the hole, cover and press the soil around the plant, take care not to break down the pot. Also take care to put the plant in such a direction that ease its growth and development. Water th etrees after planting, cover the ground by vegetal materials (leave the mulch 10 cm apart from the plant foot).

Basal application: Amount of fertilizers/hole: FYM 40 - 50 kg, lime powder 1kg, super - phosphate 1kg, Urea 0,1 - 0,15kg, potassium 0,15 - 0,2kg.

- Mango (*Mangiferum indicum*) – Van Du variety

Biological characteristics: Mango is a precious fruit tree of the tropics with originated from India and Myanmar. Mango is suitable to many kinds of soilst: yellow, red, feralits, old alluvial, alluvial soil along rivers..., soil with pH from 5,5 - 7,7. The fruit set is also dependent on climatic conditions at flowering stage: rain, low temperature, high air humidity are constraints reducing germination of pollons and stimulating disease incidence, leading to low yield and quality.

- Planting techniques:

The Van Du variety (a local variety of Phu Tho Province) was planted by grafted rootstocks at the density of 300 - 330 plants/ha, in February and March 2002, (spacing 5m x 6 m, hole dimension 60cm x 60cm x60 cm). The plantlets were treated before planting; fertilizers/hole: 1 kg NPK + 5 kg FYM + 1 kg lime powder. From the year 2, mango started fruiting, but quality fruits and plant development can be obtained from year 3 onward.

- **Pinto arachis (*Arachis pintoi*) – Variety LN99**

- Biological characteristics: A perennial cover crop variety LN99 usually found in the red soil and alluvial sandy areas …, especially in the lowland areas with highly moist soil. Suitable pH is from 4,5 - 7,2; More suitable to fertile and medium soils but can be grown in degraded soils.

Humidity: Suitable rainfall is more than 1500 mm/year; can survive long and dry winter for 4 months; has some tolerance to water lodging, but not for long or frequent flooding. In dry season the plant can survive but grwth is not vigorous.

Temperature: Best grown with the temperature at 22^0C - 28^0C. With frost, branches may die but will regrow from underground parts and seeds.

Light: Can tolerate shading well, grows better under shade than in direct sun light.

- Planting techniques:

+ Land preparation: Make soil soft, level the surface, clear weeds, make furows 30 cm apart, 10 - 15cm deep.

+ Planting method: Put the cuttings in the furrows, the cutting length is about 30 cm, distance between cuttings is 10 - 12 cm, cover with soil, keep watering for 1 week or longer after planting, pay attention to weeding until well established.

3.2.2.3. Model 3: Mangletia glauca + Guatemala grass + livestock

- *Mangletia glauca*

Biological characteristics:

- Suitable temperature 22 - 24^{o}C, highest 42^{o}C, lowest -1^{o}C; annual rainfall 1400 - 2000mm; air relative humidity 80%.

- Distribution: at elevation at 300 - 400m above the sea level, along streams with moist soil, slope of 10^{o}C.

- Suitabel to good soils, deep, moist, well drained, rich in humus (more than 3%), light texture clay.

- Not suitable to bare hill lands, *Imperata* grass lands, compacted hill soils, old and degraded land, laterite soil, water lodged soil, etc.…

- light loving, but prefer weak light when young (1-2 years old), not withstand too intensive light as well as too much shade, grows well in summer and autumn in dispersed light, but in winter nd spring needs more light. From the year 3 requires full light.

Planting techniques:

+ Time: In spring, planted when it is drizling, soil becomes moist, medium rainfall; autumn season, usaully planted at the end of August to the beginning of October; planting during cool days with rain, avoiding hot sunny days or heavy rains.

+ Land preparation:

- Clear the lands, burn all residues if hill is dwaft, slope less than 10^{o}, deep soil, tihck soil layer. However, need to plant cover and shading crops after clearing and burning, Tephrosia is recommended as it has a series of advantages.

- Clear the land along contour bands if the hills or mountains are of steep slopes, especially high mountains with strong soil erosion, and the soil is thin, and high evaporation.

+ Planting methods

- Mangletia trees are planted along the contour bands perpendicular to slopes. The left strips are used for shading, so there is no need for planting cover crops. The width of the strips is 10 m, and that of the logged bands is of 20 m. The hole dimension for planting is of 40cmx40cmx40 cm. Before planting 15 days, fill half of the hole with soil with no weeds.

+ Planting density: On the 100% burned areas, the density is of 2500 plants/ha, spacing is 2mx3m.

+ Care for planted forest: When planted in fertile soils, wild species develop fast, so there is a need for early and timely care. Clean the weeds, soften the soil, cut the climbing wines, but not at once as there is a need for shading young plants to avoid too intensive sunlight and strong eveporation. In contrast, do not keep the plants shaded for long tome.

Take care of trees within 3 first years, each year 2-3 times; pay due attension to control of diseases and insects.

3.2.3. Evaluation of the economic effects of the studied models

3.2.3.1. Economic efficiency of model 1: Acacia + Cassava + livestock

Through surveys and household interviews, we can calculate the total income and input costs, based on which we can calculate the profits and economic efficiency of different models. The economic efficiency of the model 1 is shown in table 2.

Table 2. Economic efficiency of Acacia + Cassave + livestock model

Unit: VND

Year	Ct (input)	Bt (income)	Bt - Ct (benefit)
1	69,790,000	58,600,000	- 11,190,000
2	46,450,000	68,250,000	21,800,000
3	48,830,000	73,600,000	24,770,000
4	45,580,000	69,790,000	24,210,000
5	43,090,000	73,750,000	30,660,000
6	37,820,000	67,750,000	29,930,000
Total	**291,560,000**	**411,740,000**	**120,180,000**
Average/year/ha	**48,593,333**	**68,623,333**	**20,030,000**

It can be seen from table 2 that the average annual benefit of model 1 (Acacia + Cassava + livestock) is 20,030,000 VND/ha/year; the annual average revenue is 68,623,333 VND/ha/year, and the average annual input is 48,593,333 VND/ha/year.

In this model, we can see that in the first year the invesstment is highest, as farmers have to buy plantlets and to build aninal satll (69,790,000). That is why there is a need to grow annual crops (Cassava), raisin animals that brings about the immediate income to invest to the models when the Acacia plants are still young. Beside, farmers can plant othe species like lemon, jujuba, etc., in order to make most use of lands to increase their income. In the other hand, animal raising can provide considerable income and animal manre to apply to plants in their models. In addition, while taking care of Cassava, farmers also indirectly take care of main trees.

Table 2 also shows that the model provides stable income and economic effects to farmers in mountainous regions. The average benefit is 20,030,000 VND/ha/year. The year 5 gives highest benefit (30,660,000 VND/ha/year thanks to more diverse products, use of more available manure and hence higher yield. The economic benefit of the model in year 6 influences positively on the increase and stabilization of living standards of the mountainous farmers.

3.2.3.2. Economic efficiency of model 2: Pomalo + Mango + Arachis pintoi

The results of analysis in economic efficiency of model 2 are shown in table 3.

Table 3. Econimic effectiveness of Pomelo + Mango + Arachis pintoi model

Unit: VND

Year	Ct (input)	Bt (income)	Bt - Ct (benefit)
1	12.990.000	0	- 12.990.000
2	8.100.000	10.000.000	1.900.000
3	4.140.000	16.000.000	11.860.000
4	3.921.000	32.000.000	28.079.000
5	5.515.000	36.600.000	31.085.000
6	6.800.000	46.500.000	39.700.000
Total	**41.466.000**	**141.100.000**	**99.634.000**
Average/ha/year	**6.911.000**	**23.516.667**	**16.605.667**

It can be seen from table 3 that the annual benefit of the model is 16,605,667 VNDg/ha/year, annual average income is 23,516,667 VND/ha/year and annual input is 6,911,000 VND/ha/year.

This model doesn’t require big initial investment, so is suitable for fruit trees development in Phu Tho. The average input cost ia 12,990,000 VND/ha/year. The addition income can be generated from cover crops. Perennial peanut LN99, biside providing economic income, is a good cover crop to improve the soil properties, keeping soil moisture and smothering weeds. From year 3 onward, the planted species start to generate income that is increasing from year to year. The year 6 brings about the highest economic effects. In addition, Arachis pintoi is also a beautiful ornamental species, making beautiful senery and can be used to decorate offices and streets, so can be sold with good price.

3.2.3.3. Economic efficiency of model 3: Mangletia + livestock + Guatemala grass

The economic effectiveness of model 3 is analyzied and shown in table 4.

Table 4. Economic effectiveness of

Mangletia glauca + livestock + Guatemala grass *Model*

Unit: VND

Year	Ct (inputs)	Bt (income)	Bt - Ct (benefit)
1	35.715.000	31.200.000	- 4.515.000
2	24.800.000	37.000.000	12.200.000
3	17.850.000	35.400.000	17.550.000
4	39.450.000	58.700.000	19.250.000
5	35.050.000	60.500.000	25.450.000
6	31.850.000	63.300.000	31.450.000
Total	**184.715.000**	**286.100.000**	**101.385.000**
Average/ha/year	**30.785.833**	**47.683.333**	**16.897.500**

Through table 4 one can see that the model bring about quite a good annual benefit (16,897,500 VND/ha/year). The annual income is 47,683,333 VND/ha/year and the average input is 30,785,833 VND/ha/year.

The model require considerable initial investment as farmers have to buy plantlets, fertilizers and build animal stall. In thismodel, however, income can be generated from year 1 as farmers can raise animals like pig, chicken. In the other hand, Guatemala grass in Hoang Su Phi district grows very fast, and Hoang Su Phi has become the main supplier of planting material of the grass, hence provide good additional income to farmers.

Also, year 6 gives the highest income (31,450,000 VND/ha/year) as diverse species give diversity of products. Many by products of the model can be used like FYM, crop residues, etc. Contributing tithe increase of people living standards and protecting the environment (less soil erosion, less free grazing, etc).

3.2.3.4. Comparison of economic effectiveness of 3 models.

Comparison of economic efficiency of the 3 models is very relative because the models are distributed in different localities with different natural and socio-economic conditions.

Due to the time and budget limits, we conducted surveys at present time back to 6 year ago when the main forest trees (Acacia and Mangletia) in models 1 and 3 have not provided income, but Pomelo and Mango in model 2 alredy generate income. Do, we compare only annual average benefit in the 3 models (table 5).

Table 5. Economic benefit from 3 different models

Unit: VND

Model	Benefit VND/ha/year	Place
Acacia + Cassava + livestock	20.030.000	Yen Bai
Pomelo + Mango + Arachis pintoi	16.605.667	Phu Tho
Mangletia + live stock + Guatemala grass	16.897.500	Ha Giang

The first model (Acacia + Cassava + livestock) gives highest annual benefit, followed by models 3 and 2. But due to higher input costs (291,560,000 VND/ha) in 6 years of model 1, it í necessary to arrange appropriate crops and animals to obtain good income in these years. For model 2, the investment in the 6 initial years is lowest (41,466,000 VND/ha) but provide comparatively high income. In thisperiod, the income is generated mostly from selling Arachis pintoi cuttings. Fruit trees atart to generate income from year 4. For model 3, the investment in 6 initial years is 184,715,000 VND, and the annual benefit is 16,897,500 VND/ha.

3.2.4. Evaluation of social impacts of the studied models

Job creation

The results of survey and analysis are shown in table 6.

Table 6. Job creation ability of 3 models

Year	Model 1			Model 2			Model 3		
	No of labour days	Usual worker	Seasonal worker	No of labour days	Usual worker	Seasonal worker	No of labour days	Usual worker	Seasonal worker
1	236	4	2	97	2	2	185	4	2
2	158	3	1	52	2	1	86	2	1
3	157	3	1	44	2	1	86	2	1
4	154	4	1	64	2	2	207	4	1
5	120	3	1	88	2	1	157	3	1
6	116	3	1	102	2	1	147	3	1
Total	**941**	**20**	**7**	**447**	**12**	**8**	**868**	**18**	**7**
Average	**156,8**	**3,3**	**1,17**	**74,5**	**2**	**1,33**	**144,7**	**3**	**1,17**

- Labor is often hire workers according to the model at the tree planting, care, and wild grass, fertilization, protection model, the total no of employees in the workforce often. Also work as the lease at the start of the planting and harvest time because more people need to rent. The total workforce in the entire Department of Labor and hire workers outside of the family in years.

- Data in table 6 show that the required labor days is highets in model 1 (941 days), averaging 156.83 labor days/ha/year, permanent labor days is 3.33 labor days/ha/year; seasonal labor is 1.17 labor days/ha/year. The first year consumes a lot of labors (236 days) because lots of trees must be planted; animal stall needs to be built, then the labor requirement is reducing with time. Model 3 requires 868 labor days, averaging 144.70 labor days/ha/year; permanent labor is 3 labor/year; seasonal labor is 1.17 labor/year. Model 3 requires highest labor in year 4 because of animal raising. Model 2 consumes least labor (447 labor days in 6 years) averaging 74.5 labor days/year; permanent labor is 2 labor/year; seasonal labor is 1.33 labor/year, higher than the 2 other models. In model 2, the labor requirement becomes higher from year 5 onward as the harvest of product is increasing.

- ***Adoption ability by farmers***

Interviews were made with 30 farmers/models about their adoption. The results are shown in table 7

Table 7. Evaluation of adoption ability

Model	Ability of investment and technology application (%)	Ability to meet immediate needs (%)	Adoption level by society (%)
Model 1	75	83,33	75
Model 2	58,33	50	50
Model 3	66,67	50	66,67

From table 7, it can be seen that model 1 has thehighest adoption level. This means that the ability to apply and multiply model 1 is great. Farmers dais that the model has highest ability to meet their immediate needs as it also provide high income from the first year. In the other hand, farmers usually plant cassava in their field for food, animal feed and market. So, planting cassava in this model is quite suitable. The second model is built in Phu Tho, where there are lots of alternatiives, that is why the potential for scaling up is quite limited compared to the mountainous loalities.

Soil erosion is one of main seasons causing land degradation. So, in order to have sustainable cultivation, the first duty shoud be the control of soil erosion. Soil mulching can help prevent soil erosion very much. Due to the time limit, we conducted this experiment from september 2008??? To April 2009. the methods and obtained results are as follows:

At the foot of each model, trenches were digged with dimension of 2m long x 0,7 m wide x 0,7 m deep, lined with plastic sheet. When it rained, the eroded soil was trapped in the trenches. The soil was then taken out, weighted to calculate the soil loss. The same method wasused for monocropping of trees to serve as the control plot for comparison.

Table 8. The amount of soil loss in different models

Model	Soil harvested in trenches (kg)	Area of expt plot (m^2)	Soil loss (t/ha)
Model 1	2.54	1.4	18.14
Model 2	1.20	1.4	8.57
Model 3	2.25	1.4	16.07
Acacia only (Control)	4.80	1.4	34.29

The data in table 8 show that the soil loss is biggest in the monoculture of Acacia (34.29 t/ha) within the study period. This is because there is nothing to cover the soil to prevent the erosion. The model 2 has the least soil loss (8,57 t/ha) thanks to complete cover by *Arachis pintoi* that has good ability to protect the soil by preventing the direct contact of rain drops with soil surface and reducing run off. The other two models (3 and 1) have higher soil loss (16.07 and 18.14 t/ha, respectively). This is because there are still a lot of space where the soil is not covered.

3.2.5.2. Evaluation of capacity to keep the soil moisture

Cultivation on slopes is usually irrigated, that is why the capacity to keep soil moisture is very important to ensure good growth and high yield of crops. According to the research results of the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI), the soil mulch can reduce the soil surface temperature in summer by 3 - 7^0C at 15h, thanks to that the evaporation is reduced. For our study, we took soil samples from different models to measure the soil moisture. The results are shown in table 9.

Table 9. Soil moisture in different models

Model / Soil moisture	Model 1	Model 2	Model 3	Model 4
$A_{tđ}$ (first time) %	17.80	21.23	17.42	17.08
$A_{tđ}$ (second time) %	16.68	22.60	19.50	16.86
$A_{tđ}$ (third time) %	18.56	22.05	19.25	16.6
Average	**17.68**	**21.96**	**18.72**	**16.85**

- We can see that models 1 and 3 have lower soil moisture than model 2 which is 17.68, 18.72 and 21.96%, respectively. Our observation showed that under *Arachis pintoi* the soil was softer, hence had better holding capacity, less evaporation thanks to the soil cover, so the soil moisture was higher. Model 3 aalso has high soil moisture as Guatemala grass has very strong root system that breaks the soil compaction, creating holes and cracks as water leading ways into the soil. The model 1 has least soilmoisture because of cassava cultivation, where farmers have to do disturb the soil during taking care of cassava and at harvest, making the evaporation higher. Model 4 in pure colloidal species ability to hold moisture is the lowest, this model only one species of plants and trees do not cover protection of the land should be capable of keeping moisture is lowest.

- Ability to re-birth of the same LN99 very well, if the implementation process cut about 1.5 to 2 months in the rainy season and 4 months in the dry season, with time after 1 year can return to the land of green large reach 148.7 tons per year. Especially in the middle of the rainy season for LN99 and volume is very large, this is a good ability to cover this same land. With the large amount of green, in a rush to save five year land cover can pay for the nutrition of very high equivalent to 595kgN; 140kgP2O5; 200kg K2O/ha (report nomafsi).

3.2.5.3. Evaluation of capacity to protect the water resources

Capacity to protect the water sources is the capacity to increase the water use efficiency and quality: increase in water harvest, water cleanliness, water regulation, reduction of flood, soil moisture to increase the on-the-spot yield, was well as that in surrounding places, etc.

As the water keeping capacity of a model is expressed through its influence on water use efficiency, so in principle, one can use different parameters to measure: dunamics of chemical contents, soluble elements after moving through the model system, regulation of water flow, mode of underground water flow, mode of surface water flow, crop yield and cropping systems or parammeters directly influencing water use efficiency like model structure, soil texture, etc. However, from the view point of representativeness and easiness to identify the water keeping cacacity, the surface water flow intensity is the best parameter to measure this capacity. If the flow is weak, the water quality is improved, hence the water use efficiency is higher. The water keeping capacity of a model is very much dependent on the soil characteristics like softness (porosity) and the thickness of the surface soil layer. These are determining factors of water penetration velocity and water holding capacity of the soil.

+ Canopy cover: Canopy cover is also an important factor for a model to keep the soil and can be identified through the recording of plant growth and interpolation.

Surface water flow ration (W) is identified according to the reference table of Vusoski as follows:

Table 10. Reference table of Vusoski for calculation of water surface flow

Plant canopy cover (%)	<10	10	20	30	40	50	60	70	80	90	100
Ratio of surfaceflow (%)	80	45	40	35	30	25	20	15	10	5	1.2

+ The influence of a model on the ratio of water surface flow is divided into 3 levels as demonstrated in table 11.

Table 11. Division of water surface flow into 3 levels

Level	Wtb (%)	Level of impact

Level I	<10%	Weak
Level II	10- 20	Medium
Level III	>20	Strong

Applying Vusoski method, we identified the ratio f water surface flow. The obtained results are expressed in table 12.

Table 12. Water surface flow in different models

Year	Model 1			Model 2			Model 3		
	Canopy cover (%)	Ratio of water surface flow (W%)	Level	Canopy cover (%)	Ratio of water surface flow (W%)	Level	Canopy cover (%)	Ratio of water surface flow (W%)	Level
1	0.54	23	S	0.64	18	M	0.6	20	S
2	0.63	18.5	M	0.65	17.5	M	0.66	17	M
3	0.72	14	M	0.72	14	M	0.70	15	M
4	0.72	14	M	0.79	10.5	M	0.71	14.5	M
5	0.76	12	M	0.84	8	W	0.76	12	M
6	0.80	10	M	0.86	7	W	0.83	8.5	W
Average	0.69	15.25	M	0.75	12.50	M	0.71	14.50	**TB**

Note: S: strong; M: Medium; W: weak

Data in table 12 show that the impact level of all models is medium that can ensure the stability of water resources. Model 2 has least level of water surface flow (12,50%), again thanks to high soil coverage, so the water quality is best improved, followed by model 3 (14,50%) and model 3 (15,25%).

3.2.5.4. Ability to control the pollution of soil, water and air environment

The water, soil and air pollution may be caused by application of herbicides and pesticides or phytotoxins released by trees/plants.

The arrangement of many plant species in a model can reduce and even eliminate the need of pesticide application, hence reducing the environment pollution. The appropriate use ofmineral fertilizers is good for soil and the contents of toxic agents are also considerably reduce.

3.2.6. Integrated effects of the studied AF models

When evaluating the integrated effects of the studied AF models, we examined the components of land use approaches, as they are closely interlinked, mutually interacted and supported. When one of them is changed, this will change the impacts and may change the whole system of land use. Meanwhile, the users want at the same time to have high benefits but also sustainability for long-term business. So, the comprehenssive evaluation of Af models will help identify their strengths, weaknesses, opportunities and challenges, from which one can propose appropriate measures for further development.

There are many methods for evaluation, but we select the participatory methods for integrated evaluation of AF models. The following parameters were evaluated:

+ Economic impacts: According to farmers' evaluation, a model which has high benefit it will get 7 - 10 marks, and that which has low benefit will get lower marks of 5 - 6.

+ Social impacts:

The model that has high number of the average working days it will get high marks of 7 - 10 and the lower one will only get 5 - 6.

So, the models that get 7 - 10 marks are more accepted by farmers than those that get 5 - 6 marks.

+ Ecological impacts:

The models that get 7 - 10 marks are of good capacity of soil and water protection, and vise versa for models that get lower marks (5, 6).

The results of participatory evaluation are shown in table 13.

Table 13. Evaluation of the models impacts

Target \ Model	Model 1	Model 2	Model 3
Benefit/year	8	6	7
Number of working days/year	9	7	8
Adoption level by farmers	8	6	8
Soil protection capacity	8	9	8
Soil moisture holding capacity, water keeping capacity	9	9	8
Total	**42**	**37**	**39**
Ranking	**I**	**III**	**II**

Table 13 shows that model 1 has the highest effect, then the model 3 and the last is the model 2. Model 1 is considered as the best in the social and economy aspects because of it is suitable for mountainous farmers. Model 3 is appreciated rather good and ranks second. Model 2,though ranks 3, but has high impacts on environment protection as it has good soil cover bu Arachis pintoi LN99.

3.2.7. Factors affecting economical, environmental and social effectiveness

To ensure the lives of farmers, especially in mountainous areas, many organizations and projects have continously been conducting research programs and have proposed good techniques of cultivation to stablize the current lives of the peole, but not affecting the future. In the study areas, farmers have been learning and working hard, investing money and labor to the area owned by them. However, the models' performance is still not high. Through interviews of households we found a number of factors affecting the economic, environmental, social aspects. They are as follows:

- Natural conditions:

+ There are some disadvantages: dissected and sloping topography, water resource limit, climate factors, especially the extremes of rainfall causing floods in rainy season but long period of severe drought in dry season. Land in the region is mainly sloping land therefore it requires a large investment.

+ The ability to retain water is poor, because of high percentage of sand.

- Socio-economic and cultural conditions

+ The level of people intelligence is not high, the infrastructure developes slowly poorly. At present the mounatain education and infrastructure is being improved very much but still there are many disadvantages in social conditions that influence the development of market oriented agricultural production.

+ The population distribution by geographic area has created the disparity in the level of production.

- Technological factors:

+ Farmers have not been trained on management, caring, exploiting and processing techniques in their models.

+ Seeds and animals have been mainly bought from farmers-producers in the local market.

+ Production activities are mainly based on their own experience and learning from other farmers who have implemented different models before.

3.2.8. Proposed solutions to improve the effectiveness of the models

The above analysis results show that the all the studied models have been effective on all three economic, social and environmental aspects. They are concentrating on solving technical problems of crops, animals and economic improvement, environmental protection and social performance. However, these models have not achieved the highest effectiveness. Therefore, it is necessary to propose solutions to overcome the limitations to build and expand the models locally and in other localities that have similar conditions. Through interviews of households and our own studies, we propose some solutions as follows:

- Technical solutions:

- Designed to build the model should ensure that: for travel care, in accordance with the terrain, anti-erode environmental protection.

- Designed system against erode, irrigation (system design drainage systems to combat isolation erode). Thick trees in the waterway to prevent the flow.

- Conduct training courses, training on crop management for some crops, focusing on key farmers, farmers' interest groups and local authorities to ensure the long term development.

- Organize field days for farmers to effective agro-forestry models.

- Simplify techniques to make them suitable for people in mountainous areas.

- In some plants belonging to the shadow pass effect: shade tree cover associated with the main plant forming a carpet vegetation prevents the evaporation of water, thereby reducing evaporation of water at the same time prevent prevent wind, rain and people are directly caused status erode soil washing drifting. On the other hand, tea leaves in the park also provides a significant amount of organic substances and other nutrients, especially protein and public, improve management, and by land.

* Varietal solutions:

+ Advice and sellect high economic value varieties that are suitable to local social and natural conditions.

+ Buy planting materials and animal breeds from well known and prestigeous entities such as Provincial Seed Centers, research institutes such as Institute of Animal Husbandry, Tea R&D Center, Fruit and Vegetable R&D Center of NOMAFSI, etc...

* Solutions to Market:

- It would be a forecast of the consumption of the product model.

- Product of the model advertised widely on the media's to people they know.

* Policitical:

- All Accessories and continuously improve the functions and responsibilities of local leaders.

- Accessories complement the technical personnel, extension staff - encourage responsible forest communes.

- Need to have reasonable policies on investment, finance and credit for farmers.

- Encourage people on land improvement, system development through farming economy.

- Need to have policies on human resource training programs under the national projects, mass organizations and oversea international support.

* Solutions of capital:

- Use capital the local budget, capital projects for investment and development model combines agriculture and forestry

- There are policies on investment, finance, credit reasonable to the people

- Mobilizing capital for investment partners, the company's business investment for the development of agro-forestry model combination.

- Guide for people know the economic effect from which more boldly trust investment, can quickly recover the capital and profits more.

* Training and use of human resources in place:

- Promoting local resources in response to the movement of the building model combines agriculture and forestry. Organized in collaboration between departments, groups of districts, communes propaganda campaign people understand the economic benefits, environmental and social issues in building a model farm forestry combined.

- Construction plan vocational training for farmers in mountainous areas in the North. Plans and training staff responsible for areas of agricultural forestry.Bottom of Form

CHAPTER IV
CONCLUSIONS AND SUGGESTIONS

4.1. Conclusions

* Surveys and studies have been conducted, and 4 models in different Northern mountainous areas have been selected for evaluation as follows:

- Model 1: Acacia + Cassava + livestock in Suoi Giang commune - Van Chan district - Yen Bai province.

- Model 2: Pomelo + Mango + *Arachis pintoi* at NOMAFSI in Phu Ho commune - Phu Tho town - Phu Tho province.

- Model 3: Mangletia glauca + Livestock + Guatemala grass in Ban Nhung commune - Hoang Su Phi district - Ha Giang province.

- Model 4: Acacia mangium in Phu Ho commune - Phu Tho town - Phu Tho province.

* Evaluation has been made on economic, social and environmental impacts of the models, providing orientations for farmers in mountainous areas to develop their economy sustainably by agro-forestry production approach.

- Economically: Model 1 is the best providing the best profit: 20,030,000 VND. Model 3 gives 16,897,500 VND and Model 2 gives 16,605,000 VND/ha/year.

- Environmentally: We can see the obvious effect of intercropping and cover crops that make the level of erosion reducing with time, and limit the ration of surface flow of water, maintaining and stabling the water resources.

- Socially: The models create jobs for farmers in mountainous areas and help make most use of idle local labor resources.

* Some solutions have been proposed to improve the efficiency of AF models:

- Conduct training courses, exchange visit, training on crop management, caring techniques for some suitable plants in the areas that bring about high economic efficiency.

- Simplify technical measures of crops and livestock production suitable for people in mountainous areas.

- Select plants and animals with high economic value, having clear origin and suitable to local conditions (climate, traditions and customs, access tomarkets, etc).

- Policy:

+ Issue reasonable policies on investment, finance and credit for farmers.

+ Encourage people on land improvement, system development through farm economy systems.

+ Issue policies on human resource development: training programs under the national projects, mass rganizations and international support.

4.2. Suggestions

- Continue research and test the rapid evaluation methods for agro-forestry models with different plant species. Cooperate with scientists and use supporting softwares such as climate software, biological software to achieve better research results.

- The Government should issue policies to encourage people to apply the studied AF models: support for training, field visits, and training in building demonstartion models, loan with low interest to create good conditions for farmers to use their lands more efficiently.