CHAPTER 4

Research Methods

4.1 Conceptual Framework

The study is focused on sustainability assessment of rice-based cropping system in the central plain region of Myanmar and follows the conceptual framework in Figure 4.

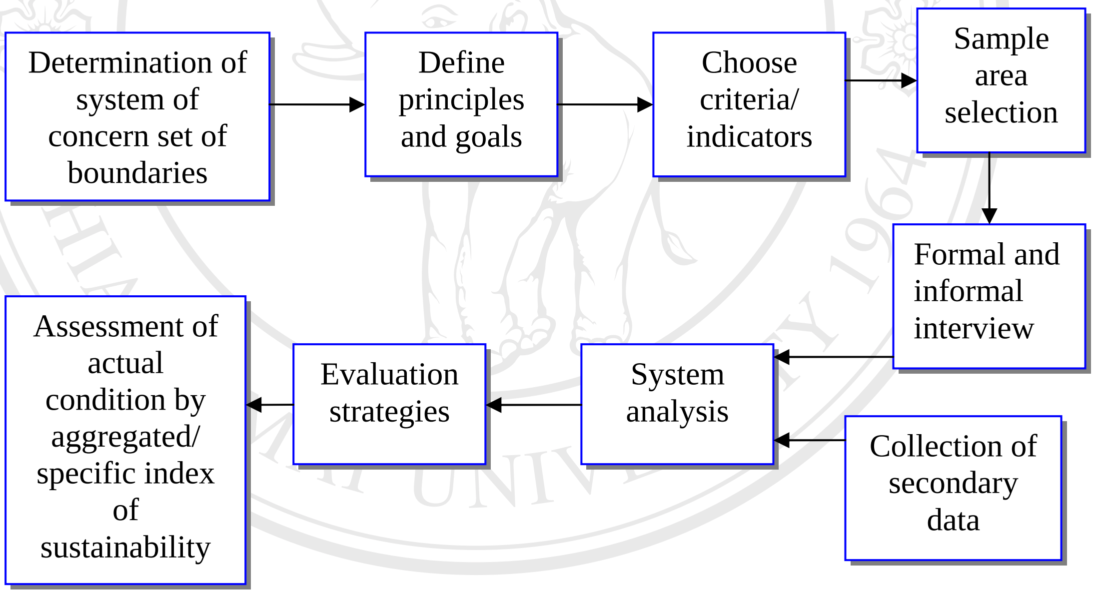


Figure 4. Conceptual framework of the study

4.2 Determination of system of concern set of boundaries

Drawing a boundary means determining what is under the control of the system's actors and owners and what is not. Human activity, inputs and outputs within the boundary of a system are to varying degrees controllable and manageable but things external to the boundary of the system are not (Wilson and Morren, 1990).

According to Yunlong and Smith, (1994), agricultural sustainability is defined by three set of boundaries as in Figure 5.

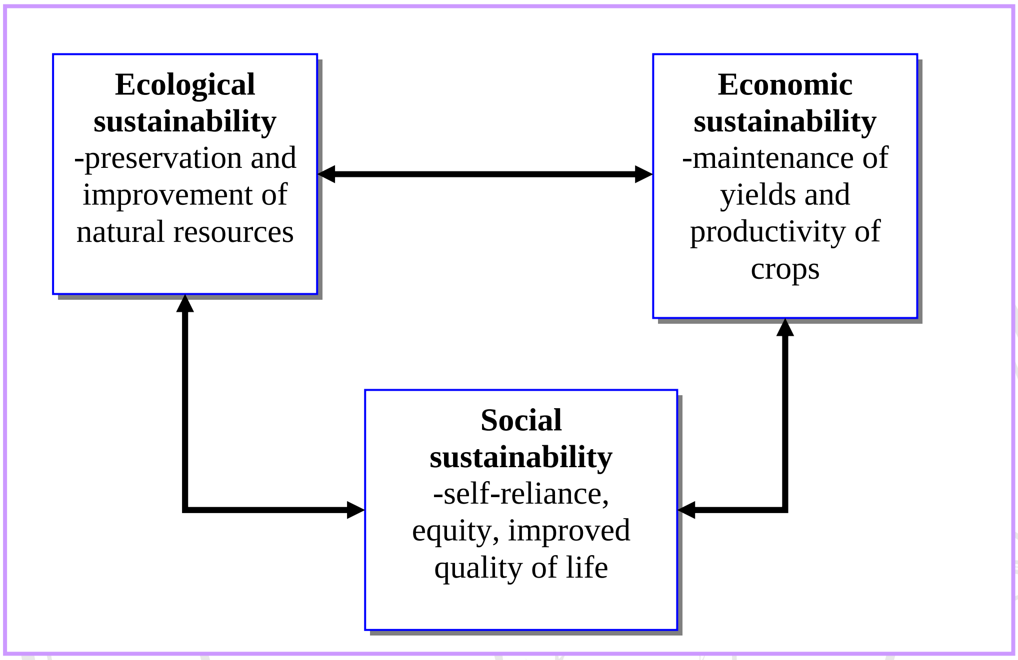


Figure 5. Boundaries established for agricultural sustainability

4.3 Defined principles and goals

Based on three basic features of sustainable agriculture, principles and goals are defined for maintenance of environment quality, stable productivity and social acceptability.

4.4 Choosing criteria and indicators

Sustainability indicators are chosen based on these criteria as proposed by Shi et al. (2004) which are; theoretically well founded, relatively stable and independent, clear in content, measurable and comparable, easy to quantify, regionally specific adapted, and based on acquirable data and can be grouped as hierarchical framework.

So, the indicators for three dimensions of agricultural sustainability in this study are presented in Table 4.

Table 4. Indicator used to assess the sustainability of cropping systems

Ecological sustainability	Economical sustainability	Social sustainability
• Use of chemical fertilizers • Use of organic fertilizers • Cultivation of legumes • Use of chemical control	• Crop yield (Rice) • Index of Yield Trend • Financial return	• Input self-sufficiency (ratio) • Family Food Adequacy

4.4.1 Ecological sustainability

Agriculture may often cause environmental problems because it changes natural environments and produces harmful by-products. Some of the negative effects are:

- Nitrogen and phosphorus surplus in rivers and lakes.
- Detrimental effects of herbicides, fungicides, insecticides, and other biocides (Wikipedia, the free encyclopedia). So that ecological sustainability was assessed by two indicators; soil fertility management and pest and disease management from the management practices of the cropping systems.

Soil fertility management was evaluated based on the amount of farmer's using chemical and organic fertilizers, meaning farmyard manure, compost and cultivation of legume crops. The average amount of chemical fertilizers applied per cropping systems and the average area cultivated legume crops in cropping systems are considered to compare the sustainability between cropping systems.

Management of pests and diseases was assessed based on the proportion of farmers using biological, mechanical and chemical methods.

4.4.2 Economic sustainability

For economic sustainability of the cropping systems, land productivity, yield stability and profitability from main crops were considered as the indicators and can be detailed as follow:

- Land productivity was measured by grain yield of rainy season rice and data of crop yield were collected by field survey.
- The stability of crop yield was examined by constructing an index based on farmer's subjective judgment to a question related to yield trend. The index was constructed based on the following formula;

$$ITY = (fi*1 + fd*{-1} + fc*0)/N \qquad (1)$$

Where:

ITY = index of trend of yield
Fi = frequency of responses indicating increasing yield
Fd = frequency of responses indicating decreasing yield
Fc = frequency of responses indicating constant yield
N = total number of responses.

Note: The higher ITY value indicates the higher stability (-1 < ITY < 1) (Duc, 2003).

Farm profitability was determined based on financial return. Financial return was analyzed through gross margin and gross revenue of the farm.

$$GM = GR - TVC \qquad (2)$$

$$GR = \sum_{i}^{n} QiPi \qquad (3)$$

$$TVC = \sum_{i}^{n} PjXj \qquad (4)$$

Where: GM = Gross Margin,
GR = Gross revenue,
TVC = Total Variable Cost,
Pi = the price of output in 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 refer to as the "farm gate" price of market price deducted by transportation cost to market and transaction cost in marketing
- Total cost of adding variable inputs to the production process are incurred only if production takes place (such as: seed, fertilizer, animal power, machine used, hired labor, opportunity cost of capital and opportunity cost of family labor etc…) (Kay and Edwards, 1999).

4.4.3 Social sustainability

Social sustainability was assessed in terms of input self-sufficiency and family food adequacy and can be described in detail 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.
- Family food adequacy was assessed in terms of adequacy of food grain produced as well as farm household's ability to purchase food grain required for consumption.

4.5 Sample area selection

Two stage stratified random sampling method was used to select the sample area. First, discussion with the district agriculture manager, cropping systems was identified as strata. After cropping systems in the district were stratified, the most important and prevailing three rice based cropping systems were decided as selected cropping systems of the district.

Through the discussion with the related agencies of the townships within district, first stage is random selection of villages within the selected cropping systems within the townships. Then, second stage is random selection of farmers within the villages by discussion of the village head committee cooperating with extension agents of the township agriculture office. By the arrangement of the committee, 100 samples among three rice-based cropping systems were collected by using interview and group discussion in the study area.

4.5.1 Primary data collection

Discussion with district manager, township managers, township extension agents, farmers group and representatives from village head committee, represented farmers for the selected cropping systems were chosen for interview.

Figure 6. Interviewing farmers in Lewe Township (Sesame-Rice-Legume system)

Interview of farmers was conducted using structured questionnaires and semi-structure interview at the village head center and center of agriculture office (Figure 6).

4.5.2 Secondary data collection

The secondary data were collected from village head committees, township agriculture office, district agriculture office, Myanmar Agriculture Service headquarter and statistical agricultural department, Department of Agricultural

Research, Myanmar (Figure 7). At the same time, data from various publications such as journals, unpublished research works, reports, proceedings etc. were collected. These include data on geographical and topographical conditions, soil and climate characteristics, and socio-economic conditions of the study area and farming systems.

Figure 7. Discussion with Yamethin district manager

4.6 System analysis, Evaluation strategies and Sustainability assessment

Sustainability is neither absolute nor discrete. There are relative degrees of sustainability determined by a range of parameters, which, in turn, define a path to sustainability (Campbell, 1992). In this study, to assess sustainability for the cropping systems, one method for evaluating indicators and three methods for evaluating both indicators and the whole system are used to compare the sustainability.

4.6.1 Descriptive data analysis

The data from semi-structured interview, formal survey and interview were analyzed using descriptive statistics such as percent, mean, standard deviation values and index to compare the different characteristics of all sustainable indicators for cropping systems in the district.

4.6.2 Sustainability Assessment by Fuzzy Evaluation (SAFE)

To assess sustainability between sustainability indicators and between cropping systems, SAFE method is suitable because sustainability is difficult to define or measure, since it is an inherently vague and complex concept. Fuzzy logic, due to its capability to emulate skilled humans and its systematic approach to handling vague situations where traditional mathematics is ineffective, seems to be a natural technical tool to assess sustainability.

Accordingly, to assess sustainability, the following have to be defined:

- Linguistic variables which best represent the sustainability of the whole system,
- Linguistic rule bases and fuzzy logical operators which express qualitatively the knowledge and the key features of the overall system, and
- A defuzzification method to convert fuzzy statements into a single crisp value of overall sustainability.

To assess sustainability by SAFE method, the following have to be defined as figure 8.

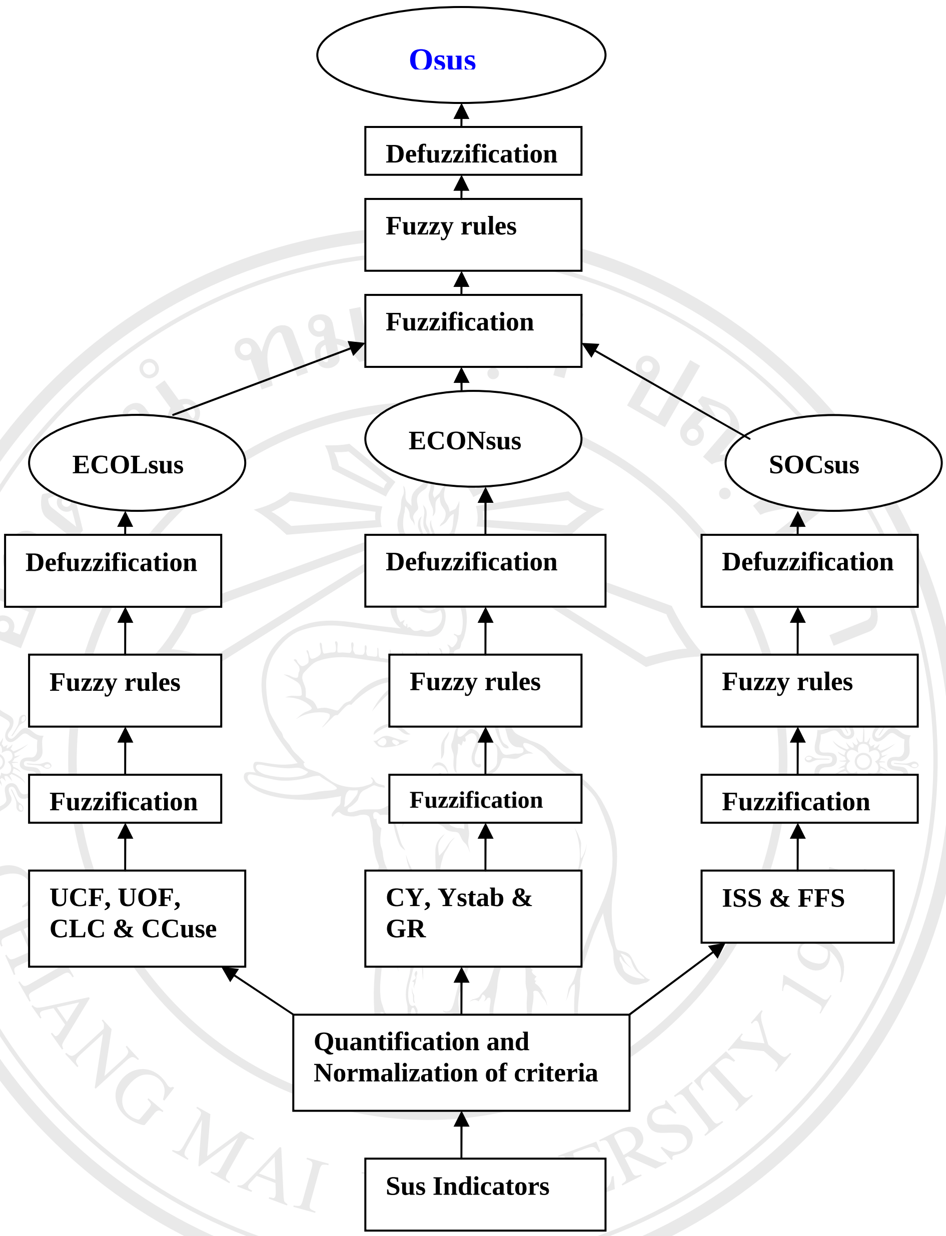


Figure 8. Methodology for the Sustainability Assessment by Fuzzy Evaluation (SAFE)

Source: Andriantiatsaholiniaina and Phillis, (2000)

4.6.2.1 The Linguistic variables

Briefly, a linguistic variable is defined by four items: (a) the name of the variable, (b) its linguistic values, (c) the membership functions of the linguistic values, and (d) the physical domain over which the variable takes its quantitative values. To assess sustainability, ECOLsus, ECONsus, SOCsus are used as primary linguistic variables to assess the overall sustainability of the system (OSUS) and

UCF, UOF, CLC, CCuse, CY, Ystab, GR, ISS, and FFS are used as secondary linguistic variables .

Notes:

OSUS = Overall Sustainability of the system
ECOLsus = Ecological Sustainability of the system
ECONsus = Economic Sustainability of the system
SOCsus = Social Sustainability of the system
UCF = Use of Chemical Fertilizer (kg/ha)
UOF = Use of Organic Fertilizer (ton/ha)
CLC = Cultivation of Legumes (ha)
CCuse = Proportion of Farmers using Chemical Control
CY = Crop Yield (rainy season rice) (kg/ha)
Ystab = Yield Stability (Index)
GR = Gross Revenue (Kyat/ha)
ISS = Input Self Sufficiency (ratio)
FFS = Family Food Sufficiency (months/yr)

The capability of each sustainability variable to fulfill criteria and principles of sustainability is called integrity. Criteria and principles of sustainability are recommended critical or target states which the system should satisfy to be sustainable. The primary linguistic variables of sustainability take the five linguistic values;

1. Very Bad (VB),
2. Bad (B),
3. Satisfactory (S),
4. Good (G), and
5. Very Good (VG).

The linguistic values for the nine secondary linguistic variables are;

1. Low (L),
2. Medium (M), and
3. High (H)

Triangular functions are used for the secondary variables, while Trapezoidal gaussian functions are chosen for the primary variables to represent an increased uncertainty involved in the computation. Instead of using the raw data Vi for each indicator directly, normalize function will be used to a common scale and allow statistical aggregation. The rationale of normalization of indicator values is illustrated in Figure 8. Different curves of normalization can be used according to needs and context. Let Vi be the data value of indicator i. Then its normalized value N (v_i) is calculated as in equations followed by figure 9.

- If the target value $T(v_i)$ corresponds to a maximum:

$$N(v_i)=\begin{cases} \dfrac{v_i - min(s)}{T(v_i) - min(s)} \; for\ v_i \le T(v_i), and \\ 1 \; for\ v_i \ge T(v_i) \end{cases} \quad \text{…………………………………………………….. (5)}$$

- If $T(v_i)$ corresponds to a minimum:

$$N(v_i)=\begin{cases} 1 \; for\ v_i \le T(v_i), and \\ \dfrac{max(s) - v_i}{max(s) - T(v_i)} \; for\ v_i \ge T(v_i) \end{cases} \quad \text{……………………………………………………..……..….. (6)}$$

- If $T(v_i)$ corresponds to an interval $[min(T_v), max(T_v)]$:

$$N(v_i)=\begin{cases} \dfrac{v_i - min(s)}{minT(v_i) - min(s)} \; for\ v_i \le minT(v_i), and \\ 1 \; for\ v_i \in [minT(v_i), maxT(v_i)], and \\ \dfrac{max(s) - v_i}{max(s) - maxT(v_i)} \; for\ v_i \ge maxT(v_i) \end{cases} \quad \text{……………………………….… (7)}$$

- If $T(v_i)$ corresponds to "Yes" or "No" statements:

$$N(v_i)=\begin{cases} 0.5 \; for\ v_i = T(v_i), and \\ 0 \; for\ v_i \ne T(v_i) \end{cases} \quad \text{…………………………………………...…… (8)}$$

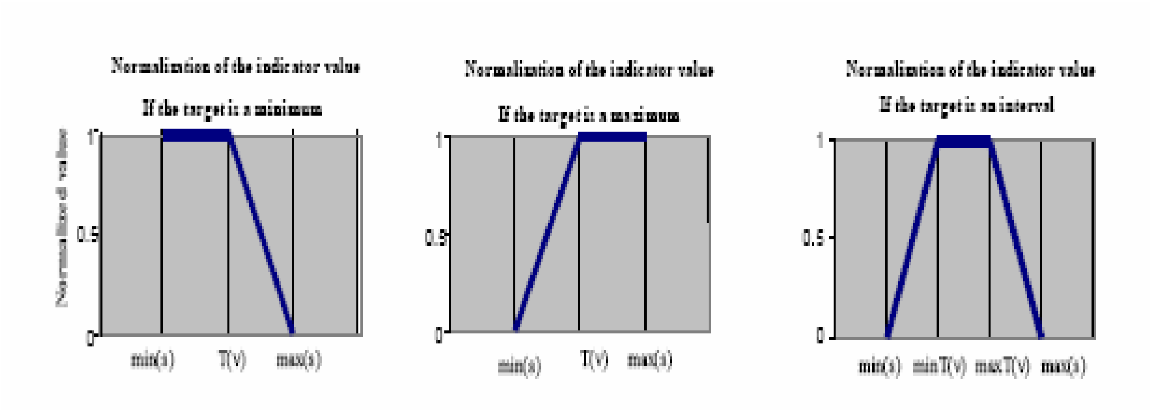


Figure 9. Examples of normalization

Source: Andriantiatsaholiniaina and Phillis, (2000)

Notes: T (v) = target values, min (s) = minimum values, max (s) = maximum values

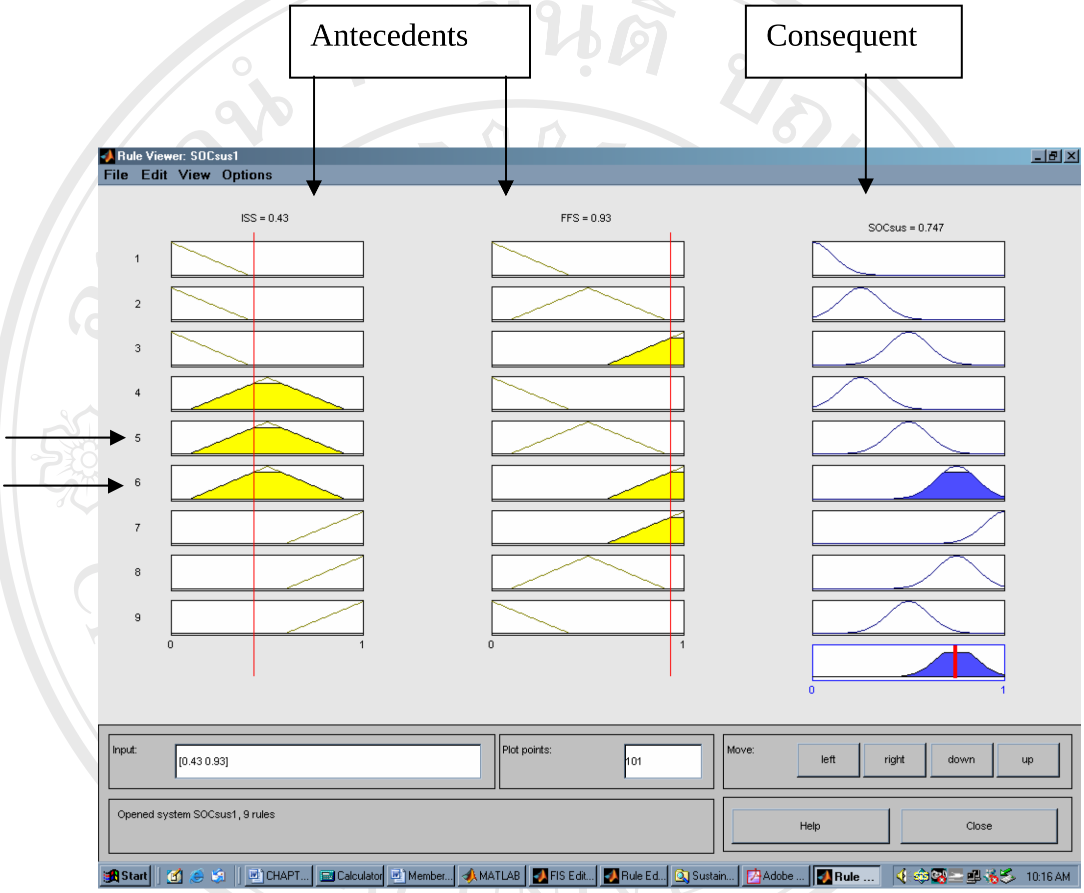
4.6.2.2 The linguistic rules

Simulation of the evolution of the overall system is represented by rules of the form of “IF (antecedents) - THEN (consequent)”, where the implication operator “THEN” and the connectives “AND” among antecedents are fuzzy. The rules are expressions of the role of interdependencies among factors of sustainability. Economists, ecologists and other experts agree that the components of sustainability should be given identical weight in an overall measurement (IUCN / IDRC, 1995). This statement serves as the basis on which we build the linguistic rule bases. Knowledge acquisition methodologies, such as interviews or questionnaires, can also be used to build the rules (Ericsson and Simon, 1984). There are many ways to quantitatively express these fuzzy rules by choosing a specific mathematical representation of the “AND”, “OR”, and “IF-THEN” connectives (Tsouverloudis and Phillis, 1998). To determine the overall sustainability, Osus, the rule base needs 5^3 =125 rules because we have 5 linguistic values and 3 variables. For ECOLsus, the rule base needs 3^4 = 81 rules, for ECONsus, the rule base needs 3^3 = 27 rules and for SOCsus, the rule base needs 3^2 = 9 rules because of different variables.

4.6.2.3 Aggregation process

The implication process evaluates individual rule over fuzzified grades and generates an output grade and output class. Now the Aggregation does two things.

First it truncates the Consequent Fuzzy Set according to the grade obtained and secondly it does the Union of all these fuzzy sets. This aggregation process is done by Fuzzy Inference System (FIS) type Mamdani in MATLAB 7.1 program, fuzzy logic toolbox (Figure 10).



Rule 5 = If (ISS) is (medium) and FFS is (medium) then SOCsus is satisfactory

Rule 6 = If (ISS) is (medium) and FFS is (high) then SOCsus is Good

Figure 10. Fuzzy Mamdani Inference over Indicator ISS and FFS for aggregation

4.6.2.4. The defuzzification

Defuzzification is the final operation that converts membership grades into a single crisp value. Several defuzzification methods have been presented in the literature (Driankov, Hellendoorn, and Reinfrank, 1996). The center-of-gravity formula, which is the most frequently referenced in the literature, is chosen because it conforms with the weighted-mean method that we use before fuzzification of the input. So the crisp value of sustainability is given by

$$Def(T_{OSUS}) = \frac{\sum_j y_j \cdot \mu_{T_{OSUS}}(y_j)}{\sum_j \mu_{T_{OSUS}}(y_j)} \quad \text{...(9)}$$

Where:

y_j is the value of the jth element of the fuzzy set T_{OSUS}, and

$\mu_{T(OSUS)}(y_j)$ is the membership grade of the jth element of the fuzzy set T_{OSUS}

(Andriantiatsaholiniaina and Phillis, 2000)

4.6.2.5 Sensitivity analysis

In this assessment method, sensitivity analysis is applied by using different confidence levels for membership curve and by varying input values. In the fuzzy reasoning approach, two major parameters are considered to be its major strength and also its weakness. First one is the membership curve and second one is the Rules. In order to check the role of membership curve in the fuzzy model, three different types of membership curve were considered: Triangular, Gaussian and Trapezoidal. These Membership functions are considered as representation of different confidence levels of the decision maker (figure 11). Triangular membership curve represents for the decision maker the least confident because he is very uncertain about belongingness of any value to a particular linguistic class except at one point for each. Trapezoidal curve represents for decision maker the most confident, because he is very certain about the belonging of certain range of values to particular class and Gaussian curve represent the moderate confidence level.

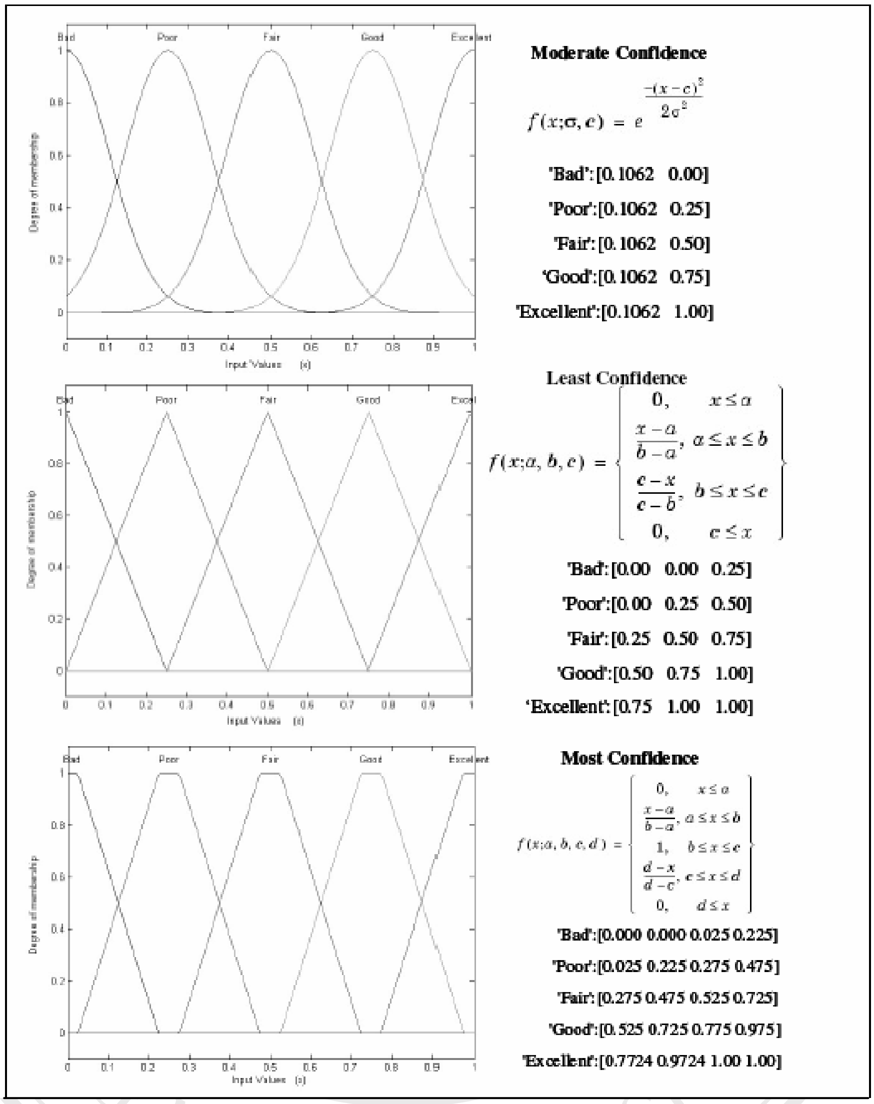


Figure 11. Membership curves with different confidence level

Source: Jeganathan, 2003. pg 61

4.6.3 Multi-criteria Evaluation (Amoeba approach)

Multi-criteria methods of evaluation are gaining attention among the economic community (Bana e Costa, 1990; Nijkamp et al., 1990; van den Bergh and Nijkamp, 1991; Munda et al., 1994). Multi-criteria evaluation has demonstrated its usefulness in conflict management for many environmental management problems (Munda et al., 1994). The major strength of multi-criteria methods is their ability to address problems marked by various conflicting evaluations. In general, a multi-criteria model presents the following two aspects:

- There is no solution optimizing all the criteria at the same time, and therefore decision making implies finding compromised solutions.
- The relations of preference and indifference are inadequate; when one action is better than another according to some criteria, it is usually worse according to others. Many pairs of actions remain incompatible with respect to a dominant relation (Giampietro and Pastore, 2000).

4.6.3.1 Quantification of indicators

Once indicator system is being set up, each indicator has to be quantified. In this study, quantification of indicators is as follow:

Use of chemical fertilizer in cropping system (UCF)	- kg/ha
Use of organic fertilizer in cropping system (UOF)	- ton/ha
Cultivation of legumes in cropping system (CLC)	-ha/farm
Proportion of chemical control in cropping system (CCuse)	- % usage of CC
Crop yield-Rainy Rice (CY)	- kg/ha
Yield stability(Ystab)	- Index (ITY)
Gross Revenue(GR)	- Kyats/ha
Input self sufficiency(ISS)	-Ratio (ISS)
Family food sufficiency(FFS)	-Months/yr

4.6.3.2. Normalization of criteria

Instead of using the data for each indicator directly, the data are normalized to obtain a common scale and allow statistical aggregation. There are different normalization methods for indicator criteria. In this study, same normalization method from earlier section (SAFE) method is used. Normalization of indicators avoid scale effects for the averaging and solve the problem due to the fact that some indicators are of the type “more is better” and some other are of the type “less is better” (Allard et al., 2004).

4.6.3.3 Aggregation of indicators

The aim of Muli-criteria Evaluation is to choose the best or most preferred alternative, to sort out alternatives or to rank the alternatives in descending order of preference. The best solution is to combine indicators with each other to obtain overall value to assess the sustainability. There are different methods for aggregation and the set of weights in multi-criteria decision analysis problem. In this study, aggregation method to assess the overall sustainability is chosen as proposed by Allard et al., 2004.

The aggregation method for each indicator is according to the following equation:

$$Isus = \sum_{i=1}^{n} wi * Ii \qquad (10)$$

The overall sustainability indicator Isus is the result of the weighing average of all the normalized indicators Ii. Wi represents the weight of the ith indicator.

4.6.3.4 Representation and assessment of the solution

To fulfill our objectives, representation must be clear and easy to understand. One tool which has proved to be useful to graphically integrate and monitor the different indicators is the Amoeba or Radar diagram (Lopez-Ridaura S. et al., 2002). The advantages of the Amoeba diagram are first a clear and global representation of all the indicators and their associated value. Secondly, solutions can be easily compared as in figure 12.

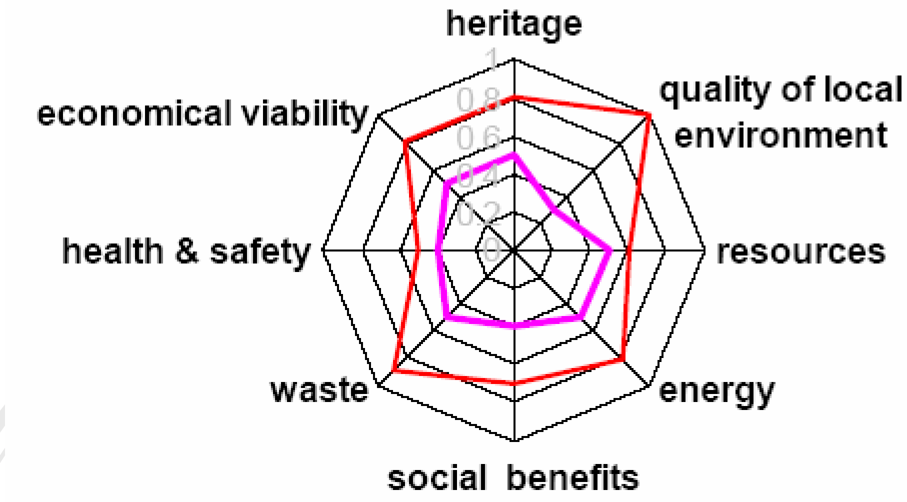


Figure 12. Example of amoeba diagram representing comparison of two solutions, the best one is the furthest to the center, the one which maximize the indicators

Source: Allard et al., 2004.

4.6.4 Sustainability Indicator Analysis (SIA) method

Sustainability Indicators were established based on the criteria and scoring technique was used. 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 cropping systems got score for each indicator through comparing them with other cropping systems. To get the normalized score for each cropping systems, matching table based on reference system was used (table 5).

Table 5. Matching table based on reference system in SIA method

Indicators	unit	Score range For N (Non-sustained)	Score range for C(Conditional sustained)	Score range for S (Sustained)
1. UCF	kg/ha	163.3-245	81.7-163.2	0-81.6
2. UOF	t/ha	0-12.3	12.3-24.6	>24.6
3. CLC	area	<1/2 of total area	1/2 of total area	Total area
4. CCuse	usage	yes		No
5. CY		<5000	5000-10000	>10000
6. Ystab	Index	+ or -		0
7. GR	Kyats/ha	< Av GR		>av GR
8. ISS	ratio	0-0.33	0.34-0.66	0.67-1
9. FFS	Months/yr	<12		12

In this matching table, data from "the sustainability of rice farming" by D.J. Greenland were used as reference system. After comparing with matching table, the score are aggregated and become cumulative scores. To assess the sustainability at the cropping system level, the household aggregated scores will be grouped at cropping system level. For comparison, coefficient index (N=0.2, C=0.4, S=0.8) will be multiplied with number of samples in respective class to calculate Sustainability Index (SI), performance values and performance percentage (PP) (DLD, 1998).

$$SI = \frac{\sum sustainable\ score}{Maximum\ score} x\, 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Where:

Sustainable 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 agriculture. In this study, it will be used to compare indicators between cropping systems.

$$PP = \frac{\sum performance\ values}{Maximum\ \ performance\ values} x\, 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Where:

Performance value = Sustainability Index x Maximum sustainable score

Maximum performance values = Maximum sustainable score x number of indicators

The PP indicates the overall performance of sustainability from all indicators. It will be used to compare the relative sustainability levels of the cropping systems (Praneetvatakul *et al*., 2001)