# Chapter 3

# MATERIALS AND METHODS

## 3.1 Selection of the villages and households

The selection of three villages and six households was based on Keil (2008)'s research on 20 villages with total 300 households within the framework of subproject F2.

In our study, three villages which were based on one geological unit (clastic sediment) were chosen as study areas (Fig 3.2). Previously, there were some studies on the relation between soil quality and family economic condition on the lime stone. However, no studies between soil quality and family economic condition on the clastic sediment have been conducted. That was a reason why we decided to do research on the clastic sediment. We used GIS to overlap geological map, village boundary map and GPS points to create one map, which helped us to identify, which villages were located on the sediment stone. We observed parent materials from cutting roads and landslide areas and used HCL solution to make sure that these villages stand on the clastic sediment unit. Three villages (Vieng Lan, Na Ten and Ta Lang Thap) were selected by this way. (Fig 3.1, Table 2 and Fig 3.2) The six households were selected randomly from these three villages. In the each village, one poor household was selected from the poor group and one rich household was selected from the rich group (Table 3.1). The rich group and poor group in each village were sorted and grouped by Subproject F2 (The Uplands Program).

**Table 3.1: Six selected Thai households**

| Village | Commune | Ethnicity group | Households (1: Poor, 2: Rich) |
|---|---|---|---|
| Kho Vang | Vieng Lan | BlackThai | 1: Lo Van Hac |
| | | | 2: Lu Van Yen |
| Na Ten | Tu Nang | WhiteThai | 1: Vi Van Yen |
| | | | 2: Luong Van Bien |
| Ta Lang Thap | Tu Nang | WhiteThai | 1: Hoang Van Tuan |
| | | | 2: Lo Thi Bau |

The fields of the selected farmers were divided into different morphological units (see detail 3.5 Field survey). According to Clemens (2010), soil quality in Yen Chau was influenced by the landscape morphology and soil erosion.

## 3.2 Study areas

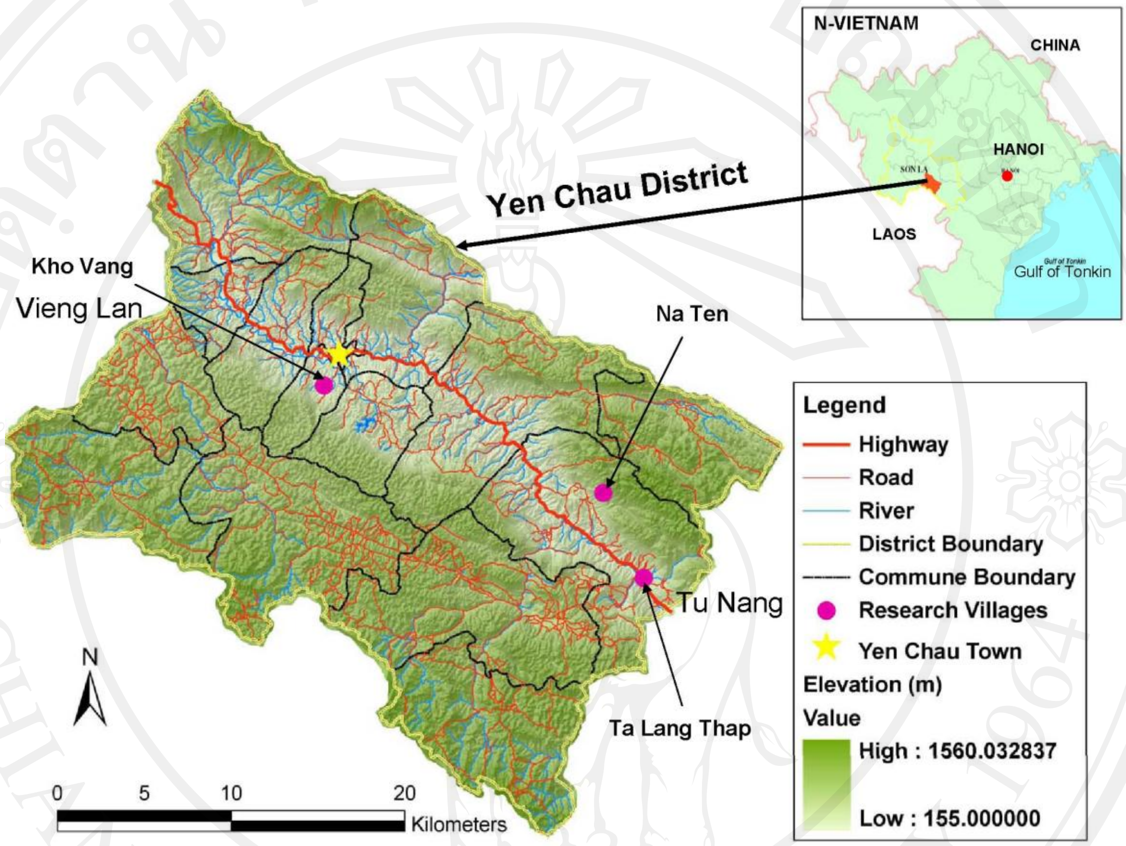



**Fig 3.1: Location of study site**

The research areas are located in three villages of two communes in Yen Chau district, Son La province, Vietnam. They are Kho Vang village (about 280m a.s.l at village and about 315m a.s.l for upland fields) in Vieng Lan commune, Na Ten village (about 465m a.s.l at village and above 480m a.s.l for upland fields) and Ta Lang Thap village in Tu Nang commune (Fig 3.1). Kho Vang and Ta Lang Thap villages, which are very close to the commune center and highway, can be easily accessed with market and traders. Thus, the farmers have chances to sell their products with high price. Na Ten village, which is far from the center and highway, is hard to access with market and traders because of very bad road conditions (steep slopes, slippery roads in rainy season and many big holes). This explains why the farmers cannot sell agricultural products with higher price than other villages. For example, in the year 2010, farmers in Na Ten sold maize with only 4,800VND/kg but in Ta Lang Thap the farmers could sell maize with 5,300VND/kg.

**Table 3.2: General information of three villages**

| Village | Ethnicity | Household | Population | Paddy area (ha) | Upland field area (ha) |
|---|---|---|---|---|---|
| **Kho Vang** | Black Thai (100%) | 98 | 431 | 10 | 54 |
| **Na Ten** | White Thai (92%)<br>Kinh (5%)<br>H'mong (3%) | 101 | 358 | 8 | 89 |
| **Ta Lang Thap** | White Thai (87%)<br>Kinh (13%) | 158 | 659 | 2 | 187 |

*Source: village heads, 2010*

In Kho Vang village, 100% people are Black Thai ethnic minority group. The total population is 431 people living in 98 households. There are 10 ha paddy rice with two crops per year (summer and spring). There are 54 ha upland field with most of the area cultivating one maize crop and little area for cassava crop.

There are three ethnic groups living in Na Ten village (White Thai 92%, Kinh 5%, H'mong 3%) with total 101 households and 358 people. The total paddy fields are 8 ha with two crops per year and the total upland fields, which are 89 ha, are cultivated only maize crop.

In Ta Lang Thap village, there are two ethnicity groups (White Thai 87% and Kinh 13%) with 659 people living in 158 households, total upland field areas are 187 ha but there is 2 ha paddy rice area.

In the three villages, most of the upland area is used to plant maize crop and very little area for cassava crop. The reason is that in recent years the maize price has grown up significantly and it brings more income than other crops.

## 3.3 Geology and Geomorphology

The three study villages are located on only one geological unit, that is clastic sediment stone (Fig 2). The characteristics of the clastic sediment (Jurassic Cretace) include the chocolate sandstone, silt stone and clay stone. Total thickness is about 950m. The sandstones and siltstones are weathered (strongly weathered and weathered) and they are easily broken by finger pressure and discoloured with movement of manganese outside into the core of stones.

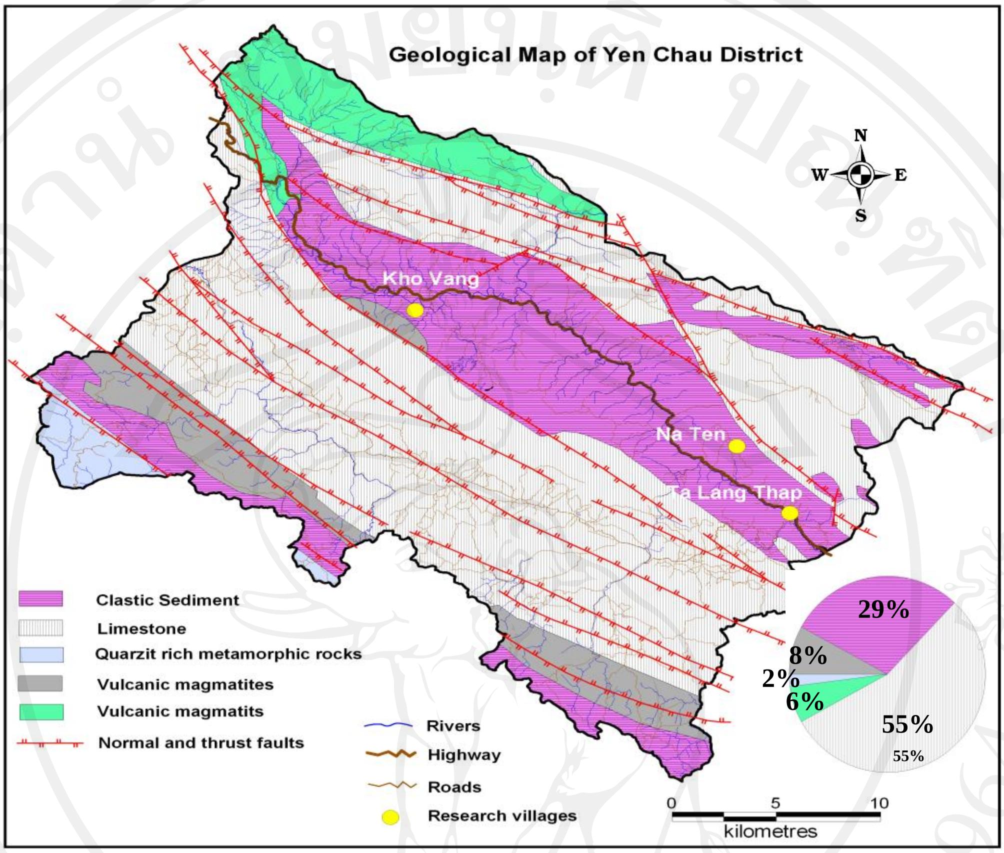
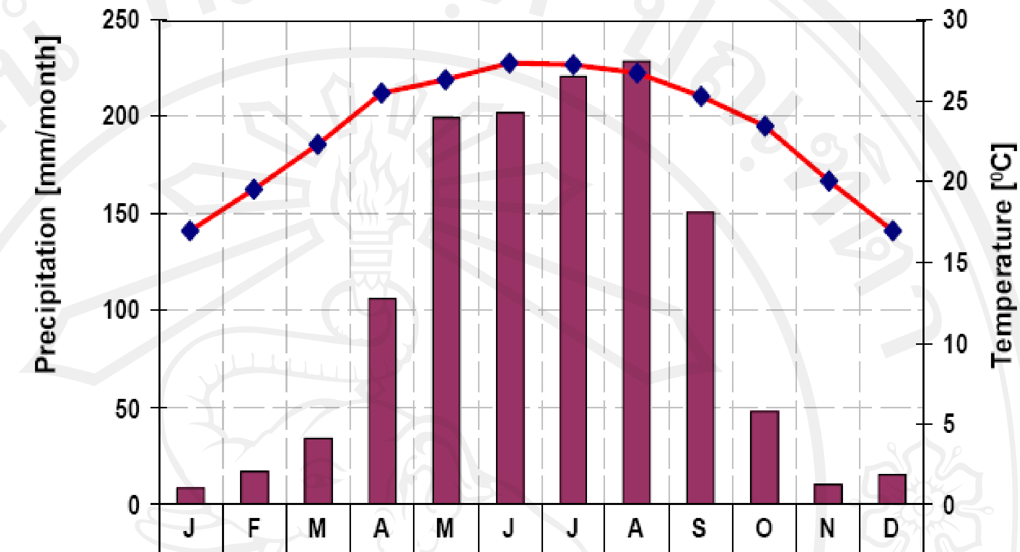



**Fig 3.2: Main geological units in Yen Chau district (Modified from sub-project B4)**

There are five main geological units in Yen Chau district (Fig 3.2), the biggest area unit is limestone that takes account for 47 119 ha (55%), the second biggest unit is clastic sediment 24 797 ha (29%), and very little amount area units are quarzit rich metamorphic 6 493 ha (8%), volcanic magmatites 5 435 ha (6%) and volcanic magmatits 1 889 ha (2%). The domination of lime-stones and clastic sediments strongly effects soil forming materials and soil characteristics in Yen Chau district.

## 3.4 Climate




| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precipitation [mm] | 8.71 | 17.3 | 33.9 | 106 | 199 | 202 | 221 | 229 | 150 | 47.6 | 10.5 | 15 |
| Temperature [oC] | 17 | 19.5 | 22.3 | 25.5 | 26.3 | 27.4 | 27.2 | 26.7 | 25.3 | 23.4 | 20.1 | 17 |

*(Source from C4), Yen Chau Climate Station*

**Fig 3.3: Climate in Yen Chau from 1998 to 2007 (Altitude 228 a.s.l)**

Yen Chau district, a mountainous area in Son La province, has four seasons a year: spring from February to April, summer from May to middle August, autumn from middle August to the end of October and winter from November to the end of January. The rainy season extends from early May to late August: 199.7 mm/month and 229.3 mm/month (Fig 3.3) respectively. The dry season, which is in winter has very little amount of rainfall: 10.5 mm in November, 15 mm in December and 8.71 mm in January. Yen Chau has a tropical monsoon climate, quite hot, wet in summer and dry, cold in winter, with annual maximum temperature at $38^0$ C and a minimum temperature at $4^0$ C, yearly rainfall amount of around 1300 mm year $^{-1}$ and humidity of 80%. Two research areas, which are located in Tu Lang commune and very near the highland Moc Chau, have a higher altitude about 460m a.s.l. Therefore, the temperature of these areas is 2-2.5$^0$C lower than other areas (Data from Mrs. Phong, the head of Yen Chau Meteorological station).

### 3.5. Field survey

The field survey was carried out to investigate typical land form unit, the biggest size and typical slope group. Each field has different slope angles and the slopes were sorted into three groups: 0-9 $^0$, 9-27 $^0$ and > 27$^0$ according to FAO, Guidelines (2006).

**First step:** We observed and took notes of general information about soil erosion status, landslide, kinds of crops and percentage of natural grass covering plots of the selected farmers. 10% HCl (Hydrochloride acid) was used to test all fields of selected farmers to assure that those fields are based on the clastic sediment stone.

**Second step:** Dividing and drawing boundaries of plots and land form units

Each plot was divided into different land form units and its boundaries was digitized, and its size and slope were calculated with GPS (Garmin, model 60Csx), GIS software (ArcGIS 9.2, Arcview 3.1 and Map Info 7.0), our observation and the topographical and land use map 2008 (Project: WGS 1984 UTM zone 48N). A single plot was divided into different landforms, slopes and aspects according to FAO, Guidelines (2006) (Fig 3.4).

**S =** Straight
**C =** Concave
**V =** Convex
**T =** Terraced
**X =** Complex (Irregular)

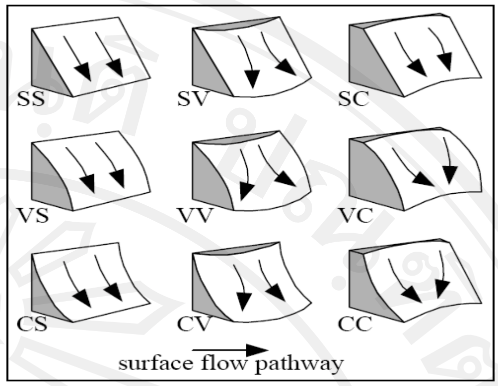



**Fig 3.4: Land forms according to FAO 2006**

All size of single landform units and slope units were counted in square meter unit. Each of these plots was divided into different land form units. Then each land form unit was divided and combined with steep gradient groups. For example, when one plot has only one land form unit but it has inhomogeneous slopes with big difference, this plot must be divided into some pieces with slope groups. A plot divided into different land form units was illustrated as an example in Fig 3.5.

**Third step:** Augering, describing soil and taking topsoil samples

Augering was carried out in all upland fields of the selected farmers and the located drills were taken exactly with GPS points. After landforms and slopes were divided into single unit, each of these landform units was drilled in the centre with depth at around 1m (Fig 3.5). By describing the soil colour, texture, and testing HCL, The soil depth was divided into different horizons. At each of these augerings, a small profile was dug with 40 cm depth to observe the depth, colour and structure of topsoil (Fig 3.5). The reason for digging small profiles is to avoid an error of the topsoil layer depth in the augering, because sometimes a layer of the topsoil depth in augering is deeper or shallower than the natural form. All descriptions of soil in the fields were based on FAO, Guideline (2006). At each of these drills, soil sample was taken at topsoil to analyse soil chemical properties with two parameters: Nt (Total Nitrogen) and Ct (Total Carbon).

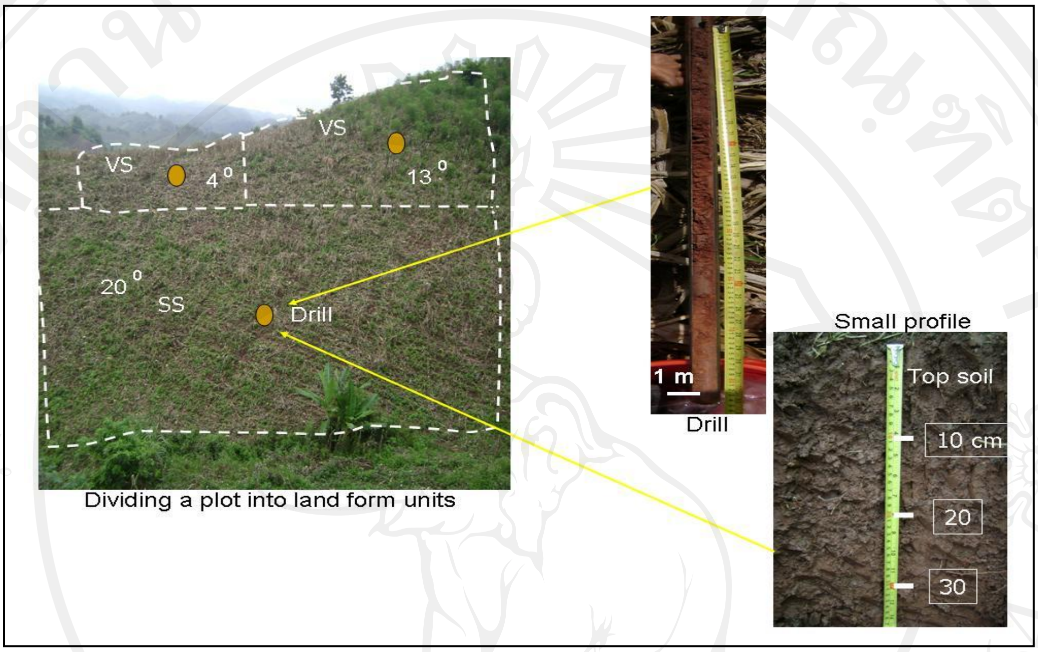



**Fig 3.5: Land form units, drills and small profile**

**Fourth step:** Selecting place to dig profile

A soil profile was dug at the typical land form unit, dominated slope group and the biggest size. Analysis of dataset was shown in Fig 3.6. With each selected farmers, we dug one soil profile at their fields. In the study area, there were six selected farmers; thus, there were six soil profiles, which should be dug with the maximum depth of about 1.8m.

In this step, a big question emerged: which plot should be dug with which slope degree and landform? All plots, land forms and augering points were mapped with GIS software and overlapped on the topographical map (scale 1:10 000, UTM-WGS 84) to calculate and analyse the biggest area unit, regular slope and dominated land forms in each farmer's fields. The area unit, slope and land form were combined and the results were used to make decision, where to dig the profile place (for an example in Fig 3.6). In fact, slopes range widely. To simplify, the slope ranges were grouped into three ranges; 0-9, 9-27 and 27-90 degrees (FAO, Guideline 2006).

The method and procedure to make a decision where to dig a profile with GIS were presented as an example in Fig 6. On the first stage, from attributed table of GIS data result (Fig 3.6-a) the landform data was analysed to show, which land form is dominated with the biggest area unit in the fields of the selected farmer (Fig 3.6-b). In this case, dominated landform, which was VS (Convex-Straight), was the biggest area with 5227 $m^2$. In the parallel with analysing landform, the slope gradient was also analysed (Fig 3.6-c) and the result showed that the slope gradient from 9 to 27 degree was prevailing (8682 $m^2$) in the fields of the selected farmers. On the second stage, GIS combined landform and slope result (Fig 3.6-d) and the result indicated, that a soil profile should be dug at VS land form with slope from 9 to 27 degree. On the final stage, GIS turned back to the attributed table (Fig 3.6-a) to find a plot, which was suitable for requirement condition (VS landform with biggest area unit, slope 9-27 degree and biggest plot). In this case, the profile should be dug at in the plot 3 (Fig 3.6-a), at augering H3-P3, point P5, because it was fit for all conditions; VS landform with the biggest area unit (1971 $m^2$), slope with 18 degree and plot 3 with biggest area (6247 $m^2$).

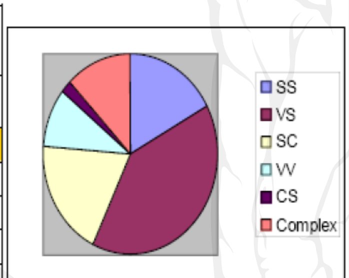
a) *GIS data result*

| Id | Land forms | Slope | Exposition | Altitude | Augering ID | Land form area (m2) | Plot area (m2) |
|---|---|---|---|---|---|---|---|
| plot 4 | SS | 30 | SW 21 | 307 | 1 | 1122.244 | 2362.38 |
| | VS | 9 | SW 21 | 332 | 3 | 599.232 | |
| | SS | 36 | SW 21 | 325 | 2 | 1140.909 | |
| Plot 3 | SC | 26 | E | 368 | 2 | 1320.865 | **6247.94** |
| | Complex-landslid | 26 | E | 367 | 3 | 842.939 | |
| | VV | 26 | E | 366 | 1 | 937.978 | |
| | SC | 16 | E | 376 | 4 | 1174.851 | |
| | **VS** | **18** | **E** | **384** | **3 - 5** | **1971.316** | |
| Plot 2 | VS | 14 | W | 356 | | 276.649 | 2588.3 |
| | VS | 22 | W | 377 | 2 | 1144.015 | |
| | Complex-landslid | 0 | ES 15 | 357 | 3 | 755.454 | |
| | VS | 14 | ES 12 | 356 | 1 | 412.183 | |
| Plot 1 | VS | 27 | ES 13 | 389 | 3 | 275.972 | 1426.28 |
| | VV | 27 | ES 13 | 375 | 4 | 325.605 | |
| | CS | 32 | ES 13 | 337 | 2 | 276.232 | |
| | VS | 28 | ES 13 | 372 | 1 | 548.474 | |
| Total | | | | | | | 12624.9 |

**Place to dig a profile**

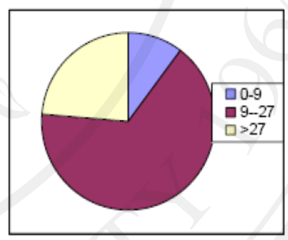
b) *Landform analysis result*

| Land form | Area ($m^2$) |
|---|---|
| SS | 2263.1 |
| **VS** | **5227.8** |
| SC | 2495.7 |
| VV | 1263.6 |
| CS | 276.2 |
| Complex | 1598.4 |

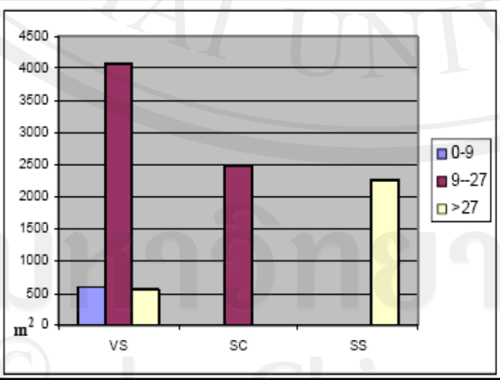



c) *Slope analysis result*

| Slope (degree) | 0-9 | 9--27 | >27 |
|---|---|---|---|
| Area ($m^2$) | 1354.69 | **8682.37** | 3087.86 |




d) *Combination of landforms and slopes result*




Combination of landforms with slopes

| Landform ($m^2$) \ Slope (degree) | 0-9 | 9--27 | >27 |
|---|---|---|---|
| VS | 599.23 | **4080.13** | 548.47 |
| SC | 0 | 2495.72 | 0 |
| SS | 0 | 0 | 2263.15 |

**Fig 6: An example of the process with GIS to decide where to dig a soil profile**

**Fifth step:** Describing the soil profiles and taking soil samples

The soil profiles were described in fields according to *the Field Guide for Soil Description, Soil Classification and Soil Evaluation* (FAO, 2006) and soil samples were taken to analyse the physical properties and chemical properties in laboratories. To determine the bulk density of soil, five soil ring samples were taken from each horizon with size 100 $cm^2$ per ring and each ring was packaged separately. At each horizon, 2 kg soil sample was taken to analyse in the laboratory of Hohenheim University – Germany and "The Soils and Fertilizers Research Institute" in Vietnam, where only soil texture was analysed.

**Final step:** Interviewing selected farmers.

Selected farmers were interviewed separately with questionnaires. The content of the questionnaire was about land use history, soil erosion, landslide, income, input, output, etc.

## 3.6 Laboratorial Methods

Each selected farmer had several fields; In order to have an over look, we decided to do augers in all fields and dig only one soil profile on the field, which met all requirements for study (typical land form, dominated slope, biggest size). The total 109 soil samples were taken from 20 upland fields of six selected farmers. The soil samples included 80 topsoil samples of augerings to analyse Nt and Ct, and 29 soil samples of six soil profiles to analysis Nt, Ct, texture, exchangeable basic cations, CECpot, pH, and available P and K (Bray 1). All soil samples were taken, air dried and then sieved (2mm).

## Physical analyses:

**Bulk density**

The five individual soil sample rings (cylinder) of each horizon were weighed fresh and an averaged value. Then they were put into a dry oven at $90^0$C (in Yen Chau laboratory, the dry oven could not reach the temperature $105^0$C). After 10 days in the drying oven soil samples reached a constant weight and dry samples were weighed and calculated average value for five rings. If one or two of the five soil samples have much different weight from the others, they were excluded, when the average weight was measured. Soil weight divided by 100 is bulk density value.

**Soil texture**

The soil texture was analysed in “The Soils and Fertilizers Research Institute” of Vietnam in Hanoi. The soil is put into hydrogen peroxide liquid ($H_2O_2$) 30 – 35% to eliminate organic elements. Then, this soil sample is diffused with sodium hexametaphosphate/ sodium carbonate and shaken over night. Clay and silt are separated from sand by wet sieve (50 μm) and identified by Pipet method. Sand is separated by dry sieve.

## Chemical analyses:

### pH values in $H_2O$ and KCl

The soil samples of the profiles were measured with $H_2O$ deion and 1 M KCl solution with the Mettler Toledo Seven Easy device type and calibration with 7, 4 and 9. The measurement of soil samples of the pH value was asymmetry (mV) 12 and Steilheit (mV/pH) 99% for $H_2O$, and asymmetry 10 (mV) and Steilheit 95% (mV/pH) for KCl (Herrmann, 2005)

### Potential Cation Exchange Capacity (CEC pot)

The measurement of CEC potential was determined according to Herrmann (2005). The fine soil at pH 7 was mixed with 1 M sodium acetate. This mixture was then shaken until it saturated and became an exchange complex. The exchange complex was washed with ethanol until a conductivity was achieved under 40μS. To displace back sodium from the exchange, 1 M $NH_4$-acetate was added and filtered. According to Herrmann (2005), the liberated sodium was measured by the flame photometer. All vials had to be rinsed with deionized water before analyses because sodium was displaced slightly.

**Interchangeable neutral cations, base saturation and S-Value**

The cations in the exchange complex were washed with 1 M $NH_4$-acetate. In the filtrate were exchanged sodium, calcium and potassium cations which were determined by the flame photometer, while magnesium was measured by the flame AAS (atomic absorption spectrometer). In the measurement of $Mg^{2+}$, the concentration of the samples was diluted with $H_2O$. Even before this analysis, all sample containers were rinsed with deionized water. The base saturation, a purely mathematical value, is the percentage of exchangeable neutral cations at cation exchange capacity. The sum of exchangeable cations accounts for the S value. (Herrmann, 2005)

**Available K and P according to Bray1**

The method according to Bray and Kurtz (1945) is used for determination of plants to which P and K are applied. The samples were mixed with Bray solution ($NH_4$ F 0.03M, HCl 0.025M), shaken and filtered. Subsequently, the filtrates were mixed with molybdenum blue solution and the P concentration at Cary 50 spectrophotometer from Varian determined (Herrmann, 2005). The K concentration was measured with flame photometer. Bray I method is used to analysis for acid soil

**Ct, Nt and Corg**

The total Nitrogen (Nt) and total Carbon (Ct) were measured by Vario EL (elemental analysis systems, Hanau, Germany) and air-dried by dry combustion.

## 3.7 Land evaluation according to FAO/ITC-Ghent method

The land evaluation method is based on FAO/ITC-Ghent (Sys et al. 1993), which is a semi - quantitative approach for bio-physical land evaluation and does not involve social and economic parameters. The bio-physical factors of the local conditions include climate, topography, wetness and soil properties. It is based on some simple plant growth functions and crop requirements.

**Table 3.3: Topography, climate and soil requirement for crops (Sys et al. 1993 and Graef 1999, modified)**

| **Land Suit. class*** | | S1 | | S2 | S3 | N1 | N2 |
|---|---|---|---|---|---|---|---|
| **Limitation level**** | | 0 | 1 | 2 | 3 | 4 | |
| **Rating** | | 100 95 85 60 40 25 0 | | | | | |
| **Category** | **Characteristics** | | | | | | |
| **Topography** | - Slope | | | | | | |
| **Wetness** | - Drainage<br>- Flooding | | | | | | |
| **Physical soil characteristics** | - Texture<br>- Coarse fragments<br>- Soil depth<br>- $CaCO_3$<br>- Gypsum | | | | | | |
| **Soil fertility characteristics** | - Apparent CEC<br>- Base saturation<br>- Sum of bases<br>- pH ($H_2O$, KCl)<br>- Organic carbon | | | | | | |
| **Salinity and alkalinity** | - ECe<br>- ESP | | | | | | |
| **Climate** | - Precipitation<br>- Temperature<br>- Huimidity<br>- Radiation | | | | | | |

*Land suitability classes: S1: very suitable; S2: moderately suitable; S3: marginally suitable; N1: actually unsuitable; N2: permanently unsuitable. **limitation level: 0: no; 1: slight; 2: moderate; 3: severe; 4: very severe.

The parametric-Storie Index Method (Sys, 1991) is used as a quantitative evaluation of the suitability of land. The numerical ratings which range from the maximum value 100 to the minimum value 0 depend on the number of different limitation levels or suitable classes of the land properties.

The climate and soil index are calculated individually according to the Storie Method as in the following formula:

$$I = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \ldots$$

($I_{[C, S]}$ = climate or landscape and soil index; A, B, C, D,…=ratings)

The climate indexing is converted into a climate rating in the following formula:

$Ic < 25$, then $Ic \times 1.6 = Rc$ (Climate rate, $Ic$= climate index)

$25 \leq Ic \leq 92.5$ , then $Ic \times 0.9 + 16.67 = Rc$

$Ic > 92.5$, then $Ic = Rc$

Finally, the land index is made by multiplying the climate rating and landscape and soil index according the Storie method (Storie 1950). The land index is then classified into various suitability classes as follows:

| INDEX | SUITABILITY CLASS |
|---|---|
| 100-75 | S1: very suitable |
| 75-50 | S2: moderately suitable |
| 50-25 | S3: Marginal suitable |
| 25-0 | N1: unsuitable |

**Table 3.4: Index value for suitability classes**