CHAPTER 3

Research Methodology

This chapter represents the conceptual framework of the research, population and sample selection, and analyzing the methodologies to achieve the aims of the research.

3.1 Conceptual framework of the research

The research questions are "how to develop the supply chain coffee on the high principles of supply chain cluster that is environmentally friendly, and would this development create value and enhance competitiveness of farmers or not" and the scope of the research focuses on the Arabica coffee farmers in Pamiang and Pang Ma-O areas. Consequently, the conceptual framework of the research starts by analyzing the production and marketing environment of Arabica coffee in the sample areas to determine the conditions or factor that interrupt or facilitate the development of the green cluster supply chain, such as the socioeconomic environment and production in these areas: the Arabica coffee cluster in the present, the economic environment of the Arabica coffee supply chain, and the adoption of the green cluster supply chain of farmers in the areas. After that, the scenarios method are used for simulating the green activities (such as green production, green waste management, and green transportation) as well as constructing the green cluster supply chains caused by horizontal collaboration of farmers (such as production planning, waste disposal, and green transport system use) and the green cluster supply chain resulting from the vertical coordination through the revenue sharing contracts among the farmers, the assemblers, and the processors. This relationship of three nodes is called three stage supply chain. This research selects some actors in the supply chain because the actions of the RPF that plays a role as the processor, and the Pamiang RPDC and Pang Ma-O RPEC which play a role as the assemblers directly affect the famers' performance in production. The development of green cluster supply chain is the choice bringing about the expected outcomes of decreasing the costs and increasing the revenue

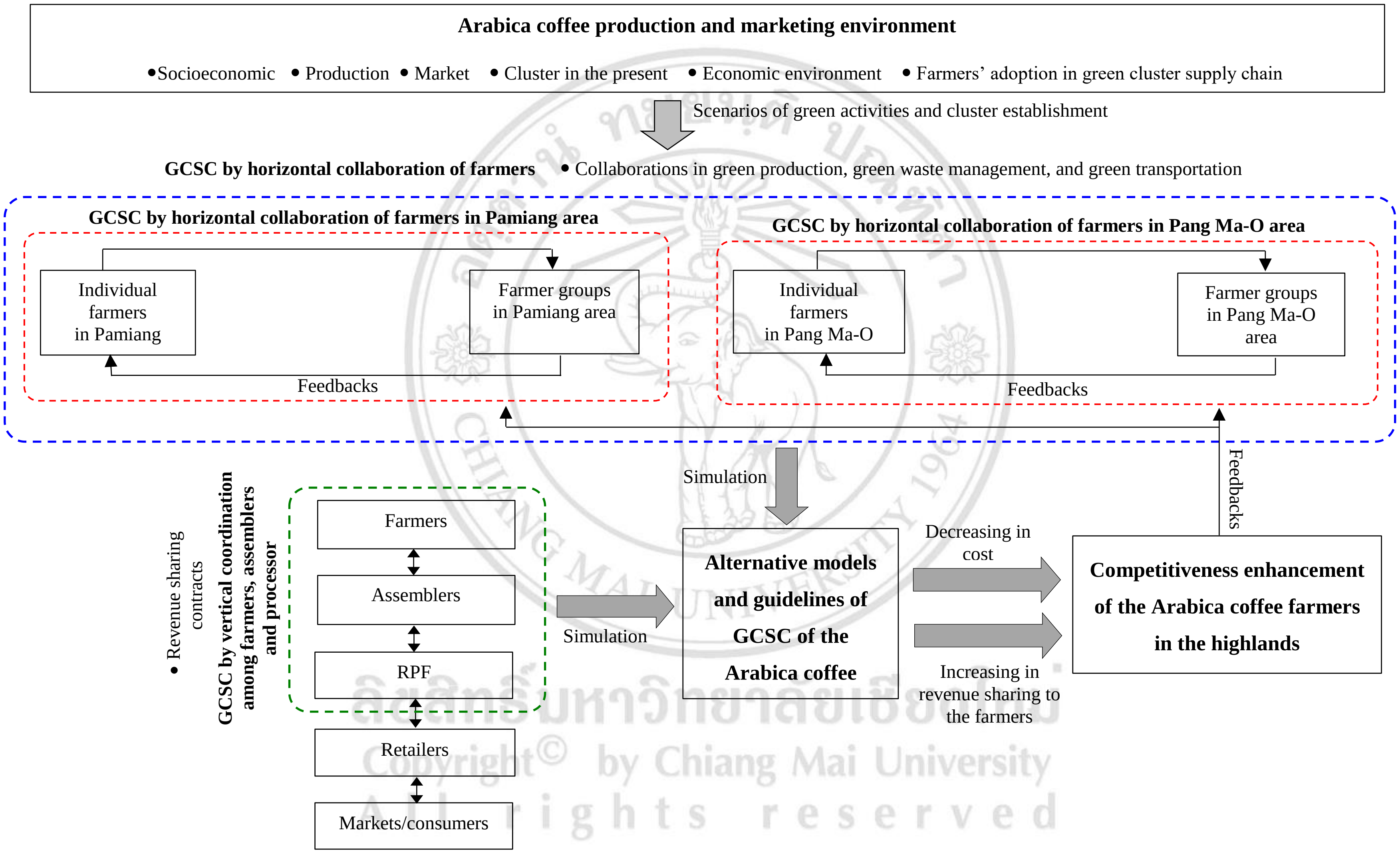

Figure 3.1 Conceptual framework of the research

of the farmers that contribute to the competitiveness enhancement of the Arabica coffee farmers in the highlands.

3.2 Population and sample selection

Because the three stage supply chain of Arabica coffee is determined by the scope and framework of this research, the population and samples are separated into three groups consisting of the farmers, assemblers, and processor.

3.2.1 Farmers

In the farmer aspect, the population is the farmers in Pamiang area, Doi Saket distric and farmers in Pang Ma-O area, Chiang Dao district, Chiang Mai province. The samples of farmers are selected for two times to be analyzed in the different objectives. The sample sizes and selection methods are the following:

1) Selecting the 119 farmers in Pamiang area and 69 farmers in Pang Ma-O area (188 total samples) by using the purposive sampling method with the criterion of over or equal to five years cultivating experiences for analyzing the interaction between the actors in cluster supply chain of highland Arabica coffee and farmers' adoption of green supply chain activities.

2) Selecting 29 farmers in Pamiang area and 27 farmers in Pang Ma-O area (56 total samples) who are willing to participate in green cluster supply chain (GCSC) by using the purposive sampling method from the samples in 1). These samples are used for designing the GCSC scenarios for the sample areas and analyzing outcomes resulted from the scenarios via supply chain optimization, value sharing, and farmers' competitiveness analyses.

3.2.2 Assemblers

The assemblers who collect the coffee products from the farmers in Pamiang and Pang Ma-O areas are Pamiang royal project development center (Pamiang RPDC) and Pang

Ma-O royal project extension center (Pang Ma-O RPEC), respectively. Therefore, there are 2 assembler samples, Pamiang RPDC and Pang Ma-O RPEC.

3.2.3 Processor

There is only one processor, the royal project foundation (RPF), in this supply chain scope that is the processor sample in this research.

3.3 Analyzing Methods

The analyzing methodologies are represented by the sequences of the research objectives.

3.3.1 Analysis of conditions and environmental factors before GCSC development of highland Arabica coffee

The samples used in the analysis of conditions and environmental factors before GCSC development are 119 farmers in Pamiang area and 69 farmers in Pang Ma-O area (188 total samples). The analyzing procedures are as followed:

1) Describing the socioeconomic environment and the production of the sample areas such as physical characteristics and community contexts of the areas, the coffee production and marketing, etc.

2) Describing and analyzing the interactions among the actors in the highland Arabica coffee supply chain by interviewing the farmer samples. The actors in coffee cluster consist of the farmers in both areas, the Pamiang RPDC, the Pang Ma-O RPEC, the RPF, Thepsadej sub-district administration, Maena sub-district administration, Chiang Mai university, Maejo university, Kasetsart university, saving groups, farmer groups/SME, cooperative, etc. Cluster mapping is used as a tool for analyzing.

3) Analyzing factor affecting the farmers' adoption of Arabica coffee GCSC by using logit model.

In terms of farmer's adoption of GCSC, this research have determined the guidelines for green practices in three ways, Green production (GP), Green waste management (GW) and Green transportation (GT), for making the decision of the farmers. The structure of farmers’ decision making on green supply chain practices is shown in Figure 3.2.

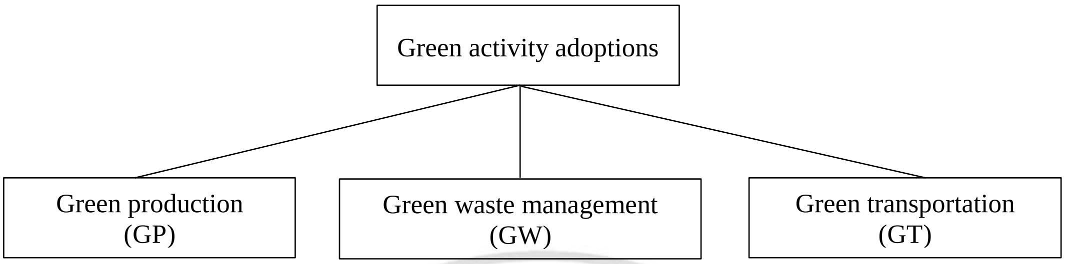

Figure 3.2 The structure of farmers’ decision making on green supply chain practices

Figure 3.2 represents that, in fact, the farmers can choose all of the green practice ways at the same time. Some farmers may choose three ways of green practices, whereas the rest may choose one or two. These situations stress that the green practice ways are independent. Thus, the tool being appropriate for estimating the impacts of the independent variables to the binary choice dependent variable (1 = adopt and 2 = don’t adopt) of three independently green practice ways is the binary logit model.

Binary logit model is suitable for analyzing the qualitative dependent variable that has two binary choices in this research: adopt or don’t adopt in the green practice ways. The data distribution of binary choices of dependent variable is logistic distribution. Therefore, the estimation of dependent variables is in the form of the probability of situation occurrences with the value in the range (0, 1). The general model of logistic regression that has the vector of independent variables, x_i, to interpret the probability of adoption occurrences in green practice ways of the farmer, y_i, is shown in equation (3.1) (Neupane et al., 2002; Aree Wiboonpongse, 2006).

$$P(y_i|x_i) = \frac{e^{x_i'\beta}}{1+e^{x_i'\beta}} = \frac{1}{1+e^{-x_i'\beta}} \qquad (3.1)$$

The binary logit model is constructed by transforming the Equation (3.1) to a logarithm of odd ratio, as expressed in equation (3.2). The approach used to estimate the logit model is maximum likelihood estimator (MLE).

$$L_i = \ln\left(\frac{P(y_i|x_i)}{1-P(y_i|x_i)}\right) = x_i'\beta \qquad (3.2)$$

From the above theoretical concept, the adoptions of the farmers in green practices are determined by many explanatory variables such as gender, age of farmers, education levels, household sizes, farm sizes, experience, information accessibility, farmers' attitude, perception on environmental problems, input cost, etc. (Fernandez-Cornejo et al., 1994, Burton et al., 1999, Herath and Takeya, 2003, Sheikh et al., 2003, Knowler and Bradshaw, 2007, Adeogun et al., 2008, Kassie et al., 2008, Läpple and Rensburg, 2011, Mzoughi, 2011). Consequently, this research has classified the explanatory variables affecting the green practice adoption into three groups consisting of farmer characteristics, physical characteristics, and attitudes and opinions.

(1) Farmer characteristics

The factors in the farmer characteristics aspect include gender (GEN), education (EDU) and experience (EXP).

(1.1) Gender (GEN)

Gender of the farmers affects the green practice adoption in different ways. The literature reviews of related researches show that males tend to adopt new technology in the higher proportion than females because men like to take part in the challenge and accept the risk rather than women (Doss and Morris, 2001, Chirwa, 2005, Fisher and Kandiwa, 2014, Fisher and Carr, 2015). Thus, the hypothesis in gender perspective is that male farmers tend to adopt the green practices rather than females. The gender variable is defined as dummy variable, 1 = male, 0 = female.

(1.2) Education (EDU)

Educational level of farmers reflects the ability of farmers to learn and understand the environmentally friendly practices and positively affect the adoption of green practices (Herath and Takeya, 2003, Sidibe, 2005, Mzoughi, 2011). This research uses the number of years in school as the indicator of educational level. The hypothesis of this factor is the farmers who have higher levels of education are more likely to adopt the green practices.

(1.3) Experience (EXP)

Experience in the coffee plantations of farmers demonstrate the skills of farmers gained from practices (Feder et al., 1985). The research of Thanh and Yapwattanaphun (2015) has shown that the experiences of the farmers have the positive impact on technology adoption because the available knowledge and skills of farmers lead to the adaptation and application of new technologies. Therefore, the hypothesis of this factor has a positive sign.

(2) Physical characteristics

The variables in physical characteristics view consist of farm size (FS), problems of input cost (CI) and information accessibility and utilization (IA)

(2.1) Farm size (FS)

The size of farms is the important factor in determining the adoption of the new practices of farmers because the large farms result in high cost of environmentally management (Feder et al., 1985). The research studies by Lee and Stewart (1993) and Adeogun et al. (2008) displayed that large farms tend to reduce technology adoption. This research used the quantities of coffee cultivating areas of the farmer representing the farm sizes and set the hypothesis of this factor having the negative sign.

(2.2) Input cost concern (CI)

The inputs is an important factor affecting the adoption of technology, that is, if the usage of the new technology helps the farmers to reduce the cost of inputs, the farmers will tend to accept this technology (Schimmelpfennig and Ebel, 2016, Bravo-Monroy et al., 2016). According the study by Mzoughi (2011), this research defines the input cost variable being the economic concern factor of the farmers about the cost reduction defined as the dummy variable (1 = if the farmer thinks that cutting cost is important, 0 = otherwise). The reasons of use the dummy variable instead of the actual cost because the prior is better than the latter in terms of indicating the real economic concerns of the farmers. For example, the suffering of the farmers having the high production costs and enough capital may be lower than the farmers having the lower costs but no budgets. Thus, in this case, the amount of the costs does not imply the concern of the farmers about the cost problem. The hypothesis of this factor is the farmers who concern about the cost tend to adopt green practices.

(2.3) Information accessibility and utilization (IA)

Accessibility to information and utilization of farmers demonstrated the implementation of new technology by practice. In general, the farmers have a high level of accessibility to information and taking advantage of the technology, thus tending to accept the new ways of doing things (Sheikh et al., 2003). The Linkert scales 1-5 are used for the farmers' assessment on their information accessibility and utilization, and the criterions of them are shown as followed:

Poor	the farmers receive the production and market information and take advantage of it in their production and marketing less than 21 percent
Fair	the farmers receive the production and market information and take advantage of it in their production and marketing from 21 to 40 percent
Average	the farmers receive the production and market information and take advantage of it in their production and marketing from 41 to 60 percent
Good	the farmers receive the production and market information and take advantage of it in their production and marketing from 61 to 80 percent
Excellent	the farmers receive the production and market information and take advantage of it in their production and marketing more than 80 percent

The hypothesis of information accessibility and utilization factor is shown as the positive direction of sign.

(3) Attitudes and Opinions

(3.1) Green attitude (ATT)

A positive attitude about being environmental friendly has a positive impact on the farming practices. The researches of Burton et al. (1999), Burton et al. (2003), Läpple (2010), Läpple & Rensburg (2011) shown that the farmers who are interested in environmental issues tend to be more accepting of organic farming.

This study defined the variable of environmentally friendly attitudes of the farmers by assessing farmers' attitudes by themselves via 10 questions with a Linkert scale from 1 to 5, the least agree to the most agree. The total scores are equal to 50 and the attitude questions are the following:

- Reduction of chemical fertilizers use will help to restore the fertility of the soil.
- Chemical fertilizers and chemicals used in the production causing the contamination in natural water.
- The wastewater from coffee fermentation should be treated before releasing to the natural water.
- Coffee husks can be used to make the fertilizers.
- The use of alternative fuels such as biodiesel fuel helps to reduce global warming.
- Green coffee production help to preserve forests and natural watersheds.
- Green coffee production help to create a good image for coffee production.
- Green coffee production help to reduce the cost of inputs.
- Increasing returns from green coffee production is higher than the rising cost of the environmental investment.
- The green coffee production have higher quality than general coffee production.

Binary logit models used for analyzing are expressed in equation (3.3) – (3.5).

Farmers' adoption on green production practice

$$\ln\left(\frac{P(GPA_i)}{1-P(GPA_i)}\right) = \beta_1 + \beta_2 GEN_i + \beta_3 EXP_i + \beta_4 ATT_i + \beta_5 FS_i + \beta_6 CI_i + \beta_7 IA_i \quad (3.3)$$

Farmers' adoption on green waste management practice

$$\ln\left(\frac{P(GWA_i)}{1-P(GWA_i)}\right) = \alpha_1 + \alpha_2 GEN_i + \alpha_3 EXP_i + \alpha_4 ATT_i + \alpha_5 FS_i + \alpha_6 CI_i + \alpha_7 IA_i \quad (3.4)$$

Farmers' adoption on green transportation practice

$$\ln\left(\frac{P(GTA_i)}{1-P(GTA_i)}\right) = \delta_1 + \delta_2 GEN_i + \delta_3 EXP_i + \delta_4 ATT_i + \delta_5 FS_i + \delta_6 CI_i + \delta_7 IA_i \quad (3.5)$$

The variables used in binary logit model to analyze the three equations above on the green practices and the impact directions of the independent variables on the dependent variable are summarized in Table 3.1.

Table 3.1 Variables and definitions for binary logit model

Variables	Definitions	Types of measure	Direction of effects
Independent variables:			
GEN	Gender of farmers	1 = male, 0 = female	+
EDU	Number of years in school of the farmers	In years	+
EXP	Farming experience of the farmers	In years	+
ATT	Attitude of farmer to green supply chain practices	In scores of 10 sub-questions	+
FS	Farm sizes	In rais	-
CI	Input cost concern	1 = cutting cost is important, 0 = otherwise	+
IA	Information accessibility and utilization of the coffee farmer	1 = poor, 2 = fair, 3 = average, 4 = good, 5 = excellent	+

Table 3.1 (Continued)

Variables	Definitions	Types of measure	Direction of effects
Dependent variables:			
GPA	Farmer's adoption on green production (such as chemical used reduction)	1 = willing to adopt, 0 = otherwise	-
GWA	Farmer's adoption on green waste management (such as wastewater management, waste management)	1 = willing to adopt, 0 = otherwise	-
GTA	Farmer's adoption on green transportation (such as alternative energy use)	1 = willing to adopt, 0 = otherwise	-

The approach for estimating equations (3.3) - (3.5) is the maximum likelihood (Greene, 2008, Gujarati and Porter, 2009).

4) Analyzing the economic environments by modifying the GEM model that extend the GEM model of Padmore & Gibson (1998) by adding the concept of Porter's five forces and environmental friendly relation. This model facilitates the conversion of quality variable to the quantitative indicators to be used for evaluating the agricultural or food cluster (Li & Zhou, 2006). The procedures are as follow:

4.1) Interviewing 14 farmer agents, two Pamiang RPDC staffs, two Pamiang RPDC staffs, two Pang Ma-O RPEC staffs, one RPF staff, and one HRDI staff to determine the important weights of indicators (shown in Table 3.2). Because the definition of weight of each samples are different, it represents the ambiguity of the information. Thus, the analytic hierarchy process (AHP) is used for assessing the weights of each sub-indicator. Following the method of Saaty (1980, 1990), sample will score the key points of sub-indicators by considering pairwise matric with the score 1 to 9. In this study, there are 8 main indicators such as resources; infrastructures; suppliers and related agencies; structure and strategies; competition; green relation; local markets; and external markets. Each main indicator contains own sub-indicators. Let *Wi* (where i = 1, 2, …, n) represent the weight of each sub-indicator and *aij* denote the values obtained from the comparison of the pairwise of sub-indicators *i* and *j* (where *j* = 1, 2, …, *n* and $i \neq j$) which are calculated by $a_{ij} = W_i/W_j$. Thus, the matrix $A_r = [a_{ijr}]$ of the comparison of the pairwise of sub-indicators of each sample (*r*) can be wrote as equation (3.6).

The weights of each sub-indicators have been weighted by each sample (w_{ir}) and the average weights of each sub-indicators is used by Geometric mean (Kallas et al., 2009) are displayed in equation (3.7) and (3.8).

$$A_r = \begin{bmatrix} a_{11r} & a_{12r} & \dots & a_{1nr} \\ a_{21r} & a_{2r} & \dots & a_{2nr} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1r} & a_{n2r} & \dots & a_{nnr} \end{bmatrix} = \begin{bmatrix} W_{1r}/W_{1r} & W_{1r}/W_{2r} & \cdots & W_{1r}/W_{nr} \\ W_{2r}/W_1 & W_{2r}/W_1 & \cdots & W_{2r}/W_{nr} \\ \vdots & \vdots & \ddots & \vdots \\ W_{nr}/W_1 & W_{nr}/W_1 & \cdots & W_{nr}/W_{nr} \end{bmatrix} \quad (3.6)$$

$$w_{ir} = \sqrt[n]{\Pi_{i=1}^{n} a_{ijr}} \quad (3.7)$$

$$w_i = \sqrt[R]{\Pi_{r=1}^{R} w_{ir}} \quad (3.8)$$

The weights of the sub-indicators obtained from the equation (3.8) are used as the weight to calculate the scores of main indicators in the GEM model.

4.2) Let each farmer assesses the current situation of the economic factors of each sub-indicator with the scores from 1-10, from the least to the most.

Table 3.2 Indicators of microeconomic environment in GEM model

Dimensions	Indicators	Sub-indicators	Descriptions
Grounding	Resources	Natural resources	Appropriate geographic and climate conditions
		Capital	Adequacy of capital
		Human resources	Training and skill improving of the farmers
		Techniques & Technology	The knowledge and accessibility of the farmers in production techniques and technologies
		Information	Accessibility of information of the farmers
	Infrastructures	Transport and Communication	Convenience to community access and transportation
		Business environment	Regulation, socioeconomic, technology supporting coffee production
		Policy	Policy promoted for coffee cultivation
		Associations	There are the farmer groups in community
		R&D institutes and university	Knowledge supporting from R&D institutes and universities
Enterprise	Suppliers and Related agencies	Supplier strength	Ability of suppliers to provide inputs on farmers' orders
		Quality of suppliers	Quality of inputs for coffee production
		Cooperation with suppliers	There is cooperation between farmers and suppliers
		Related agencies strength	Ability to effectuate the related agencies for promoting the farmers
		Quality of related agencies	Knowledge or opportunity supporting from related agencies
		Cooperation with related agencies	There is cooperation between farmers and related agencies

Table 3.2 (Continued)

Dimensions	Indicators	Sub-indicators	Descriptions
Enterprise (Continue)	Structure and Strategies	Unanimous in group	Unanimous decisions of farmer group that are agreement, solidarity, and unity
		Ownership	Proportion on input ownership in coffee production such as land, equipment, labors, etc.
		Production and strategies plans	Having production and strategies plans and actually utilization
	Competition	Bargaining power of suppliers	Comparing bargaining power between the farmers and the suppliers
		Bargaining power of buyers	Comparing bargaining power between the farmers and the buyers
		Intensity of rivalry	Low level of rivalry in coffee products
		Threat of substitute products	Differentiation between the coffee products of the farmer and other one
		Threat of new entrants	Difficulty to produce of new farmers
	Green relation	Green production management	Levels of practice in green production management
		Green transportation	Levels of practice in green transportation
		Green disposal of waste	Levels of practice in green disposal of waste
Market	Local markets	Scale of local markets	Amount of buyers in local market
		Local market share	Local market share of the farmer’s product
		Growth and opportunity	Reputation and quality of coffee products
		Local market boundary	Boundary of local market covering overall community area
		Specific demand	Amount of the specific purchasing order of the buyers

Table 3.2 (Continued)

Dimensions	Indicators	Sub-indicators	Descriptions
Market (Continue)	External markets	Distances to external markets	Distances to external markets don't bring about high transportation cost
		Scale and growth rate	Rising of product quantity sold in external market
		External market share	External market share of the farmer's product
		Final consumers	There are the regular consumer
		Entry to external markets	Ease to entry to external markets

4.3) Calculating the GEM scores by starting from the calculation of the scores of the main indicators by using the average scores of each sub-indicator multiplied with the relatively important weight from 4.1), the formula shown in the equation (3.9).

$$DET.SCORE_d = \sum_{i=1}^{n}\left(\sum_{r=1}^{R} S_r^i / R\right)\cdot w_i \qquad (3.9)$$

where $DET.SCORE_d$ is the average scores of each main indicator *d* (*d = 1, 2, …, D*), S_r^i is the score of sub-indicator *i* of sample *r* (*i = 1, 2, …, n* and *r = 1, 2, …, R*), and w_i is the average weight of sub-indicator *i*.

The average score of each main indicator represents the strengths or weaknesses of that indicators affecting the cluster development. The criterions for the interpretation of these scores are as follow:

$DET.SCORE_d \leq 2.00$ This indicator is the most weakness in cluster developing.

$2.00 < DET.SCORE_d \leq 4.00$ This indicator is the weakness in cluster developing.

$4.00 < DET.\,SCORE_d \le 6.00$	This indicator is neither the strength nor the weakness in cluster developing.
$6.00 < DET.\,SCORE_d \le 8.00$	This indicator is the strength in cluster developing.
$DET.\,SCORE_d > 8.00$	This indicator is the most strength in cluster developing.

Then calculating the average score of the main indicators based on the three dimensions including grounding, enterprise and market dimensions by using equation (3.9). The average scores of the main indicators are obtained. Moreover, the total modified GEM scores are calculated from equation (3.10).

$$GEM\ SCORE = 2.5\left(\prod_{i=1}^{3}(DET.\,SCORE_i)\right)^{2/3} \qquad (3.10)$$

4.4) The scores obtained from equation (3.9) are used to build the radar graph for analyzing the impacts of each main indicators on cluster development.

The results from the method of analysis 4.1) – 4.4) help to perceive the interaction between actors in the cluster and know the strengths or weaknesses of environmental factors on the cluster. This knowledge is used to develop GCSC.

3.3.2 Simulations of horizontal collaboration of the farmers to analyze the optimization of GCSC

In this section, the horizontal collaborations of farmers are simulated to analyze the pattern of the proper operation in GCSC to answer the research question about the green cluster supply chain being able to reduce the cost or not. The samples used in this study are 56 coffee farmers who are willing to participate in GCSC, 1 staff of the Pamiang RPDC, 1 staff of the Pang Ma-O PREC, and 1 staff of the RPF.

From the definition of green supply chain cluster in the glossary, which focuses on green production, as well as waste disposal and green transportation, these activities will affect the costs in the supply chain. The two GCSC models obtained from scenario method are as follow:

1) *Model A1*: *The non-GCSC model*. There is not the cluster in the supply chain. Each farmer sells his product independently.

The structure of model presents in Figure 3.3

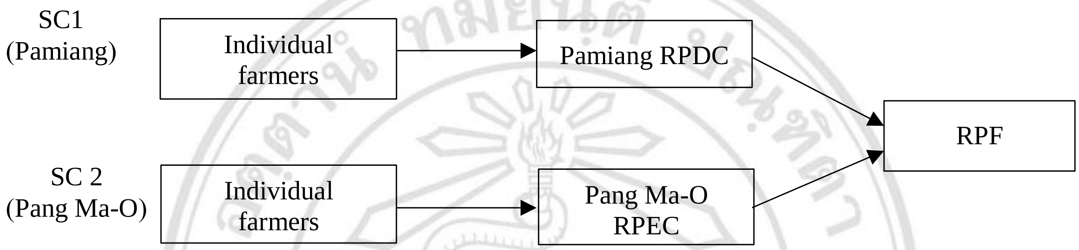

Figure 3.3 Model A1: The non-GCSC model

The objective function of the supply chain of individual farmers in each community can be written in the equation (3.11).

$$\begin{aligned}\min\ TC \ = & \sum_f \sum_s (PRC_{fs}^{green} + DC_{fs}^{green}) \cdot Q_{fs} + \sum_f \sum_a \sum_s TRC_{fas}^{green} \cdot TR_{fas} \cdot \gamma_s \\ & + \sum_a \sum_s IC_{as} \cdot I_{as} + \sum_a \sum_p \sum_s TRC_{aps}^{green} \cdot TR_{aps} + IC_p \cdot I_p \\ & + (PRC_p + DC_p^{green}) \cdot Q_p \end{aligned} \tag{3.11}$$

The objective function

The objective function is the cost minimization in partial supply chain consisting of 1) costs of the farmers such as production cost (PRC_{fs}^{green}), waste disposal cost (DC_{fs}^{green}), and transportation cost (TRC_{fas}^{green}), 2) costs of assemblers such as inventory cost (IC_{as}), and transportation cost (TRC_{aps}^{green}), and 3) costs of processor such as inventory cost (IC_p), production cost (PRC_p), and waste disposal cost (DC_p^{green}).

However, since the adoption of the green activities of each samples giving different values, for example, the acceptance in moderate level of one farmer may be more acceptable than the other. Thus, the decision makings are vague. As a result of ambiguity in decision making, the costs associated with environmentally friendly practices, such as the cost of production, the cost of waste disposal, and the costs of transportation are uncertain. Consequently, the nature of the costs is quite fuzzy.

The constraints functions

The constraints functions consist of 1) farmers constraints such as the ability to produce, the ability to transport, and the demand of the assemblers, 2) assemblers constraints such as the ability to purchase products, the ability to store inventory and the ability to transport, and 3) processor constraints such as the ability to produce, the ability to store inventory, the demand of consumers. Moreover, all of the decision variables must be equal or more than zero. The details of constraints functions are as follows:

1.1) Amount of parchment coffee of the farmers should not be less than the ability to produce coffee for delivery to the RPF and should not exceed the total parchment coffee.

$$Q_{fs}^{\text{capacity1}} \leq Q_{fs} \leq Q_{fs}^{\text{capacity2}} \qquad (3.12)$$

1.2) Amount of parchment coffee of the farmers must be equal to the amount of parchment coffee transported from the farmers to the assemblers. Farmers sell all of their available products to assemblers gathering the product for the RPF, so all of the parchment coffee products will be delivered to the assemblers without stock.

$$Q_{fs} = TR_{fas} \qquad (3.13)$$

1.3) Amount of inventory parchment coffee of the assemblers derived from the amount of parchment coffee obtained from farmers minus the amount of parchment coffee delivered to RPF.

$$I_{as} = \sum_f \sum_a \sum_s TR_{fas} \cdot \gamma_s - TR_{aps} \tag{3.14}$$

1.4) Amount of parchment coffee inventory of the assemblers should not be more than their ability to store inventory.

$$I_{as} \leq I_{as}^{capacity} \tag{3.15}$$

1.5) Amount of parchment coffee of the assemblers transported to RPF should not be more than RPF's ability to store inventory.

$$\sum_a \sum_p \sum_s TR_{aps} \leq \tilde{I}_p^{capacity} \tag{3.16}$$

1.6) Amount of parchment coffee inventory of the RPF are equal to amount of parchment coffee received from the assemblers minus amount of parchment coffee used for producing green coffee bean. The conversion rate from parchment coffee to green coffee bean is equal to 100 kg parchment coffee per 80 kg of coffee bean.

$$I_p = \sum_a \sum_p \sum_s TR_{aps} - 1.25Q_p \tag{3.17}$$

1.7) To avoid excess demand problems, PRF must determine the minimal amount of parchment coffee inventory in their warehouse. In this case, minimum volume can be calculated by amount capacity of RPF, 50 tones, divided by 25 areas providing the products to RPF, after that considering 2 of 25 proportions for only two areas. Thus, the minimum amount of parchment coffee inventory of RPF for each area is 2000 kg.

$$I_p \geq 2,000 \tag{3.18}$$

1.8) Amount of green coffee bean produced by RPF should not exceed the amount of parchment coffee received from the assemblers by multiplying the conversion rate from parchment coffee to green coffee bean.

$$Q_p \leq 0.8 \cdot \sum_a \sum_p \sum_s TR_{aps} \tag{3.19}$$

1.9) Amount of green coffee bean produced by RPF must be equal to the volume of demand because the RPF will produce green coffee bean when having the orders from consumers. The demand of green coffee bean is uncertain, so the volume of demand in constraints function is fuzzy.

$$Q_p = \tilde{D}_m \tag{3.20}$$

1.10) The variable, γ_s, is an integer with the binary value 1 and 0.

$$\gamma_s \in \{0, 1\} \tag{3.21}$$

1.11) All decision variables must be greater than or equal to zero.

$$Q_{fs}, Q_p, TR_{fas}, TR_{aps}, I_{as}, I_p \geq 0 \tag{3.22}$$

The definitions of the variables used in four models for analyzing the optimization of GCSC are shown in Table 3.3.

Table 3.3 Definitions of the variables for analyzing the optimization of GCSC

Variables	Definitions
Indices	
f	farmer *f (f = 1, 2, …, 56)*
a	Assembler *a (a = 1, 2)*
p	RPF *p (p = 1)*
g	Farmer cluster *g (g = 1, 2)*
green	Green relation
Parameters	
TC	Total cost of supply chain (Baht)
PRC_{fs}^{green}	Fuzzy green production cost per unit of parchment coffee of *f* in supply chain *s* (Baht)

Table 3.3 (Continued)

Variables	Definitions
PRC_{gs}^{green}	Fuzzy green production cost per unit of parchment coffee of farmer cluster *g* in supply chain *s* (Baht)
PRC_p	Production cost per unit of green coffee beans of processor (Baht)
DC_{fs}^{green}	Fuzzy green waste management cost per unit of farmer *f* in supply chain *s* (Baht)
DC_{gs}^{green}	Fuzzy green waste management cost per unit of farmer cluster *g* in supply chain *s* (Baht)
DC_{p}^{green}	Fuzzy green waste management cost per unit of RPF (Baht)
TRC_{fas}^{green}	Fuzzy green transportation cost per unit of parchment coffee from farmer *f* to assembler *a* in supply chain *s* (Baht)
TRC_{gas}^{green}	Fuzzy green transportation cost per unit of parchment coffee from farmer *c*luster *g* to assembler *a* in supply chain *s* (Baht)
TRC_{aps}^{green}	Fuzzy green transportation cost per unit of parchment coffee from assembler *a* to RPF *p* in supply chain *s* (Baht)
IC_{as}	Inventory cost per unit of parchment coffee of assembler *a* in supply chain *s* (Baht)
IC_p	Inventory cost per unit of parchment coffee of processor (Baht)
$Q_{fs}^{\text{capacity1}}$	Production capacity to produce parchment coffee for RPF of farmer *f* in supply chain *s* (kg)
$Q_{fs}^{\text{capacity2}}$	Total production capacity to produce parchment coffee of farmer *f* in supply chain *s* (kg)
$Q_{gs}^{\text{capacity1}}$	Production capacity to produce parchment coffee for RPF of farmer cluster *g* in supply chain *s* (kg)
$Q_{gs}^{\text{capacity2}}$	Total production capacity to produce parchment coffee of farmer cluster *g* in supply chain *s* (kg)
Q_{p}^{capacity}	Total production capacity to produce green coffee beans of RPF (kg)
$\tilde{D}_m$	Fuzzy demand of green coffee beans of RPF consumer (kg)
I_{as}^{capacity}	Inventory capacity of assembler *a* in supply chain *s* (kg)
$\tilde{I}_{p}^{\text{capacity}}$	Fuzzy inventory capacity of RPF (kg)
γ_s	= 1 if the transportation occurring in the same supply chain = 0 Otherwise
<u>*Decision variables*</u>	
Q_{fs}	Amount of parchment coffee of farmer *f* in supply chain *s* (kg)

Table 3.3 (Continued)

Variables	Definitions
Q_{gs}	Amount of parchment coffee of farmer cluster *g* in supply chain *s* (kg)
Q_p	Amount of green coffee beans of RPF (kg)
TR_{fas}	Amount of parchment coffee transported from farmer *f* to assembler *a* in supply chain *s* (kg)
TR_{gas}	Amount of parchment coffee transported from farmer cluster *g* to assembler *a* in supply chain *s* (kg)
TR_{aps}	Amount of parchment coffee transported from assembler *a* to RPF *p* in supply chain *s* (kg)
I_{as}	Amount of parchment coffee inventory of assembler *a* in supply chain *s* (kg)
I_p	Amount of parchment coffee inventory of RPF (kg)

2) *Model A2*: *The GCSC Model*. There is the farmer cluster in each area. The structure of the model is presented in Figure 3.4.

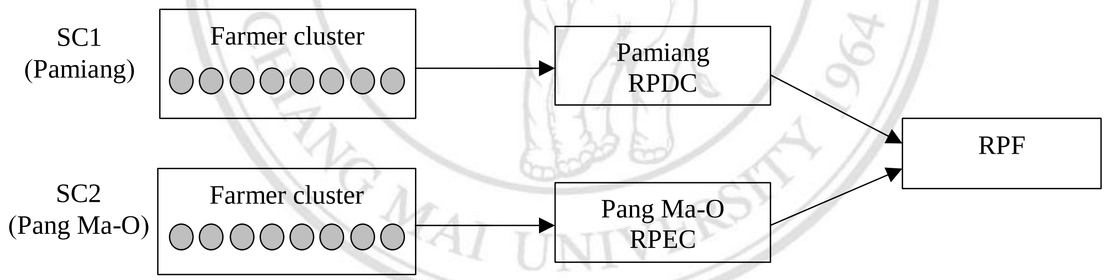

Figure 3.4 Model A2: The GCSC Model

The objective function can be written in the equation (3.23).

$$\begin{aligned} \min\ TC\ =\ & \sum_g \sum_s (PRC_{gs}^{green} + DC_{gs}^{green}) \cdot Q_{gs} + \sum_g \sum_a \sum_s TRC_{gas}^{green} \cdot TR_{gas} \cdot \gamma_s \\ & + \sum_a \sum_s IC_{as} \cdot I_{as} + \sum_a \sum_p \sum_s TRC_{aps}^{green} \cdot TR_{aps} + IC_p \cdot I_p \\ & + (PRC_p + DC_p^{green}) \cdot Q_p \end{aligned} \tag{3.23}$$

The constraints functions consist of equation (3.15) – (3.21) and

$$Q_{gs} \leq Q_{gs}^{capacity} \tag{3.24}$$

$$Q_{gs} \geq TR_{gs} \tag{3.25}$$

$$I_{as} = \sum_{f}\sum_{a}\sum_{s} TR_{gas} \cdot \gamma_s - TR_{aps} \tag{3.26}$$

$$Q_{gs}, Q_p, TR_{gas}, TR_{aps}, I_{as}, I_p \geq 0 \tag{3.27}$$

From the models above, due to the nature of the data being complex with raw data and that the integer data has been chosen between 1 and 0, the method selected to analyze the GCSC optimization is a Fuzzy mixed-integer linear programming (FMILP).

3.3.3 Simulations of the value sharing of GCSC

This section represents the vertical coordination among the farmers, assemblers, and processor simulated to analyze the value sharing among the farmers, assemblers, and RPF to answer the research question about the GCSC being able to increase the farmers' revenue or not. The samples used in this study are the same to the model of horizontal development.

To achieve the vertical coordination, this research has applied the revenue sharing contracts as mechanism for creating the GCSC by extending the concept of Giannoccaro and Pontrandolfo (2004).

Table 3.4 Definitions of the variables for analyzing the revenue sharing in GCSC

variables	Definitions
Variables associated with farmers and farmer cluster.	
c_{f1i}	Cost in supply chain of farmer i in supply chain 1 (Baht/kg)
c_{f2j}	Cost in supply chain of farmer j in supply chain 2 (Baht/kg)
c_{f1}	Cost in supply chain of farmer cluster in supply chain 1 (Baht/kg)
c_{f2}	Cost in supply chain of farmer cluster in supply chain 2 (Baht/kg)
p_{f1i}	Selling price of parchment coffee of farmer i in supply chain 1 (Baht/kg)
p_{f2j}	Selling price of parchment coffee of farmer j in supply chain 2 (Baht/kg)
p_{f1}	Selling price of parchment coffee of farmer cluster in supply chain 1 (Baht/kg)

Table 3.4 (Continued)

variables	Definitions
p_{f2}	Selling price of parchment coffee of farmer cluster in supply chain 2 (Baht/kg)
q_{f1i}	Selling volume of parchment coffee of farmer i in supply chain 1 (kg)
q_{f2j}	Selling volume of parchment coffee of farmer j in supply chain 2 (kg)
q_{f1}	Selling volume of parchment coffee of farmer cluster in supply chain 1 (kg)
q_{f2}	Selling volume of parchment coffee of farmer cluster in supply chain 2 (kg)
$\pi_{f1}^{\text{model } k}$	Profit of farmer in supply chain 1 in model k (k=1, 2) (Baht)
$\pi_{f2}^{\text{model } k}$	Profit of farmer in supply chain 2 in model k (k=1, 2) (Baht)
$\beta_1, (1-\beta_1)$	Proportion of selling volume of parchment coffee of farmer cluster in supply chain 1 to the assembler 1 and 2, respectively (Percent)
$\beta_2, (1-\beta_2)$	Proportion of selling volume of parchment coffee of farmer cluster in supply chain 2 to the assembler 2 and 1, respectively (Percent)
Variables associated with assemblers:	
c_{a1}	Cost in supply chain of assembler 1 (Baht/kg)
c_{a2}	Cost in supply chain of assembler 2 (Baht/kg)
p_{a1}	Selling price of parchment coffee of assembler 1 (Baht/kg)
p_{a2}	Selling price of parchment coffee of assembler 2 (Baht/kg)
q_{a1}	Selling volume of parchment coffee of assembler1 (kg)
q_{a2}	Selling volume of parchment coffee of assembler 2 (kg)
$\pi_{a1}^{\text{model } k}$	Profit of assembler 1 in model k (k=1, 2) (Baht)
$\pi_{a2}^{\text{model } k}$	Profit of assembler 2 in model k (k=1, 2) (Baht)
$\phi_{a1}, (1-\phi_{a1})$	Proportion of revenue sharing of assembler 1 (Percent)
$\phi_{a2}, (1-\phi_{a2})$	Proportion of revenue sharing of assembler 2 (Percent)
Variables associated with processor:	
c_p	Cost in supply chain of RPF (Baht/kg)
p_p	Selling price of green coffee beans of RPF (Baht/kg)
q_p	Selling volume of green coffee beans of RPF (kg)

Table 3.4 (Continued)

variables	Definitions
$\pi_p^{\text{model } l}$	Profit of RPF in model *l* (*l* =1, 2) (Baht)
ϕ_p	Proportion of revenue sharing of RPF (Percent)
$\alpha,(1-\alpha)$	Weights of proportion of revenue sharing across the chain of RPF (Percent)
Variables associated with supply chain:	
$\pi_{sc}^{\text{model } l}$	Profit of supply chain in model *l* (*l* =1, 2) (Baht)

The analysis uses the scenario techniques by determining GCSC with revenue sharing in the four scenario models, as follows:

1) *Model B1*: *Non-GCSC model without revenue sharing contracts*. There is not the cluster and revenue sharing contracts

The profit of RPF is shown in equation (3.28).

$$\pi_p^{\text{model1}} = p_p q_p - p_{a1}q_{a1} - p_{a2}q_{a2} - c_p q_p \quad (3.28)$$

The profits of assemblers are represented as follow:

$$\pi_{a1}^{\text{model1}} = p_{a1}q_{a1} - \sum_{i=1}^{n} p_{f1i}q_{f1i} - c_{a1}q_{a1} \quad (3.29)$$

$$\pi_{a2}^{\text{model1}} = p_{a2}q_{a2} - \sum_{j=1}^{m} p_{f2j}q_{f2j} - c_{a2}q_{a2} \quad (3.30)$$

The profits of the farmers are displayed as follow:

$$\pi_{f1}^{\text{model1}} = \sum_{i=1}^{n} p_{f1i}q_{f1i} - \sum_{i=1}^{n} c_{f1i}q_{f1i} \quad (3.31)$$

$$\pi_{f2}^{\text{model1}} = \sum_{j=1}^{m} p_{f2j}q_{f2j} - \sum_{j=1}^{m} c_{f2j}q_{f2j} \quad (3.32)$$

The overall supply chain profits are expressed as follow:

$$\begin{aligned}\pi_{sc}^{\text{model1}} &= \pi_{p}^{\text{model1}} + \pi_{a1}^{\text{model1}} + \pi_{a2}^{\text{model1}} + \pi_{f1}^{\text{model1}} + \pi_{f2}^{\text{model1}} \\ &= p_p q_p - c_p q_p - c_{a1} q_{a1} - c_{a2} q_{a2} - \sum_{i=1}^{n} c_{f1i} q_{f1i} - \sum_{j=1}^{m} c_{f2j} q_{f2j}\end{aligned} \tag{3.33}$$

The structure of model is presented in Figure 3.5.

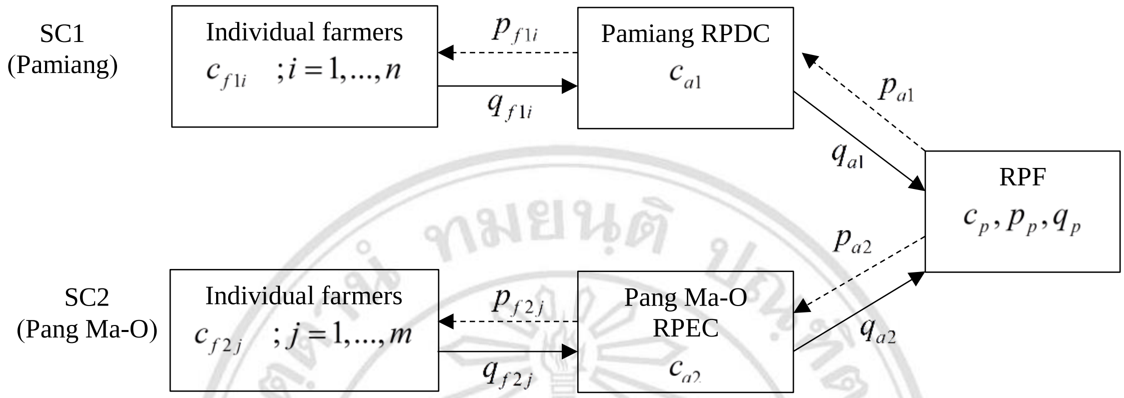

Figure 3.5 Model B1: Non-GCSC model without revenue sharing contracts

2) *Model B2: GCSC model with revenue sharing contracts.* There are the farmer clusters in each area and revenue sharing contracts.

The profit of RPF is shown as follow:

$$\pi_{p}^{\text{model2}} = (1-\phi_p)(p_p q_p) - p_{a1} q_{a1} - p_{a2} q_{a2} - c_p q_p \tag{3.34}$$

The profits of assemblers are represented as follow:

$$\pi_{a1}^{\text{model2}} = (1-\phi_{a1})\left[(p_{a1} q_{a1}) + \alpha\phi_p (p_p q_p)\right] - p_{f1} q_{f1} - c_{a1} q_{a1} \tag{3.35}$$

$$\pi_{a2}^{\text{model2}} = (1-\phi_{a2})\left[(p_{a2} q_{a2}) + (1-\alpha)\phi_p (p_p q_p)\right] - p_{f2} q_{f2} - c_{a2} q_{a2} \tag{3.36}$$

The profits of the farmers are displayed as follow:

$$\pi_{f1}^{\text{model2}} = p_{f1} q_{f1} + \phi_{a1}\left[(p_{a1} q_{a1}) + \alpha\phi_p (p_p q_p)\right] - c_{f1} q_{f1} \tag{3.37}$$

$$\pi_{f2}^{\text{model2}} = p_{f2} q_{f2} + \phi_{a2}\left[(p_{a2} q_{a2}) + (1-\alpha)\phi_p (p_p q_p)\right] - c_{f2} q_{f2} \tag{3.38}$$

The overall supply chain profits are expressed as follow:

$$\pi_{sc}^{\text{model2}} = \pi_{p}^{\text{model2}} + \pi_{a1}^{\text{model2}} + \pi_{a2}^{\text{model2}} + \pi_{f1}^{\text{model2}} + \pi_{f2}^{\text{model2}}$$
$$= p_p q_p - c_p q_p - c_{a1} q_{a1} - c_{a2} q_{a2} - c_{f1} q_{f1} - c_{f2} q_{f2} \quad (3.39)$$

The structure of the model is presented in Figure 3.6.

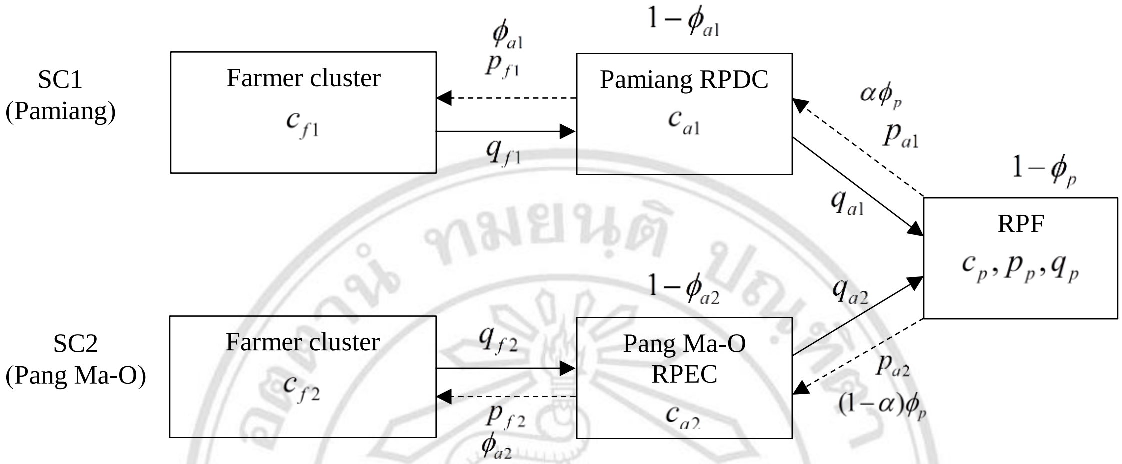

Figure 3.6 Model B2: GCSC model with revenue sharing contracts

All two models above are estimated by using the adjustment of the parameters for investigating the best results.

The results of the optimization and revenue sharing analyses results in the suitable model of GCSC with minimized cost and rising revenue which play as the alternatives for the farmers to joy the GCSC.

3.3.4 Analysis of competitiveness of the farmers in GCSC

Although the model is chosen above bringing about a minimum cost of supply chain and increasing the profit of farmers, the results do not show the competitiveness from participating in GCSC. Thus, this section represents the method to analyze farmers' competitiveness by using the composite index which is constructed in the SCOR, diamond model and environmental friendly perspectives. The model obtained from 3.3.2 and 3.3.3 is used to be compared with the traditional model without green and cluster. The procedures are as followed:

1) Assessing the competitiveness of the farmers by determining the indicators that are shown in Table 3.5.

Table 3.5 Indicators of competitiveness of the farmers

Dimensions	Indicators
Competitive position:	
- Supply	• Capital accessibility • Production factors accessibility
- Demand	• Scale of internal demand • Scale of external demand
Supply chain performance:	
- Trust	• Orders replenishment • Product quality
- Flexibility	• Information flow • Adaptation
- Cost	• Cost of supply chain • Cost of product
- Asset and profitability	• Payback period • ROA • Turnover
- Green relation	• Green prodictivity • The use of organic/biomass in production • Waste disposal • Extravagant energy control

2) Calculating the index values by applying the method of UNDP (2002).

$$S_k^{\text{model i}} = \frac{C_k^{\text{model i}} - C^{\text{min\_model i}}}{C^{\text{max\_model i}} - C^{\text{min\_model i}}} \tag{3.40}$$

where $S_k^{\text{model i}}$ denotes the index score of indicator k in model i, $C_k^{\text{model i}}$ represents the scores of indicator k in model i, $C^{\text{min\_model i}}$ is minimum scores of indicator k in model i, $C^{\text{max\_model i}}$ is the maximum scores of indicator k in model i, and i is the analysis models

3) Calculating the competitiveness index by using the equation (3.41).

$$CI^{\text{model i}} = \left[\frac{\sum_{k=1}^{K}(S_k^{\text{model i}})^3}{K}\right]^{\frac{1}{3}} \tag{3.41}$$

where $CI^{\text{model i}}$ denotes competitiveness index of the farmers and K is the number of indicators.

4) Comparing the farmers' competitiveness index of the traditional model (Non GCSC) and the model selected from 3.3.2 and 3.3.3 (GCSC) by using radar graph.

3.4 Summary

The research methodologies used in this research are summarized as follows:

1) The research questions are "how to develop the supply chain coffee on the highland with the principles of supply chain cluster concerning environmentally friendly, and would this development create value and enhance competitiveness of farmers or not". The scope of this research focuses on the Arabica coffee farmers in Pamiang and Pang Ma-O areas.

2) Because of the three stage supply chain of Arabica coffee is determined by the scope and framework of this research, the population and samples are separated into three groups consisting of numerous farmers, two assemblers, and one processor.

3) The research methodology starts by analyzing the conditions and environmental factors before GCSC development consists of:

3.1) The socioeconomic environment and the production of the sample areas such as physical characteristics and community contexts of the areas, the coffee production and marketing, etc.

3.2) The interactions among the actors in the highland Arabica coffee supply chain by using cluster mapping.

3.3) The factor affecting the farmers' adoption of Arabica coffee GCSC by using logit model.

3.4) The economic environments by modifying the GEM model.

4) The simulation of the horizontal collaboration of the farmers bringing about the non-GCSC and GCSC models. The analysis of the optimization of GCSC by using the FMILP technique is employed for assessing the horizontal collaboration performance.

5) The scenarios of the vertical coordination of the farmers, the assemblers, and the processor by using the pairwise value sharing contracts.

6) The analysis of competitiveness of the farmers in GCSC by using the composite index and radar graph.

The approaches in 3) bring about the driven factors of the GCSC used as the information for simulating the GCSC models, whereas the approaches in 4) – 6) result in the GCSC modeling and evaluating the GCSC performance. The outputs of all approaches bring to establishing the policy implication. The method summary is shown in Figure 3.7.

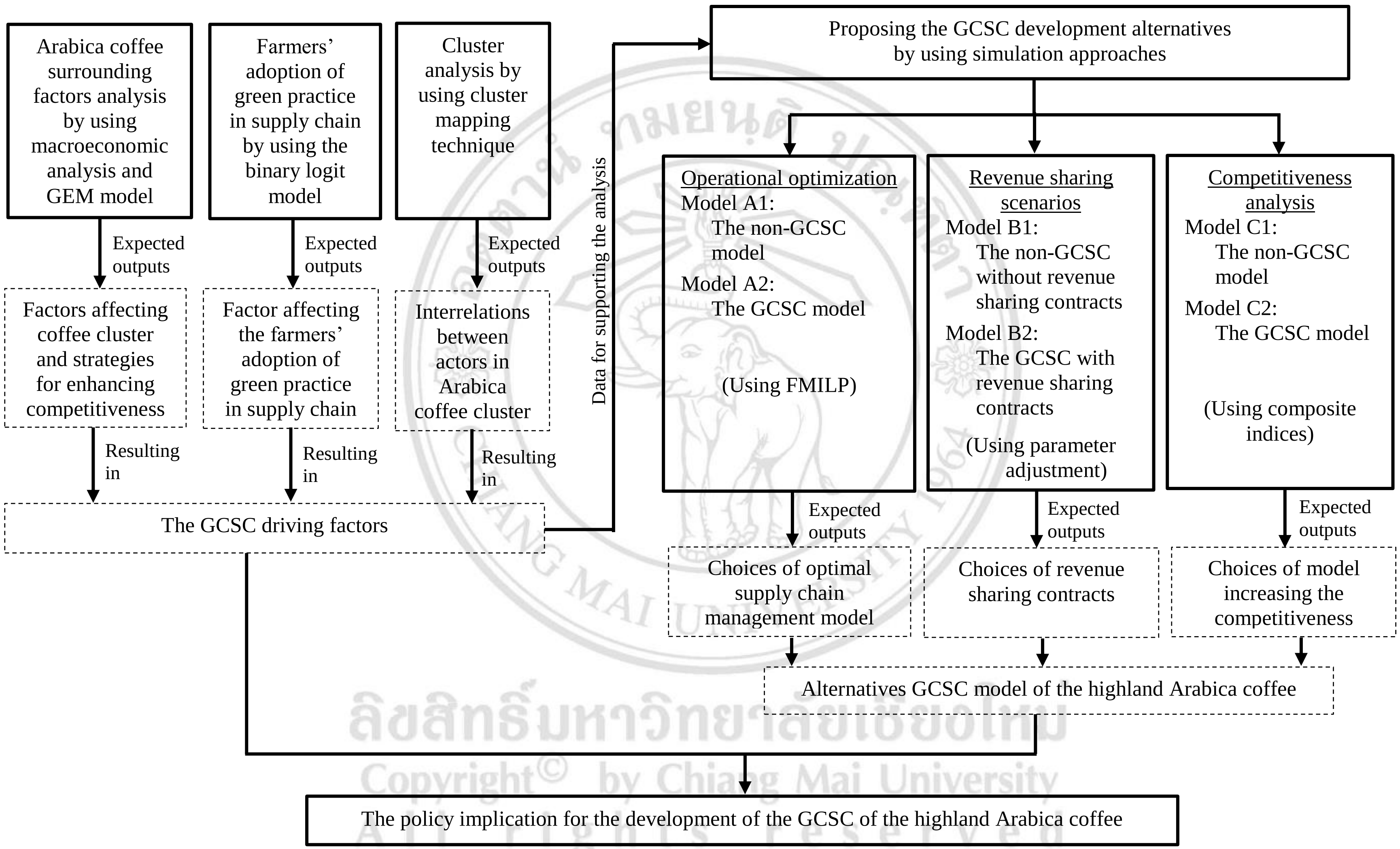

Figure 3.7 Research methodology summary