The Vietnam-Finland Forestry Sector Co-operation Programme

The Department of Agriculture and Rural Development
of Bac Kan Province

TECHNICAL REPORT No. 8

STUDY ON AGROFORESTRY SYSTEMS AND SOIL SURVEY

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The Vietnam-Finland Forestry Sector Co-operation Programme in brief

The Programme started in March 1996 and the first phase will last three years. The Programme is financed jointly by the Governments of Finland and Vietnam. The geographic coverage of the Programme is concentrated in the mountainous regions of Bac Kan Province where forestry is taken as a key potential activity which could contribute to social and economic development. Local population, mainly people from different ethnic minorities, suffer from social and economic problems due to lack of income generating opportunities. At the same time the mountainous regions are facing severe deforestation and forest degradation due to mismanagement and non-optimal use of the resources. The development objective of the Programme is to contribute to sustainable rural development in the mountainous regions of Vietnam, through the integration of forestry activities in the rural land-use and economy. The target groups of the Programme are rural households, ethnic groups, professional personnel at province, district and commune level and in national forestry administration. The Programme strategy is to introduce and disseminate sustainable forest management and other farm-forestry practices as viable alternatives to shifting cultivation and other forms of unsustainable land use. The Programme implementation will be a continuous process of participatory learning and application. The following Programme components form the implementation strategy: (i) community development, (ii) capacity building, (iii) dissemination and (iv) monitoring and evaluation. The immediate objectives respective to the above components are (i) established and tested mechanism to assist farmers/forest owners at the village level, (ii) improved capacity of the existing institutions in providing services for forestry extension, (iii) transferred practical experience from the pilot villages/communes to neighbouring areas, province level and finally national level and (iv) established monitoring and evaluation system at different levels. The implementing agencies of the Programme are Department of Agriculture and Rural Development in Bac Kan Province and Ministry of Agriculture and Rural Development, while the People’s Committee of Bac Kan Province and the Ministry of Agriculture and Rural Development are the competent authorities of the Programme. The supporting consultant is Indufor Ltd. in partnership with Enso Forest Development Ltd. and FTP International Ltd.

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The objective of this study is to identify appropriate agroforestry systems for Cho Don which provide sustainable land use to meet the needs of local people as well as environmental protection.

Soil classification and PRA techniques were used to identify constraints and opportunities to establish agroforestry systems. The study was concentrated to the Programme pilot villages in Ngoc Phai and Dong Lac Communes.

Ecological and Socio-economic Conditions of Cho Don

Slopes are dominant land form and they are frequently interspersed with sinuous alluvial valleys. The elevations vary from 200 to 800 m, while the slopes vary from 15° to 40°. Thus sloping lands and steep terrain make soil a major concern of land use in this area. In the four pilot villages Coc Thu and Na Tum have more advantages in marketing and transport and communication. The climate conditions allow to grow high diversity species. However, low temperature in winter may effect some tropical species.

The main problem of land use is land degradation. Land use in upland area can be divided into four sub-systems include forest, shifting cultivation, plantation and homegarden. Forest is mainly regeneration forest. Regeneration is relatively fast as a favour of forest land characteristics. Rice, maize and cassava are main crops in shifting cultivation plots. Abandon shifting cultivation plots are used as grazing area. There is small area of plantation in the abandon sites. Recently, the dominant planted species is cinnamon. Crop destruction is one of the main problem for expanding the planted area. Homegarden is very poor in both species and production due to poor techniques were applied. Paddy area is dominated by rice. Seasonal water is the main problem of paddy area.

The local people is mostly employed in agriculture. More than 80% of the population is ethnic minority. Agriculture the predominant sector is mainly at a subsistence level. Even though the district has a great potential in forestry, but the main income comes from agricultural activities. The high potential of agroforestry has not been realised due to lack of funds for investment and the use of poor techniques.
Assessment of the Soils

Chemical fertility: The soils examined generally have a quite low pH and small amounts of humus and nitrogen. The shortage of nitrogen can be alleviated by using nitrogen-fixing trees and grasses. Using commercial fertilisers or manure is not practicable on forest lands even if they were available in sufficient quantities. The amount of available phosphorus can be increased by liming or phosphate fertilisation or by increasing the humus content of the soil. Using green manure to decrease P-fixation is probably the most efficient way to increase the availability of phosphorus. Soil erosivity and erosion control: Considering both the contents of silt and clay as well as the amount of organic matter it can be estimated that in general local soils are not very susceptible to erosion. If the organic matter content decreases as a result of farming, the topsoil will become more erodible and rates of erosion can be great because of the steepness of slopes and high intensity of rainfall.

Problem soils: Two types of soil were mentioned by the farmers as being especially useless. Firstly, ‘Imperata soil’ such as that on Na Tum hill and, secondly, soil colonized by Dicranopteris fern. The problem of ‘Imperata soil’ is extremely low contents of organic matter and nitrogen. Chemical soil analysis revealed that soil under Dicranopteris vegetation is necessarily not less fertile than similar soil under forest.

Existing Agroforestry Systems

Agroforestry systems has been recently applied in the district. The existing agroforestry systems included taungya, alley cropping, multi-storey forest, home garden and apiculture. Cinnamon was a dominant species grown recently as it provides high benefit in other areas of the country. However, farmers are more interested in growing fruits as these not only have a high rate of return but also provides income in a short time. However, more studies are needed for a selection of suitable species. There is a lack of short term crops which provide immediate income. Free grazing was one of the main constraints to the expansion of new plantations as most investment for establishment is for a protection.

Potential Agroforestry Systems

Requirement for agroforestry systems in Cho Don

- meet the needs of local people regarding: food, cash, firewood, timber, fodder, and handicraft material
- sustainable
- high productivity with low investments
- provide products of high unit value that are easy to process locally
- diversified production
- provide marketable products

Recommended forestry species are mangletia, canarium, cinnamon, de Fagaceae, doi Michelia anise, bamboo spp., styxra and de Lithocarpus. The recommended of dominant fruit species are longan, persimmon, apricot, citrus spp. Timber species can be grown in a larger range of soil while it is more strict for fruit species. Longan and persimmon are species for upland rice soil while apricot and citrus spp. are species for maize soil.

The most suitable agroforestry systems for the district include:

- alley cropping as hedgerow is simple to establish and not require much investment.
- multi-storey forest which is mostly based on natural species is enrichment by high timber value species.
- taungya which includes forest species and food crops provides both short-term and long-term product.
- fruit garden and apiculture provide high rate of return and provides income in a short time.

2. INTRODUCTION

2.1 Programme Background

Cho Don is a mountainous district in northern Vietnam where forestry plays an important role in the economical welfare of the local people. The people face economic and social difficulties due to lack of income generating opportunities. The forest area occupies 90766 ha or about 86 % of the territory. However, deforestation and forest degradation is rapid as a result of mismanagement and non-optimal use of the resources. The forest was destroyed mainly for growing food crops, collections of wood and firewood. The area classified as bare land in the district is about 39700 ha or 40% of the land (Technical Report N° 3). Soil degradation is serious as a result of erosion. The reasons include: deforestation; steep slopes, and high rainfall combined with growing short time crops on slopes without erosion control measures. Even though the land holding per person in the district is much higher than in the lowlands, several months food shortage is common. More than 20 % of the households in the four pilot villages are classified as poor (Technical Report N°3).

Agroforestry is seen as a solution for this district to improve the living conditions for the local people and to protect the environment. Agroforestry is a sustainable land use system which increases the total productivity of plants and animals, especially under conditions of low levels of technology inputs and marginal lands (Nair, 1989). As agroforestry is a combination of agricultural crops and trees in the same plot, it can provide both long term and short term products that meet the needs of farmers. At the same time agroforestry systems can be an appropriate land use form to gain sustainable development in an environment where deforestation and degradation of forest resources have been serious (FAO, 1991).

2.2 Objectives

An agroforestry study was carried out as a part of the Vietnam - Finland Forestry Sector Co-operation Programme. The objective of the study is to identify appropriate agroforestry systems which have a high productivity and efficiency and that are sustainable. These systems will provide both short term and long term products. Low investment, simple techniques, diversity and marketability are desirable characteristics of these systems.

2.3 Scope of Study

The study was carried out from 9.6.1997 to 18.7.1997 in the two pilot communes Dong Lac and Ngoc Phai, with special focus on four pilot villages: Coc Thu, Na Tum (in Ngoc Phai) and Ban Chang, Na Anh (in Dong Lac).

2.4 Methodology

In this study the Rapid Rural Appraisal method was used to classify land use, identify constraints and opportunities to establish appropriate agroforestry systems and survey existing agroforestry systems. It was based on secondary sources, oral information, especially through semi-structured interviewing, and observation carried out by the study team.

The team consisted of two consultants and two trainees:
In addition, local staff such as extension workers and village chiefs participated in the field work.

The Chief Technical Adviser Mr. Petri Lehtonen and the study team identified the objectives of the study on the first day. Then all available relevant background information was collected. About thirty farmers were interviewed. The selected sites were identified on maps with the help of the village chiefs, who also accompanied the group during surveys. Sites representing all available land types and existing agroforestry systems in the pilot villages were included in the survey. During visits to their fields, farmers were interviewed about soil quality, land classification, past cropping patterns, yields and their future plans. After two days of field research the group reviewed the results and modified the study techniques accordingly.

As the field survey revealed a need for further information, the team visited Thai Nguyen Agroforestry College and the Hanoi Research Institute of Vegetable and Fruit to consult experts in the fields of soil science, forestry and fruit tree growing. The findings of the study were presented in a dissemination workshop to have comments of the local people to complete the technical report. More discussion and conclusion on potential agroforestry systems and suitable species for the district were carried out in an agroforestry training course with staff of the Department of Agricultural and Rural Development of the province and district, and the Cho Don Forest Enterprise.

### Soil Survey

The agroforestry study used the results of the soil survey which was conducted by Mr. Jussi Kauppi, a postgraduate student in the Continuing Education Centre of the University of Joensuu, Finland. The study consists of two parts: conventional and participatory surveys.

#### Conventional soil survey

The soil was examined in points placed systematically around the main residential areas of each village. Soil profiles were described and soil samples collected. Only one sample was taken at each location at the depth of 0-20 cm for analysis because only a very limited number of soil samples could be analysed. Some subsoil samples were also taken from the depth of 20-40 cm. Fields currently under cultivation were usually excluded to minimise the disturbance caused to farmers. However, demonstration plots were included when possible.

The analysis were carried out in the Research Centre for Forest Ecology and Environment in Hanoi. The following analysis were made: pH (KCl), total nitrogen (Kjeldahl), humus (Chiurin), available phosphorus (Oniani), available potassium (Maslova), exchangeable Ca$^{2+}$ and Mg$^{2+}$ (Triton B titration) and texture by sieving.

#### Participatory soil survey

During the survey, photographs of soil profiles were presented for the farmer’s appraisal. The farmers’ views of different soil types’ uses and limitations were gathered. Farmers were also asked to identify the position of different soil types around their farm using village maps.

Results of the RRA-exercise were combined with the analysis result (Annex 1) and geological data provided by the Australian Golden Tiger Resources Ltd to draw a soil map for each village.

### 3. ECOLOGICAL AND SOCIO-ECONOMIC CONDITIONS OF CHO DON

#### 3.1 Geography

Located in the mountainous area of northern Vietnam Cho Don occupies an area of almost 91000 ha. Slopes are dominant land form and they are frequently interspersed with sinuous alluvial valleys. The elevations vary from 200 to 800 m, the highest point is 1527 m (the Phiang Lieng mountain). The slopes vary from 15° to 40°. Difficult access, fragility and marginal lands are the main difficulties which district faces due to mountainous conditions. Thus sloping lands and steep terrain make soil erosion a major concern of land use. The district is a watershed area of three rivers: Binh Trung, Cau and Nam Cuong. Therefore, establish and protect forests on watershed areas would have a great impact not only for the district but also for the low land areas. The protection forest of the district accounted for about 77000 ha (Technical Report № 5).

Ngoc Phai and Dong Lac are the pilot communes of the programme. Ngoc Phai commune is located in the central of the district while Dong Lac commune is located in the North of the district. Coc Thu and Na Tum are villages of Ngoc Phai and Ban Chang and Na Ang are villages of Dong Lac. There are few differences between villages. The two villages in Ngoc Phai are located at a higher elevation and have steeper slopes in comparison with the villages of Dong Lac (Table 1). As Coc Thu and Na Tum located near the district centre they have better conditions in marketing, transport and communication in comparison with two villages of Dong Lac.

#### Table 1. Topographic Characteristics of the Pilot Villages

<table>
<thead>
<tr>
<th>Village</th>
<th>Elevation (m)</th>
<th>Slope (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coc Thu</td>
<td>350 m to 500</td>
<td>12-24</td>
</tr>
<tr>
<td>Na Tum</td>
<td>300m to 450 m</td>
<td>23-40</td>
</tr>
<tr>
<td>Ban Chang</td>
<td>240m to 350 m</td>
<td>16-26</td>
</tr>
<tr>
<td>Na Ang</td>
<td>230 to 350 m</td>
<td>12-32</td>
</tr>
</tbody>
</table>

#### 3.2 Climate

In general, the climatic conditions in Cho Don are suitable for growing both tropical and temperate species. This is an opportunity for high bio-diversity in the agroforestry systems. However, some characteristics should be concerned when decide species to grow. For example, low temperature in winter and long rainy period in spring may be not suitable for some fruit trees. The minimum temperature in January falls to 2,2°C (Table 2) it may be not suitable for some tropical species such as custard apple. The average rainy days in February and March were 22 to 20 days (Table 2) respectively, this may be not suitable for some fruits flowering during these months such as mango and lychee. It is said that the period of September and October may be too wet for anise as it is the time for developing the anise oil.

It is said that the Northern area is colder and more humid than the South. Khau Sam pass is a border between north and south of the district. In the North fog occurs earlier and last longer, from late of June to Spring. There was more ice rain in the North than in the South.
Table 2. Climatic Characteristics of Cho Don District

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp. °C</td>
<td>14.77</td>
<td>16.26</td>
<td>19.1</td>
<td>22.29</td>
<td>26.1</td>
<td>27.6</td>
<td>27.4</td>
<td>27.4</td>
<td>25.9</td>
<td>22.8</td>
<td>19.4</td>
<td>16.9</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>11.9</td>
<td>14.5</td>
<td>16.3</td>
<td>21.5</td>
<td>24.4</td>
<td>27.3</td>
<td>26.4</td>
<td>26.7</td>
<td>25.2</td>
<td>21.7</td>
<td>17.8</td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>17.1</td>
<td>18.9</td>
<td>22.9</td>
<td>23.8</td>
<td>27.7</td>
<td>28.1</td>
<td>28.2</td>
<td>29.6</td>
<td>26.6</td>
<td>23.6</td>
<td>20.6</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>6.7</td>
<td>7.8</td>
<td>10.7</td>
<td>15.4</td>
<td>18.5</td>
<td>21.6</td>
<td>22.3</td>
<td>21.9</td>
<td>18.9</td>
<td>13.2</td>
<td>9.9</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Rain, mm</td>
<td>2.2</td>
<td>2.4</td>
<td>4.9</td>
<td>12.4</td>
<td>14.9</td>
<td>16.8</td>
<td>20</td>
<td>19.3</td>
<td>15.4</td>
<td>10.8</td>
<td>6.2</td>
<td>2.7</td>
<td></td>
</tr>
</tbody>
</table>


3.3. Land Use in Pilot Villages

The pilot villages as well as the whole district have a great potential in forest products. More than 80% of the territory is upland (Table 3). Paddy area is recognised as a main area which provide food for the local people. With only about ten percent of paddy area it is clear that paddy rice can not provide enough food for the population. Further more, the paddy area is mainly rain-fed, in a combination with poor techniques, so shortage of food is common. Low rate of fertiliser apply and low yield varieties are counted for the poor techniques in rice production. As a result growing food crops on upland area is unavoidable. Thus short term crops in agroforestry should be taken into account to meet the immediate needs of the local people.

Table 3. Land use in the pilot villages

<table>
<thead>
<tr>
<th>Land type</th>
<th>Na Tum</th>
<th>Coc Thu</th>
<th>Na Ang</th>
<th>Ban Chang</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>area %</td>
<td>area %</td>
<td>area %</td>
<td>area %</td>
</tr>
<tr>
<td>Upland (ha)</td>
<td>225</td>
<td>89</td>
<td>236</td>
<td>93</td>
</tr>
<tr>
<td>Paddy land (m²)</td>
<td>18</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Upland/person (ha)</td>
<td>0.9</td>
<td>2.7</td>
<td>2.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Paddy land/person (m²)</td>
<td>670</td>
<td>250</td>
<td>465</td>
<td>705</td>
</tr>
<tr>
<td>Barren land (ha)</td>
<td>108</td>
<td>43</td>
<td>80</td>
<td>32</td>
</tr>
</tbody>
</table>


Figure 1 is a transect of a typical agro-ecosystem in the pilot villages. As there are differences in use of upland area so it can be divided into sub-areas include forest, shifting cultivation, grazing, plantation and homegarden. The forest is mainly regeneration forest as a result of shifting cultivation and heavy exploitation. Regeneration forest occupies an area of about 70% in the four pilot villages (Technical Report No. 3). The forests are mainly classified as IIA and IIb (see annex 7). The regeneration is relatively fast as soils still have characteristics of forest land. After being abandoned for 3 to 5 years after shifting cultivation, the plot becomes a forest of class IIA. This has timber species of about 10 cm diameter and 7 to 10 m high. After 7 to 10 years, it becomes forest of class IIA and IIb with timber species of about 15-17 cm diameter and 12 to 15 m high. Most high value timber such as dinh (Markhamia stipulata), lat (Chukrasia) were exploited heavily from the forests. Now these timber are rare and can be found only in very steep slopes and areas with difficult access.

The regeneration forest has a high bio-diversity. Seventy timber species are found in Ngoc Phai and Dong Lac. They are listed in the Technical Report No. 3. The most common species are gie (Lauraceae), khao (Phoebe cuneata), de (Fagaceae), man rung, xoan dao (Melia azedarach), which are in a upper layer. Volunteer and light-demanding species include bo de (styrax), cheo (Engelhardta chrysolepis Hance), xoan nhan, and sao sau. In the lower layers bamboo species such as mua (Neohouzeana), vau (Indosaca crassiflora) and other species demanding high humidity, such as cardamom, wild bananas. They are fast growing species and are common in the areas which have good protection. Climbers, and banana are dominant in poor forests. Heavily degraded areas are characterised by species such as thanh nganth, thu sau, co lao Eupatorium odoratum, mua Melastoma candidum, co tranh Imperata cylindra and co guoi Dicranopteris. Those species are indicators of poor nutrition and acid soil. Thus vegetation is used as indicators for soil classification. Table 4 presents soil classification according to vegetation. More detail about characteristics of soil under different vegetation is given in section 3.4.2.

Table 4. Soil classification according to vegetation

<table>
<thead>
<tr>
<th>Soil under grass</th>
<th>Soil under bush and small tree</th>
<th>Soil under trees</th>
<th>Plantation area</th>
</tr>
</thead>
<tbody>
<tr>
<td>imperata grass</td>
<td>low</td>
<td>average</td>
<td>bushes,</td>
</tr>
<tr>
<td></td>
<td>high</td>
<td>high</td>
<td>bushes,</td>
</tr>
<tr>
<td>tolerat drought</td>
<td>thanh nganth,</td>
<td>co lao Eupatorium</td>
<td>trees</td>
</tr>
<tr>
<td>mua Melas.</td>
<td>cao hu, ba,</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Currently, shifting cultivation plots can be found in places far away from villages. Upland rice, maize and cassava are the main crops in the shifting cultivation plots. There is not much land available for shifting cultivation due to soil degradation. Other crops such as mung bean, soy bean, dong rieng and cucumber can be found in this area. In some area there are two seasons of rice and maize in the upland area. It is said that grow mung bean is easier than soy bean. The reason was vegetation grow of soy bean was vigorous but provided very poor seed. A new hybrid variety of soy bean has better yield than local varieties.

Areas which have been abandoned after growing food crops are used for grazing and for planting trees. Abandon shifting cultivation plots are recognised as a grazing place. The area of plantation is small and has barely increased since 1991 by the supports from programs such as Fixed Cultivation and Sedimentation, 327 and PAM programs. The objectives of this programs are forest protection and afforestation. The planted species include mangletia, canarium, de Fagaceae, doi Michelia. Recently the dominant planted species are cinnamon, anise and fruit trees. The reason for this trend is that these species proved a higher economic return in other provinces. In spring 1997, 74% of the planted trees in the four pilot villages was cinnamon. Crop destruction due to free grazing is the main problem for expanding of the planted areas. Attended grazing is in a growing season of paddy rice from April to November. Some encountered farmers paid 4-6 million for protection a plantation. Forest is recognised as a grazing place.

Homegardens are poor in terms of both diversity and productivity. Gardens mostly consist of fruit trees which seem to grow naturally. Pig, chicken and cattle are the main raised animal. There is room for improvement of the productivity of homegardens. That includes diversity of plant species, and a great potential in cassava and maize production that animal production can utilize.

Paddy area is dominated by rice. The mono-culture of rice in this area must be changed to improve productivity of land and have more sustainable system. Seasonal water is the main problem of this area. Thus there is about 30 to 50% of the paddy area which can be used for growing one rice season per year. Sedimentation is a problem that causes a reduction of the paddy areas. Increase growing season and more intensive growing in the paddy area would provide much more food. That also more efficiency than grow food crops on upland.

Land degradation due to inappropriate techniques applied is the main problem in land use specially on upland areas. In general, there is no erosion measure on slope area. After harvesting food crops there is no vegetation cover. On the other hand, the regeneration of many natural species is destroyed due to free grazing. As upland occupies most of the territory it is clear that forest products should be the major concern of the local people. However, as food production is the first priority of the local people agroforestry should be employed to meet the needs for both short term and long term products. This also meets the needs for environmental protection on a larger scale.

### 3.4.1 Parent Material

The bedrock around the pilot villages is mainly formed of acidic metamorphic rocks. The most common types are metamorphosed sand- and siltstones. There are also different schists containing large amounts of graphite. Graphite can give the soil a dark colouring so that the soil is mistakenly believed to be calcareous. In Ngoc Phai there are significant areas of graphitic bistite and garnet schist containing graphite, biotite mica and garnet. Gossan can be found in both Ngoc Phai and Dong Lac. It is residual weathering material that contains large amounts of iron, aluminium and manganese. Most of other minerals have been removed. Soils on this material are thus poor on nutrients. There are also some areas with limestone or marble bedrock.

The chemical characteristics of the soil depend mainly on the parent material (Table 5). There are no great differences between soils formed on different acidic rocks. The soils on limestone have higher pH as well as significantly higher contents of potassium, calcium and magnesium than the soils formed on acidic parent material. The variation within each group is, however, great due to different vegetation and different kind of use in the past.

#### Table 5. Chemical soil characteristics according to parent material

<table>
<thead>
<tr>
<th>Parent rock</th>
<th>pH</th>
<th>Humus (KCl)</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>%</td>
<td>mg/100g soil</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bistite</td>
<td>3.8</td>
<td>3.3</td>
<td>0.19</td>
<td>3.5</td>
<td>5.9</td>
<td>0.49</td>
<td>0.19</td>
<td>35</td>
<td>33</td>
<td>32</td>
</tr>
<tr>
<td>Metam.</td>
<td>3.8</td>
<td>3.3</td>
<td>0.21</td>
<td>3.4</td>
<td>7.6</td>
<td>1.1</td>
<td>0.31</td>
<td>47</td>
<td>24</td>
<td>29</td>
</tr>
</tbody>
</table>

Zone		Top hill	Upper slope	Slope	Down slope	Paddy field	Fish ponds

<table>
<thead>
<tr>
<th>Use</th>
<th>forestry</th>
<th>shifting cultivation</th>
<th>grazing, planting</th>
<th>homegarden</th>
<th>paddy rice</th>
<th>fish raising</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>natural species</td>
<td>upland rice, maize, cassava</td>
<td>natural species, plantation</td>
<td>fruit tree</td>
<td>rice</td>
<td></td>
</tr>
<tr>
<td>Product</td>
<td>timber, fire wood</td>
<td>food</td>
<td>fodder, firewood</td>
<td>food, cash</td>
<td>food, cash</td>
<td></td>
</tr>
<tr>
<td>Animal</td>
<td>cattle</td>
<td>food</td>
<td>cattle</td>
<td>pig, chicken</td>
<td>fish, duck</td>
<td></td>
</tr>
<tr>
<td>Disadvantages</td>
<td>erosion, regeneration destruction</td>
<td>long distance, steep erosion, crop destruction</td>
<td>soil degradation, crop destruction</td>
<td>poor techniques, sedimentation, rainfed</td>
<td>autotrophication, rained</td>
<td>poor technique</td>
</tr>
<tr>
<td>Advantage</td>
<td>diversity species</td>
<td>relatively fertile soil</td>
<td>short distance</td>
<td>short distance, diversity</td>
<td>relative fertile soil</td>
<td>natural form</td>
</tr>
</tbody>
</table>

Figure 1. Transect of landscape
3.4.2 Vegetation

Vegetation and land use patterns are other major factors that influence soil development. It is beyond the scope of this study to explain the interactions of these factors. Vegetation was classified as forest, bush land or fields and grassland.

Table 6 shows that soil humus content is somewhat higher in forest than on bush land and fields. There are, however, no differences in the nitrogen and phosphorus contents of the soil. The reason for this is that human activities and not soil will determine the vegetation in each locality.

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>pH</th>
<th>humus</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>KCl mg/100g soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>3.8</td>
<td>3.7</td>
<td>0.22</td>
<td>3.6</td>
<td>7.3</td>
<td>1.5</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>Bush land</td>
<td>4.2</td>
<td>2.9</td>
<td>0.20</td>
<td>3.7</td>
<td>11.5</td>
<td>3.6</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>Field/Grassland</td>
<td>4.1</td>
<td>2.8</td>
<td>0.20</td>
<td>3.5</td>
<td>11.5</td>
<td>2.8</td>
<td>1.13</td>
<td></td>
</tr>
</tbody>
</table>

3.4.3 Farmers’ soil classification

As the farmer’s were being interviewed, it became evident that they judged the soil more on its productive capabilities than on any morphological features. The farmers use indicator plants as guides to find out the fertility of soil. Although they distinguished between ‘red’, ‘brown’ and ‘black’ soil, the actual soil colour could vary considerably. ‘Black’ soil was usually a soil having a deep humus layer, but such soil was also often called ‘red’ soil or ‘black and yellow’ soil. The most common way of classifying the soil was according to its suitability to the main food crops: maize, upland rice and cassava. Some farmers also had different opinions about what kind of soil is suitable for each main crop.

According to most farmers ‘maize soil’ is rich in clay, moist and usually rocky. Rice soil has a deep humus-rich surface layer that has a high porosity. Once the humus content of the topsoil is reduced as a result of cultivation and erosion, upland rice no more gives good yields and is replaced by cassava. Cassava soil is otherwise similar to rice soil but has less organic matter and therefore lower porosity.

The chemical soil analysis did reveal significant differences between the different soil groups (Table 7). The reason may be that most ‘maize soil’ areas that were sampled were on calcareous bedrock whereas most other samples were taken from places with acidic parent material.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>pH (KCl)</th>
<th>humus %</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Sand %</th>
<th>Silts %</th>
<th>Clay %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize soil</td>
<td>4.5</td>
<td>3.2</td>
<td>0.24</td>
<td>3.3</td>
<td>17.1</td>
<td>6.0</td>
<td>1.9</td>
<td>47</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>Rice and cassava soil</td>
<td>3.8</td>
<td>3.1</td>
<td>0.19</td>
<td>3.7</td>
<td>6.6</td>
<td>0.9</td>
<td>0.3</td>
<td>43</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Average</td>
<td>4.1</td>
<td>3.1</td>
<td>0.21</td>
<td>3.6</td>
<td>10.1</td>
<td>2.6</td>
<td>0.81</td>
<td>45</td>
<td>26</td>
<td>29</td>
</tr>
</tbody>
</table>

Because a number of soil characteristics have an effect on the yield of crops, the farmer’s classification is not compatible with the Russian soil classification system currently used in forestry in Vietnam. According to field observations the local soils usually fall into the following soil groups:

- red-yellow and yellow-red ferralitic soil on acidic metamorphic rock
- black soil on limestone
- yellow soil on limestone

3.4.4 Soils in Ngoc Phai Commune

The bedrock east of the villages of Na Tum and Coc Thu is dominated by limestone. Mixed with limestone is a fairly wide streak of graphite-rich schists and siltstone, which can give the soil a deep black colour like those of calcareous soils. Soils formed of these materials are, however, not calcareous but fairly acidic.

West of the villages the bedrock consists of biotite, a dark schist containing graphite, biotite and garnet. Further west the parent material is metamorphosed sandstone. In the south are fairly large areas of gossan, a residual weathering material: rich in iron and aluminum. Soils formed on gossan are bright red in colour and quite poor in nutrients.

**Soils in Na Tum**

The soil around Na Tum is to a great extent ‘maize’ soil. The Mountain behind the village is mostly limestone. Therefore, the soils have a higher pH and higher amounts of cation nutrients. The amounts of nitrogen and phosphorus are not higher than in the other villages.

Aluminium toxicity is less likely to occur in soils of Na Tum because the pH is not very low. On the other hand, shallow calcareous soils on top of the mountain may suffer from drought and phosphorus deficiency.

**Soils in Coc Thu**

Most of the area around village of Coc Thu was described by the farmers as ‘red’ soil good for rice and cassava. These soils are generally quite deep except where made shallower by erosion. Soil depth varies from 30 cm to more than 1.5 meters. Soil humus content is adequate under forest but there is considerable variation according to vegetation.

![Figure 2. Soil map of Na Tum and Coc Thu](image-url)
Legend for the soil map of Na Tum and Coc Thu

1. Rice paddies.
2. Soil suitable for maize on limestone. Depth from 20 cm up to more than 100 cm. Texture varies from sandy loam to clay. Dark brownish humus-rich surface horizon. Above yellowish subsoil. Russian soil class: brown soil on limestone. Vegetation consists of timber species and climbers.
3. Maize soil on graphite-rich schist and metamorphosed sandstone. Vegetation includes timber species, *Neohouzeana*, *Indosaca crassiflora* and *Eupatorium odoratum*. Cassava yield in 1995-1996 was 40 ton/ha, maize was 3 ton/ha.
4. Soil good for cassava and rice on graphite bistite, garnet schist and metamorphosed sandstone. Texture varies from sandy clay loam to clay loam. Russian soil class: yellow-red ferrallitic soil on acidic parent material. Vegetation includes timber species, *Neohouzeana*, *Indosaca crassiflora* and *Eupatorium odoratum*, and *Dicranopteris*. The yield of cassava was 15-20 ton/ha, rice was 1-1.5 ton/ha.
5. "Imperata soil" on gossan and metamorphosed siltstone. Sandy clay loam more than 1.5 m deep. Russian soil class: red ferrallitic soil on acidic parent material. Vegetation includes bushes such as *Melastoma candidum*, *Imperata cylindra* and *Dicranopteris*. The yield of cassava was 12 ton/ha, maize was 1 ton/ha.
7. Soils formed on limestone. Characteristics depend on depth. Near the top and at steeper slopes there are shallow black soils with a high pH (6-6.5) and fairly high chemical fertility. Where the soil is deeper, it has brownish colours, lower pH and lower chemical fertility.

### Table 8. Characteristics of Soils in Na Tum and Coc Thu

<table>
<thead>
<tr>
<th>Soil number</th>
<th>PH (KCl)</th>
<th>humus(%)</th>
<th>N(%)</th>
<th>P (mg/100g)</th>
<th>K (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2</strong></td>
<td>average</td>
<td>4.8</td>
<td>3.0</td>
<td>0.24</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>4.1-6.1</td>
<td>1.6-3.9</td>
<td>0.12-0.32</td>
<td>2.4-6.1</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>average</td>
<td>3.8</td>
<td>3.3</td>
<td>0.19</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>3.6-3.9</td>
<td>2.0-4.4</td>
<td>0.17-0.21</td>
<td>2.4-4.5</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>average</td>
<td>4.2</td>
<td>0.9</td>
<td>0.09</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>4.4-4.4</td>
<td>0.4-1.4</td>
<td>0.05-0.14</td>
<td>3.7-7.4</td>
</tr>
</tbody>
</table>

Note: Soils of types 1, 3, 6 and 7 were not among the analysed samples.

### 3.4.5 Soils in Dong Lac Commune

#### Soils in Na Ang

The valley of the river flowing through Na Ang is carved out of metamorphosed sand- and siltstone. Gossan is fairly common on eastern slopes of the valley. Highest hills are marble as well as the plateau to the west of the village. The highest parts of the hill east of the river are also limestone.
According to the farmers, the soils on both slopes of the valley are mostly suitable for rice and cassava. Soil is mainly clay loam or sandy clay loam. On the west slope the soil has a moderately deep humus-rich top layer which contains adequate nutrients (areas 2 and 5 on Figure 3). The subsoil consists of yellow, humus-poor clay loam that has a very low nutrient content. The depth of soil varies between 30 cm and 100 cm.

The east slope has fairly similar soil types except that there is an area of humus-poor reddish soil where gossan forms a significant part of the bedrock. The farmers did not distinguish between areas 3 and 4 (Figure 3). However, the morphological and chemical differences were thought to be large enough to justify the division. According to the farmers the soil on the east slope is generally shallower than on the west slope.

Soil samples were not taken from the higher limestone hills. The chemical characteristics of the soil there depend much on the depth of the soil. On steeper slopes and near the tops of ridges the soil is probably of shallow calcareous type. On more stable slopes a deeper soil can develop the surface layer of which is less affected by the parent material. Such soil can be brown or even red in colour and have a relatively low pH.

**Figure 3. Soil map of Na Ang**

---

**Legend for Soil Map of Na Ang**

1. Alluvial soils consisting of gravel, sand and clay. Several fish ponds and some paddies.
2. ‘Red’ soil good for cassava and rice formed on metamorphosed siltstone. Clay loam 40-100 cm deep. Russian soil class: yellow-red ferrallitic soil on acidic parent material
3. Soil suitable for rice and cassava on metamorphosed siltstone and gossan. Soil depth 30-100+ cm. Soil texture varies from sandy loam to sandy clay loam. Brownish red to red colour, no dark surface horizon. Russian soil class: Red ferrallitic soil on acidic parent material.
4. Soil suitable for rice and cassava on metamorphosed siltstone and limestone. Depth more than 50 cm. Has a deep (20-50 cm) humus-rich topsoil. Russian soil class: yellow-red ferrallitic soil on acidic parent material. Rice yield was 1-1.5 ton/ha, cassava was 20 ton/ha.
5. Soil suitable for rice and cassava on limestone.
6. Soil suitable for rice and cassava on metamorphosed siltstone and gossan. Soil depth more than 60 cm. Russian soil class: Red ferrallitic soil on acidic parent material
7. & 8. Soils formed on limestone. Characteristics depend on depth. Near the top and at steeper slopes there are shallow black soils with a high pH(6-6.5) and fairly high chemical fertility. Where the soil is deeper, it has brownish colours, lower pH and lower chemical fertility.

**Table 9. Characteristics of Soils in Na Ang**

<table>
<thead>
<tr>
<th>Soil number</th>
<th>pH (KCl)</th>
<th>humus(%)</th>
<th>N(%)</th>
<th>P (mg/100g)</th>
<th>K (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>average</td>
<td>3.8</td>
<td>3.7</td>
<td>0.22</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Soils of Ban Chang

The bedrock is characterised by alternating veins of metamorphosed siltstone and graphite-rich schists. The veins run along the river valley towards north-west. The hilly areas west of the centre and east side of the river are formed on metamorphosed siltstone. The hill north of the village is formed on graphite-rich schist.

Soil texture on both slopes varies from sandy loam to sandy clay loam. The soil under *Dicranopteris* fern has slightly lower content of available phosphorus than similar soil under forest but otherwise the differences are small. Humus content is high (5-5.3%) in mid slope under forest as well as under grassland. However, where the forest has been cleared to a field or where the soil is shallow, the humus content is lower.

According to the farmers nothing can grow on a soil colonized by *Dicranopteris* because it uses up all soil nutrients. The chemical results indicate that soil fertility is necessarily not poorer than that of a forest soil on similar parent material.

![Figure 4. Soil map of Ban Chang](image)

Legend for soil map of Ban Chang

1. Rice paddies on clayey alluvial soil.
2. Alluvial soil under permanent agriculture.
3. Soil good for rice and cassava on metamorphosed siltstone. Soil texture varies from sandy loam to sandy clay loam. Russian soil class: yellow-red ferralitic soil on acidic parent material.
5. Soil good for rice and cassava.
6. Maize soil on metamorphosed siltstone. Soil is sandy clay loam more than 50 cm deep. Russian soil class: yellow-red ferralitic soil on acidic parent material.
7. Soil good for rice and cassava on metamorphosed siltstone. Soil is clay loam and 40 cm to more than 70 cm deep. Russian soil class: yellow-red ferralitic soil on acidic parent material.

Table 10. Characteristics of Soils in Ban Chang

<table>
<thead>
<tr>
<th>Soil number</th>
<th>pH (KCl)</th>
<th>humus(%)</th>
<th>N(%)</th>
<th>P (mg/100g)</th>
<th>K (mg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 average</td>
<td>3.7</td>
<td>4.1</td>
<td>0.23</td>
<td>3.3</td>
<td>6.8</td>
</tr>
<tr>
<td>range</td>
<td>3.6-3.8</td>
<td>2.8-5.3</td>
<td>0.21-0.25</td>
<td>2.4-4.5</td>
<td>5.6-8.0</td>
</tr>
</tbody>
</table>
3.4.6 Assessment of the Soils

Chemical fertility

The soils examined generally have a quite low pH and small amounts of humus and nitrogen (Table 11). The shortage of nitrogen can be alleviated by using nitrogen-fixing trees and grasses. Using commercial fertilizers or manure is not practicable on forest lands even if they were available in sufficient quantities. The soil’s ability to retain nutrients is fairly low as a result of low organic matter content. Using commercial fertilizers would cause increased leaching of nitrogen and poor efficiency. The amounts of exchangeable K, Ca and Mg are also low except in soils developed on limestone.

The amount of free Al\(^{3+}\) was not analysed but is likely to be fairly high as a result of low pH and low amount of organic matter. In a study made by Hung (1996) soil was analysed on several shifting cultivation plots in Ngoc Phai commune. In these places the amount of free aluminium varied between 15 and 31 mg/100g soil. These amounts are much in excess of the hazardous threshold (6.0 mg/100g soil). These results suggest that aluminium toxicity can be a problem for food crop production in the area.

For the majority of upland crops the critical level of soil phosphorus content is about 10 mg/100g of soil. Amounts of available \(\text{P}_2\text{O}_5\) vary between 2.4 and 7.4 mg/100 g of soil. Total amount of phosphorus can be much higher because a large portion of the soil’s \(\text{P}_2\text{O}_5\) has formed weakly soluble aluminium phosphates. The amount of available phosphorus can be increased by liming or phosphate fertilisation or by increasing the humus content of the soil. Using green manure to decrease P-fixation is probably the most efficient way to increase the availability of phosphorus because the costs of liming and P-fertilisation are much higher. To achieve lasting results green manure should be applied to soil regularly because the rate of decomposition is fast.

### Table 11. Average chemical soil characteristics for the pilot villages

<table>
<thead>
<tr>
<th>Village</th>
<th>pH (KCl)</th>
<th>Humus %</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coc Thu</td>
<td>3,8</td>
<td>3,0</td>
<td>0,18</td>
<td>3,5</td>
<td>5,8</td>
<td>0,47</td>
<td>0,18</td>
</tr>
<tr>
<td>Na Tum</td>
<td>4,8</td>
<td>2,7</td>
<td>0,20</td>
<td>4,3</td>
<td>18,5</td>
<td>7,00</td>
<td>0,49</td>
</tr>
<tr>
<td>Na Ang</td>
<td>3,9</td>
<td>3,1</td>
<td>0,21</td>
<td>3,4</td>
<td>7,5</td>
<td>1,84</td>
<td>0,49</td>
</tr>
<tr>
<td>Ban Chang</td>
<td>3,7</td>
<td>3,9</td>
<td>0,23</td>
<td>3,3</td>
<td>7,9</td>
<td>0,87</td>
<td>0,29</td>
</tr>
</tbody>
</table>

Soil erosivity and erosion control

When under forest the soil generally has a reasonably high organic matter content (2,3-5%), which protects it from erosion. Soils having less than 3,5% organic matter are usually considered easily erodible. Soils with 40 to 60 per cent silt content are the most erodible (Morgan, 1986). High amount of clay, on the other hand, makes the soil more resistant. Soils with restricted clay content, between 9 and 30 per cent, are most susceptible to erosion. Considering both the contents of silt and clay as well as the amount of organic matter (Table 11), it can be estimated that in general local soils are not very susceptible to erosion. If the organic matter content decreases as a result of farming, the topsoil will become more erodible and rates of erosion can be great because of the steepness of slopes and high intensity of rainfall.

Slopes in the study area are mostly between 20 and 40%. Birn (1994) has estimated that a 18-20% slope without plant cover can lose 170 ton/ha of soil annually. This would mean the loss of 1,7 cm of soil every year assuming average density of activity. With the soil is lost also 442 kg/ha of nitrogen, 123 kg/ha of phosphorus and 2068 kg/ha of potassium annually.

Erosion control by tree planting must take care of two points to be effective. Firstly, the impact of raindrops must be reduced by establishing good ground cover. The most effective cover is a continuous litter layer but a multi-layer canopy can also be effective. Systems with a high closed canopy and little vegetation in lower layers should be avoided. Secondly, the amount of surface runoff should be reduced by maintaining the porosity of topsoil. In practise this means that the agroforestry system used should maintain a high level of soil organic matter.

One factor limiting the effect of erosion is the great depth of humus-rich surface layer found in soils under forest cover. This soil horizon is often 30-50 cm deep which means that with even quite great rates of erosion the infertile subsoil will not be bare for at least 10 years.

**Problem soils**

Two types of soil were mentioned by the farmers as being especially useless. Firstly, ‘Imperata soil’ such as that on Na Tum hill and , secondly, soil colonized by Dicranopteris fern.

The problem of ‘Imperata soil’ is extremely low contents of organic matter and nitrogen. Resulting low water-holding capacity and dry topsoil make establishment of trees difficult, especially if the area is used for grazing. Currently the grass growing on this soil cannot produce enough litter to improve the soil. Thus there is little hope of natural regeneration even if the grazing would end.

Chemical soil analysis revealed that soil under Dicranopteris vegetation is necessarily not less fertile than similar soil under forest. The problems are caused by strong competitiveness and flammability of the fern and could be solved by choosing appropriate management techniques and tree species.

3.5 Social and Economic Conditions

The population of Cho Don is about 46000 of which about 45000 are employed in agriculture. The labour force at village level is abundant (Tissari, 1996) as they do not have any off farm job. Ethnic minorities dominate the local population (more than 80%). They are not very skilled in cultivation on sloping land under conditions of general farmers lack knowledge of new technologies and economic development. Inaccessibility and poor infrastructure are the most important reasons. The result is poor communication with the surrounding environment. Difficult transportation leads to difficulties in marketing of agricultural products. This is a point that should be of concern when deciding the species that will be used in agroforestry systems. Thus, a first priority should be given to products that can be locally processed.

Agriculture, the predominant sector in the district economy, is mainly at subsistence level. About 70% of income generated in the district is derived from agriculture. Crop growing is the main source of income. Forest land which accounts for more than 80% of the area provides only about 9% of the income (The Department of Agricultural and Rural Development of the district, 1996). A survey in 1993 found that 100% of the households in the district earned incomes between 40,000 to 300,000
VND per month. As farmers are poor, the low investment on agriculture hinders the potential for development (Technical report No 3).

4. EXISTING AGROFORESTRY SYSTEMS

An overview of existing agroforestry systems in the pilot villages is given in Table 12:

Table 12. Existing agroforestry systems in pilot villages

<table>
<thead>
<tr>
<th>System</th>
<th>Tree</th>
<th>Crop</th>
<th>Soil type</th>
<th>Animal or other plant</th>
<th>Village found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taungya</td>
<td>cinnamon, anise, canarium</td>
<td>rice, cassava, pineapple</td>
<td>rice soil</td>
<td></td>
<td>All</td>
</tr>
<tr>
<td>Alley cropping</td>
<td>apricot, plum, mango; rice, cassava, maize</td>
<td>rice and maize soils</td>
<td>Tephrosia candida, pineapple</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td>Multilayer tree garden</td>
<td>natural species with mangletia, canarium, cinnamon, anise</td>
<td>rice and maize soils</td>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>styrax, de,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mandarin,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>soybean</td>
<td></td>
<td></td>
<td></td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>palm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>truc</td>
<td></td>
<td></td>
<td></td>
<td>Ban Chang</td>
</tr>
<tr>
<td></td>
<td>cassava</td>
<td></td>
<td></td>
<td></td>
<td>Ban Chang</td>
</tr>
<tr>
<td>Fruit garden</td>
<td>apricot, plum, soy bean, maize</td>
<td>maize soil</td>
<td>Na Ang</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mango, litchi mung bean</td>
<td>rice soil</td>
<td>Na Ang, Ban Chang</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>orange, plum, maize, cassava</td>
<td>maize soil</td>
<td>Na Ang, Ban Chang</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>orange, plum, sugar cane, rice</td>
<td>rice soil</td>
<td>Na Ang,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantation crop</td>
<td>tea with mango, orange</td>
<td>rice soil</td>
<td>Na Tum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>combination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homegarden</td>
<td>banana, apricot, plume, litchi, mango, pineapple, papaya, legume, sweet potato</td>
<td>pig, chicken, duck, cattle, fish</td>
<td>All</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apiculture</td>
<td>apricot, plum, litchi, mango, pineapple, papaya</td>
<td></td>
<td>Coc Thu</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.1 Taungya

Taungya is a system in which agricultural crops are planted between trees in the first three years. This system is popular on allocated forest land. Cinnamon, canarium and anise are common trees of the system. Rice and cassava are grown between trees in the first three years. The spacing of cinnamon is 2*2 m; of canarium it is 5*5 m. According to encountered farmers, rice soil is suitable for cinnamon and anise. It is the reason that the combination of cinnamon or anise with cassava is popular. The local people seem very interested in growing special species. This system is found in all pilot villages and 100% of the households we visited used this system. It appears that cinnamon and anise grow well in the area (Table 13). There is only one farm which has a combination of truc (Phyllostachys pubescens Maxe) with cassava in Ban Chang.
Table 13. Height Growth of Cinnamon and Anise

<table>
<thead>
<tr>
<th>Year after planting</th>
<th>anise (cm)</th>
<th>cinnamon (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>170</td>
<td>150</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>n.a</td>
</tr>
</tbody>
</table>

n.a.: not available

4.2 Alley Cropping (hedgerow inter-cropping)

Alley cropping consists of growing agricultural species between hedgerows of shrubs and trees. In some new plantation Tephrosia candida was planted to make hedgerows. Erosion control and improved soil nutrition are the objectives of the Tephrosia candida hedgerow. The species planted between the hedgerows consist of fruit trees such as apricot, pineapple, mandarin; food crops such as rice, cassava. Tephrosia candida is new to the local people. Most of interviewed farmers wanted to grow more but some said that seed was not available. However, lack of income from Tephrosia candida may be one of the reasons that discourages farmers from growing it.

4.3 Multilayer Forest

Multilayer tree garden is a combination of tree plantations include conventional forest species and other commercial tree crops. Species include Mangletia, cinnamon, anise, canarium, and gie Lauraceae are commonly planted under natural trees to improve a value of forest. Rattan is planted as a live fence.

4.4 Fruit Garden

The most common fruit is apricot as 5 to 7 years ago apricot proved very profitable in the district. Soy bean and mung bean are planted between apricots. Recently, farmers tried new varieties and species such as orange, plum, lychee, and mango. Orange accounted for 40% of the fruit trees provided by the Programme in 1997.

4.5 Fruit Trees on Tea Plantation

Tea with fruit trees is found in Na Tum, but it is not popular. Orange and mango are fruits in tea garden. Tea does not grow very well as soil nutrition seems very poor and it is not a concern of the local people. In Na Tum, Coc Thu and Ban Chang there are unattended tea gardens.

4.6 Homegarden

Homegarden consists of natural tree species and fruit trees with annual crops and livestock which are raised in adjacent to homesteads. Farmers do not pay enough attention to their homegardens. Fruit trees include banana, apricot, peach, persimmon, plum, mandarin etc. Banana is grown mainly to provide feed for pig by its stem. The arrangement in home gardens is not very well planned and seem naturally grown. Poor techniques is given as the main reason that the production of homegarden is not very well. Examples are: low yield varieties, no fertiliser, poor feeding for animal and fish. Green leaves are the main food for fish.

Animals, including pig, chicken, duck and cattle usually roam freely around home and garden. Fish ponds are found in places that are topographically suitable. Animals usualy are sold when cash is needed for household expenses and in times of hunger.

Fish ponds are very popular in Na Ang. Every household has fish pond as the topography of Na Ang is more suitable to create ponds than in other areas. A fish pond of about 300 m² provides about 60-70 kg fish per year. In 1997, the price of fish is about 15000 VND per kg, equal to about 6 kg of rice. This is one of the advantages of Na Ang that should be exploited because it is a very important source of cash. Seedlings and protection for a new plantation can be financed by that income. Encountered farmers who paid about 4 to 6 million Dong to dig trenches around a new plantation to protect it from free grazing said that the source of payment for this was from fish and cattle.

4.7 Apiculture

Apiculture with fruit tree was found in only two of the interviewed households in Ngoc Phai. A bee hive was collected from a forest then put in a fruit garden. Farmers lack techniques in honey production. They said that honey production is highly profitable. Without investment, one hive provides 4 litres of honey per year. The price of honey was 60000 VND per litre in 1997. This equals to the price of 25 to 30 kg of rice.

4.8 Appraisal of Existing Agroforestry Systems

Agroforestry systems are sustainable land use forms financially and environmentally as they are used instead of growing annual crops. In general selected species are suitable with the local ecology. However, more studies are needed for a selection of suitable species. For example analysis of the oil contents of cinnamon and anise to have a more scientific base for the species selection.

The farmers choice of species often depends on the choice of their neighbour and not on the financial analysis. The local people are more interested in special species so they did not pay much attention on fast growing timber such as mangletia, and fruit such as apricot, persimmon, mandarin, orange and longan which are very suitable for a larger range of soil types. About more than 70% of planted plant is cinnamon. If the trend in selected species is maintained for a few years it is not necessarily sustainable in term of financially and ecologically.

It is too early to assess financial viability of the existing systems as all of them are still in the starting stage. It is necessary to have an adequate planting area for a certain species for maker a oriented product. The planted area is small that production could be used locally not for a marked oriented production.

There is lack of short-term crops which provide immediate income. Rice, maize and cassava are only the popular food crops. In food production there is a lack of high yield species.

The investment for the establishment of a new plantation mainly consists of the costs for digging a trench for protection and buying seedlings. A trench is prepared around the plantations to protect plants from grazing animals. Thus crops destruction due to free grazing should be concerned. If seedlings were produced locally, the costs of establishing plantations would reduce. However, the quality of seedlings might not be ensured when produced by farmers.

5. POTENTIAL AGROFORESTRY SYSTEMS

5.1 Introduction to the potential agroforestry systems

5.1.1 Requirement for agroforestry systems in Cho Don

- meet the needs of local people regarding: food, cash, firewood, timber, fodder, and handicraft material
sustainable
- high productivity with low investments
- provide products of high unit value that are easy to process locally
- diversified production
- provide marketable products

**Advantages and Disadvantages of Agroforestry Development in Cho Don**

**Advantages**
- large area for agroforestry
- fast regeneration and diversity of natural species
- abundant labour
- farmers willing to try new systems

**Disadvantages**
- distant from major markets and transport difficulty
- high erosion potential
- lack of money for investment
- degraded soil with low chemical fertility ($\text{P}_2\text{O}_5$, N), low pH, high contents of $\text{Al}^{3+}$
- crop destruction due to free grazing
- lack of technical knowledge

**5.1.3 Market opportunities**

Market opportunities are the basis for the decision on which species to grow. The results of market study (Technical Report 6) revealed that Cho Don has opportunities to produce the following products:
- **timber and firewood.** There is a strong demand on wood and fire wood. Shortage of wood products and firewood is likely to happen in Cho Don in the next 5-10 years if the present trend of forest management remains (Tissari, 1996). The annual firewood consumption in the district is high with about 1,6 to 1,8 m$^3$/household (5-6 member/household)
- **fruit products** such as apricot, longan, persimmon and banana. These fruits can be used as fresh as well as dry.
- **material for handicraft** such as bamboo species and rattan. Beside that, bamboo species also provide bamboo shoot.
- **tea**
- **medicinal plants and spices** such as ginger

**5.1.4 Suggestion of Species which Can Be Used in Agroforestry Systems**

Tree, fruit tree and food crop are three main components of the agroforestry systems. Trees here refer to timber tree and commercial tree. The maturing period of trees is very long. However, tree can be grown in a large area and a place which is not suitable for crops. Fruit trees provide income earlier than tree and have high interest but require high investment in comparison with tree. In Cho Don there is large range of suitable food crops. Thus this suggestion more concerns about tree and fruit tree species. However, hybrid varieties for is necessary for food crops as local varieties have low yield.

The production of the current species have been used as a base for suggestions on suitable species. The list of potential species was discussed and concluded in a training course on agroforestry with the staffs of the Department of Agricultural and Rural Development of Bac Kan Province and Cho Don District and the District Forest Enterprise. However, further study on suitable species is needed.

**5.1.4.1 Tree species**

The maturing period of trees is very long (from 8 to 40 years) thus the selection of tree species is more important than any other.

Three groups of tree species which can have a first priority to grow in Cho Don include:
- fast growing timber species such as manglelia, styrrax
- bamboo species for pulp material, handicraft
- commercial species

Ten species which are recognised suitable in Cho Don are presented in table 14. Manglelia, and canarium are the most suitable species. Manglelia is a fast growing species and grows well in Cho Don for many years. Canarium has not only timber value but also provides high value fruit. Canarium is popular in natural forest. The assessment of species which can be grown in Cho Don was based on the following characteristics:
- suitable with the local condition
- high economic value
- early harvest
- fast growing
• easy to sale
• easy to grow
• easy to find seedling

Table 14 presents results of the discussion on assessments on forest species. Mark 10 was given to a good one and mark 1 was given to a bad one. To have more complete assessment the last column presented the distribution of different species in a total of 100 plants which farmer would planted.

### Table 14: Assessments on Timber Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Suitable With CD</th>
<th>Fast Growing</th>
<th>Easy to Sale</th>
<th>High Profit</th>
<th>Easy to Find seed</th>
<th>Easy Grow</th>
<th>Quick Harvest</th>
<th>Total % mark</th>
<th>% in 100 Planted plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangletia</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>66</td>
</tr>
<tr>
<td>Canarium</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>7</td>
<td>65</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>10</td>
<td>7</td>
<td>60</td>
</tr>
<tr>
<td>Fagaceae</td>
<td>10</td>
<td>7</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>10</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Michelia</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td>44</td>
</tr>
<tr>
<td>Anise</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>55</td>
</tr>
<tr>
<td>Bamboo sp.</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>10</td>
<td>7</td>
<td>56</td>
</tr>
<tr>
<td>Chukrasia</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>Styxias</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>Fagaceae</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>58</td>
</tr>
</tbody>
</table>

The ranking of timber species which is presented in Table 15 was based on the assessments of Table 15.

### Table 15. Ranking of Timber Species which can be grown in Cho Don

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Species</th>
<th>Years to harvest</th>
<th>Price of production (thousand VND)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mangletia</td>
<td>8 to 12</td>
<td>200-250/ m³</td>
</tr>
<tr>
<td>2</td>
<td>canarium</td>
<td>20-30</td>
<td>380 / m³</td>
</tr>
<tr>
<td>3</td>
<td>cinnamon</td>
<td>8-40</td>
<td>25-27/kg bark</td>
</tr>
<tr>
<td>4</td>
<td>Fagaceae</td>
<td>30-40</td>
<td>450/ m³</td>
</tr>
<tr>
<td>5</td>
<td>Michelia</td>
<td>30-40</td>
<td>450/ m³</td>
</tr>
<tr>
<td>6</td>
<td>anise</td>
<td>8-100</td>
<td>25-30/kg flowers</td>
</tr>
<tr>
<td>7</td>
<td>bamboo species</td>
<td>2</td>
<td>200/ton</td>
</tr>
<tr>
<td>8</td>
<td>Chukrasia</td>
<td>30-40</td>
<td>1000/ m³</td>
</tr>
<tr>
<td>9</td>
<td>styxias</td>
<td>8-10</td>
<td>200-220/ m³</td>
</tr>
<tr>
<td>10</td>
<td>Lithocarpus</td>
<td>30-40</td>
<td>380/ m³</td>
</tr>
</tbody>
</table>

There are arguments of growing cinnamon and anise in Cho Don. Cinnamon is a new species for Cho Don while anise has been grown previously. However, anise has not been utilised commercially. It seems that cinnamon and anise grow well in Cho Don. Studies of the Thai Nguyen Agroforestry College on anise and cinnamon confirmed this observation (Dang Kim Vui, 1997). There are about 100 years old anise trees in Yen Thinh commune which is located in the South of the district. The yield varies from 40 to 120 kg per plants. However, there is a need for a study on the oil content of these species as oil is the main product. A study would give a base for a more scientific decision on whether to grow these species on a larger scale.

5.1.5.2 Fruit species

The basis for selecting fruit species are:

- suitable with local condition.
- high value fruits
- can be used as fresh as well as dried.

High diversity in fruit production is seen as a solution to cope with a fluctuating market. That also provides income around the year (Table 15).

### Table 16. Harvesting time of different fruits
Fruit species which can be grown in Cho Don are presented in Table 16. The species are put in order according to the income per plant. The production is according to a high yield and quality varieties with a good establishment and maintain.

Table 17 Production and Outcome Per Plant of Different Species (thousand VND)

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pomelo</td>
<td>10</td>
<td>70</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>400</td>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>5</td>
<td>20</td>
<td>40</td>
<td>50</td>
<td>50</td>
<td>70</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persimmon</td>
<td>8</td>
<td>56</td>
<td>160</td>
<td>210</td>
<td>320</td>
<td>320</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plum</td>
<td>9</td>
<td>30</td>
<td>60</td>
<td>90</td>
<td>90</td>
<td>120</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apricot</td>
<td>25</td>
<td>100</td>
<td>200</td>
<td>250</td>
<td>250</td>
<td>350</td>
<td>350</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lychee</td>
<td>1</td>
<td>7</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandarin</td>
<td>3</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plum kg</td>
<td>9</td>
<td>30</td>
<td>60</td>
<td>90</td>
<td>90</td>
<td>120</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apricot kg</td>
<td>5</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>10</td>
<td>20</td>
<td>60</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apricot kg</td>
<td>3</td>
<td>7</td>
<td>20</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>9</td>
<td>27</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pomelo kg</td>
<td>5</td>
<td>10</td>
<td>30</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>10</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common jujube kg</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>15</td>
<td>30</td>
<td>30</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peach kg</td>
<td>3</td>
<td>10</td>
<td>12</td>
<td>20</td>
<td>20</td>
<td>25</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>6</td>
<td>20</td>
<td>24</td>
<td>40</td>
<td>40</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banana kg</td>
<td>15</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>10</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Custard apple kg</td>
<td>8</td>
<td>12</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>16</td>
<td>24</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pineapple kg</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorny stone kg</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The dominant species which can be planted in large areas for production of fruits for the market are:

- Apricot is the most suitable fruit in Cho Don as climate and soil are favourable. The Yellow Apricot Bach Thong is the best one.
- Citrus species have high economic value, long harvest season. Favoured soil is formed on limestone with high pH, and erosive. The good species are chum, sen
Longan has a high economic return, especially dried longan. The best variety is Long Hung Yen.

Persimmon is called tree of the poor as it is easy to grow and has a larger ecological region. It can be grown soil with poor nutrition as well as on acid soil. The best varieties are Son Duong and Luc Yen.

Grafting and vegetative propagation are new technologies that should be used as they have fruit earlier (normally 4-5 years after planting) than seed growing. According to some experts in the Research Institute of Fruit and Vegetable, grafting seedling has a better drought resistance than other seedlings. Straight and deep growing roots are characteristics that promise drought resistance of plants.

5.2 Potential Agroforestry Systems

5.2.1 Alley cropping (SALT)

The alley cropping system consists of growing agricultural species between hedgerows of shrubs and woody species. Thus this system is applied in the area growing food crops and fruit trees. The hedgerows create micro-zones favourable for agricultural crops. The main purpose of hedgerows are to reduce erosion and runoff. Thereby, the soil nutrients are maintained and improved. As the soil nutrients are maintained and improved, the productivity of plants in this combination increases and the system becomes more sustainable.

Species suitable to be grown in hedgerows are:

- Pineapple: besides soil protection pineale provides income in a short time.
- Tephrosia candida: this is a common species used in SALT systems. In terms of soil improvement Tephrosia candida or other leguminous species are the best ones to plant in hedgerows. The physical and chemical properties of soil are improved as hedgerow pruning provides nutrient-rich much. The notable amount of nutrient improvement and reduction of soil loss are shown in Table 17 and Table 18. However, Tephrosia candida does not provide any other income so it can be replaced by Leucaena glauca, Flemingia congesta. These species can provide fodder.
- Natural species: maintain the natural vegetation by trees or grasses with about 30-40 cm width. In this system no investment is required.
- tea with high density will has a good effect on erosion protection and do not require much investment. Tea also provides income. However, in term of soil improvement tea is not an ideal species.

It will be more practical if the species of in hedgerows provide sources of income like fruit, fodder and not require much labour for pruning and maintenance. For these reasons, in the above ranking pineapple is the first one. An survey of SALT in five provinces in Vietnam found that the most popular species used in hedgerow are Tephrosia candida then pineapple and tea (Bui The Hung, Nguyen Nam Hai, 1996).

The techniques to establish hedgerow are simple and not labour intensive. The distance between hedgerows depends on a slope degree (Table 19). Hedgerows are established along contour lines with the width of about 30-40 cm. With this density the hedgerows of Tephrosia candida require 20-25 kg seed/ha.

<table>
<thead>
<tr>
<th>Year after planting</th>
<th>Green manure (ton)</th>
<th>N (kg)</th>
<th>P (kg)</th>
<th>K (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>43</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>71</td>
<td>8</td>
<td>119</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>71</td>
<td>8</td>
<td>119</td>
</tr>
</tbody>
</table>

Source: Do Tuan Khiem, 1995

<table>
<thead>
<tr>
<th>Slope degree</th>
<th>With hedgerow</th>
<th>No hedgerow</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>8.5</td>
<td>13</td>
</tr>
<tr>
<td>15-20</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>&gt;20</td>
<td>21</td>
<td>26</td>
</tr>
</tbody>
</table>

Source: Do Tuan Khiem, 1995

<table>
<thead>
<tr>
<th>Slope degree (°)</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-25</td>
<td>6-7</td>
</tr>
<tr>
<td>10-20</td>
<td>7-8</td>
</tr>
<tr>
<td>&lt;10</td>
<td>9-10</td>
</tr>
</tbody>
</table>

Disadvantages of hedgerows: labour is required to establish and maintain the hedgerow, reduction of planting area by shade of hedgerow, this can be solved by natural grass. The comparisons between SALT and non-SALT farms showed that SALT requires more labour than the conventional farming methods in the first year, but increase in yields outweighs this added use of labour (Tej Partap and Watson, 1994).

5.2.2 Improved fallow

Improved fallow is a system which has fallow and cultivation phases. This system can be used in shifting cultivation areas. The cultivation phase lasts approximately 3 years and the fallow phase from 7 to 10 years. In Cho Don, after 10 years the natural regeneration gains about 50-70 m³/ha. However, the natural regeneration has a low timber value.
Fast growing species such as mangletia, and bamboo species can be planted in the fallow phase to improve economic value (Table 21). Other species such as banana, pineapple and legume species are grown in the first few years to provide income in a short time and to prevent water run-off. Growing bananas and maintaining the existing bamboo in areas such as near springs, short term income can be generated.

Thus the system supplies food and immediate cash for households and does not need external inputs. Trees protect soil surface, reduce leaching and erosion. Therefore, the trees improve soil nutrients and physical characteristics (Table 21).

<table>
<thead>
<tr>
<th>Type of farm</th>
<th>Humus</th>
<th>pH (Kcl)</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 years of cassava</td>
<td>1.3</td>
<td>4.7</td>
<td>5.0</td>
<td>3.6</td>
</tr>
<tr>
<td>12 year of magletia</td>
<td>2.8</td>
<td>5.3</td>
<td>5.1</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Source: Pham Chi Thanh, Le Thanh Ha, Pham Tien Dung, 1996

### 5.2.4 Shade trees on tea plantation

A plantation of tea with shade trees such as fruit trees and timber trees can be grown in the acidic soil and poor regeneration areas. Tea provides a harvest three years after planting and continuous income throughout the years. The tea crop rarely fails. In India tea production increases 10 to 30 % as a benefit of shading trees.

Species that can be grown in the tea plantation are longan, persimmon custard apple and hoe (nitrogen fixing, herb medicine). Hoe provides sub-product by its flower. The planting density of the shading species is 200 plants per ha, which is later reduced to 100 plants. In the first three years legume species can be grown between rows of tea to prevent water run-off.

Tea can be grown from seeds or propagated vegetatively. Sowing is simple and cheap but usually the yield and quality is not as high as by vegetative propagation. Tea grown by vegetative propagation requires more techniques and input. The TRI-777 variety which have a high production and quality tea can be planted in Cho Don. It is a Shan variety, so it is suitable for the mountainous climate in Cho Don. Cash flow of 1 ha tea plantation is presented in Table 24.
5.2.5 Taungya

Tangya is a system of plantation forestry in which crops are planted between the rows of trees for the first few years. All the suggested species can be used in this system. Agricultural crops include rice, cassava, legume and pineapple. The agricultural crops meet farmer’s immediate needs such as food while trees provide long-term products such as bark, oil and wood production. In this combination trees grow better as they facilitate a microclimate favourable for crops. Manglieta grown in a combination with rice increase their height by 33% and their diameter by 200% as compared with monocultures (Vu Biet Linh and Nguyen Ngoc Binh, 1995). The soil surface is protected and young trees are free from weeds. Labour is saved as both trees and food crops are planted in the same area. The saving in labour is about 30 days for clearing and 60 days for weeding (Vu Biet Linh and Nguyen Ngoc Binh, 1995).

Tangya can be applied on bare land. Thus available land for this system is great as the area is recognised as bare land of the district is 39700 ha. By this system the potential of the district in forest can be exploited. An example on cash flow of tangya is presented in table 27 and 25.

5.2.6 Trees on a grazing land

Trees on a grazing land consists of trees which has thorn around a grazing place to keep cattle inside instead of free grazing. Thus cattle can grow better as they save energy for moving. Other more important benefits is the saving of money which otherwise would have been paid for fencing to protect the regeneration and diversity of natural species. Bamboo and rattan are the most suitable and practical species to be used as a live fence.

5.2.7 Fruit garden and apiculture

It is recognised that fruit garden provides a very high income. All the suggested fruit species can be used in this system. However, to have a high benefit it is necessary to identify the dominant species and supplement species. The dominant species are planted with a big amount while the supplement species are planted with a small amount. The supplement species are for local consumption while the dominant species are for exported. According to soil characteristics the dominant species are different in different soil types. The dominant species for maize soil are apricot and citrus. The dominant species for upland rice soil are persimmon and longan. Legume species such as mung bean, soy bean, pineapple, sweet potato, and maize can be grown in lower layers. They can provide immediate income and protect soil surface.

Apricot and citrus require high pH soil so it is suitable to establish garden of these species on the maize soil. Banana, papaya and custard apple grow well on high pH soil so they can be grown between rows of main crops to provide income in the first few years. Table 25 gives an example of the distribution of species grown in fruit garden on maize soil. After 2-3 years 50% of the banana and papaya are removed. After 5 years only the main species remain. An example of cash flow of apricot and citrus is presented in Table 29 and 30 respectively.

Table 24. Distribution of species in a fruit garden on maize soil with (500 plants/ha)

<table>
<thead>
<tr>
<th>Species</th>
<th>Apricot</th>
<th>Orange, mandarin</th>
<th>Custard apple</th>
<th>Banana, papaya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>200</td>
<td>200</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>4*5</td>
<td>4*5</td>
<td>8*10</td>
<td>8*10</td>
</tr>
</tbody>
</table>

Persimmon and longan are the main species that can be used on the rice soil. Plum, common jujube and pineapple can be grown between the rows of the main species to have income in the first few years. Pineapple can be grown in the first three years, common jujube be grown for 5-6 years. An example of the distribution of species in this garden is presented in Table 26. Cash flow of 1 ha longann and persimmon are presented in Table 32 and 33 respectively.

Table 25. Distribution of species in a fruit garden on the rice soil with the density of 500 plants/ha

<table>
<thead>
<tr>
<th>Species</th>
<th>Persimmon</th>
<th>Longan</th>
<th>Plum</th>
<th>Pineapple</th>
<th>Common jujube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>150</td>
<td>100</td>
<td>100</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>4*5</td>
<td>4*5</td>
<td>8*5</td>
<td>0.3*8</td>
<td>8*5</td>
</tr>
</tbody>
</table>

Table 26 Input for 1 ha of fruit (thousand VND)

<table>
<thead>
<tr>
<th>Species</th>
<th>Plants/ha</th>
<th>Material</th>
<th>Seedling</th>
<th>Labour</th>
<th>Total</th>
<th>Input/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persimmon</td>
<td>500</td>
<td>7640</td>
<td>3500</td>
<td>700</td>
<td>1184</td>
<td>24</td>
</tr>
<tr>
<td>Apricot, plum, peach, common jujube</td>
<td>500</td>
<td>9700</td>
<td>3000</td>
<td>700</td>
<td>1340</td>
<td>26</td>
</tr>
<tr>
<td>Mandarin, orange</td>
<td>500</td>
<td>13350</td>
<td>3000</td>
<td>750</td>
<td>17100</td>
<td>34</td>
</tr>
<tr>
<td>Longan, lychee</td>
<td>200</td>
<td>6560</td>
<td>3000</td>
<td>540</td>
<td>10100</td>
<td>50</td>
</tr>
<tr>
<td>Mango</td>
<td>400</td>
<td>9600</td>
<td>10000</td>
<td>790</td>
<td>20390</td>
<td>51</td>
</tr>
</tbody>
</table>

Source: Tran The Tuc, 1996

Material includes: fertiliser, insecticide and seed of legume species.
5.2.8 Homegardens

Homegardens are systems which combines multipurpose trees, shrubs, crops and livestock. This is a very common way to produce food for household consumption. Homegarden provided very high production in the low-land. The system provides continuous production throughout the year as a favour of high bio-diversity.

The main purpose of the homegarden is to improve the nutritional condition of a household. Thus high diversity is needed. Species that are grown in homegardens depend on the needs of the family. All the suggested species in 5.1.4.2 can be grown in the homegarden.

Vegetables should be one of the main component of the system. Animal production is an important source of income for household expenses. Chicken, ducks, pigs, and fish are the common animal in Cho Don. The animal production can be more efficient if cassava and maize products are used as fodder.

Supplemental labour, such as old and young people of a household whose can not work hard on the field can be employed in the homegarden.

5.2.9 Silk production

Silk production can use cassava leave as a source of fodder. Labour like children, old person of a household can assist in the silk production. Thus, the labour source of a household is used more efficiently.

Local people have experience on silk production as they did have mulberry silk product before 1970s for making fish nets. Thus they can apply this system. In 1996 some households tried cassava worms which were provided by the Women’s Association with good results. However, the local people is not familiar with techniques to produce larvae.

5.2.10 Maintaining and improving cardamom under forest

Cardamom is a medicinal plant which is common in humid forests. The existing cardamom in the forests of Ngoc Phai and Dong Lac is an opportunity for the local people to maintain and improve to provide additional income. According to Nguyen Ngoc Binh (1995), in Thanh Ba (Phu Tho) 300 ha natural forest provided 2-3 ton of cardamom. Cardamom with the density of 1000 plants/ha under shade of the 20 year old mangletia trees provide 25-30 kg/ha (Nguyen Ngoc Binh, 1995). In 1997 the price of dried cardamom was 45000VND/kg. Thus one ha of cardamom can provide about more than 1000000 VND with very little input.

6. CONCLUSION

With about 30% of the territory (just enough for environment security) it is not too late to protect and maintain forest in Cho Don. However, it would be late if the current trend maintains.

The most advantages for agroforestry system are soil still has forest soil characteristics and diversity of species. However, the main constrain here is distance from market and low investment. No market for the product is a reason that the area of some crops such as legume and sugar can is smaller than before. Food security is the main concern of the local people thus increase production of paddy area is needed. The increase of food production can be improved by used more diversity of food crops and high yield varieties. It is one of solutions to increase investment for plantation such as special species and fruit tree.

For the expanding of new plantation it is necessary to identify a main crops to have more focus in investment. Diversity of main crops also needed and use of the local species are needed.

The most suitable systems for Cho Don at present include:

- *alley cropping* as slop land is dominant and shifting cultivation still maintain. Hedgerow also is one of the important component of fruit garden which the local people are mostly interested.

- *multi-storey forest*, as the system utilize the advantage of the fast regeneration and suitable with low investment.

- *taungya* to exploit a great potential of land and to cover bare area. The system also as it provides both food and long term products.

- *fruit garden*, it is recognised that the fruit garden system provides a highly profitable product. The garden of apricot, persimmon, orange, mandarin and longan would have promise future. An establish a parent garden can ensure a quality of seeding and reduce cost for establishment, and increase survival rate as long distance for transport is avoided.

Some institutional changes are necessary for a successful adoption of agroforestry in Cho Don: processing and market for agroforestry production. Improved physical accessibility increases the access to new ideas and technologies. That may help to transform from being purely subsistence-oriented to being market oriented. Credit systems and extension supports are the key factors for the adoption.

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