CHAPTER 5

Simulation of the GCSC Practices and Costing

This chapter focuses on the simulation of green activities in GCSC in highland with the units of analysis being confined to three main components of this coffee supply chain namely the farmers that play the role as focal node, the Pamiang RPDC and Pang Ma-O RPEC as the assemblers, and the RPF as the processor. Specifically, it is concerned with the flows of parchment coffee from the farmers via the assemblers to the RPF for processing into green coffee beans. The analysis is conducted in three steps including first analyzing the cost and the quantity of greenhouse gas emissions arising in the Arabica coffee supply chain before setting the green simulation, next simulating the green activities and calculating the cost and the amount of greenhouse gas emissions again, and then comparing the results between before and after setting the simulation.

5.1 The activities and costing in highland Arabica coffee supply chain

In order to achieve the purpose of GCSC development, the cost of supply chain must be known. This research applies the activity-based costing (Lin et al., 2001) for assessing the total cost of supply chain. The approach begins with analyzing the supply chain functions and activities, and then, determining the cost of the activities. The results of supply chain costing provide the useful data for simulating the GCSC in the next section.

5.1.1 Activities in Arabica coffee supply chain

The analysis of activities in the Arabica coffee supply chain found that at the level of highland farmers, the activities are classified into two main types which are parchment coffee production and transportation. At the assembler level, the activities are classified in three main types including procurement, inventory management, and transportation, whereas the operations of the RPF involve three main activities namely input factor management, inventory management and green coffee bean production. All detailed activities in the supply chain are illustrated in Figure 5.1

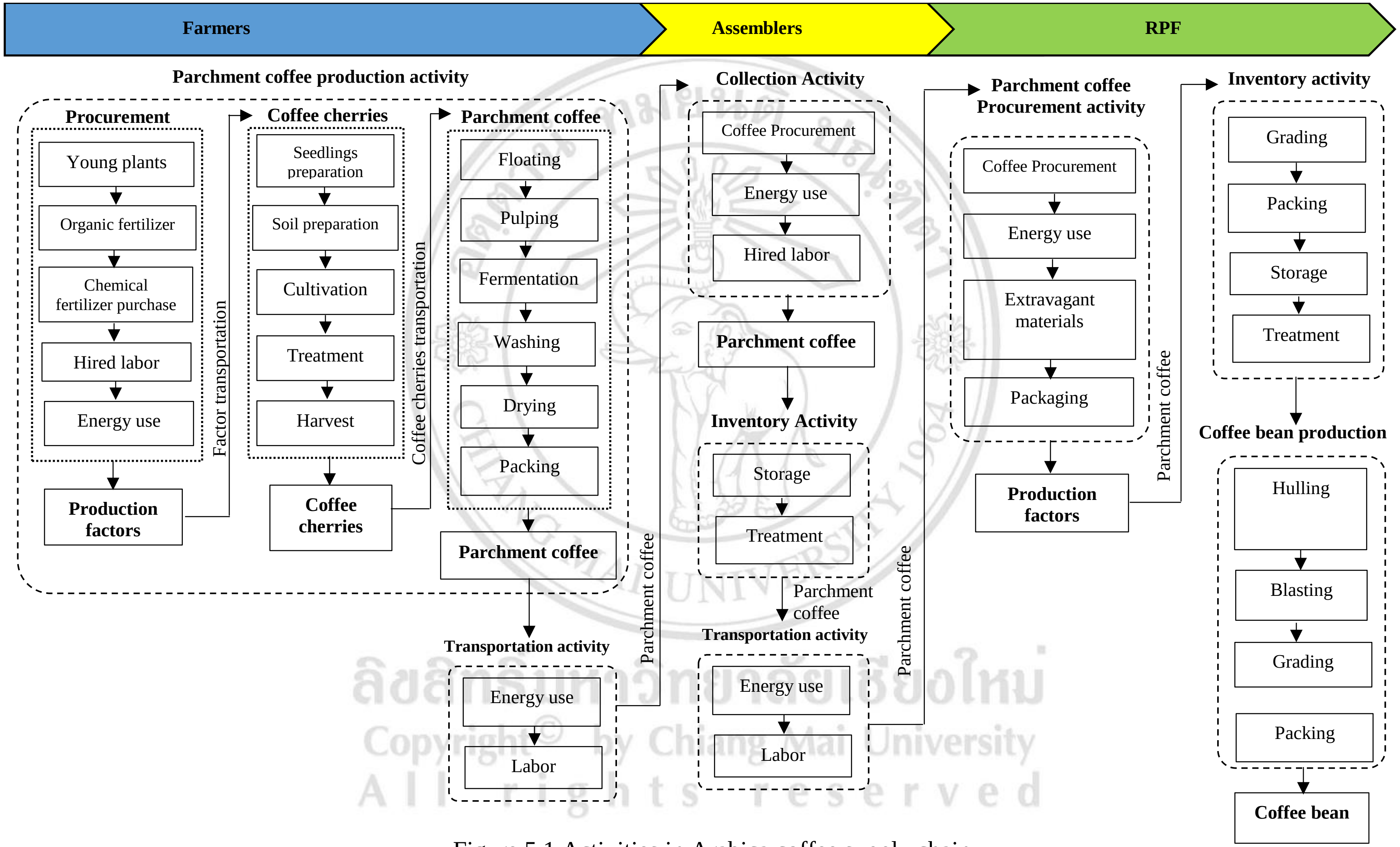


Figure 5.1 Activities in Arabica coffee supply chain

Details of the activities in the highland Arabica coffee supply chain in Figure 5.1 can be described as follows:

1) Activities at farmer level

The main activities of the farmers in Arabica coffee supply chain consist of parchment coffee production and transportation.

1.1) Parchment coffee production

As seen from Figure 5.1, before producing parchment coffee, the farmers have to produce coffee cherries. Thus, the parchment coffee production activity includes three sub-activities as follows:

(1) Procurement of production inputs

The findings regarding Arabica coffee clusters in Chapter 4 indicate that such production inputs as young plants, chemical fertilizers, organic fertilizers, labors, energy, fuels, and other materials are provided by local suppliers and external suppliers. Young coffee plants come mostly from certain local farmers and the RPF that undertake plant multiplication for cultivation themselves as well as for selling to other farmers. On the part of fertilizers and chemicals, coffee farmers usually buy these inputs when their input inventory is nearly depleted by using their own vehicles for input transportation. In terms of labor, the main laborers used for tending coffee trees are household members. However, during harvest season, farmhands from outside the local area have to be hired because all coffee fruits of farmers mature more or less at the same time bringing about the inadequacy of household labors. The wages are paid in two ways: daily wage and wage paid following the weight of the harvested crops. For energy, fuel, and other material inputs, coffee farmers generally buy them from external communities using their own vehicles for transportation.

(2) Coffee cherries production

The key activities in the coffee cherries production consist of seedlings preparation, soil preparation, cultivation, treatment, and harvesting (Figure 5.2).

In seedlings preparation, the farmers in Pamiang and Pang Ma-O areas will choose good quality coffee seeds from their own coffee trees for propagation. They believe that the seeds from coffee plants grown locally are resistant to disease and have a high germination rate. The seedlings will be cultivated, watered and shaded from the sunlight for around 46-60 days. After that, the young plants are removed to grow in the plastic bags until they are healthy enough to be permanently planted for approximately 8-12 months.

Figure 5.2 Activities in coffee cherries production

In terms of soil preparation, the appropriate areas for cultivating Arabica coffee should be located in a high area that is above the sea level at around 800-1,200 meters. The soil should be fertile and well drained, and has a pH value between 5.5 and 6.5. The analysis of the appropriate physical conditions in Chapter 4 reveals that both Pamiang and Pang Ma-O areas are suitable in all dimensions. However, the cultivation activities are different according to the environment of the areas. In the sample areas, coffee tree spacing is approximately 2.5 meters x 2.5 meters, allowing the establishment of about 180-200 coffee trees per rai.

In view of coffee tree care and maintenance in Pamiang and Pang Ma-O areas, because of the rainy and shade-grown conditions, the Arabica coffee cultivation does not require irrigation system. However, the treatments of coffee trees by weeding and fertilizing are necessary activities. Coffee farmers in both areas will weed the land before applying fertilizers commonly using both organic fertilizer and 15-15-15 formula chemical fertilizer. The frequency of fertilizing is approximately 2-3 times per years.

For harvesting, when the fruits are mature at around 6-8 months after flowering, the harvest of coffee should begin. The farmers in Pamiang and Pang Ma-O areas pick the ripe coffee cherries by hand. Although this method is more costly and takes more time to search for ripe cherries on the same tree, the results are the best coffee qualities being received by the purchasers.

(3) Parchment coffee processing

One of the methods for parchment coffee processing that is popularly used in Pamiang and Pang Ma-O areas is known as wet processing. This approach would result in more homogenous color of coffee than dry processing. The activities in wet processing of parchment coffee are shown in Figure 5.3.

Figure 5.3 Activities in coffee cherries production

Figure 5.3 represents a case where after the coffee cherries are harvested, they are brought to be floated in the water for separating the bad seeds out of the good seeds. This stage must be done in the same day to maintain the quality of the parchment coffee. Next, the good seeds are peeled by using a pulping machine which is supported by the RPF and

HDRI. The farmers who use the machines provided for common use should pay one baht per kilogram of coffee cherries for the purpose of equipment maintenance. The power of the peeling machine is around 746 watts and the peeling ratio is approximately 400 kilograms per hour. This machine uses water as a lubricant to peel the fruits. After that, the peeled coffee cherries are fermented in water to get rid of the seed coat. The fermentation takes about 24 hours or more, depending on the weather conditions. However, if the fermentation takes time more than 24 hours, it would result in a sour-smelling, different taste and quality reduction of the coffee. When the coffee fermentation matures at the right time, the farmers bring them to be rinsed with clean water to remove the mucilage and obtain the wet parchment coffee. The wet parchment coffee are dried for 7-10 days. The interviews with the farmers in the sample areas reveal that from the farmers' experiences of drying the wet parchment coffee, the drying equipment should be elevated off the ground at approximately 1-1.5 meters, and the drying areas should be closed to preserve the quality, flavor and taste of the coffee. After drying the wet parchment coffee, the moisture content of the parchment coffee should not exceed 13 percent. Finally, they will be packed in the mesh plastic bags containing 30 kg which are sent to the assemblers.

1.2) Transportation activities of the farmers

The transportation activities at the level of farmers consist of the transportation of inputs from the input sources located at both internal and external communities to the coffee plantations, the transportation of coffee cherries from coffee plantations to the mills for peeling coffee cherries, the transportation of the peeled coffee cherries from the mills to the farmers' houses, and transportation of the parchment coffee to the assemblers. The vehicle that is mostly used for transporting within the community is motorcycle with gasohol fuel, while the vehicle used for transportation to and from external community is the diesel pickup car.

2) Activities at the assembler level

The activities at the assembler level consist of the collection of the parchment coffee, the inventory, and transportation.

2.1) Collection of parchment coffee

The assembly of parchment coffee begins with purchasing parchment coffee from farmers. The farmers bring their products in mixed grade to sell to the assemblers. Coffee farmers sell their outputs not solely to the RPF channel, but they also sell to other buyers such as the local agricultural cooperative and local merchants. However, this study has focused on the supply chain from the farmer to the RPF, so the assemblers who gather the outputs for supplying to the RPF include the only one agent in each area, Pamiang RPDC in Pamiang area and Pang Ma-O RPEC in Pang Ma-O area.

2.2) Inventory activity

To manage the inventory, the Pamiang RPDC and Pang Ma-O RPEC will have spaces to store the parchment coffee which are packed in mesh plastic bags. The coffee products of all farmers are weighed and labeled with the name of the farmer, the weight of the coffee, and receiving date for the traceability.

2.3) Transportation activity

The bulks of parchment coffee collected from farmers are stored in warehouse. The Pamiang RPDC and Pang Ma-O RPEC will schedule to transport some part of the products at a time to the central coffee processing plant of the Royal Project Foundation because the coffee processing center cannot handle the entire volume of coffee collected from all 25 coffee growing areas under RPF supervision at the same time.

3) Activities at the RPF level

The activities at the RPF level consist of parchment coffee procurement, inventory and green coffee bean production.

3.1) Parchment coffee procurement

The RPF buys parchment coffee through the Pamiang RPDC and Pang Ma-O RPEC. The parchment coffee purchasing period is between January and May each year. However, during January - March, the amount of parchment coffee gathered by all assemblers (25 Royal Project Development Centers and Royal Project Extension Centers) exceeds the storage capacity of the RPF. Thus, the excess parchment coffee will be stored at each assembly center and the marketing staff of the RPF will contact market buyers to buy coffee products in the stock of each center.

3.2) Inventory activity

The RPF usually stores the products in the form of parchment coffee as this is effective for moisture and quality control. The parchment coffee received from Pamiang RPDC and Pang Ma-O RPEC is repacked and separated for each area of origin. Then, the QA staff will check the inventory. The problems faced by the RPF consist of the mismatching between the amount of coffee indicated by the famers and the actual quantity rechecked by the RPF staff, the errors in labeling, etc. The warehouse capacity of the RPF is approximately 500 tons of parchment coffee.

3.3) Green coffee bean production

As mentioned above about the inventory, the RPF stores the products in the form of parchment coffee and transform the parchment coffee into green coffee beans according to the orders of market buyers. The marketing department of the RPF will procure the orders from market buyers and specify the delivery date. The major buyers of green coffee beans are large companies and coffee shops. These buyers generally pick the green coffee beans themselves at the coffee processing plants for roasting according to the secret recipe of each company. For processing into green coffee bean, the husks of parchment coffee are peeled off using the mill with the power of 11 kilowatts and the milling capacity at around 800-1,000 kilograms per hour. After peeling the husk, the green coffee beans are brought to be air blown for cleaning and separating the sizes and quality of the product for grading. Finally, the green coffee beans are packed and delivered to the market buyers.

The information provided above regarding activities in the highland Arabica coffee supply chain is very useful for calculating the costs in the highland Arabica coffee supply chain as presented in Section 5.1.2.

5.1.2 Costs of activities in highland Arabica coffee supply chain

This research has identified the costs to various stakeholders in Arabica coffee supply chain by activity item i.e., the costs to coffee farmers that include parchment coffee production cost and transportation cost; the costs to the assemblers including the cost of parchment coffee purchasing, the cost involving the storage of parchment coffee, and transportation cost; the costs to the RPF that include the cost of parchment coffee purchasing, the cost involving the storage of parchment coffee, and the cost of green coffee bean production, as shown in Table 5.1 to 5.3.

1) The supply chain costing at farmer level

Considering the costs to coffee farmers in the Arabica coffee supply chain (Table 5.1), in the production process, the costs are separated into two main activities such as the cost of coffee cherries production and the cost of parchment coffee production. As coffee cherries is in fact an intermediate input for processing into parchment coffee. The unit of the cost of production is baht per kilogram parchment coffee. So, the unit of coffee cherries has to be transformed into parchment coffee basis. The unit transformation is assessed based on the ratio of the weight loss from processing coffee cherries into parchment coffee, from 100 kilograms of coffee cherries to produce 22 kilograms of parchment coffee.

The data in Table 5.1 show that the costs of coffee cherries production to the farmers in Pamiang and Pang Ma-O areas are 76.38 and 74.78 baht per kilogram of parchment coffee, respectively. In Pamiang area, production costs of the farmers have a high proportion of labor costs, fertilizers, and chemicals expenses. While in the Pang Ma-O area, the labor cost is higher, but the cost of fertilizers and chemicals are less than in Pamiang area because of the use of organic fertilizers instead of chemical fertilizers.

In terms of the costs of parchment coffee processing, the result reveals the high cost in labor component. In addition, coffee farmers have to pay the fee to share the use of common coffee pulping machine about one baht per kilogram. Thus, the total costs of farmers in the Arabica coffee supply chain in the Pamiang and Pang Ma-O area are 81.58 and 77.99 baht per kilogram of parchment coffee, respectively.

Table 5.1 Supply chain costs of the Arabica coffee: Farmer level

Unit: Baht/Kg. parchment coffee

Cost item	Pamiang (N = 29)	Pang Ma-O (N = 27)
1) Parchment coffee production cost	**76.38**	**74.78**
1.1) Coffee cherries production cost	49.31	41.75
- Cost of labors	25.74	23.32
- Cost of chemical fertilizer and materials	16.39	6.39
- Cost of organic fertilizer	1.74	3.66
- Cost of other factors	5.44	8.37
1.2) Parchment coffee processing cost	27.07	33.03
- Cost of labors	22.28	28.30
- Cost of electricity used	0.01	0.02
- Cost of packaging	0.17	0.17
- Cost of other factors	4.62	4.55
2) Transportation cost	**5.20**	**5.21**
2.1) Labor expenses in transportation	4.01	3.86
2.2) Fuel cost	1.19	1.35
Total cost of the farmers in supply chain	**81.58**	**79.99**

Source: Calculated.

2) The supply chain costing at the assembler level

As shown in Table 5.2, if excluding parchment coffee procurement cost, storage cost is the major cost item incurred by the assemblers in the highland Arabica coffee supply chain. This is because the warehouse capacity of the RPF is not enough for accommodating all of the products from all areas thus forcing the assemblers in Pamiang RPDC and Pang Ma-O RPEC to store the undelivered coffee in their areas and wait for the time to deliver to the RPF. So, the expenses for storing and maintaining are higher than normal.

Table 5.2 Supply chain costs of the Arabica coffee: Assembler level

Unit: Baht/Kg. parchment coffee

Cost item	Pamiang (N = 1)	Pang Ma-O (N = 1)
1) Procurement cost	**102.50**	**102.56**
1.1) Cost of labor	2.50	2.56
1.2) Cost of purchasing	100.00	100.00
2) Inventory cost	**3.76**	**3.76**
2.1) Cost of warehouse	3.75	3.75
2.2) Cost of treatment	0.01	0.01
3) Transportation cost	**0.68**	**0.77**
3.1) Labor expenses in transportation	0.42	0.43
3.2) Fuel cost	0.26	0.34
Total cost of the assembles in supply chain	**106.94**	**107.09**

Source: Calculated.

3) The supply chain costing at the processor level

The RPF appeared to have inventory cost in high proportion at 37.55 baht per kilogram of parchment coffee (Table 5.3). The parchment coffee delivered from the assemblers would be repacked and piled separately for each area of origin to make it easy for the QC staff to check the coffee quality. However, although its warehouse capacity can accommodate about 400-500 tons of parchment coffee, the RPF still faces with the problems of the warehouse system that is not efficient and lacking storage space. Parchment coffee from all 25 areas will be delivered during January - May, but from January to March, the volume exceeds the capacity of the storage, thus giving rise to problem in inventory management. The RPF stores the coffee products in the form of parchment coffee because it can retain the moisture and better quality of coffee. With respect to green coffee beans, the RPF will do the processing according to the purchasing orders from market buyers. The green coffee beans are graded before being delivered to the customers.

Table 5.3 Supply chain costs of the Arabica coffee: Processor level

Unit: Baht/Kg. parchment coffee

Cost item	RPF
1) Procurement cost	**152.64**
1.1) Cost of labor	0.14
1.2) Cost of purchasing	152.50
2) Inventory cost	**37.55**
2.1) Cost of warehouse	0.05
2.2) Cost of treatment	37.5
3) Green coffee bean production cost	**0.36**
3.1) Cost of labors	0.19
3.2) Cost of electricity used	0.0014
3.3) Cost of packaging	0.17
Total cost of the RPF in supply chain	**190.55**

Source: Calculated.

The costs of the highland Arabica coffee supply chain are used for analysis in the non-GCSC model in Chapter 6.

5.2 Life cycle of Arabica coffee and the quantity of greenhouse gas emissions in the highland Arabica coffee supply chain

Life cycle analysis of the Arabica coffee reveals the activities and quantity of greenhouse gas emissions in the highland Arabica coffee supply chain, helpful for simulating the GCSC model concerning the practices or activities in environmentally friendly nature.

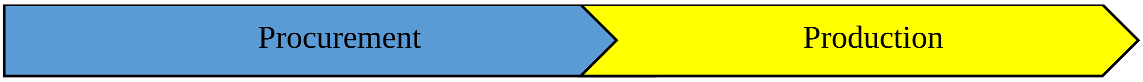
5.2.1 Life Cycle of Coffee Arabica coffee supply chain in highland

Because the units of analysis of Arabica coffee supply chain in this research consist of farmers acting as the focal node, the assemblers such as the Pamiang RPDC and the Pang Ma-O RPEC, and the processor which is the RPF, the flows of products take place with the moving of parchment coffee from the farmers to the assemblers, and delivering of parchment coffee from the assemblers to the RPF for processing into green coffee beans. Thus, the life cycle analysis of Arabica coffee supply chain in the sample areas are divided into three levels namely farmer level, assembler level and RPF level. The scope of analysis is the cradle to gate assessment from the acquisition of the production inputs to the end of the production process at the RPF coffee plant. The greenhouse gas emissions (GHG emission) occur in each process. This type of analysis would clearly point out the proportion of GHG emission in each activity of the individual stakeholders rather than the overall analysis (BSI, 2011). The systems boundaries for assessing the life cycle of coffee products and the GHG emission of highland Arabica coffee supply chain is shown in Figure 5.4 to 5.6.

In the farmer level, which is shown in Figure 5.4, the activities of the farmers consist of the production of coffee cherries and the processing of parchment coffee. The beginning process of both stages are the procurement of inputs and the transportation would occur in this process. The results from operating the activities such as coffee cultivation, coffee cherries harvesting, and parchment coffee processing, cause waste and extravagant energy in the consumption. Then, the parchment coffee products are forwarded to the assemblers.

Considering the assembler level as shown in Figure 5.5, after buying the parchment coffee from farmers, the assemblers store the products in the warehouse by tagging the farmers' name, weights, and date of purchase on the mesh plastic bags. Then, some part of the products would be delivered to the RPF and the rest would be stored at their area. The results of the assemblers' activities cause extravagant energy consumption from the transportation.

In view of the RPF level, the life cycle of products are considered from the parchment coffee to the green coffee beans (Figure 5.6). The processes start from sorting the parchment coffee, packing, storing, milling, air-blowing, grading, and packing the green coffee beans. During this life cycle of green coffee beans, there are a waste of husk, waste of damaged products, and an extravagant energy consumption from the production.



Farmer level

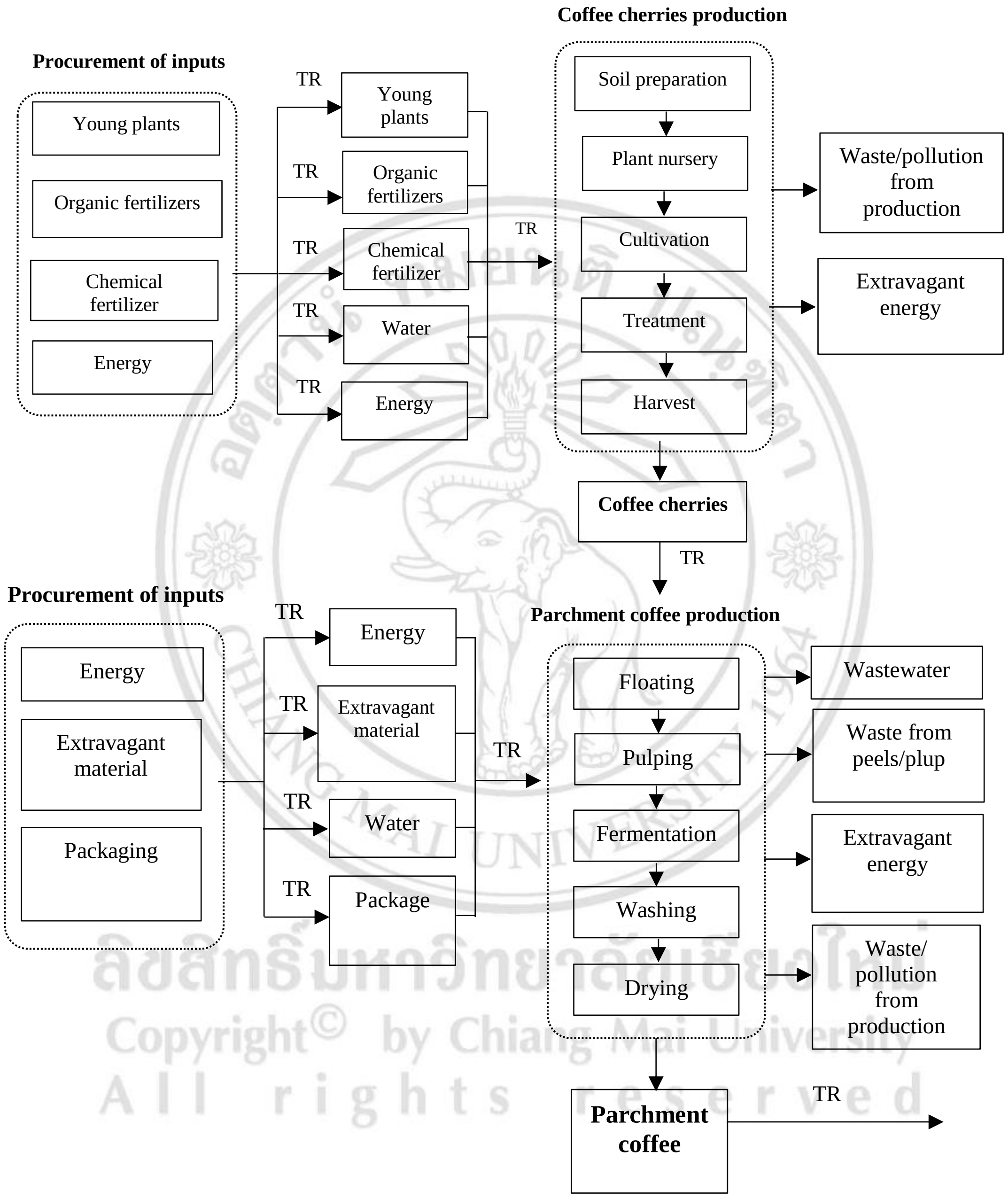


Figure 5.4 Life Cycle of Arabica coffee from Cradle to gate: Farmer level

Source: Author's analysis.

Note: TR means transportation.

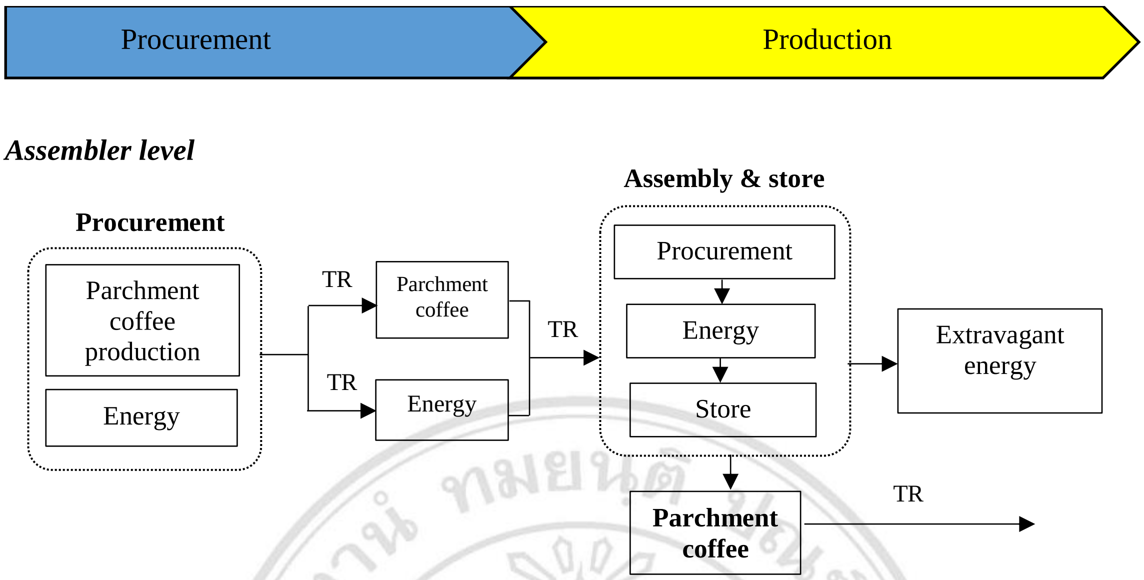


Figure 5.5 Life Cycle of Arabica coffee from Cradle to gate: Assembler level

Source: Author's analysis.

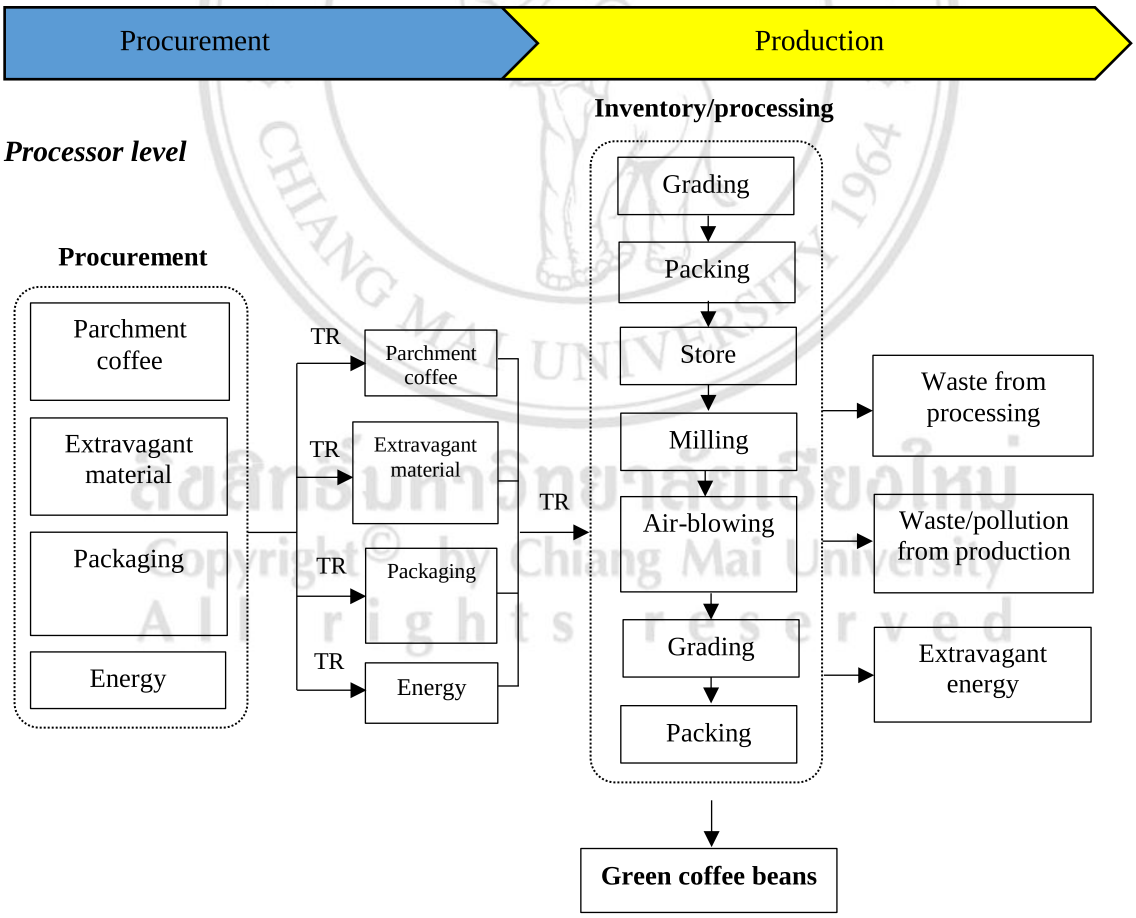


Figure 5.6 Life Cycle of Arabica coffee from Cradle to gate: Processor level

Source: Author's analysis.

5.2.2 The quantity of greenhouse gas emissions in the Arabica coffee supply chain

The life cycle of Arabica coffee from cradle to gate (expressed in Figure 5.4 to 5.6) has shown the product systems in order to analyze the amount of GHG emissions throughout the highland Arabica Coffee supply chain from the supply of inputs to the green coffee beans processing. Functional units used to calculate the GHG emissions are one kilogram of parchment coffee and one kilogram of green coffee beans. The GHG assessed following what under the control of the Kyoto Protocol consisting of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFCs), perfluorocarbon (PFCs) and sulfur hexafluoride (SF_6).

However, in this research, the greenhouse gases that cause the global warming, are used for evaluation include carbon dioxide, methane and nitrous oxide. The emissions for each gas type or the potential to actually cause global warming is calculated by conversing the value in the form of carbon dioxide equivalent (CO_2e) under the criterions of the Global Warming Potential 100 years (GWP_{100}) of the Intergovernmental Panel on Climate Change (IPCC) (BSI, 2011). The system boundary based on the above product systems following the life cycle of coffee products is shown in Table 5.4 and the calculation of the amount of GHG emissions in the highland Arabica coffee supply chain is shown in Table 5.5.

The amount of GHG emissions in the supply chain of highland Arabica coffee (Table 5.5) at farmer level revealed the activity that highly caused greenhouse gas emission is the transportation of inputs for coffee cherries production followed by the peel or pulp of coffee cherries from the parchment coffee processing, and the use of chemicals in coffee cultivation. This finding guarantees the change of farmers' behavior by giving the priority to being environmentally friendly such as having green production, green transportation, and green waste management; would reduce the GHG emissions as well.

Table 5.4 Lists of GHG and GHG emission factors

Activity	List of item	Unit	GHG Emissions ($kg.CO_2e/unit$)	Reference
Farmer level:				
Coffee cherry transportation	Fuel – Diesel	L	2.7446	IPCC (2006), DEQP (2011), TGO (2011)
	Fuel – Benzyl	L	2.1896	IPCC (2006), DEQP (2011), TGO (2011)
Coffee cherry cultivation and harvest	Fertilizers formula 15 : 15 : 15	kg	2.0500	DEQP (2011), TGO (2011)
	Urea	kg	5.5300	DEQP (2011), TGO (2011)
	Organic fertilizer	kg	0.3473	Office of Agricultural Economics (2013)
	Fuel – Benzyl	L	2.1896	IPCC (2006), DEQP (2011), TGO (2011)
Parchment coffee production	Coffee cherry peel /pulp (Food waste)	kg	2.5300	IPCC (2006), DEQP (2011), TGO (2011)
	Electricity	kwh	0.5610	DEQP (2011), TGO (2011)
	Wastewater	L	0.6250	IPCC (2006), TGO (2011)
Transportation	Fuel – Diesel	L	2.7446	IPCC (2006), DEQP (2011), TGO (2011)
	Fuel – Benzyl	L	2.1896	IPCC (2006), DEQP (2011), TGO (2011)
Assembler level:				
Transportation	Fuel – Diesel	L	2.7446	IPCC (2006), DEQP (2011), TGO (2011)
Processor level:				
Green coffee bean production	husk of parchment coffee (Food Waste)	kg	2.5300	IPCC (2006), DEQP (2011), TGO (2011)
	Electricity	kwh	0.5610	DEQP (2011), TGO (2011)

Source: IPCC (2006), DEQP (2011), TGO (2011), Office of Agricultural Economics (2013).

Table 5.5 The quantity of greenhouse gas emissions of Arabica coffee supply chain

Activity	GHG Emission ($kgCO_2e$/kg Product)			
	Parchment coffee		Green coffee beans	
	Pamiang	Pang Ma-O	Pamiang	Pang Ma-O
Farmer level:				
1) Coffee cherry transportation				
Fuel – Diesel	40.4101	32.4420	50.5127	40.5525
Fuel – Benzyl	5.7565	9.3647	7.1956	11.7058
2) Coffee cherry cultivation and harvest				
Fertilizers formula 15 : 15 : 15	1.6809	0.5907	2.1011	0.7383
Urea	0.3851	0.3814	0.4814	0.4768
Organic fertilizer	0.1208	0.2545	0.1510	0.3182
Fuel – Benzyl	0.0127	0.0057	0.0159	0.0072
3) Parchment coffee production				
Coffee cherry peel/pulp (Food waste)	8.9700	8.9700	11.2125	11.2125
Electricity	1.0463	1.0463	1.3078	1.3078
Wastewater	6.2500	6.2500	7.8125	7.8125
4) Transportation				
Fuel – Diesel	0.0213	0.0292	0.0266	0.0365
Fuel – Benzyl	0.0421	0.0807	0.0526	0.1008
Assembler level:				
1) Transportation				
Fuel – Diesel	1.0124	1.6671	1.2654	2.0839
Processor level:				
1) Green coffee bean production				
husk of parchment coffee (Food Waste)	-	-	0.6325	0.6325
Electricity	-	-	0.0009	0.0009
GHG Emission ($kgCO_2e$/kg Product)	**68.9139**	**66.3614**	**86.7757**	**83.5851**

Source: Calculation.

5.3 Simulations of green activities in GCSC

From the results in Chapter 4 and the findings in Section 5.2.2, there are three possible practices accepted by the farmers. Thus, the simulations of independent green activities in GCSC in this research consist of 1) green production by simulation of the chemical used reduction in the cultivation and care of the coffee trees, 2) green waste management by simulation to build the sewage manholes and do composting for waste and wastewater disposals, and 3) green transportation by using alternative energy (Table 5.6).

Table 5.6 Simulations of green activities in GCSC

Practice	Green activity		
	Farmer	Assembler	RPF
Green production	• Chemical used reduction - Using organic fertilizers instead of chemical fertilizers (GF1)	-	-
Green waste management	• Wastewater disposal - Sewage manholes (GF2) • Waste disposal - Composting (GF3)	-	• Waste disposal - Composting or other doing (GP1)
Green transportation	• Alternative energy use - Using biodiesel instead of diesel and E20 instead of gasoline (GF4)	• Alternative energy use - Using biodiesel instead of diesel (GA1)	-

Source: Simulations with stakeholders.

However, the decision to conduct activities related to the environmental friendliness of the farmers, the assemblers and the RPF are uncertain because of the concerns about the cost and the yield, and the market acceptance of environmentally friendly products. As a result, the adoptions to abide by the environmental practices are ambiguous (Fuzzy) and contribute to the vagueness of the costs of changing from the conventional supply chains to the environmentally friendly supply chains.

This research assumes the vague decision making levels of the farmers, the assemblers, and the RPF as the triangular fuzzy number and applies the fuzzy rules following the study of Rahman and Yuan (2013) and Uygun and Dede (2016) that divide the linguistic terms of the green adoption into five levels (very high, high, medium, low, and very low). Thus, the linguistic terms used to measure the ambiguity in the adoption of environmentally friendly practices are expressed in Table 5.7 and Figure 5.7.

Table 5.7 Linguistic variables used in the adoption of green practices

Linguistic terms of green adoption	Corresponding triangular fuzzy number
Very high (VH)	(0.75, 1.00, 1.00)
High (H)	(0.50, 0.75, 1.00)
Medium (M)	(0.25, 0.50, 0.75)
Low (L)	(0.00, 0.25, 0.50)
Very low (VL)	(0.00, 0.00, 0.25)

Source: Applied from Rahman and Yuan (2011), and Uygun and Dede (2016).

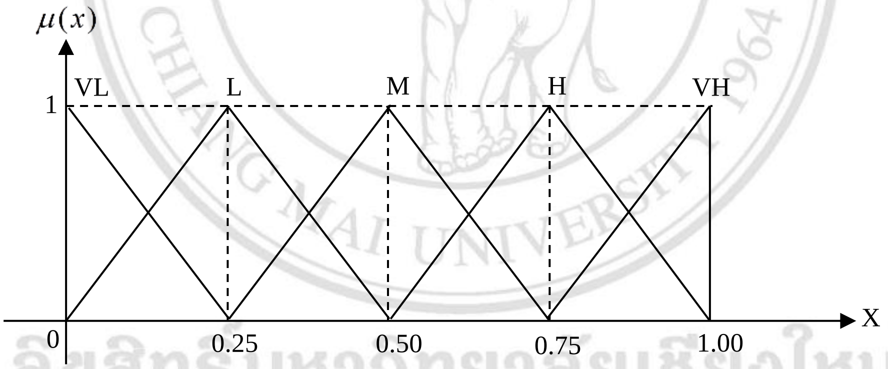


Figure 5.7 Triangular fuzzy numbers for linguistic variables

Source: Applied from Rahman and Yuan (2013), and Uygun and Dede (2016).

The linguistic terms of the adoption of the green practices shown in Table 5.7 are applied for making the levels of fuzzy adoption of farmers, the assemblers and the RPF in environmentally friendly practices.

5.3.1 The fuzzy adoption of green practices of the farmers, the assemblers, and the RPF

For analyzing the fuzzy adoption of green practices of the farmers, the assemblers, and the RPF, the questions of green practice adoption are applied again in the different way by using the 1-5 Linkert scale levels, from “very low” to “very high”. The 56 farmers who are willing to participate in the green cluster supply chain (GCSC) research, the Pamiang RPDC, the Pang Ma-O RPEC, and the RPF are selected for the samples.

Table 5.8 shows the summary of the fuzzy adoption of green practices of the farmers and the details of the triangular fuzzy numbers of each farmer are shown in Appendix C. The result in Table 5.8 reveals that most of the farmers adopt the chemical used reduction format by using the organic fertilizers instead of chemical fertilizers (GF1), and waste disposal by composting (GF3) at a high level with the triangular fuzzy number of (0.50, 0.75, 1.00). While the wastewater disposal by building the sewage manholes (GF2) and the use of alternative energy such as using the biodiesel instead of diesel and E20 instead of gasoline (GF4) are adopted at the medium level with the fuzzy numbers of (0.25, 0.50, 0.75).

Table 5.8 Summary of the fuzzy adoption of green practices of the farmers

Linguistic terms	Triangular fuzzy number	Amount of the farmers (Persons)			
		GF1	GF2	GF3	GF4
Very high (VH)	(0.75, 1.00, 1.00)	9 (16.07)	3 (5.36)	6 (10.71)	4 (7.14)
High (H)	(0.50, 0.75, 1.00)	25 (44.64)	9 (16.07)	22 (39.29)	18 (32.14)
Medium (M)	(0.25, 0.50, 0.75)	10 (17.86)	20 (35.71)	18 (32.14)	24 (42.86)
Low (L)	(0.00, 0.25, 0.50)	11 (19.64)	19 (33.93)	10 (17.86)	6 (10.71)
Very low (VL)	(0.00, 0.00, 0.25)	1 (1.79)	5 (8.93)	0 (0.00)	4 7.14
Total		56 (100.00)	56 (100.00)	56 (100.00)	56 (100.00)

Source: Calculation.

Note: The value in ( ) represent the percentage.

Considering the fuzzy adoption of green practices of the assemblers and the RPF (Table5.9), the results indicate that the adoption of the Pamiang RPDC and Pang Ma-O RPEC in the alternative energy consumption by using biodiesel instead of diesel (GA1) are at the high level with the triangular fuzzy number of (0.50, 0.75, 1.00), whereas the fuzzy adoption of the RPF in waste disposal by composting or other doing (GP1) are at the medium level with the triangular fuzzy number of (0.25, 0.50, 0.75).

Table 5.9 The fuzzy adoption of the green practices of the assemblers and the RPF

Node	The fuzzy adoption of green practice	
	GA1	GP1
Assemblers		
Pamiang RPDC	(0.50, 0.75, 1.00)	-
Pang Ma-O RPEC	(0.50, 0.75, 1.00)	-
Processor		
RPF	-	(0.25, 0.50, 0.75)

Source: Calculation.

The fuzzy adoption of the green practices of the farmers, the assemblers, and the RPF in Table 5.8 and 5.9 leads to the uncertainty of the cost in the supply chain. For example, the farmers who adopt the organic fertilizers instead of chemical fertilizers at high levels may increase the use of organic fertilizers to 50%, 75% or 100%, as well as reducing the purchasing of chemical fertilizer. The ambiguity of the organic and chemical fertilizers consumption brings about the uncertainty of the input cost. Therefore, section 5.3.2 describes the fuzzy cost such as the fuzzy production cost, the fuzzy waste disposal cost, and the fuzzy transportation costs resulting from green practices.

5.3.2 The fuzzy cost resulting from green practices

The choosing of the green activities such as the green production, the green waste management, and the green transportation brings about the change in the structure of costs in the supply chain containing the fuzzy production cost ($PR\tilde{C}^{f-green}$), the fuzzy waste disposal cost ($D\tilde{C}^{f-green}$) and the fuzzy transportation cost ($TR\tilde{C}^{f-green}$). The average costs of the farmers in the green cluster supply chain (GCSC) are shown in Table 5.10

and more details of the fuzzy cost of green practices separated to each farmer are displayed in Appendix D.

Table 5.10 Average costs of the farmers in the GCSC

Unit: Bath/Kg. parchment coffee

Farmer	Average cost of the farmers in GCSC				Cost of the farmers in non-GCSC	% Δ
	$PR\tilde{C}^{f-green}$	$D\tilde{C}^{f-green}$	$TR\tilde{C}^{f-green}$	Total cost		
Pamiang area	(57.51, 60.91, 64.82)	(1.97, 3.72, 5.42)	(0.21, 0.22, 0.22)	(59.69, 68.85, 70.46)	81.58	-26.83 to -13.63
Pang Ma-O area	(61.58, 62.77, 64.18)	(2.03, 4.05, 6.07)	(0.85, 0.87, 0.89)	(64.46, 67.69, 71.14)	79.99	-24.09 to -11.06

Source: Calculation.

The average costs of the farmers in the GCSC (Table 5.10) reveal the key points of green practice adoption bringing about the reduction of costs compared with the costs of conventional practice (the non-GCSC), in Table 5.1,which are accounted for the range from 13.63% to 26.83% in Pamiang area and 11.06% to 24.09% in Pang Ma-O area. The decrease in the costs is caused from the reduction of the chemical used in the production, and using the alternative energy for transportation. Although there are the escalations of the cost of the wastewater and waste disposal managements such as the construction of sewage manholes and the composting from agricultural wastes, the proportions of the cost reduction in the production and transportation processes are higher than the proportion of cost increasing from the waste disposal management. In addition, the fertilizer obtained from the compositing process helps reduce the input cost. Consequently, the total costs after changing to being environmentally friendly concern are lower than the costs of the conventional practices.

Moreover, the findings in Table 5.10 indicate that the fuzzy costs of the farmers in Pamiang area are lower than the fuzzy costs of the farmers in Pang Ma-O area that display the opposite result from conventional costs in Table 5.1. This phenomenon can be described by the contexts of the farmers in both areas. In the conventional practices, the non-GCSC, the farmers in Pamiang area would rather consume the chemical fertilizers than the farmers in Pang Ma-O area because they believe that the use of chemical fertilizers results in the high quantity of products. So, the Pamiang farmers have faced the higher total costs compared with the Pang Ma-O farmers, as mentioned in Chapter 4 and Table 5.1. The change from the conventional practices of the farmers to the green practices leads to the higher proportion of cost reduction of the Pamiang farmers compared with the Pang Ma-O farmers. Consequently, the study on the cost confirmed that the encouragement for the farmers to adopt and employ green practices will lower the overall cost of farmers.

Considering the assemblers, the costs in the GCSC of the Pamiang RPDC and the Pang Ma-O RPEC consist of the purchasing cost of parchment coffee (FC^{a}), the inventory cost (IC^{a}), and the fuzzy transportation cost ($T\tilde{RC}^{a-green}$) which is shown in Table 5.11.

Table 5.11 Costs of the assemblers in the GCSC

Unit: Bath/Kg. parchment coffee

Assembler	Cost of the assemblers in the GCSC				Cost of the assemblers in non-GCSC	% Δ
	FC^{a}	IC^{a}	$T\tilde{RC}^{a-green}$	Total cost		
Pamiang RPDC	102.50	3.76	(0.56, 0.57, 0.60)	(106.82, 106.83, 106.86)	106.94	-0.11 to -0.07
Pang Ma-O RPEC	102.56	3.76	(0.61, 0.62, 0.66)	(106.93, 106.94, 106.98)	107.09	-0.15 to -0.10

Source: Calculation.

In the GCSC, if the Pamiang RPDC and the Pang Ma-O RPEC do the green activity by using alternative energy, their total cost will decrease approximately 0.07-0.11% and 0.10-0.15%, respectively (Table 5.11). Although the costs are scarcely decreased, the behavioral change to green practice of the Pamiang RPDC and the Pang Ma-O RPEC will lead to the reduction of global warming.

At the same time, the costs in the GCSC of the RPF consisting of the purchasing cost of the parchment coffee (FC^{p}), the inventory cost (IC^{p}), the green coffee bean production cost (PRC^{p}), and the fuzzy waste disposal cost ($D\tilde{C}^{p-green}$) are shown inTable 5.12.

Table 5.12 shows a little increase in the cost of the RPF that has resulted from the implementation of waste disposal management. This practice is added in the GCSC to solve the problem of the waste from the husk of parchment coffee. From the interviews with the RPF staff, they raised the issue about the utilization of the high quantity of the waste from parchment coffee husk which is obtained from the milling in the green coffee bean production. Thus, the way to bring this waste for composting or transforming to other products not only reduces the greenhouse gas emission, but also adds the value from the garbage.

Table 5.12 Costs of the RPF in the GCSC

Unit: Baht/Kg. green coffee beans

Processor	Cost of the RPF in the GCSC					Cost of the processor in non-GCSC	% Δ
	FC^p	IC^p	PRC^p	$D\tilde{C}^{p\_green}$	Total Cost		
RPF	152.64	37.55	0.36	(0.14, 0.29, 0.43)	(190.69, 190.84, 190.98)	190.55	0.07 to 0.23

Source: Calculation.

The results of the costs mentioned in Section 5.1.2 and Section 5.3.2 are used for analyzing the performances of the GCSC of Arabica coffee in the highland including the proper operation, the revenue sharing, and the competitiveness in the next chapter.

5.4 Summary and discussion

Chapter 5 aims to simulate the green activities in GCSC in the highland by beginning with the analysis of the main activities in the supply chain of the farmers, the assemblers (the Pamiang RPDC and the Pang Ma-O RPEC), and the processor (the RPF) to explore the costs of supply chain. After that, the product life cycle of Arabica coffee is analyzed to assess the GHG emission and investigated for which activity has the highest impact on the environment. The outputs from both analyses are used for simulating the green activities and modeling the GCSC. The results are summarized as follows:

1) In the conventional model, the activities of the farmers in the Arabica coffee supply chain consist of two major activities such as the parchment coffee production (procurement of production factors, coffee cherries production and parchment coffee processing) and transportation. At the assembler level, the main activities are classified to include the parchment coffee collecting, the inventory management, and transportation. Meanwhile, the operations of

the RPF are divided into the factor management, the inventory management and the green coffee bean production. The results of these activities bring about the average cost of the farmers in the Pamiang and Pang Ma-O areas at around 81.58 and 79.99 baht per kilogram of the parchment coffee, respectively. The highest proportion of the cost comes from the cost of labor, and followed by the cost of chemical fertilizer and materials. Considering the assemblers, the Pamiang RPDC and the Pang Ma-O RPEC, their costs are equal to 106.94 and 107.09 baht per kilogram of the parchment coffee, respectively, with the highest proportion of costs in purchasing the parchment coffee and warehouse components. While the cost of the RPF is approximately 190.55 baht per kilogram of the parchment coffee. The purchasing of parchment coffee and inventory shares the highest proportion of the costs.

2) In terms of being environmentally friendly, the greenhouse gas emissions are assessed to indicate the impact of the product life cycle of Arabica coffee on the environment. The results show that the activities causing global warming in high proportion consist of transportation, waste and wastewater from parchment production, and chemical use of the farmers; transportation of the assemblers, and the wastes from the green coffee bean production of the RPF.

3) From the findings mentioned above and the possibility of farmers' adoption of green practices in Chapter 4, the simulations of the green practices are set to reduce the costs and the environmental impacts including the green production by simulation of the chemical used reduction, the green waste management by building sewage manholes and composting, and the green transportation by using alternative energy. The adoption to abide by the environmental practices are ambiguous because the judgment levels of each other are different in terms of contributing to the fuzziness in the costs of changing activities from the conventional to the green supply chains. The results present that the green activities bring about the reduction of the total cost of the farmers. For the assemblers and the RPF, although the green practices have a little effect on their costs, the changes are beneficial for

decreasing the global warming and solving the problem of having a high volume of garbage.

The findings from the analysis on the simulations of the GCSC models confirm that the adoption and implementation of the green practices contribute to the reduction in the total cost and environmental impacts. How does the GCSC arise?

Considering the Pamiang area context, although the plantations are located under the responsibility of the RPF that promotes the reduction of chemical usage, some farmers understand that the use of chemical fertilizers will provide a high yield. They also believe that if they used to apply the chemical fertilizer to nourish the coffee trees, the switching from the chemical to the organic fertilizers will have an influence on the lowering of the coffee yield and cause the death of the coffee plants. Consequently, the farmers still use the chemical fertilizers in the coffee tree care process. These opinions are contrary to the study of Goyal et al. (1999) who have indicated that the application of organic fertilizer helps improve soil fertility and microbial content, reduce the soil nitrogen accumulation and soil erosion, increase yield and quality of outputs, and improve ecological environment. The studies of Liu et al. (2010) and Liu et al. (2011) mentioned that in the long-term, the organic manure has the most beneficial effects on yield and soil quality. Therefore, the success of the GCSC promotion in the Pamiang area should begin from the establishment of the correct understanding to the farmers through the transferring of the knowledge about the actual findings from various researches and the demonstration of the comparing experiments between organic and chemical fertilizer applications for spurring the farmers to perceive the empirical knowledge. Moreover, the indication about the high proportion of costs which can be reduced by the practical changes to the green ways is necessary to persuade the farmers to adopt and practice the ways of being environmentally friendly. Moreover, as for the farmer collaboration establishment, for example, the joint transportation, the co-composting, etc., are also the key factor to decrease costs and pollutions, and achieve the GCSC in the Pamiang area.

For promoting the GCSC in the Pang Ma-O area, because this area has the strength of the environmental relation mentioned in Chapter 4, the starting point of the GCSC establishment should initially build the collaboration among the farmers. The main problem of the farmers in this area which is an obstacle for achieving the GCSC is the trust. Although there is a farmer group in this area, the power of the group is weak due to the timid nature of the leader and the intervention by local middlemen. The collaboration among the farmers for joint green practices such as mutual input purchase can bring about the reduction of the transportation cost and GHG emission, just like in the case of jointly managed waste and wastewater disposal, etc. The studies of Stank et al. (2001), Barratt (2004), Manthou et al. (2004), Simatupang and Sridharan (2005), Sheu et al. (2006), Mangan et al. (2008) and Cao and Zhang (2011) mentioned that the key success factor of cluster supply chain development is the collaboration of all units in the supply chain. This process is concerned with two or more partners that closely work together in planning and implementing to achieve the main goals and mutual benefits.

In terms of waste and wastewater managements, the farmers in both areas do not have the systems of waste disposal from the production. The wastes from peels of coffee cherries are dropped on the coffee plantations or piled around residential areas causing a foul smell and GHG emissions. In fact, the coffee peels can be used to make compost. Meanwhile, the wastewater from fermentation is released to the natural water sources without separating the fermenting sludge and sewage which leads to pollutions. Upon learning of Haddis and Devi (2008), Selvamurugan et al. (2010), Suwasa Kantawanichakul (2011) and Novita (2016) pointed out that the wastes generated from wet processing of parchment coffee is in two types such as liquid wastes which are part of the peel and flesh of the coffee and fermented water of parchment coffee, and solid wastes including the peels. The release of both wastes to nature without prior treatment brings about water and air pollutions because the organic compounds in the coffee peels and fermenting wastewater can affect the chemical oxygen demand (COD) and the biological oxygen demand (BOD), which will contribute to the decrease in dissolved oxygen in water causing the sewage. Accordingly, the waste and wastewater disposal by building sewage manholes and composting are the choices for the farmers to abide by the green manner. The wastewater treatment basin will be constructed from concrete buildings or cement tanks following the anaerobic treatment approach that offers the farmers the simple method of wastewater disposal, whereas the composting from the pulp and peels of coffee will be done at their plantations.

From the perspectives of assemblers (the Pamiang RPDC and the Pang Ma-O RPEC) and RPF, they also implement the green practices, namely, using alternative energy, composting from the husks of the parchment coffee for the purposes of the global warming reduction and the garbage problem improvement.

In addition, the coordination among the farmers, the assemblers, and the processor is a necessary tool for the GCSC creation. Dyer and Singh, (1998) and Walter et al. (2001) made reference to the goal of coordination as the higher value creation arising from a cooperative comparing with an individual operation. In the supply chain system there are many actors having different operations and complex network, thus the necessary and beneficial tool is the coordination through profit sharing, revenue sharing, etc. mechanisms for creating an added value in the supply chain. Thus, the evolving network of the farmers, the assemblers, and the processor by using coordination approach will strengthen the GCSC of Arabica coffee in the long term.

In summary, the findings in Chapter 4 and 5 contribute to the GCSC modeling of the highland Arabica coffee in two models, namely, the non-GCSC model and the GCSC model.

1) The non-GCSC model

The non-GCSC model is the conventional model of the highland Arabica coffee supply chain that does not implement the green practices and cluster manner. The farmers, the Pamiang RPDC, the Pang Ma-O RPEC, and the RPF in this case are independently operating their activities (Figure 5.8). Thus, the costs of them in the supply chain are expressed in Tables 5.1-5.3 which are used in the evaluations of the performances of the GCSC in Chapter 6.

2) The GCSC model

The GCSC model is the innovative model of the highland Arabica coffee supply chain that integrates the environmental friendly practices and cluster concept. For the green practices of the farmers, mentioned in Table 5.6, they consist of the chemical used reduction by using the organic fertilizers instead of chemical fertilizers and the waste disposal by composting, the wastewater disposal by building the sewage manholes, and the use of alternative energy such as using biodiesel instead of diesel and E20 instead of gasoline. In the case of the assemblers and the RPF, the green practices include the alternative energy consumption by using biodiesel instead of diesel and the waste disposal of the parchment coffee husks by composting other items respectively. The results of the compliance with green practices bring about the reductions in their costs represented the ambiguity of the decision making (fuzzy costs) which are mentioned in Tables 5.10-5.12.

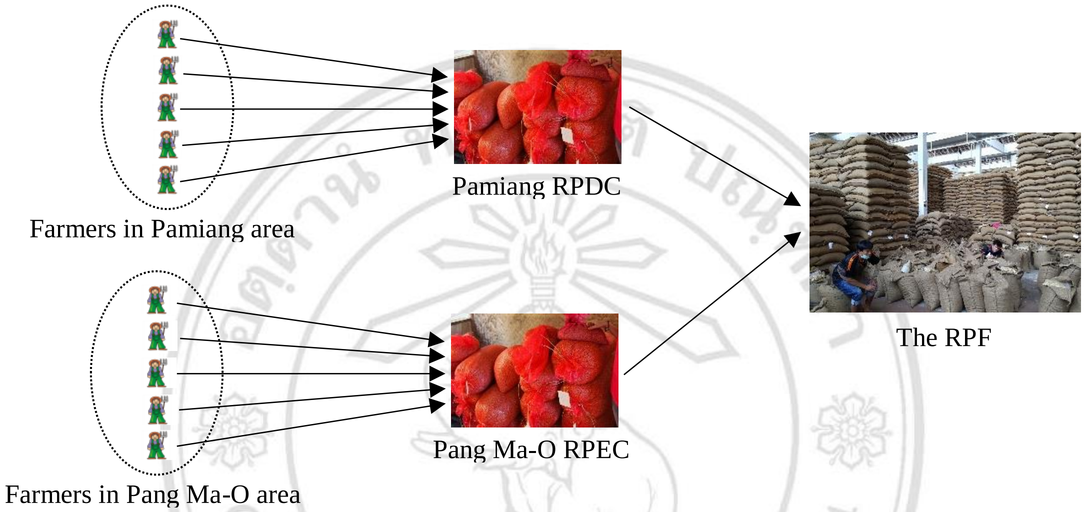


Figure 5.8 Non-GCSC model

For establishing the cluster, there are two ways for clustering such as the horizontal collaboration of the farmers in the supply chain and the vertical coordination among the farmers, the assemblers, and the processor.

2.1) The horizontal collaboration of the farmers in the supply chain

This way is associated with closely working together among the farmers in planning and implementing to achieve the main goals and mutual benefits, such as information sharing, joint decision, resource sharing and joint transportation by establishing the group of the interested farmers. This research assumed that results of horizontal collaboration lead to the reduction in the production; waste disposal costs around 20%, and the decrease in the transportation cost approximately 50%. The GCSC model using the horizontal collaboration approach is represented in Figure 5.9.

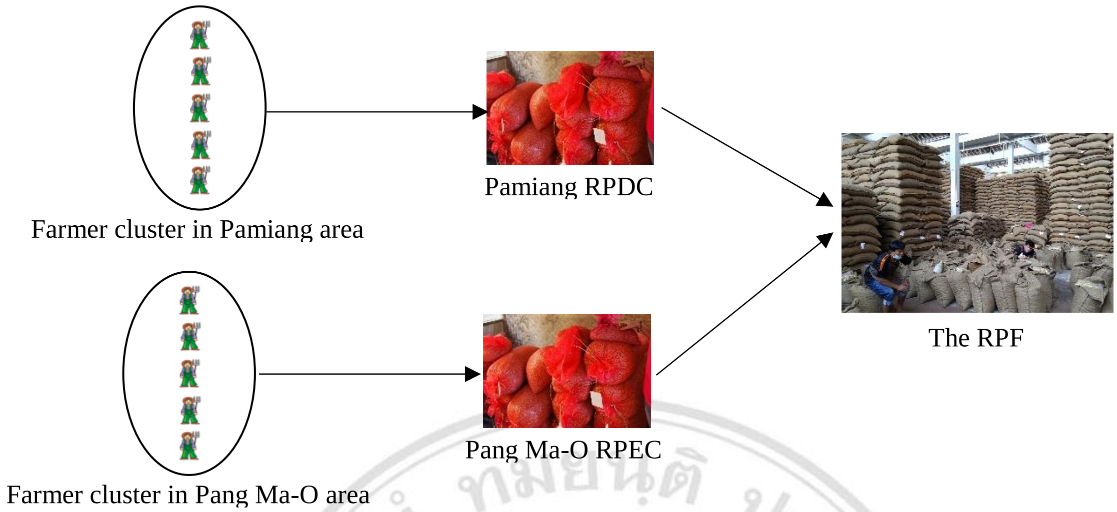


Figure 5.9 GCSC model

2.2) The vertical coordination among the farmers, the assemblers, and the processor in the supply chain

The vertical coordination is the cooperation with at least two partners in the different levels of supply chain, which, in this research, are the farmers, the Pamiang RPDC, the Pang Ma-O RPEC, and the processor. The tool applied for setting the vertical coordination among them is the revenue sharing with pairwise contracts between the farmers and the assemblers, and between the assemblers and the RPF. The GCSC model using the vertical coordination approach is also presented in Figure 5.8, but is added with the strong contracts between the farmer cluster in Pamiang area and the Pamiang RPDC, farmer cluster in Pang Ma-O area and the Pang Ma-O RPEC, the Pamiang RPDC and the RPF, and the Pang Ma-O RPEC and the RPF.

Both models are used for evaluating the GCSC performances consisting of the operational optimization, the proper revenue sharing contracts and the competitiveness from the GCSC in the next chapter.