CHAPTER 4

RESEARCH METHODS

4.1 Conceptual framework

The study focused on assessment of sustainability of crop production system (CPS), and follows the conceptual framework as shown in Figure 4.1. Secondary data analysis and household surveys were made to facilitate in the formulation of the sustainability of CPS. The assessment of sustainability of CPS using three approaches, namely sustainability indicator analysis (SIA), analytic hierarchy process (AHP), and AMOEBA were conducted as explained in Chapter 2.

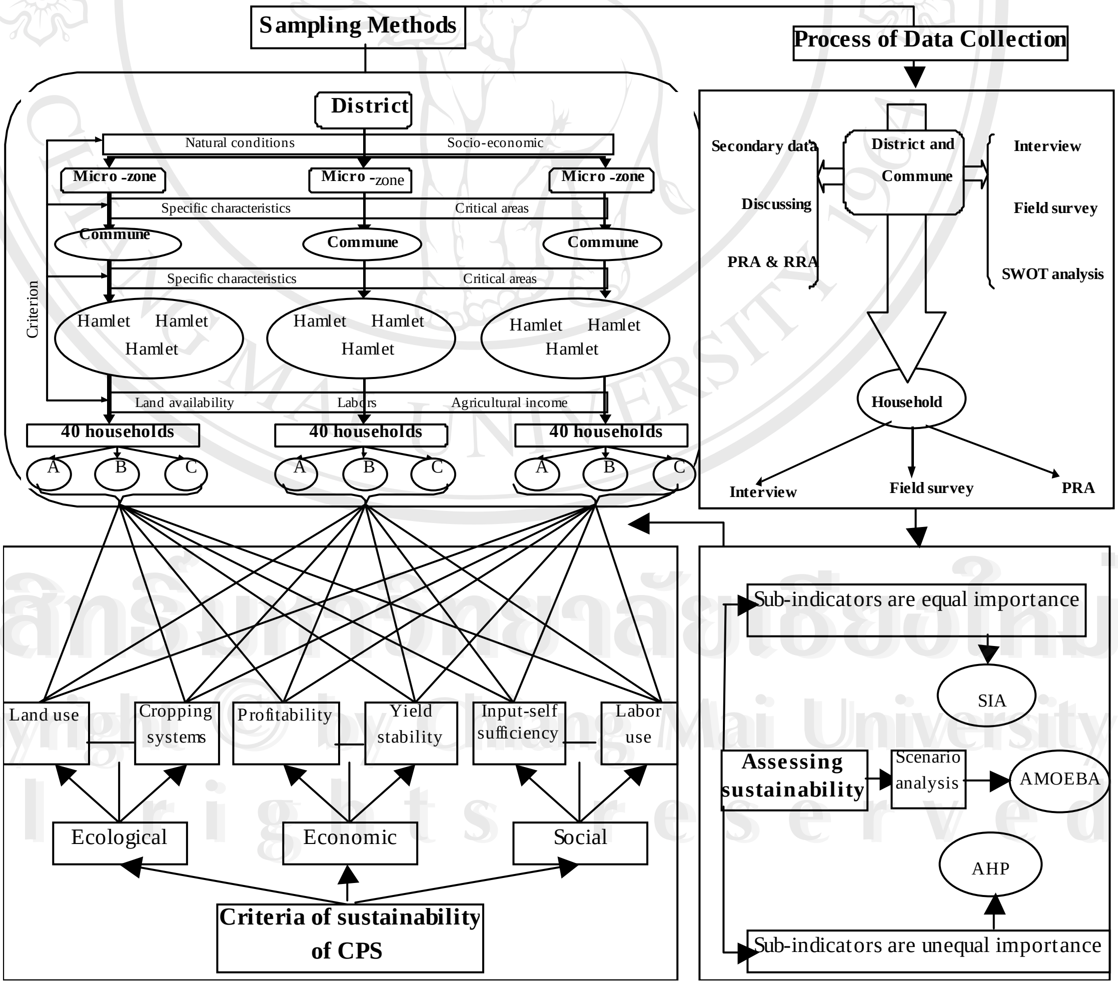


Figure 4.1 Conceptual framework of the study

Figure 4.1 shows the overall conceptual framework for the assessment of sustainability of crop production system (CPS) at the household and commune level in the context of upland agriculture. The framework consists of four main components as criteria of sustainability of CPS, sampling methods, process of data collection, and assessment of sustainability. The criteria of sustainable CPS component are broken down into ecological, economic, and social criteria. Each criterion is broken down into sub-criteria depended on specific level of analysis. The sampling method is carried out through three steps from district to household level. Both field surveys and collecting secondary data from relevant organizations are applied. Finally, multi-criteria techniques are used for making decisions among the selection of alternatives governed by these various environmental, economic and societal criteria for CPS through three approaches, namely SIA, AHP, and AMOEBA approach.

4.2 Identification of study areas and sampling methods

4.2.1 Criteria for classification of micro- zone in the district

Natural environment

The natural conditions such as geography, topography, climate, soil, and hydrology determinate the basic characteristics of cropping systems, because these factors play a role as the boundary or restriction of selecting species and cultivation.

Socio-economic and infrastructure conditions

Socio-economic situation and infrastructure decide and effect directly on the CPS development. Some main criteria were chosen for site selection are: Position and history of inhabited area; infrastructure and market; and land holding size of households.

4.2.2 Commune sampling

Through the discussion with the related agencies in the district, principles for commune sampling were defined as the investigated communes take three communes in the district, especially the sampled communes in each micro-zone must be represented for its specific characteristics as defined.

4.2.3 Household sampling

Based on the results of CPS survey at commune level and the consultation of commune's authorities, the criteria of sampled households are identified those are land availability (mainly based on land area and topography), labors, and income from agriculture production. Thus, 120 households are selected for data collection (3 communes/district, 3 hamlets/commune, 40 households/commune)

4.3 Methods and tools for data collection

To serve for assessing CPS in the study sites, all of data relating to CPS, which were collected by semi-structure interviews and formal interviews of individual farmer households in three communes of Nam Dong district. Besides this, secondary data were also collected to support the primary data in process of problem and data analyses. Moreover, some tools in Participatory Rural appraisal (PRA) approach were applied in evaluating the problems relating to crop production systems (CPSs).

4.3.1 Methods and tools for commune level

Secondary data collection

The secondary data were firstly collected from people committees of the communes, head of village, the district extension center, veterinary station and statistical agricultural division. At the same time, the data from various publications such as journals, unpublished research works, reports, proceedings, etc. also collected. This includes data on land distribution, land use, population, income and others relating to agricultural production.

Primary data collection

- Discussion with officers and farmers in the district and commune level. Semi-structured interviews of some key informants representing different farmer groups to gather information on all of aspects of crop production system (CPS).

- Field surveys of CPS components with a purpose to gain the knowledge relative to CPS as well as the potentials and constraints affecting to CPS.

- Transect walk to identify and analyses distinct CPS characteristics of each commune. This also gave more detail on the potentials and problems in different parts of landscape. It included soil characteristics, water resources, crops and farmer's practices, advantage and problems in special locations.

- Matrix analysis and ranking of feasibility. These were used to get insight into feasibility aspects of each CPS, and constraints based on the determined indicators. The result of this was to show the relative importance of each CPS, and constraints that were of concern by farmers in their community. The ranking technique was followed the analytic hierarchy process (AHP) procedure.

- SWOT (Strengths-Weakness-Opportunities-Threats) analysis applied to the core group of cadres and farmers in communes.

- Community validation. At the end of all workshops, all information gathered were fed back to farmer's groups for further verification and filling in identified gaps. The participants were able to present and explain their findings. The validation also aimed to assess farmer's participation and provide recommendations.

4.3.2 Methods and tools for household level

Taking more samples for analysis, the interviewing of individual farmer households by questionnaires and semi-structure interviews was conducted. Total of 120 households were interviewed in three communes. The data collected consist of information that was related with CPS (Table 4.1) as well as constraints in CPS. Moreover, the data on other sources of income were also collected to evaluate livelihoods of households. In addition, field surveys were done to get more information on farmer's CPS.

4.4 Framework for measuring sustainability indicators

4.4.1 Definition of measurable indicators

Defining sustainability criteria is the first basic step towards developing an analytical framework for environment-economic-social decision-making. In this study, CPS sustainability is assessed at the household and commune level. Based on the concept of sustainable agriculture, especially, in view of biophysical and socio-economic conditions in the study area, 10 indicators are selected for the evaluation. The indicators at household and commune level are showed in Table 4.1, in which each level will have particular evaluative indicators.

Table 4.1 Indicators used to assess sustainability of crop production systems

Household level		**Commune level**
Land use	Yield stability	Input self-sufficiency
Crop diversification	Profitability	Labor use
Soil fertility management	Input self-sufficiency	Food security
Pest-disease management		Land use
		Crop diversification

4.4.2 Measurement of indicators

4.4.2.1 Ecological sustainability

Ecological sustainability was assessed based on four indicators: land use, crop diversification, soil fertility management, and pest-disease management.

- Land use was examined through the proportion of land under field crops, homestead and orchard (or through the proportion of land under each CPS).

- Cropping systems were analyzed using crop diversification criteria. Crop diversification was measured through a crop diversification index, using a formula developed by Bhatia (1965):

$$ICD = 1 - \frac{(Pa + Pb + Pc ... + Pn)}{Nc} \qquad [4.1]$$

Where:

ICD = index of crop diversification

P_a = Proportion of sown area under crop *a*

P_b = Proportion of sown area under crop *b*

P_c = Proportion of sown area under crop *c*

P_n = Proportion of sown area under crop *n*

N_c = Number of crops.

Note:

- ✓ Crops occupying less than three percents of cropped area were excluded from the analysis.
- ✓ The higher ICD value indicates the higher diversity

- Soil fertility management was evaluated based on the proportions of farmers using chemical and organic fertilizers, meaning farmyard manure and compost, and cultivating legume crops. The ratio of the amount of chemical fertilizers applied per CPS to total amount used will be also considered and also it was used to compare sustainability between CPSs in AMOEBA, AHP, and SIA method.

- Management of pests and diseases was assessed based on the proportion of farmers using biological, mechanical, and chemical methods. The ratio of the amount of chemical pesticide applied per CPS to total amount used will be also considered and also it was used to compare sustainability between CPSs in AMOEBA, AHP, and SIA method.

4.4.2.2 Economic sustainability

Land productivity, yield stability and profitability from staple crops were considered the indicators of economic viability. These are detailed as follows:

- Land productivity was measured through physical yield of crops. Crop yield data were collected through a household survey.

- The stability of crop yield was examined by constructing an index based on farmer's subjective reported to a question related to yield trend. The index was constructed based on the following formula:

$$ITY = \frac{(fi * 1 + fd * (-1) + fc * 0)}{N} \quad [4.2]$$

Where:

ITY = Index of trend of yield
f_i = Frequency of reported indicating increasing yield
f_d = Frequency of reported indicating decreasing yield
f_c = Frequency of reported indicating constant yield
N = Total number of responses.

Note: The higher ITY value indicates the higher stability ($-1 \leqslant$ ITY $\leqslant 1$)

- Farm profitability was determined based on financial return. Financial return was analyzed through gross margin of whole farm.

$$GM = GR - TVC \quad [4.3]$$

$$GR = \sum_{i}^{n} Q_i P_i \quad [4.4]$$

$$TVC = \sum_{j}^{m} P_j X_j \quad [4.5]$$

Where:

GM = Gross Margin,

GR = Gross Revenue,

TVC = Total Variable Cost,

Pi = the price output system i,

Qi = the output of system i,

Pj = the price of variable input j, and

Xj = the quantity of variable input j.

Note:

- ✓ Price here referred to as the "farm gate" price of market price deducted by transport cost to market and transaction cost in marketing
- ✓ Total costs of adding variable inputs to the production process and are incurred only if production takes place (such as: seed, fertilizer, chemicals, hired labor, fuel, interest for capital, etc.)

4.4.2.3 Social sustainability

Social acceptability was assessed in terms of input self-sufficiency, labor use, and food security. These are detailed as follows:

- Input self-sufficiency was determined based on ratio of local input costs to the total input costs. The higher local inputs mean higher input self-sufficiency.
- Labor use was determined on the ability to generate employment within the CPS through calculating the amount of labor for each crop as well as the whole CPS.
- Family food security was assessed in terms of adequacy of food grain produced as well as farm households' ability to purchase food grain required for consumption.

4.5 Method of data analysis

Descriptive statistical methods with contingency table, diagram, chart, and map were used to display the finding results in PRA and RRA workshop. Moreover, in order to assess sustainability of CPS in this area, the methods included AMOEBA approach, as well as AHP and SIA method were employed.

4.5.1 Descriptive statistical analysis

To review the general information on CPS in study sites, the results from semi-structured interview, formal survey and interview were analyzed using descriptive statistics such as percentage, mean, standard deviation values, and presented with support of relevant contingency table to compare the different characteristics of all sustainable indicators for CPSs in each commune.

4.5.2 AMOEBA approach

In this approach, the results obtained by monitoring the indicators are summarized and integrated. Quantitative, qualitative, and graphical or mixed procedures have been used to integrate results. To achieve an adequate integration and synthesis of the results, the process of evaluation followed three major stages:

- Selecting indicators of performance on different scales and related to different perspectives. A list of indicators of agricultural performance (and the range of their values) that can be used to reflect the various perspectives generated at the household level, and commune level is shown at Table 4.1.
- Defining feasibility domains for selected indicators. Having chosen the variables on different axes, one must define a range of 'feasible' values for each indicator. Within the 'feasibility domain' 'target values' may be added to the graph that reflect the goals expressed by the representatives of different perspectives.
- Assessing current situation on a multi-dimensional state space. In this step, the actual value of each indicator of performance is recorded on the graph. This makes it possible to visualize the position of the actual values. The results of integrating and monitoring the different indicators are presented at the AMOEBA diagram (Figure 4.2).

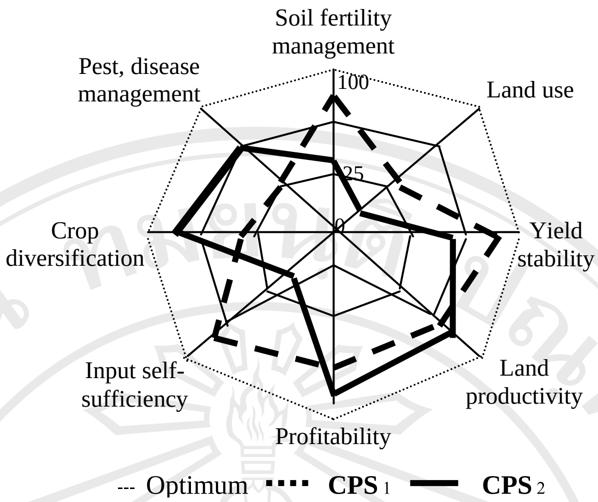


Figure 4.2 AMOEBA diagram reveals integration of different indicators

4.5.3 Assessing sustainability

4.5.3.1 Assumed indicators are equal importance

The method used is SIA (Praneetvatakul *et al.,* 2001). Sustainability indicators were established based on the criteria and scoring technique will be used for assessment. In the first step, sustainability indicators at the household and commune level are established as illustrated in Table 4.1. All the indicators have been assumed to have equal importance in terms of their contribution to crop production sustainability. Score identified for each indicator were ranked into three classes as non-sustained (N), conditional sustained (C) and sustained (S). The methods of score computation in this analysis are based on the value of each indicator that is collected from field survey. Each CPS got score for each indicator through comparing them with other CPSs. So, the highest value was given score of 10 and other lower value was given specific score depended on comparable value with the highest value. Thus, the score is ranged from 1 to 10 score.

To assess the sustainability of CPSs at household, each household is converted to scores correlated with each indicator. The scores were aggregated from all indicators and become cumulative scores for a household. They are used as a reference for sustainability class:

Household level (indicators used to assess are shown as Table 4.1): cumulative scores less than 25 are classified as N, between 25-40 is classified as C, and greater than 40 are classified as S.

Commune level (indicators used to assess are shown as Table 4.1): cumulative scores less than 15 are classified as N, between 15-25 is classified as C, and greater than 25 are classified as S.

To assess the sustainability of each CPS at the commune level, the household aggregated scores are grouped at commune level. For the comparison between CPSs in each commune, coefficient index (N=0.2, C=0.4 and S=0.8) is multiplied with number of samples in respective class to calculate sustainability index (SI), performance value, and performance percentage (PP).

$$SI = \frac{\Sigma \text{ Sustainability score}}{\text{Maximum score}} \times 100 \qquad [4.6]$$

Where:

Sustainability score = (Coefficient index) x (Number of samples)
Maximum score = (Maximum coefficient) x (Total samples of the village)

The SI indicates the significance of each indicator in sustainable CPS. In this study, it is used to compare indicators within the household and the commune.

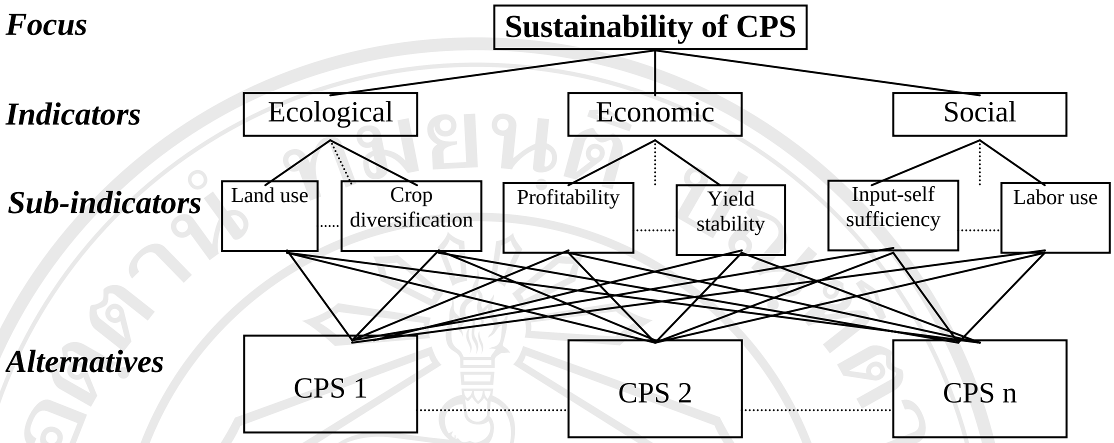
$$PP = \frac{\text{Sum of performance values}}{\text{Maximum performance values}} \times 100 \qquad [4.7]$$

Where:

Performance value = Sustainability Index x Maximum sustainability score
Maximum performance value = Maximum sustainability score x Number of indicator

The PP indicates the overall performance of sustainability from all indicators. It is used to compare the relative sustainability levels of each CPS in the commune.

4.5.3.2 Assumed indicators are unequal importance



Note: CPS is crop production system

Figure 4.3 Hierarchy for the determination of sustainability of CPS

The method was employed is AHP. The AHP is a decision-aided method, which decomposes a complex multi-factor problem into a hierarchy, and each level is composed of specific elements. It uses hierarchic structures, matrices and linear algebra to formalize the decision processes (Saaty, 1980). The hierarchy of problem is showed in Figure 4.3. The overall objective of the decision lies at the top of the hierarchy, and the criteria, sub-criteria and alternatives are on descending levels of this hierarchy.

AHP is a multi-criteria decision method that uses hierarchical structures to represent a problem and then develop priorities for alternatives based on the judgment of the user (Saaty, 1980). So, once the hierarchy model has been structured for the problem, the participating decision makers provide pairwise comparisons for each level of the hierarchy, in order to obtain the weight factor of each element on that level with respect to one element in the next higher level. This weight factor provides a measure of the relative importance of this element for decision maker.

To compute the weight of factors of *n* elements, the input consists of comparing each pair of the element using the following scale set:

$$S = \left[\frac{1}{9},\frac{1}{8},\frac{1}{7},\frac{1}{6},\frac{1}{5},\frac{1}{4},\frac{1}{3},\frac{1}{2},1,2,3,4,5,6,7,8,9\right]$$

The pairwise comparison of element *i* with element *j* is placed in the position of a_{ij} of the pairwise comparison matrix A as shown below:

$$A = \begin{pmatrix} a_{11} & a_{12} & . & . & a_{1n} \\ a_{21} & a_{22} & . & . & a_{2n} \\ . & & & & \\ . & & & & \\ a_{n1} & a_{n2} & . & . & a_{nn} \end{pmatrix}$$

The reciprocal value of this comparison is placed in the position *aij* of *A* in order to preserve consistency of judgment. Given *n* elements, the participating decision maker thus compares the relative importance of one element with respect to second element, using the 9-point scale showed in Table 4.2.

Table 4.2 The AHP scales for paired comparisons.

Intensity of importance	Definition and explanation
1*	Equal importance - two activities contribute equally to the objective.
3	Moderate importance - Experience and judgment slightly favor one activity over another.
5	Essential or strong importance - Experience and judgment strongly favor one activity over another.
7	Demonstrated importance - An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance - The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values between the two adjacent judgments when compromise is needed.
Reciprocal of above numbers	If an activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.
Rational	Ratios arising from the scale - If consistency were to be maintained by obtaining n numerical values to span the matrix.

* The scale 1.1, 1.2,.................1.9, or even a finer one, can be used to compare elements that are close together, or near equal in importance. Similarly for 2,.....,9

Source: Adapted from Saaty (1980)

From the preference matrix a corresponding set of weights (the eigenvector w) and a consistency ratio (CR) are determined by the AHP computer program known as “Expert choice”. The consistency ratio is ratio of the decision maker’s inconsistencies and the inconsistencies obtained from randomly generated preferences.

Determining the priorities of each alternative with the assigned weight for each alternative by analyzing the judgmental matrices. Then combining both subjective and objective judgments in an integrated framework based on ratio scales from simple pair-wise comparisons. It finally gives the ranking of each alternative through a simple calculation.