CHAPTER 3

RESEARCH METHODOLOGY

3.1 Conceptual framework

The study is focused on assessment of sustainability of integrated coffee-based farming systems at the household level, where details of its shown in Figure 3.1 below.

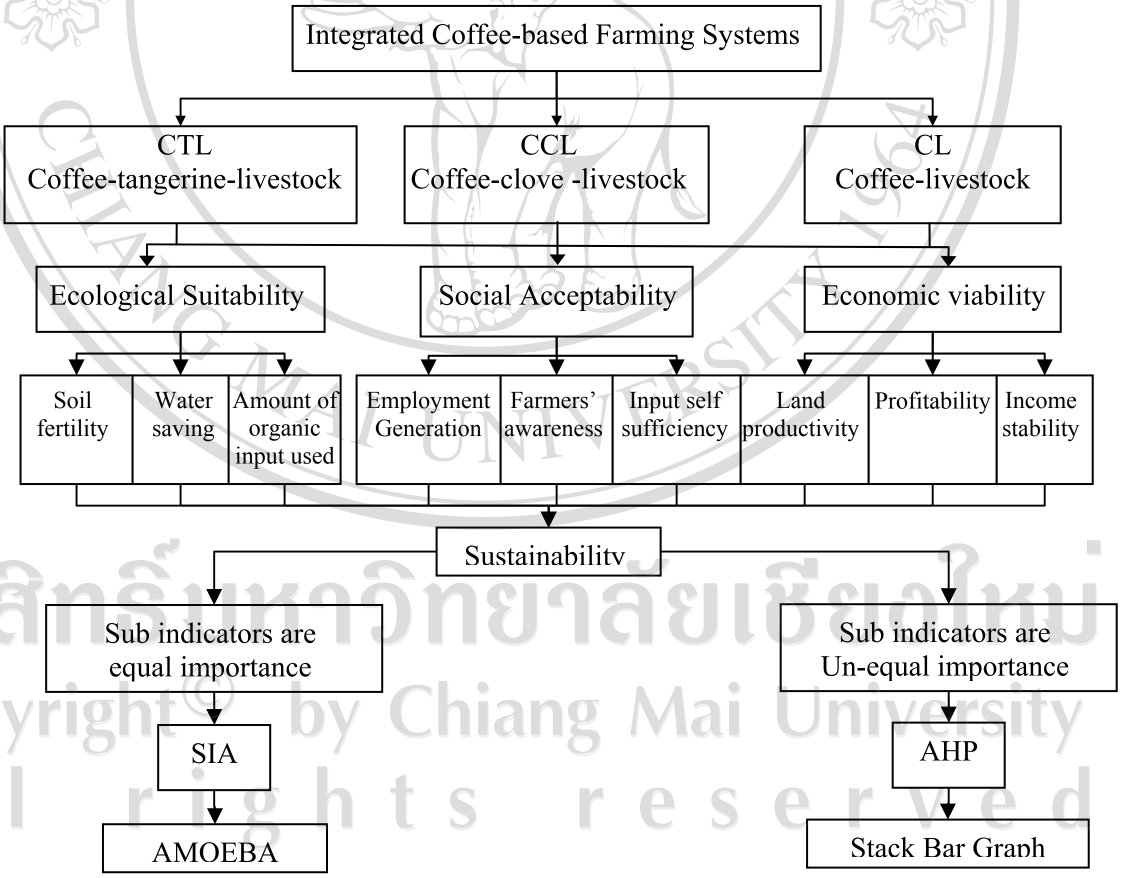

Figure 3.1 Conceptual framework

Sustainability of integrated coffee-based farming systems was assessed using three criteria, namely: ecological suitability, social acceptability, and economic viability. Soil fertility, water saving, and amount of organic input used were applied as indicators to measure the ecological suitability. To evaluate the social acceptability, input self sufficiency, farmers' awareness, and employment generation were used as indicators. The economic viability was measured through three indicators, namely land productivity, income stability, and profitability. Finally, the assessment of sustainability will be determined by multi criteria techniques, namely AHP, SIA, and AMOEBA approach.

The study has used household level primary data on identified sustainability indicators and weights assigned by stakeholders to calculate overall sustainability index for the systems. Household level data were gathered by using structured questionnaire (see Appendix A). One workshop was utilized to get the weights for each indicator. Before computing the overall sustainability index for the systems, indicator values were normalized using empirical formula. After getting normalized indicator for individual farmer, average value of the systems for each normalized indicator was calculated. So, these average normalized values multiplied with respective weights which assigned at AHP workshop and obtained weighted average normalized values for each indicator. Eventually, weighted average normalized indicator values were combined at system level and calculated overall sustainability index for the systems.

3.2 The study area and sampling method

Due to the time limitation for data collection, only household samples in the large areas of Arabica coffee production in Bali province were selected for the study. This research used multistage purposive sampling technique in determining the study area with consideration to the production area of Arabica coffee. Bali consists of eight districts and one multiplicity. Bangli is the district that has the largest production area of Arabica coffee with 3,753 ha from the total 7,498 ha of Bali province. The total land area of Bangli district is 520.81 km^2 or 31.08% from the total land of Bali Province. Within Bangli district, the production area of Arabica coffee in Kintamani sub district was 3,537 ha (Estate Crop Service of Bali, 2006). The study was conducted in three villages which have the largest coffee production areas, namely Catur village (224.1 ha with 561 coffee growers), Pengejaran village (124.55 ha with 191 coffee growers), and Belantih village (121.44 ha with 241 coffee growers) (CBS, 2006).

Samples within those three villages were chosen by proportional purposive sampling technique with consideration of the coffee grower population in three villages. According to the time involved in measuring sustainability in this study, only a household that has grown Arabica coffee for more than 15 years were selected as a sample for this study with consideration to farmer experience and economic year of Arabica coffee. For those reasons, 66 samples from Catur village, 22 samples from Pengejaran village, and 31 samples from Belantih village were purposively selected. In total, 119 households from the three villages were selected for the survey.

In addition, to get the different weights in AHP, a workshop was organized which engaged (1) representative farmers from three villages, and (2) the extension officer or technician or person who was in charge of the coffee based farming systems at the official level. Furthermore, during the workshop, farmers also asked to score the farmers' awareness of usefulness of intercropping systems based on arabica coffee.

3.3 Data collection

A semi-structured interview approach was conducted in order to gain information in the study sites which covered:

3.3.1 Primary data collection

Primary data collection was divided into two parts. Firstly, field observation and measurement using group discussions and key informants interview were used to gain understanding about current patterns and its management practices of arabica-coffee based farming systems. Also, in gathering information on farmers' awareness about usefulness of intercropping in coffee-based farming systems and determined AHP value. Secondly, the detailed information on social economic and other information related with criteria under sustainability as well as potential and constraints in integrated coffee based farming systems from households were achieved from interview by structured questionnaires.

3.3.2 Secondary data collection

Secondary data collection was collected from extension office, statistical agricultural division, and geophysics and meteorology agency. Also, other references that related to the research objectives, such as: journals, reports, proceedings, etc. The data collected were climatic data, agricultural statistic figures, topography of the study area, etc.

3.4 Method of data analysis

In response to the first objective regarding the characteristics of integrated coffee based faming systems, the primary data collected from interview with questionnaire was analyzed using descriptive statistics, such as percentage, mean, standard deviation values with table and diagram to illustrate. Furthermore, it described management practices, input and resources allocation, current technology, production management, and role of *Subak Abian* as farmer organization in integrated coffee based farming systems.

The second objective, regarding the assessment of sustainability of the integrated coffee based farming systems, the data obtained were analyzed based on various indicators in three dimensions of sustainability (see details in 3.5) and the overall sustainability were evaluated by AHP, SIA, and AMOEBA approach, which details explained in Chapter 2. The third objective responded by using the descriptive statistics concerning about potentials and constraints to the sustainability in the coffee based farming systems.

3.5 Sustainability indicators

Sustainability of the integrated coffee-based farming systems was assessed at household level, by using nine farm-level indicators to capture three criteria: ecological suitability, social acceptability, and economic viability in term of sustainability. Each of indicators being used in this study has their own unit measurement, which can be seen in the Table 3.1.

Table 3.1 Unit of measurement of nine indicators of sustainability

Sustainability indicators	Unit
Soil fertility (SF)	Rupiah (IDR)/ha/year → Indonesian currency 1 USD = 10,000 IDR; 1 THB = 265 IDR
Water saving (CWR)	m^3/ha/year
Amount of organic input used (OU)	Kg/ha/year
Employment Generation (EG)	Man-day/ha/year
Farmer awareness (FA)	a measured score
Input Self Sufficiency (ISS)	Percentage (%)
Land Productivity (LP)	n/a
Profitability (Pt)	NPV → Rupiah (Rp.) IRR → percentage (%)
Income stability (IS)	Percentage (%)

3.5.1 Ecological suitability

Ecological suitability was evaluated based on three sub-indicators as follows:

1. Amount of organic input used, it is assessed based on the annual proportions of chemical fertilizer that farmer applied in each of pattern of integrated coffee based farming systems compared to the use of organic input. The more use of organic input indicated the system is more sustainable.

2. Soil fertility, it is measured by calculating cost of land use which aggregating the cost of amount of fertilizer applied by farmer to increase soil fertility and the difference of yield (in value unit) that farmer get from two periods of time, where in one period is consist of three years. The equation is as follows:

$$CLU = \left(\sum_{i=10}^{12} Y_i - \sum_{i=13}^{15} Y_i \right) + \sum_{i=13}^{15} CSI_i \ \ldots (5)$$

Where

CLU = cost of land use per ha,

$\sum Y_i$ = sum of value of yield of coffee/integrated crops over three years

$Y_i = Q_i \times \overline{P}_{10-15}$, Where:

Q_i is yield of coffee/integrated crops (kg/ha) year i. For time measurement baseline, the year tenth (i = 10) of coffee tree (2002) is pointed to be the beginning year to calculate the cost of land use, with assumption that annual productivity of coffee started from this year were relatively stable. Two period of time was considered to distinguish the differences of yield: before and after farmers improving soil fertility. The most recent data collected was in 2007. In total, there is a-six-years data available. Due to this limitation, each period divided into three years to get an even comparison. Accordingly, the first period was year 10^{th} to 12^{th} (2002–2004) and the second period was year 13^{th} to 15^{th} (2005–2007).

$\overline{P}_{10-15}$ is the average farm-gate price of each crop of the two periods.

CSI = Cost of Soil Improvement per ha (in Rupiah), will be measured from the cost of fertilizer used for improving soil fertility in a farmer's land in the last three years (12^{th} to 15^{th} year).

In this study, CLU is used to explain what has been taken from the soil and what has been added into the soil. A farmer added fertilizer into the soil to improve soil fertility which has been reduced due to crop production in the last year. If CLU is high, it means that a farmer spent much more money for fertilizer than the increased value of yield in the second period compared with the first period. Thus, the high value of CLU shows that the soil fertility caused by crop production in the past is high. That means the higher the cost of land use, the lesser the sustainability.

3. Water saving is assessed through water requirements of each crop in an integrated coffee based farming system by using secondary data. The study area is a mountainous area where surface water resources are inadequate, and mostly farmers depend on rainfall in maintaining their farming systems. So, sustainability in this matter will be defined by the water requirement of the three systems. The system that required less water will be considered as more water-saving system. The high value of water saving indicator in a system means that the system use less water compared to other two systems.

To calculate the irrigation water requirement, the Penman Method (Doorenbos, 1984) was employed, where data required are temperature, humidity, wind, and sunshine duration were available.

The form of the equation used is:

$$ET_0 = c\left[W \bullet R_n + (1-W) \bullet f(u) \bullet (ea - ed)\right] \ldots(6)$$

Where:

ETo	: reference crop evapotranspiration in mm/day
W	: temperature – related weighting factor
Rn	: net radiation in equivalent evapotranspiration in mm/day
f(u)	: wind-related function
(ea – ed)	: difference between the saturation vapor pressure at mean air temperature and the mean actual vapor pressure of the air, both in mbar
c	: adjustment factor to compensate for the effect of day and night weather conditions

The detail of variables and the method for calculation are described as follows:

a. Vapor pressure (ea – ed)

Air humidity affects ETo. Humidity is expressed here as saturation vapour pressure deficit (ea – ed): the difference between the mean saturation water vapour pressure (ea) and the mean actual water vapour pressure (ed).

Air humidity data are reported as relative humidity (RH max and RH min in percentage). Time of measurement is important but is often not given. Fortunately actual vapour pressure is a fairly constant element and even one measurement per day may suffice for the type of application envisaged. Vapour pressure must be expressed in mbar, if ed is given in mm Hg, multiply by 1.33 to find mbar.

b. Wind function [f(u)]

The effect of wind on ETo has been studied for different climates resulting in a revised wind function and defined as:

$$f(U) = 0.27 + \left(1 + \frac{U}{100}\right) \quad \ldots (7)$$

Where: U is 24 hour wind run in km/day at 2 m height. This expression is valid when (ea – ed) is expressed in mbar.

c. Weighting factor (1 – W)

(1-W) is a weighting factor for the effect of wind and humidity on ETo.

d. Weighting factor (W)

W is the weighting factor for the effect of radiation on ETo.

e. Net radiation (Rn)

Net radiation (Rn) is the difference between all incoming and outgoing radiation. It can be measured, but such data are seldom available. Rn can be calculated from solar radiation or sunshine hours (or degree of cloud cover), temperature, and humidity data.

Total net radiation (Rn) is equal to the difference between Rns and Rnl. Radiation can be expressed in different units; converted into heat it can be related to the energy required to evaporate water from an open surface and is given here as equivalent evapotranspiration in mm/day. The steps involved to calculate Rn:

(i) If measured solar radiation (Rs) is not available, select Ra value in mm/day from table given month and latitude.

(ii) To obtain solar radiation (Rs) correct Ra value for ratio of actual (n) to maximum possible (N) sunshine hours; Rs = (0.25 + 0.50 n/N) Ra. Both n and N are expressed in hours as mean daily values for the period considered.

(iii) To obtain net shortwave radiation (Rns) the solar radiation (Rs) must be corrected for reflectiveness of the crop surface, or Rns = $(1 - \alpha)$ Rs. For most crops $\alpha = 0.25$.

(iv) Net longwave radiation (Rnl) can be determined from available temperature (T), vapour pressure (ed) and ratio n/N data.

(v) To obtain total net radiation (Rn), the algebraic sum of net shortwave radiation (Rns) and net longwave radiation (Rnl) is calculated. Rnl always constitutes a net loss so Rn = Rns – Rnl.

f. Adjustment factor (c)

The Penman equation given assumes the most common conditions is medium to high, maximum relative humidity is medium to high and moderate day time wind about double the night time wind.

After the reference crop evapotranspiration (ETo) predicted by considering the effect of climate using Penman method above, then considered effect of crop characteristics to the crop water requirements by presenting crop coefficient (kc) to relate ETo to crop evapotranspiration (ETcrop). Thus,

$ET_{crop} = kc \times ET_o$ … (8)

Where:

ET_{crop} = crop evapotranspiration in mm/day

kc = crop coefficient

ET_o = reference crop evapotranspiration in mm/day

Factors affecting the value of the crop coefficient (kc) are mainly the crop characteristics, crop planting or sowing data, rate of crop development, length of growing season and climatic conditions. For this reason, this study was using some references to determine the crop coefficient for arabica coffee, tangerine, and clove.

Doorenbos (1984) affirmed that for mature coffee grown without shade and where cultural practices involve clean cultivation with heavy cut grass mulching, crop coefficients of around 0.9 are recommended throughout the year. If significant weed growth is allowed, coefficient close to 1.05 to 1.1 would be more appropriate. In contrast, Wintgens (2004) verified that coffee crop coefficient is of the order of 0.8 whilst at the widest spacing used with moisture conservation measures in place, the coffee crop coefficient may be reduced to as little as 0.65.

The crop coefficient for tangerine, according to Doorenbos (1984), there were three types in which considered the maturity of trees, tree ground cover, and weed control (see Table 3.2).

Table 3.2 Crop coefficient (kc) values for citrus

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Large mature trees providing 70% tree ground cover												
Clean cultivated	0.75	0.75	0.7	0.7	0.7	0.65	0.65	0.65	0.65	0.7	0.7	0.7
No weed control	0.9	0.9	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Trees providing 50% tree ground cover												
Clean cultivated	0.65	0.65	0.6	0.6	0.6	0.55	0.55	0.55	0.55	0.55	0.6	0.6
No weed control	0.9	0.9	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Trees providing 20% tree ground cover												
Clean cultivated	0.55	0.55	0.5	0.5	0.5	0.45	0.45	0.45	0.45	0.45	0.5	0.5
No weed control	1.0	1.0	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

Source: Doorenbos (1984) p.47.

3.5.2 Social acceptability

Input self sufficiency, employment generation, and farmer awareness about usefulness of intercropping in coffee-based farming systems were used as the indicators to assess the social acceptability, with details as follows:

1. Input self sufficiency determined based on ratio of local input costs to the total input costs. The higher local inputs mean higher input self sufficiency. Input costs considered in this study were cost of inputs that farmers spent for farming activities during 2007, especially for crops and livestock, such as: fertilizer, labor, maintenance, and transportation cost.
2. Employment generation determined on the ability to generate employment or absorption of labour (Man-day/ha/year) within the integrated coffee based farming systems.
3. Farmer awareness about usefulness of intercropping in coffee-based farming systems determined by applied indicators related to role of intercropping system with scoring system. The role of intercropping system indicators used in this study related with (a) role of maintaining their livelihood, such as income stability, income diversification, and labor generation; (b) role of plant protection, as: shade and windbreak, reduces insect attack, suppresses weed, moderates temperature; and (c) role of management, like: pest and disease, difficulties, water and nutrient competition, and its effect to coffee yield. The score given by farmers will be ranging from 1 to 5 in respond to each role of intercropping system indicator. If the score is 1, means that role of

intercropping system indicator is least useful for farmer, and 5 means most useful.

3.5.3 Economic viability

Land productivity, income stability, and profitability from the integrated coffee based farming systems were considered as the indicators of economic viability, with details as follows:

1. Land productivity evaluated by Land Equivalent Ratio (LER). According to FAO, land equivalent ratio (LER) is ratio of the area needed under sole cropping to one of intercropping at the same management level to give an equal amount of yield. LER is the sum of the fractions of the yields of the intercrops relative to their sole crop yields.

$$LER = (\frac{y_i}{y_m})_1 + (\frac{y_i}{y_m})_2 + ... + (\frac{y_i}{y_m})_n \quad ... (9)$$

Where y_i is the yield (kg/ha) of each crop or variety in the intercrop or polyculture, and y_m is the yield of each crop or variety in the sole crop or monoculture. For each crop (n) a ratio is calculated to determine the partial LER for that crop, and then the partial LERs are summed to give the total LER for the intercrop. LER is usually greater than 1.0 which indicates that the intercropping is advantageous, and less than 1.0 show disadvantageous.

2. Income stability

According to McConnell (1997) income stability is most conveniently measured in terms of the coefficient of variation, denoted by CV, thus

$$CV = \frac{SD}{\overline{X}} \qquad \text{or} \qquad CV = \frac{\left[\dfrac{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}{(n-1)}\right]^{\frac{1}{2}}}{\left(\sum_{i=1}^{n}\dfrac{X_i}{n}\right)} \qquad \ldots (10)$$

Where CV is coefficient of variation of farm income in five year term (%), SD is standard deviation of the farm income, and $\overline{X}$ is sample's farm income mean value (yearly). If a farmer has higher value of CV, it implies that his farm income has fluctuated over the past five years, but if it is low, it means that the income of farmer is stable over time.

3. Profitability

Since coffee is perennial crops, the farm profitability was measured by financial return which is determined by Net Present Value and Internal Rate of Return. as follows:

a. Net Present Value (NPV)

$$\text{NPV} = \sum_{t=1}^{n} \frac{\text{B}_t - \text{C}_t}{(1+i)^t} \qquad \ldots (11)$$

b. Internal Rate of Return (IRR)

$$IRR = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t} = 0 \qquad IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2}(i_2 - i_1) \qquad \ldots (12)$$

Where B_t is benefit in each year, C_t is cost in each year, t is 1,2,3,…,n; n is number of years, and i is interest (discount) rate.

Net present value was calculated considering of economic year of crops (coffee, tangerine, and clove). In 2008, when this study is done, the age of coffee is on average 15 years, so, with considering age of coffee, it is assumed that the duration of time for calculating NPV is from 1993 – 2013.

The costs considered in the study were those related with crops and livestock, where comprised of fixed cost and variable cost. The fixed costs consisted of land rent cost, tax of land, livestock investment, depreciation, and social cost. To measure depreciation, the straight line depreciation method was used. This method gives the same annual depreciation for each full year of item's life.

$$\text{annual depreciation} = \frac{\text{buying cost} - \text{salvage value}}{\text{useful lifetime}}$$

While, variable costs contained of fertilizer cost, maintenance, transportation cost, and hired labor cost for fertilizing, pruning, weeding, harvesting, and livestock rising. Cost of family labor counted by using opportunity cost of family labor. Costs were calculated based on 2007 market prices of consider items. Benefit referred to the value of crops (coffee, tangerine, and clove) and value of livestock.

3.6 Assessing sustainability

After all of values of indicators gained for each households, those values were normalized in order to calculated the overall sustainability score for each pattern in integrated coffee-based farming systems. The normalization of indicators was using equation adapted from Kranj and Glavic (2005).

$$I_i^j = \frac{I_{aj} - I_{\min}}{I_{i\max} - I_{i\min}} \quad \ldots \quad (13)$$

$$I_i^j = 1 - \frac{I_{aj} - I_{\min}}{I_{i\max} - I_{i\min}} \quad \ldots \quad (14)$$

Where:

I_i^j = standardized value for indicator i^{th} of household j^{th}

I_{aj} = actual value for indicator i^{th} for household j^{th}

I_{imax} = maximum value for indicator i^{th} in the samples,

I_{imin} = minimum value for indicator i^{th} in the samples.

Equation (13) was used for "more is better" indicator in sustainability, while equation (14) was used for "less is better" indicator.

Afterward, those values were aggregated to get the average normalized values for each indicator of each system, with using this equation.

$$\overline{I}_{ik} = \frac{\sum_{i=1}^{n} I_i^j}{n} \quad \ldots (15)$$

Where:

$\overline{I}_{ik}$ = normalized average value for i^{th} indicator for k^{th} system

I_i^j = normalized value for indicator i^{th} of household j^{th}

n = number of household in system k^{th}.

The assessment of sustainability of integrated coffee-based farming systems in this study is using two ways of comparison: (1) when indicators are assumed to have equal importance; and (2) when indicators are assumed to have un-equal importance.

3.6.1 Indicators assumed to have equal importance

For first assumption, sustainability score gained from summation of average normalized value of each indicator of each system, and called as Sustainability Index Analysis (SIA), with equation as follows:

$$SUS^{k} = \sum_{i=1}^{9} \overline{I}_{ik} \qquad \ldots (16)$$

Where:

SUS^k = overall sustainability score for k^{th} system

$\overline{I}_{ik}$ = normalized average value for i^{th} indicator for k^{th} system

3.6.2 Indicators assumed to have un-equal importance

For responding the second assumption, un-equal importance of indicators was weighted by using analytical hierarchy process (AHP). In this study, the weight of indicators determined by farmers in the AHP workshop by using AHP software which designed by Dr. Methi Ekasingh *et al*., Multiple Cropping Center, Chiang Mai University.

AHP which developed by Saaty (1980) 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). The overall objective of the decision lies at the top of the hierarchy, criteria, sub-criteria, and alternatives are on descending levels of this hierarchy.

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 follow:

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

The reciprocal value of this comparison is placed in the position a_{ij} 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 9-point scale showed in Table 2.2.

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. Thus,

$$CR = \frac{CI}{RI} \quad , \quad CI = \frac{\lambda_{\max} - n}{n-1}$$

Where CR is consistency ratio, CI is called the consistency index, RI is random index. λ_{max} is the largest eigenvalue of the matrix A and the corresponding eigenvector *w* contains only positive entries.

Size of the matrix	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Finally, after weight for each indicator of each system obtained, the sustainability score was calculated by multiplied average normalized values of each indicators of each system with weighted indicator values, which combined through this formula.

$$SUS^k = \sum_{i=1}^{9} \bar{I}_{ik} \times W_i \qquad \ldots \qquad \text{Adopted from Pinnalanda (2007)}$$

Where SUS^k is the sustainability index for system k^{th}. The $\bar{I}_{ik}$ is the normalized average value for indicator i^{th} system k^{th}. And, W_i is the weights assigned at AHP for indicator i^{th}.

3.6.3 AMOEBA diagram

In this approach, according to Brink *et al*. (1991) cited in Htwe (2006), the results obtained by monitoring the indicators are summarized and integrated. 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.
- 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 'feasibility domain' 'target values' may be added to the graph that reflects 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 is recorded on the graph. This makes it possible to visualize the position of the actual values.