Chapter III

Research Method

This chapter is devoted on methods and material which are used in the study. The chapter discusses detail on sustainability indicator selection, samples selection and conducting field survey, conducting stakeholder workshops to take weights for indicators, indicator normalization method, and aggregation of indicators in order to get sustainability index for the systems.

3.1 Research procedures

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 pre structured questionnaire (see Appendix 2). Two workshops were utilized to get weights for each indicator. Before compute 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 workshops 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. At the end, two irrigation methods under banana cultivation were compared using these sustainability indexes. Framework for research process that used in study is presented in Figure 3.1.

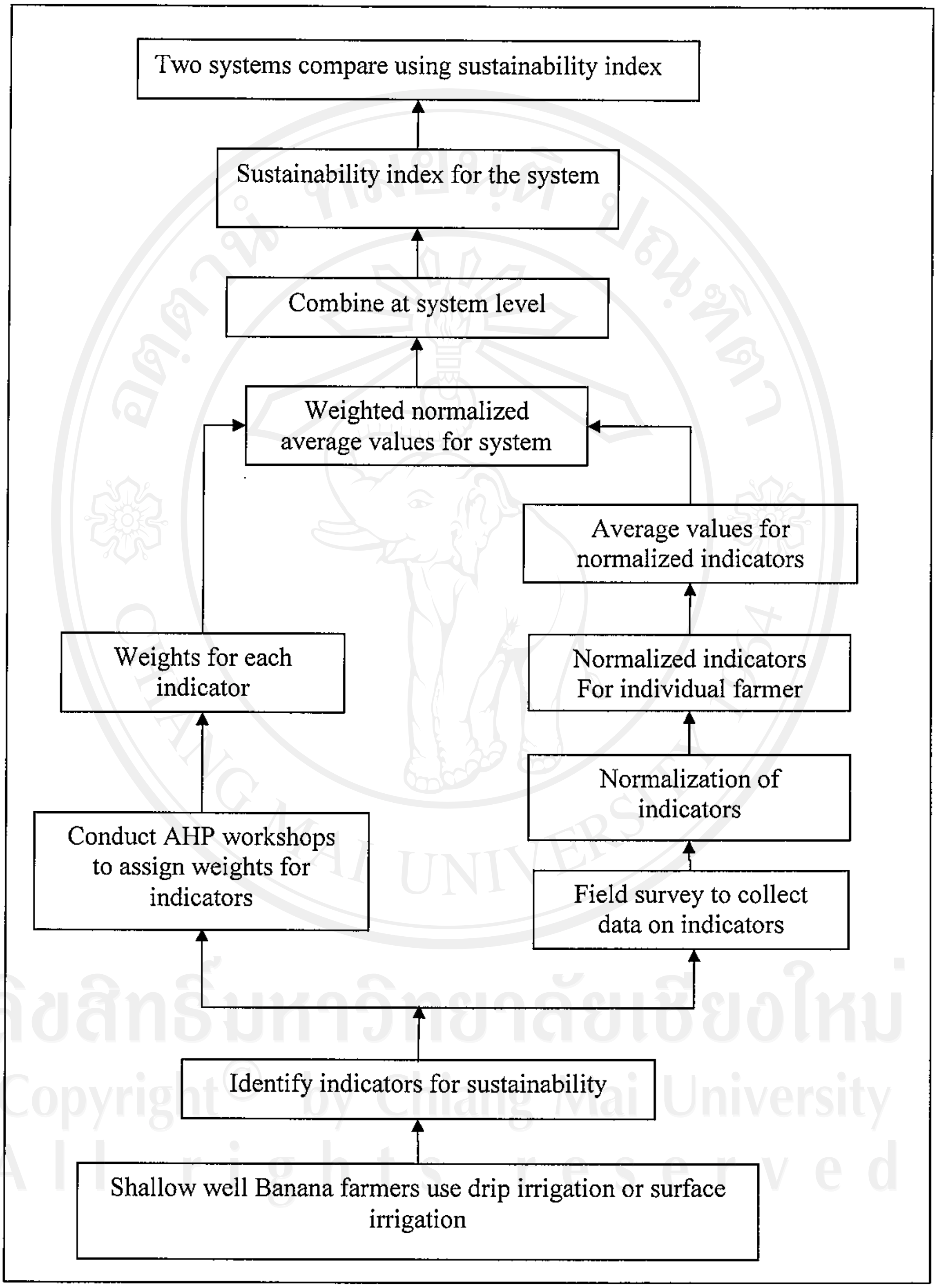

Figure 3.1 Framework for research process

3.2 Sustainability indicator

Sustainability comprises multidiscipline aspects. In the literature different indicators were developed to assess sustainability in a variety of studies. Although, many indicators have been developed they do not cover all aspects on sustainability. Moreover, due to variation of biophysical and socio economic conditions, indicators used in one country are not necessarily applicable to other country (Rasul and Thapa, 2003).

In the study area majority of farmers are smallholder and they use ground water to cultivate banana. To extract ground water, they use their owned wells. Therefore, ground water usage is not directly link with social context. Most of the upland banana farmers, banana cultivates as their main income source. They use their owned labor to irrigate banana and most of the agronomic practices are same in drip irrigated and surface irrigated banana. Considering above biophysical and socio economic conditions three criteria were selected: socioeconomic sustainability, ecological sustainability, and agronomic sustainability to assess overall sustainability of drip irrigated banana farmers and surface irrigated banana farmers.

3.2.1 Socio-economic sustainability

Economic terms which related to irrigation and banana production: profitability of irrigated banana and social effects due to irrigation methods were considered to select socio economic indicators. Representing above context, water productivity of banana cultivation, annual profitability of banana production, monthly income variation of banana field and social participation of banana farmer were selected as socio economic indicators.

3.2.1.1 Water productivity (WP)

Water productivity is essentially an economic concept that builds on the physical concepts of the water balance and efficiency. In estimating the productivity of water, the measurement is to determine the true economic value of the product of water. An intermediate stage in this process is estimating the physical productivity of water, such as the kilogram of crop produced per drop of water defined either in terms of optimal evapotranspiration (ETa) or water deliveries (Ds) (Seckler, 1999).

The term water productivity is also defined and used in a variety of ways. There is no single definition that suits all situations (Barker *et al.*, 2002).

The definitions of WP used in any study depend on the aim, stakeholders and scale. To indicate which drop we are talking about, it would be better to talk about, e.g. irrigation water productivity, basin water productivity, etc (Bessembinder *et al.*, 2004).

Playan and Moteos (2005) defined water productivity as agricultural production per unit volume of water; the numerator may be expressed in term of crop yield (kg ha^{-1}). Alternatively, Crop yield may be transformed in to monitory units. The latter will be particularly convenient when comparing different crops or different types of water use.

Water productivity can be express by fallowing formula (Molden *et a*l., 2001).

$$WP = \frac{\text{Production}}{\text{Water diverted}}$$

In this formula, numerator can be calculated by income of the banana field during considered time period and the denominator can be expressed volume of water pumped during considered time period. The study modified above formula as fallows.

$$WP = \frac{\text{Annual income from unit banana land } (\text{Rs ha}^{-1})}{\text{Annual water diverted per unit banana land } (\text{m}^{3}\ \text{ha}^{-1})}$$

Annual income from unit banana land

The amount of banana bunches (kg) and planting material which produces during year is considered to calculated total annual income.

Annual Water divert per unit banana lands

The amount of pumped water form well (m^3) during a year is considered as annual diverted water for banana cultivation.

3.2.1.2 Annual net profit from unit banana lands (NP)

This term explain profitability of banana cultivation. Net profit can be derived, using total revenue and total cost per considered time.

NP = ATR – ATC

Where: NP = Annual net profit from unit banana land
ATR = Annual total revenue from unit banana land
ATC = Annual total cost spent for unit banana land

Annual total revenue

Total revenue was calculated using total production of the individual farm and farmer's selling price. Some farmer sale their product at farm gate and some farmer sale directly to market place. When farmer use their product to other purpose (consumption, giving to neighbor etc), farmer usual selling price used to calculate monitory value of this part.

Annual total cost

Total cost comprised two main components: total variable cost and total fixed cost.

Total annual cost = Total annual variable cost + Total annual fixed cost

Total annual variable cost

Cost which farmer was expended to manage for banana cultivation during considered year was taken in to account to calculate annual total cost.

Cost of family labor is counted by using opportunity cost of the family labor. Labor cost for application of fertilizer, application of agrochemicals, and prop supply are included in to labor cost item. Costs were calculated based on 2005 market prices of consider items.

Total fixed cost

Depreciations of farm equipments, structures, and machinery considered as fixed cost items for the study. Even though, some farmers were given subsidies for buying drip irrigation equipments by various agencies, when depreciation was done actual price was considered. Water pump, Drip irrigation equipments, fertigation unit, simple farm equipments (Hoe, Knife, Pork, axis, hand sprayer Slashing knife), agro well, farm hut, vehicles were subjected to depreciation to calculate fixed cost.

To depreciate the considered items strait line depreciation method was used. This method is probably most appropriate for small Asian farmers suffer no loss in value due to obsolescence (McConell and Dillon, 1997).

The straight line depreciation method of calculating depreciation is widely used. This easy-to use method gives the same annual depreciation for each full year of item's life (Kay and Edwards, 1999).

$$\text{Annual depreciation} = \frac{\text{Byuing cost} - \text{Salvage value}}{\text{Usful lifetime}}$$

Farmer uses his private vehicle for other purpose. When depreciate the vehicles, few assumptions were taking in to account. First one is when farmer has bicycle; it's used two hours per day for other purposes. Second one is if farmer has other vehicles (mo. bike, track etc); it's usage for other purpose is depending on number of members in the family. If it is two members, assume vehicle is used two hours per day for other purpose. For additional each number added one hour. Based on these assumptions depreciation of vehicles were calculated.

3.2.1.3 Income variation of banana field (IV)

Banana is one of main income sources of these farmers. Due to farm income fluctuation, farmers face economical difficulties as well as social inconvenience. Rasul and Thapa (2003) considered farm income variation of farming system as social sustainability indicator.

Year around income fluctuation of banana cultivation was considered indicator under socio economic sustainability criteria of the study.

Income stability is most conveniently measurement in term of the coefficient of variation (McConnell and Dillon, 1997).

$$CV = \frac{\left[\sum^{n}\left(x_i - \bar{x}\right)^2 \Big/ (n-1)\right]^{1/2}}{\left(\sum_{i=1}^{n} x_i \Big/ n\right)}$$

Where:

CV = Coefficient of variation
x_i = Income of the *i* month from banana cultivation
$\bar{x}$ = Mean monthly income from banana cultivation
n = Number of month

If a farmer has higher value of CV, it does imply income from banana cultivation is fluctuating through out the year. If it is low, income stability of the banana cultivation is higher.

3.2.1.4 Farmer social participation (SOP)

Individual farmer participation on social organization of the village is important factor in term of social and economic of their life. Participation of social organization activity enhances collective action of the village. It will help to improve rural economy and individual can get benefits from that.

Social participation also reflects right and opportunity to enjoy of community and interact with other community members and strengthen social cohesiveness. It is very important phenomenon in rural social life.

Generally, farmer with full of activity on his farm, opportunity to participate in social activity may decrease. It will affect performances of the village level social organizations.

On the other hand levels of individual social participation depend on the number of social originations and their activities available in the village. Therefore the study has considered common social organization in the district and their activities to estimate individual participation rate at village level. Following formula was utilized to estimate individual farmer social participation rate.

$$SOP = \frac{\text{Number of social activity which farmer participated during last year}}{\text{Number of social activity organized in the village during last year}}$$

Where: SOP = Individual farmer social participation rate

3.2.2 Ecological sustainability

Ground water is vital part in ecology. Pollution of ground water creates many adverse effects on other ecological components and phenomenon. Inorganic fertilizer and agro chemical are main ground water pollutants in agricultural activity.

The increased use of chemical fertilizers, agro chemical (insecticides, fungicide and herbicide) has led to the contamination of water bodies and the spread of diseases, which have adversely affected aquatic life, livestock and people's health (Rasul and Thapa, 2003). Not only that using of high amount of chemical fertilizer and agro chemical badly effect on some soil properties.

Improper maintenance of soil creates ecological impacts on other component of the ecology. Surface soil salinity development is one of the key problems in most of irrigation project in dry area. Soil salinity development may create affect plant health, soil properties, water quality and other land and other resource uses.

Based on these facts, amount of inorganic fertilizer used for unit banana lands during one year period, amount of agrochemical used for unit banana land during one year period and soil salinity level in banana field have been considered as indicators under ecological sustainability criteria.

3.2.2.1 Amount of inorganic fertilizer used for unit banana land during a year (CFU)

Almost all the farmers use urea to provide nitrogen for banana and meuriate of potash (MOP) for supply potassium and triple super phosphate (TSP) to give phosphorous to banana plants. Total amount of kilogram that used above three types of fertilizer for one hectare during 2005 has considered measuring the indicator value.

When consider farmers behavior of chemical fertilizer usage, some farmers use three types of fertilizer as recommendations but some use two and some use only one type of fertilizer. Therefore, when construct the indicator for total fertilizer use, these differences should be considered. The recommendation amount of each fertilizer reflect how important of the amount of each fertilizer in banana cultivation. So, before add used amount of all fertilizer to gather, used amount of each type of fertilizer was divided by recommended amount of each fertilizer and obtained proposition, based on recommended amount. After that these figures were combined at household level and got indicator for total fertilizer used in considered time period.

3.2.2.2 Amount of agrochemical used for unit banana land during a year (AGCU)

Pseudo stem weevil and rhizome weevil are one of main pest problems in banana cultivation. When reduce sanitation of banana cultivation weevil attack may be increased. One of recommendation is construct trap with pesticide (not to apply directly in to mature plants) to reduce weevil population.

But the majority of the farmers apply systemic pesticide directly plants. Most of the farmers apply carbofuran granule in to the soil. Farmers use either directly or as a trap, finally extra amount or pesticide residual release to soil and ground water. It will create ecological hazard as well as health risk. When application amount increased, that vulnerability also increased.

Other pest attacks are not commonly appearing. Therefore farmers don't apply any other chemical

Commonly use other agro chemical is herbicide. Some farmers use glyphosate to control weed in their field. Especially when weed infestation is high and labors are not available farmers trend to use herbicide. Higher amount of herbicide create hazard same like pesticide.

Therefore, the study uses amount of applied pesticide (carbofuran) and amount of applied herbicide (glyphosate) as indicator under ecological criteria. When calculate total amount of agrochemical used, there is another problem to add these amount, because these two type of agrochemical has different unit. Before add the used amount, behaviors of two agrochemical usage of two systems were statistically tested. The statistical test realized in the case of carbofuran utilization in two systems is not significantly different at five percent level. But glyphosate utilization of two systems is significantly difference at five percent level. Considering statistical test results and problem that related with adding of different types of units, only glyphosate utilization is considered as indicator for total agrochemical usage in considered time.

3.2.2.3 Soil salinity level in the banana field (SS)

Salinity is common problems under irrigated agriculture especially in areas of low rainfall and high evaporative demand (Rietz and Haynes, 2003). Usually dry zone agro well are not very deep. Farmers extract shallow ground water using these wells. The shallow groundwater has higher electrical conductivity (E.C) than the deep groundwater dry zone in Sri Lanka and the rate of soil evaporation during the dry season became very high (Song and Kayane,1996).

Banana grower use shallow well ground water to irrigate their cultivation. Salts which associated with ground water come to the soil surface when irrigation is occurred. Higher soil evaporation removes water from soil and remained salts on the soil surface. Based on this fact, ground water irrigated banana lands have possibility to develop salinity in surface soil. Therefore, study used soil salinity level of the surface soil as ecological sustainability indicator. To determine soil salinity, electrical conductivity of soil solution was measured using standard soil solution and electrical conductivity meter.

3.2.3 Agronomical sustainability

Weed infestation one of important agronomic constrains for field level sustainable production. Banana plant has very shallow root system. Usually root spared from surface to 40 cm depth. When weed population are too much, competition for water and nutrients with banana is high. It will affect to banana yield. Not only that due to some weed, nematode attack for banana may be increased, because these weed can act as host plant for nematode. Therefore, farmers consider weed management as important agronomic practice.

Strong wind greater than 4 m / sec is a major cause of crop loss due to pseudo stems being blown down (Doorenbos *et al*., 1986). Lodging tolerance of banana plant may depend on various reasons like vigorous and well distributed root system, strong pseudo stem, weight of the bunch. If there are tend to fall down due to wind in their fields farmers try to prevent this damage by using props. For this support supply farmer should spend extra labor and cost for props. Considering above facts, weed infestation of the banana fields and lodging tolerance of banana plants considered as agronomic sustainability indicators.

3.2.3.1 Weed infestation of banana field (WI)

The study has considered weed infestation of banana plant as indicator under agronomic criteria. Weed infestation was measured by using number of weeding during year. Some farmer use manual weeding to control weeds but some farmers use chemical control method. When count the frequency of weeding both methods were taken in to account. In term of manual weeding, some use slash knife to slash upper part of the weed and some use hoe to scrape (uproot) the weed. When count the frequency either method considered as weed control attempt.

Some time some farmers in the sample had done weeding only part of the total land extent and some time they did weeding in total land extent. When calculate the total frequency of the year, if farmer did weeding part of the land considered percentage of the one time weeding based on total land extent and weeding land extent.

3.2.3.2 Lodging tolerance of banana plants (LT)

If banana plant has less tolerance against wind more plant may be fallen. At the mean time if farmer has experience on lodging tolerance of their banana cultivation they trend to supply props to prevent falling. Considering these two issues, falling rate during last year and support provided during last year are used to determine lodging tolerance of banana cultivation. Following equation has used to calculate lodging tolerance.

$$LT = 1 - \frac{FP + SP}{TP}$$

Where:

LT = Lodging tolerance

FP = Falling plants during last year

SP= number of support proving during year

TP = Total number of plant in the cultivation

3.3 Data collection

Field level data were collected by farmer field survey and stakeholder workshops were used to assigned weights for the indicators. When field survey was done, at the same time soil samples were collected to measure soil salinity.

3.3.1 Farmer's field survey

To determine the existing value of above indicators sample survey was conducted during April to May 2006. Shallow well (agro well) banana farmers were considered as population.

3.3.1.1 Study area

Anuradapura district was selected to conducting survey. This district is largest district in dry zone. Here more than 10,000 farmers use ground water to cultivate their up land fields. Twenty years before, banana cultivation in this area was very little but now there is tend to cultivate banana, specially using ground water. Central government department of agriculture, province agriculture department, some other government organization, and non government organization attempt to promote drip irrigation among shallow well farmers. At the present, some shallow well farmers grow banana using surface irrigation and some grow banana using drip irrigation.

Considering these facts Anuradapura district was selected to carry out the study. Detail of the study site has discussed in Chapter IV.

3.3.1.2 Sample selection for field survey

Using information from north central province agriculture office, central government agriculture office of Anuradapura, and Farm mechanization training center in Anururadapura, primarily two lists of farmers were prepared separately for drip irrigation and surface irrigation. From these lists, young plantations were removed (age less than four years), discussion with field level agriculture extension staff and grass root level staff who work in agrarian department and final lists were prepared. Considering time and other constrain, 60 households in each group were randomly selected using simple random technique from final list.

3.3.1.3 Conducting survey

Even though, 120 individual were selected to carry out the survey, when conducting field survey, total sample could not afford due to various reason. Only 48 individual from banana grower with drip irrigation and 54 individual banana farmers with surface irrigation were covered by survey. Pre structured questioner was utilized to gather information form the farmers. Main components of questioner were basic information of household, information on selected sustainability indicators, some factors which influenced on sustainability indicators and changing trend of observable sustainability indicators and trend of some factors that affect on sustainability indicators. Complete out line of the questioner is in Appendix 2.

3.3.2 Soil sample collection

To determine the soil salinity of individual banana field soil samples were collected form each field and prepared standard soil solution. Electrical conductivity was measured using these solutions to determine soil salinity of the fields.

There were no literatures on surface salinity concentration pattern in irrigated banana field in this area. No guideline to determine soil sampling depth. Therefore, before collect the soil sample sampling depth was determined.

3.3.2.1 Determination of soil sampling depth

Two banana plots under drip irrigation and two from surface irrigation were selected and took soil samples from these plots before collect the soil samples from individual farmer fields. Soil auger was used to take soil samples. Using one point for one plot, three soil samples were taken in different depth (0-10 cm, 10-20 cm, 20-30 cm). These soil samples were tested for soil salinity. Results of the test are show in Table 3.1.

Table 3.1 Soil salinity distribution of deferent depth in two systems

	Surface Irrigation		**Drip Irrigation**	
Depth (cm)	**EC of Plot 1 (ds/ m)**	**EC of Plot 2 (ds/m)**	**EC of Plot 1 (ds/m)**	**EC of Plot 2 (ds/m)**
0 to 10	0.90	1.04	0.96	1.11
10 to 20	1.03	1.22	0.78	1.09
20 to 30	0.86	1.55	1.70	1.5

Source: Computed from field survey during 2006

But there was no regular pattern on soil salinity distribution in the soil. Therefore, to cover all ranges maximum depth (0 – 30 cm depth) was selected to take soil samples in farmers' fields.

3.3.2.2 Taking soil sample in individual field and preparing for soil salinity test

Points for soil collection were selected randomly to representing entire plot. Number of points will be 25-37 per hectare. Theses samples were allowed to air dried, mixed thoroughly and prepared composite bulk sample for the plot. The bulk sample were spread on a surface and divided in to four equal parts, from which two diagonal parts were retained and the remaining two parts were removed. This process was repeated until the successive quarter is reduced to a weight 500 g. These samples were utilized to measure soil salinity.

3.3.2.3 Measuring electrical conductivity (EC)

To measure the electrical conductivity of the soil, the one of method (soil water extract method) which proposed by International Rice Research Institute (IRRI) (2006) was utilized. This method is easier than other proposed methods. It need very little laboratory facilities.

Prepared mixture of soil water (1:5 by weights) using air dry soil and distilled water. Shake the solution by hand for one minute at lest 4 time at 30 minute interval. Allowed to soil to settle and filtered the solution. Added one drops of 0.1% of $(NaPo_3)_6$ solutions for each 25ml of extract. Using electrical conductivity meter, EC was measured above the settled soil. Measurements are depending on soil texture. To convert these $EC_{1:5}$ to EC in soil, multiply by the factors which related with soil texture. The factor witch should be multiplied based on texture shown in Table 3.2. The textures of the samples were determined by the feeling method.

Table 3.2 Multiplication factors to calculate soil electrical conductivity

Soil texture	Multiplication factor
Sandy loamy, Clay sand	23
Sandy loam, Light sandy clay loam	14
Clay loams, Silty, Fine sandy clay loams	10
Sandy, Silty, Light clay, Light medium clay	9
Medium clay soil	8
Heavy clay soil	6

Sources: IRRI, 2005

3.3.3 Conducting of AHP workshops

Two Stakeholder workshops were conducted separately to assign weights for each criterion and each indicator using analytical hierarchy process (AHP). Twelve farmers, who use drip irrigation under banana, five training officers on drip irrigation, and four field level extension officers were participated to one workshop and eight farmers who use surface irrigation under banana and four field level extension officers, four training officers and one researcher related with irrigation were participated to other workshop. Based on Alphonce (1996) following steps were used to calculate weights for criteria and indicators.

(1) Determine the hieratical structure for the problem
(2) Giving priorities on criteria (indicators)
(3) Rating of criteria / indicators by using 1 to 9 scales.
(4) Pairwise comparisons
(5) Checking of consistency of stakeholder decisions.

3.3.3.1 Determine the hieratical structure for the problem

At the workshops overall sustainability of the systems considered as the objective. Under this objective socio economic criterion, ecological criteria and agronomic criteria were considered as lower hieratical level. Under each criterion have indicators. Theses indicators were considered lowest level of the hierarchy (Figure 3.2).

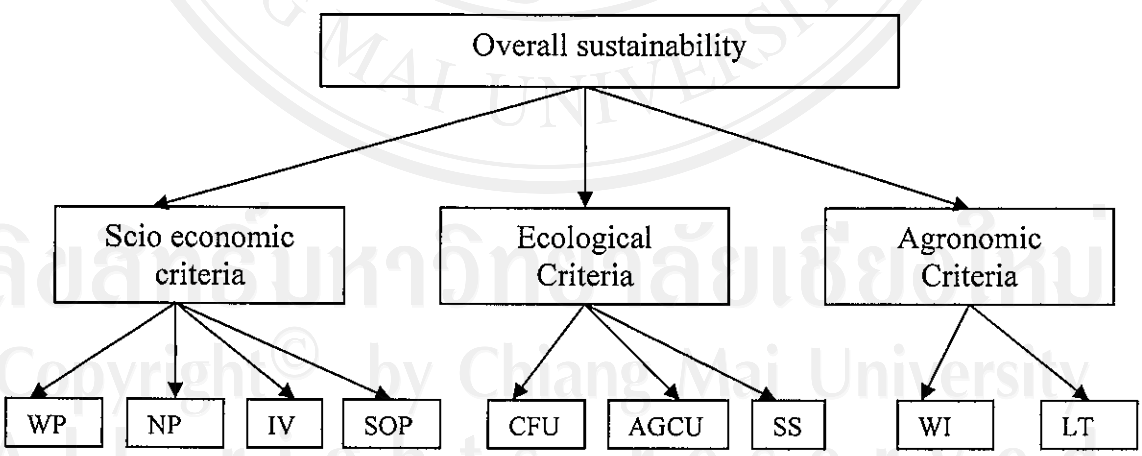

Figure 3.2 Hieratical structure for weighting procedure

3.3.3.2 Stakeholder priorities on sustainability criteria

After explaining of the objective of the workshops participant were asked to give priority for sustainability criteria. At the both work shops, stake holder gave same priorities on sustainability criteria. They considered socio economic criterion is more important than other two criteria. Agronomic criteria and ecological criteria were given as second and third respectively. Priorities given on sustainability criteria in both workshops are shown below.

Socioeconomic criteria > Agronomic criteria> Ecological criteria

3.3.3.3 Pairwise comparison and consistency checking on criteria

After giving priorities on criteria, participants were asked to give rate for each criterion using the 1 to 9 scales. Using this rate pairwise comparison was done. At the end of this procedure weights for each criterion were calculated. After calculating the weights, consistency of decisions of stakeholder was checked.

3.3.3.4 Stakeholder priorities on indicators

After getting weights for criteria, next step was calculating weights for indicator under each criterion. Here same procedure was fallowed. First, participants were asked to give priorities on indicators considering each criterion. They gave same priorities on indicators in socio economic criteria and agronomic criteria in both workshops. But stakeholder who concern of surface irrigation gave priorities, low agrochemical usage is more sustain than low inorganic fertilizer usage. But stakeholder who concern with drip irrigation gave more priority on low agro chemical usage is more sustain than more agro chemical usage. Both of the stakeholders gave last priority on soil salinity.

Priorities given at both workshops for socio economic criteria

NP>WP>IV>SOP

Priorities given at both workshops for agronomic criteria

WI>LT

Priorities given at surface irrigation farmer's workshops for ecological criteria

AGCU>CFU>SS

Priorities given at drip irrigation farmer's workshops for ecological criteria

CFU>AGCU>SS

3.3.3.5 Pairwise comparison and consistency checking on indicators

The priorities given by stakeholder were subjected to further rating using same scale which used in rating for criteria. Then pairwise comparison was done. After getting weights for indicators, consistency of stakeholder was checked. The detail calculation of weights and consistency checking is in Appendix 3.

3.4 Analysis of data

3.4.1 Independent two sample t- test

To fulfill the first objective of the study, a descriptive statistic test has utilized. Means of the indicators in both systems were compared by using independent two sample t-test. SPSS software package was used to obtained results.

3.4.2 Calculation of overall sustainability index for the systems

To fulfill second objective overall sustainability index for two systems were calculate. For that two empirical formula were utilized, one for normalization of raw indicator values and other for aggregation normalized indicator values.

3.4.2.1 Normalization of indicators

To find out the overall sustainability of the two systems using indicator values of household level, sustainability index for two systems has calculated. Raw values that obtained from individual farm are in different scale and different units. Before calculate the sustainability index, indicator value should be normalized. Unit for the used indicators are in Table 3.3.

To normalize the indicator values, based on Malczewski (1999) fallowing formula has utilized in the study.

$$I_i^j = \frac{I_{i\max} - I_{ij}}{I_{i\max} - I_{i\min}}$$

Where: I_i^j = Standardized value for indicator i^{th} of household j^{th}

I_{ij} = Raw 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

But in term of sustainability, some indicator value "more is better" but some are "less is better". For less is better indicator above equation can be directly used. But "more is a better" indicator, the equation modified as fallows.

$$I_i^j = 1 - \frac{I_{i\max} - I_{ij}}{I_{i\max} - I_{i\min}}$$

Table 3.3 Used indicators and their units

Indicator	Units
Water productivity	RsM^{-3}
Annual net profit	Rs per Year
Income variation	No units
Farmer social participation	No units (Rate)
Annual chemical fertilizer	Kg. per year
Annual agro chemical used	Kg. per year / Litters per year
Level of Soil salinity	decisiemens per meter
Weed infestation	Number of Weeding per year
Lodging tolerance	Rate (no units)

Noet: Rs = Sri Lankan rupees (Currency unit)

3.4.2.2 Calculate normalized average indicator values for the system

The aim of the study is calculate sustainability index for the systems. To fulfill this aim, normalized indicator values at household level converted to normalize average value in the system.

To calculate normalized average values for the system fallowing formula was utilized.

$$\bar{I}_{ik} = \frac{\sum_{i=1}^{n} I_i^j}{n}$$

Where: $\bar{I}_{ik}$ = 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}

3.4.2.3 Combine the normalized average indicators at system level

After calculating average normalized values for the systems for each indicator, the weights which were calculated by using AHP methodology, multiplied with these average normalized values. At the end, these normalized average weighted indicator values were combined at system level and obtained overall sustainability index for the system.

Fallowing formula that proposed Malczewski (1999) has used to combine normalized average indicator values.

$$SUS^k = \sum_{i=1}^{9} \bar{I}_{ik} \times W_i$$

Where: SUS^k = Sustainability index for system k^{th}

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

Wi = Weights assigned at AHP for indicator i^{th}

Sustainability index reflects overall sustainability of the system. Using these sustainability indexes, overall sustainability of two irrigation methods under banana cultivation can be compared.