CHAPTER 6

ASSESSMENT OF SUSTAINABILITY

This chapter is presenting the results and discussions in respond to the second and third objective of this study, regarding the assessment of sustainability of the three integrated coffee-based farming systems, namely: 1) coffee integrated with tangerine and livestock (CTL), 2) coffee integrated with clove and livestock (CCL), and 3) coffee integrated with livestock (CL). The detailed information and results from each indicator used to assess the sustainability of these three systems are presented and discussed in this chapter. Afterward, the overall sustainability scores are presented by using sustainability indicators analysis (SIA) method with two conditions: 1) all indicators assumed to have equal weight, and 2) weight of each indicator is unequal and obtained from farmer focus group discussion by using Analytical Hierarchy Process (AHP). Then, the results are discussed and illustrated with AMOEBA diagram. Finally, some potential and constraint founded in the study are also discussed at the end of this chapter.

6.1 Sustainability indicators

This study was focusing on three aspects of sustainability: ecological suitability, social acceptability, and economic viability. Each aspect consists of three indicators. In total, there were nine indicators used to assess the sustainability of the three integrated coffee-based farming systems.

6.1.1 Ecological suitability

Regarding the assessment on ecological aspect, this study was focusing on the suitability of the three integrated coffee-based farming systems in terms of three indicators: soil fertility, water saving, and amount of organic input used. The detailed information regarding these indicators is discussed below.

6.1.1.1 Soil fertility

As mentioned in Chapter 3, soil fertility was examined by calculating the cost of land use (CLU). Firstly, the difference of yield (in value unit) gained from two periods of time (each period consist of three years) was considered. The value computed from the yield quantity in respective year multiplied with the average farm gate price of the two periods. As the time measurement baseline, the year tenth of coffee tree (2002) is pointed to be the beginning year to calculate the cost of land use, with assumption that annual productivity of coffee started from this year were relatively stable. So, the first period started from 2002 until 2004, and the second period started from 2005 until 2007. Farm gate prices and yields of each crop in both periods are presented in Table 6.1 and 6.2, respectively.

The average prices of all crops in the second period were higher than the first period, especially in coffee and clove. For coffee price in CTL, CCL, and CL in the second period was higher 19.79%, 17.79%, and 22.89% respectively from the first period. For clove, the price in the second period was higher 134.37% from the first period. The tangerine prices of these two periods were not so different. In contrast to the prices, the average yields of coffee in the second period in all three systems were lower than the first period and also in the case of tangerine yield whereas the clove yield in the second period was slightly higher than the first period.

Table 6.1 Average farm gate price of crops (in IDR/kg)

Detail (in IDR/kg)	CTL		CCL		CL
	Coffee	**Tangerine**	**Coffee**	**Clove**	**Coffee**
Period I (2002-2004)					
Minimum	2,400.00	1,300.00	2,400.00	20,000.00	2,400.00
Maximum	2,500.00	2,000.00	2,600.00	25,000.00	2,500.00
Mean	**2,490.29**	**1,991.14**	**2,490.00**	**21,333.33**	**2,490.00**
Period II (2005-2007)					
Minimum	2,900.00	1,833.33	2,900.00	50,000.00	2,933.00
Maximum	3,100.00	2,000.00	2,966.67	50,000.00	3,100.00
Mean	**2,983.12**	**1,997.89**	**2,933.33**	**50,000.00**	**3,060.00**
Average price (2002 – 2007)	**2,736.71**	**1,994.51**	**2,711.67**	**35,666.67**	**2,775.00**

Source: computed from primary data, 2008

From Table 6.2, it was observed that the yield of coffee in CL is highest compared to CTL and CCL. However, this amount was quite low compared to the number of trees exist in this system which is significantly different from the other two systems. This was indicated that the productivity of coffee under the shade (CTL and CCL) is better than coffee in monoculture (CL).

The main point in CLU is to observe the differences of yield between the two periods in order to conduct the measurement of soil fertility. In order to avoid the price differences in the two periods, value of yield in each period was calculated by using the average price during 2002–2007 (see Table 6.1) multiplied with the average yield of each period (see Table 6.2).

Table 6.2 Yield of Crops in 2002 – 2007

Detail (in Kg/ha/year)	**CTL**		**CCL**		**CL**
	Coffee	**Tangerine**	**Coffee**	**Clove**	**Coffee**
Period I (2002-2004)					
Minimum	307.37	455.3	650	85	633.33
Maximum	1,600	3,016.67	1,533.33	261.11	1,566.67
Mean	**951.73**	**1,211.05**	**971.47**	**169.82**	**1,098.86**
Period II (2005-2007)					
Minimum	382.72	444.44	600	101.67	633.33
Maximum	1,500	2,916.67	1,400	269.44	1,533.33
Mean	**926.86**	**1,163.35**	**906.69**	**172.35**	**1,062.92**

Source: computed from primary data, 2008

Finally, value of yield in each period and its difference are shown in Table 6.3. Almost all crops in three integrated coffee-based farming systems, the values of yield in the second period were lower than the first period, except for the clove that the value of clove yield was higher. The highest difference of yield value between two periods happened in CTL. However, among the three coffee-based farming systems, CCL had the highest value of yield with total 8 millions IDR/kg/ha compared with the other two systems.

After identifying the difference of yield value of the three systems, cost of soil improvement, which is the cost of fertilizer that farmers added into the soil to improve the soil fertility, were calculated as shown in Table 6.4.

From Table 6.4, the average operating expense for improving the soil fertility was highest in CCL, with spending in average more than 8 millions IDR per hectare during the second period (2005-2007). For those in CTL, they spent averagely around 7.5 millions IDR per hectare for improving their soil fertility. In average, farmers in CL spent less in improving soil with around 5 millions IDR per hectare. So, in term of cost of soil improvement, farmers in CCL invested more than other systems. Finally, the cost of land use was calculated by adding the difference of yield value between the first and second periods with the cost of soil improvement (see Table 6.5).

Table 6.3 Value of yield in the period of 2002 – 2007 (in IDR/kg/ha)

Detail	**CTL**		**CCL**		**CL**
	Coffee	**Tangerine**	**Coffee**	**Clove**	**Coffee**
Period I (2002-2004)					
Minimum	1,006,172.00	910,666.70	1,755,000.00	3,187,500.00	1,773,333.00
Maximum	4,346,667.00	6,033,333.00	4,114,436.00	9,791,667.00	4,334,444.00
Mean	**2,605,645.74**	**2,418,083.37**	**2,633,309.69**	**6,054,061.77**	**3,048,368.68**
Period II (2005-2007)					
Minimum	1,039,714.00	868,888.90	1,620,000.00	3,812,500.00	1,773,333.00
Maximum	4,200,000.00	5,833,333.00	3,756,658.00	10,104,167.00	4,242,222.00
Mean	**2,538,713.09**	**2,322,581.36**	**2,458,130.37**	**6,145,993.91**	**2,950,062.50**
Difference of yield value(Period I-Period II)	66,932.65	95,502.01	175,179.32	(91,932.14)	98,306.18
Difference of yield value of system (Period I-Period II)	**162,434.70**		**83,247.18**		**98,306.18**

Source: computed from primary data, 2008. Note: ( ) is showing negative value

Table 6.4 Cost of soil improvement in the year of 2005-2007 (in IDR/ha)

Detail	**CTL**	**CCL**	**CL**
Minimum	2,625,000	5,250,000	2,800,000
Maximum	15,166,667	12,950,000	12,250,000
Mean	**7,549,986**	**8,526,258****	**4,993,333**

*Source: computed from primary data, 2008. **mean difference significant at the 0.01 level*

Table 6.5 Cost of land use during 2002-2007 (in IDR/ha)

Detail	**CTL**	**CCL**	**CL**
Minimum	2,388,889	4,197,917	2,800,000
Maximum	15,509,818	13,633,333	12,589,583
Mean	**7,712,421**	**8,609,505****	**5,091,640**

Source: computed from Survey, 2008.

*Notes: 1 USD = Rp.10, 000. 1 THB = Rp.265, **mean difference significant at the 0.01 level*

Afterward, the lowest and highest cost of land use among 119 samples of the three systems observed was 2,388,889 (I_{min}) and 15,509,818 (I_{max}). Then, the soil fertility index of each household among the three systems were calculated and normalized with these values. Finally, in each system, the normalized value was averaged to compare the soil fertility of the three systems (see Table 6.6)

The outcomes of soil fertility measurement by using cost of land use (in IDR/ha) during 2002-2007 were showing positive values for all three integrated coffee-based farming systems. In term of ecological suitability, especially for soil fertility indicator, positive value of CLU is a sign of less sustainable, as spending for improving soil fertility by adding fertilizer can not cover the loss of soil nutrient which affected the reduction of yield. In other words, cost for improving soil fertility was much lower than the loss of yield value due to the use of land for crop production in a period of time. This indicates that the soil fertility caused by crop production systems was high. Averagely, farmers in CCL spent the cost of land use with around 8.6 millions IDR per hectare, which is significantly higher than the other two systems, according to the F-test of One-Way ANOVA. The results of soil fertility index showed that the average normalized value in CL (0.79) is higher than CTL (0.59) and CCL (0.53) (see Table 6.6).

Table 6.6 The average normalized value of soil fertility indicator

Detail	CTL	CCL	CL
Minimum CLU	<------------------2,388,889------------------>		
Maximum CLU	<-----------------15,509,818------------------->		
Average normalized value	**0.59**	**0.53**	**0.79**

6.1.1.2 Water saving

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

The overall water demand of coffee-based farming systems varies from situation to situation depending on the relationship between rainfall and evapotranspiration and this relationship will vary from year to year. In this study, water requirement incorporates measurements of evapotranspiration and crops coefficient was calculated by using Penman method which is acknowledged as the most likely method to calculate reference crop evapotranspiration (ET_0) where measured data on temperature, humidity, wind, and sunshine duration or radiation are available (Doorenbos, 1984). But, there is limitation of the data in this study, since the latest data available was in 2002. Due to this limitation, water requirement was calculated by comparing crop evapotranspiration using data in 2002 with water availability in the area (from rainfall data) in the same year.

The formula of Penman incorporated measurements of climatic factors, including temperature, humidity and vapor pressure, wind velocity, solar radiation (or sunshine hours), to derive the reference evapotranspiration rates (ETo) for particular situations. In coffee plantations, the tree cover varies from the initial planting to maturity and with the spacing used. Also, the coffee evapotranspiration rate varies through the year since it depends on the level of soil moisture. In calculating actual evapotranspiration of coffee, an adjustment were applied to the reference evapotranspiration rate, by applying the crop coefficient which has been devised and compared with calculated potential evapotranspiration (ETo).

It has been demonstrated in a number of countries that under conditions of ample soil moisture supplies and at the closest tree spacing's used in commercial production, the coffee crop coefficient is of the order of 0.8 whilst at the widest spacing used with moisture conservation measures in place, the coffee crop coefficient may be reduced to as little as 0.65. The need for irrigation can be illustrated by comparing potential evapotranspiration with rainfall. Generally reference crop evapotranspiration is between 120 and 150 mm/month, so actual coffee evapotranspiration is between 84 and 105 mm/month. The dry season has been defined arbitrarily as including those months with less than 50 mm of rainfall (Wintgens, 2004).

The results of reference evapotranspiration calculation showing that ETo in the study area were varies between 93 mm/month in rainy season (December) to 144 mm/month (May). And, when compared with monthly rainfall, it showed that irrigation water is required during April until October (see Table 6.7).

Table 6.7 Reference evapotranspiration and rainfall in 2002

Items	Reference Evapotranspiration (ET_0) (in mm/month)	Rainfall (in mm/month)
January	104.73	711
February	0	883
March	119.25	259
April	135.98	**90**
May	144.16	**30**
June	122.50	**0**
July	129.81	**0**
August	104.52	**10**
September	138.98	**0**
October	109.39	**5**
November	100.69	144
December	93.27	538

Source: computed from secondary data, BMG 2002. Value in ***Bold*** *indicated irrigation is needed*

Regarding water requirement evaluation based on rainfall and reference evapotranspiration (ET_0) in 2002, the result shows that in a year period, irrigation was needed during April–October. Afterward, the reference evapotranspiration multiplied with the crop coefficient (see Table 6.8) based on months when rainfall is insufficient to determine actual crop evapotranspiration (ET_c). To get the detailed crops coefficient, trees percentage of each crop in a hectare unit of land was also considered. The detailed of crop evapotranspiration can be seen in Appendix B.

Table 6.8 Crops coefficient (k_c) during April - October

Crop coefficient	Apr	May	Jun	Jul	Aug	Sep	Oct
1. Coffee	<------------0.8[a], 0.9[b]------------>						
2. Tangerine*)	<-------0.6------>		<---------- 0.55 ---------->				
3. Clove**)	<------------ 0.8 ------------>						

*Source: Doorenbos (1984), *) CTL only, where trees providing 50% tree ground cultivated, **) only for CCL, [a] for CTL and CCL, [b] for CL*

Next, water requirement during April – October is calculated by deduction of crops evapotranspiration (ETc) from rainfall to get the particular amount of water requirement per hectare (in m^3/year). Finally, the monthly required water summed up to get the annual amount (m^3/ha/year) (see Table 6.9). Averagely, the CTL needed 785 mm/year or 7,850 m^3/ha/year, while the CCL required 860.1 mm/year or 8,601m^3/ha/year, and the CL needed 550.8 mm/year or 5,508m^3/ha/year. According to the F-test of One-way ANOVA, the CCL required significantly highest additional water compared to the other two systems. So, these values indicated the CCL as the least water-saving system, while CL is the most water-saving system, in other word, the CL is more sustainable in terms of water saving indicator compared with CTL and CCL.

Table 6.9 Annual amount of water requirement in 2002 and average normalized value of water saving indicator

Detail	Amount of water required (m^3/ha/year)		
	CTL	**CCL**	**CL**
Minimum	4,941.00	6,077.72	3,630.23
Maximum	8,659.95	9,097.07	6,847.46
Average	7,850.00**	8,601.00**	5,508.00**
SD	593.06	669.08	773.58
Average normalized value of water saving indicator	**0.23**	**0.09**	**0.66**

Source: computed from primary and secondary data

*Note: ** mean difference significant at the 0.01 level*

6.1.1.3 Amount of organic input used

Regarding amount of organic input used evaluation in the last five years (2003-2007), it was found that most farmers were applying organic fertilizer and only two percent of farmers in the CTL applied chemical fertilizer in their farm in 2003. The amount of chemical fertilizer used in the farm had been reduced over time until in 2007; all farmers were applying organic inputs in all three patterns of integrated coffee-based farming systems. Overall, the average normalized value of CCL and CL systems are 1.0 which indicated that these systems were more sustain compared to CTL (average normalized value 0.98) in terms of application of organic input indicator.

6.1.2 Social acceptability

As mentioned earlier, the acceptability of integrated coffee-based farming systems in term of social aspect were valued by employment generation, awareness of farmers of usefulness of intercropping, and self-sufficiency in input of the three systems of integrated coffee-based farming systems.

6.1.2.1 Employment generation

For employment generation measurement, annual labor requirements for farming activities such as crops and livestock in man-days per hectare for each system were considered.

Based on survey's results, there were eight processes in the farm practices related with crops: land clearing, ploughing, planting, fertilizing, pest and disease control, weeding, pruning, and harvesting. In relation with livestock rearing, averagely 120 man-days of employment per year were employed in all of the three systems.

On the process of land clearing and ploughing, the requirements of employment in all systems were averagely 12-14 man-days per hectare. On the process of fertilizing, pest disease control, and weeding; averagely in all systems required 4-11 man-days per hectare. However, in the process of planting, pruning, and harvesting, they were differentiated by crops. For planting coffee, the results shown that the requirement for employment was averagely 12 man-days per hectare in CL and 10 man-days in CTL and CCL. Then, in the process of pruning of coffee, 9 man-days per hectare were needed in CL, while those only 7 man-days per hectare for

CTL and CCL. As additional in CTL, the employment needed during pruning process for tangerine was averagely 11 man-days per hectare. Whilst in CCL, the pruning process for clove required 8 man-days per hectare.

The final process that required employment was harvesting, where in CTL averagely entailed 12 man-days per hectare for coffee and 14 man-days per hectare for tangerine. In CCL, for harvesting coffee, there were generally 12 man-days per hectare needed, and for clove harvesting, it was commonly employed 12 man-days per hectare. For CL, there were 15 man-days per hectare required to harvest coffee.

In the first year, CTL required more labor (49 Man-day/ha) than CCL and CL. During every harvesting year, CTL required 187 Man-day/ha, CCL required 181 Man-day/ha, and CL required 161 Man-day/ha. For assessing the sustainability, the annual labor requirement during every harvesting year is considered. Thus, CTL generates employment more than CCL and significantly higher than CL (see table 6.10).

Table 6.10 Employment generation in integrated coffee-based farming systems

Activities	**CTL**	**CCL**	**CL**
	In average (Man-day/ha/year)		
First year			
Land clearing	14	13	12
Ploughing	12**	11	10
Planting	23	22	13**
Total labor generated I	49	46	35

Table 6.10 (Continued)

Activities	**CTL**	**CCL**	**CL**
	In average (Man-day/ha/year)		
Every harvesting year			
fertilizing	12	11	9
Pest and disease control	4	4	3
Weeding	6	6	5**
Pruning	19**	16**	9**
Harvesting	26	24	15**
Livestock rearing	120	120	120
Total labor generated II	187	181	161**
Average normalized value	**0.54**	**0.52**	**0.40**

Source: computed from primary data, 2008. ** *mean difference significantly at α<0.05*

6.1.2.2 Farmer awareness of usefulness of intercropping

The second indicator used to assess the social acceptability is farmer awareness of usefulness of intercropping. The result is obtained from group discussion concerning farmer perception about usefulness of integrated coffee-based farming systems by scoring system ranging 1 to 5 scale, where 1 indicated the role of intercropping system indicator was least useful and 5 was indicated most useful. There are three main roles related with usefulness of intercropping being discussed: a) role of maintaining their livelihood, b) role of plant protection, and c) role of management (see Table 6.11).

In the role of maintaining farmers' livelihood, farmers valued CTL and CCL as the most useful systems especially in terms of income stability, income diversification, and labor generation. In the role of plant protection, CTL has been valued by farmers as the more-useful system than the other two systems. And, in the role of management, farmers worth the CTL as the more functional system compared to the other two systems. Overall, to conclude the best system according to farmers' perception, all score are summed up, and in total, for CTL the total score is 65, while CCL is 64, and CL is 55 (see Table 6.11). As a conclusion, based on farmers' perception, overall, CTL is acknowledged as the most useful integrated coffee-based farming systems compared with CCL and CL.

Table 6.11 Farmers' perception of usefulness of intercropping

Role of intercropping system	**CTL**	**CCL**	**CL**
	score of farmers perception		
I. Role of maintaining livelihood			
Income stability	5	5	4
Income diversification	5	5	3
Labor generation	5	5	5
Total I	15	15	12
Average I	5	5	4
Normalized value	1	1	0
II. Role of plant protection			
Shade and windbreak	4	3	2
Reduces insect attack	4	4	2
Reduces soil erosion	5	4	4
Returns organic matters	5	4	3
Provides firewood	4	4	3
Suppresses weed	4	4	3
Moderates temperature	4	4	2
Total II	30	27	19
Average II	4.3	3.8	2.7
Normalized value	1	0.73	0

Table 6.11 (Continued)

Role of intercropping system	CTL	CCL	CL
		score of farmers perception	
III. Role of Management			
Decrease pest on farm	2	2	4
Decrease diseases	2	2	3
Easiness of management	2	3	4
Water competition	2	3	3
Nutrient competition	2	2	3
Decreases coffee yield	5	5	4
Increases total yield	5	5	3
Total III	20	22	24
Average III	2.8	3.1	3.4
Normalized value	0	0.5	1
TOTAL score (I + II + III)	**65**	**64**	**55**
Average normalized value	**0.67**	**0.74**	**0.33**

Source: Group discussion, 2008.
1 = least useful, 2 = slight useful, 3 = useful, 4 = more useful, 5 = most useful

6.1.2.3 Input self sufficiency

Input self sufficiency of each system was calculated in percentage comparing the proportion of internal input used (self-provided by farmers) with external input used (purchased). The results show that the average ISS value of the three systems in 2007 were more than 50% in which means the proportion of local input usage were higher than external one. However, the CCL system shows the significant lowest ISS percentage with the average of 65.34% compared with the other two systems.

Table 6.12 Input self sufficiency of integrated coffee-based farming systems in 2007

Input Self Sufficiency (%)	Total	CTL	CCL	CL
0 – 20	1	1 (1.2%)	0	0
41 – 60	23	13(16.5%)	10 (33.34%)	0
61 – 80	80	53 (67.1%)	19 (63.33%)	8 (80%)
81 – 100	15	12 (15.2%)	1 (3.33%)	2 (20%)
total	119	79 (100%)	30 (100%)	10 (100%)
Average ISS		70.0419	65.3425**	74.0599
Average normalized value		**0.82**	**0.71**	**0.93**

*Source: Survey, 2008.** mean of ISS of CCL is significantly difference from CTL and CL(α<0.05)*

6.1.3 Economic viability

The third aspect of sustainability measured in this study is economic viability. There are three indicators has been used to determine the economic viability of three integrated coffee-based farming systems: land productivity, profitability, and income stability. The detail results of these indicators are discussed below.

6.1.3.1 Land productivity

As mentioned earlier in Chapter 3, LER is the sum of fractions of the yields of intercrops relative to their sole crop yields (FAO, 1985). LER is usually greater than 1.0 which indicates that intercropping system is advantageous, while LER less than 1.0 showing that intercropping system disadvantageous. The result of land productivity measurement by LER showed that the LER of CTL and CCL are mostly greater than 1 whereas only 50% of CL farms had LER greater than 1. As a conclusion, on average, all of three integrated coffee-based farming systems had LER more than 1.0, which means that intercropping system is advantageous (see Table 6.13).

Table 6.13 Land equivalent ratio of integrated coffee-based farming systems

LER	CTL	CCL	CL	Total
0 < LER < 1	1 (1.3%)	0	5 (50%)	6
LER ≥ 1	78 (98.7%)	30 (100%)	5 (50%)	113
Total	79 (100%)	30 (100%)	10 (100%)	119
Average LER	1.98**	1.46	1.06	
Average normalized value	**0.44**	**0.26**	**0.13**	

*Source: computed from primary data, 2008. **mean of LER significantly different (α < 0.05)*

6.1.3.2 Profitability

In the case of profitability, indicators used for measuring the profitability were net present value (NPV) and internal rate of return (IRR). NPV was calculated based on the cost and benefit for each system in one hectare unit (the whole system in one). Costs and benefits here were referring to all expenses and earnings from farm activities including crops and livestock. To evaluate the cost and benefit from three systems of integrated coffee-based farming systems, some parameters and assumptions have been made as the basic for calculation of the whole system, as follows:

1. Discount rate used to calculate the net present value is 15%, the same with the bank interest rate for agriculture credit in 2007
2. The year included in the calculation is twenty years as the economical year of arabica coffee in this regard, and the first year of production is the third year (year 3) for arabica coffee and tangerine, while for clove, the first production is assumed start from the sixth year (year 6). For livestock, since it is difficult to measure precisely, so it is assumed that farmers sold their livestock at the end of each year.

Finally, based on those assumptions, NPV and IRR for the three systems were calculated as the details in Appendix C. From the results, NPV for the CCL is the highest among three systems, but its IRR is slightly lower than the other two systems (see Table 6.14). Even though the CL had the lowest NPV, but it had the highest IRR value. This was the result of the different harvesting year among coffee, tangerine, and clove. For coffee and tangerine, the first harvesting year is the same, which started from the third year, the IRR between CTL and CL were almost the same. For clove, since its first harvesting year was on the sixth year, so it affected to the IRR, which made it lower than other two systems.

Table 6.14 NPV and IRR of integrated coffee-based farming systems (in IDR/ha)

Indicators	**CTL**	**CCL**	**CL**
Cost	87,116,081.25	86,868,487.94	83,146,477.16
Benefit	113,842,015.16	119,011,161.98	106,281,813.37
NPV	25,652,065	**32,142,674**	<u>23,135,336</u>
IRR	37.27%	<u>35.63%</u>	**37.51%**
Average normalized value	**0.64**	**0.5**	**0.5**

Source: computed from primary data, 2008. Notes: 1 USD = Rp.10, 000. 1 THB = Rp.265

6.1.3.3 Income stability

This study was using coefficient of variation (CV) (%) of farm income during 2002 – 2007 to measure income stability of the three systems. The higher of CV means lower income stability. From F-test ANOVA, the result shows that the mean difference among the three groups are significant with $\alpha = 0.00$. From multiple comparisons using LSD, the mean of CTL is significantly different with CCL ($\alpha = 0.00$) but not significant difference with CL ($\alpha = 0.966$) (see Table 6.15). Hence, it can be concluded that the income variation is highest in the CCL compared to the other two systems. In other words, farmers in CTL and CL systems had higher income stability than the farmers in CCL system. Income in CCL is quite varying compared to the other two systems because of price fluctuation of clove during 2002-2007. The average price of clove in 2002-2004 was around 21,000 IDR/kg, and during 2005-2007, the price became 50,000 IDR/kg. So this condition affected the farmers' income in CCL system.

Table 6.15 Coefficient of variation of income during 2002-2007

CV (%) 2002 – 2007	**Total**	**CTL**	**CCL**	**CL**
0 – 10	94	78 (98.7%)	6 (20%)	10 (100%)
10.1 – 20	18	0	18 (60%)	0
20.1 – 30	5	0	5 (16.7%)	0
>30	2	1 (1.3%)	1 (3.3%)	0
Total of farmers	119	79	30	10
Average CV (%)		3.16%	15.2%	3.1%
Average normalized value		**0.90**	**0.52**	**0.90**

Source: computed from survey, 2008

6.2 Sustainability assessment

Since each indicator had their own unit, such as: percentage, m/ha/year, Man-day/ha/year, etc., they were normalized by using equation (13) and (14) in Chapter 3, to be aggregated to define the sustainability score. Generally, the mean differences of nine sustainability indicators values among three groups was analyzed using one-way ANOVA and the results was shown that most of the mean were significant different at $\alpha = 0.05$, except for amount of organic input used indicator. However, profitability (Pt) and farmer awareness (FA) are excluded from statistical test since the results obtained as groups result not individual one. Then, the average normalized values of nine indicators gained were compared in two ways: (1) equal importance of each indicator assumption which is called sustainability indicator analysis (SIA) in this study; and (2) un-equal importance of indicators assumption by using analytical hierarchy process (AHP) to get weight from farmer groups.

6.2.1 Indicators assumed having equal weight .

Based on results of nine indicators discussed above, the overall score of sustainability of the normalized value in respective system are calculated by aggregating all of average normalized values of nine indicators (see Table 6.16).

The normalization of indicators was using equation adapted from Kranj and Glavic (2005) as follows:

$$I_i^j = \frac{I_{aj} - I_{\min}}{I_{i\max} - I_{i\min}} \quad \dots (13) \quad \text{and} \quad I_i^j = 1 - \frac{I_{aj} - I_{\min}}{I_{i\max} - I_{i\min}} \dots (14)$$

Where:

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

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

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

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

Equation (13) was used for “more is better” indicator in sustainability, while equation (14) was used for “less is better” indicator. The score range is from 0 to 1. In this study, if the score is 1, meaning that it is the best practices of farmer or the highest value among 119 samples of the three integrated coffee-based farming systems according to the survey’s result, and it does not indicated the best standard of the three systems. Also for value score 0, indicated the poor practices or the least value among the 119 samples found in the study.

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

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

Where:

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

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

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

Table 6.16 Average normalized values of sustainability indicators

	Indicator	Average normalized value CTL	CCL	CL
Ecological aspect	Soil fertility (SF)	0.59	0.53	0.79
	Water saving (CWR)	0.23	0.09	0.66
	Amount of organic input used (OU)	0.98	1.00	1.00
	Total normalized value	**1.80**	**1.62**	**2.45**
Social aspect	Employment generation (EG)	0.54	0.52	0.40
	Farmer awareness (FA)	0.67	0.74	0.33
	Input self sufficiency (ISS)	0.82	0.71	0.93
	Total normalized value	**2.03**	**1.97**	**1.66**
Economic aspect	Land productivity (LP)	0.44	0.26	0.13
	Profitability (Pt)	0.64	0.5	0.5
	Income stability (IS)	0.90	0.52	0.90
	Total normalized value	**1.98**	**1.28**	**1.53**
	Total sustainability score	**5.81**	**4.87**	**5.65**

Source: computed from primary data, 2008.

The contrast between sustainability scores of three systems resulted in SIA also can be seen in Figure 6.1 below.

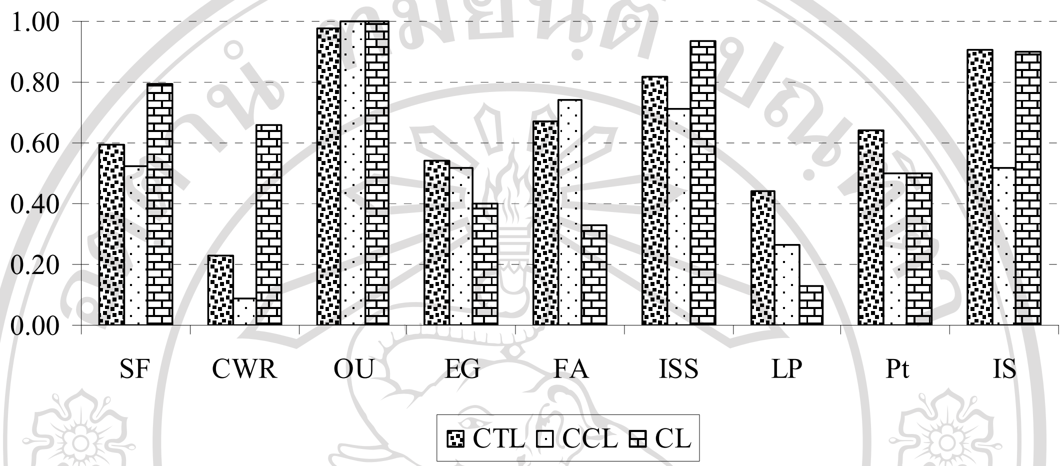

Figure 6.1 Sustainability score with SIA

From Figure 6.1 and Table 6.16 above, the total score of sustainability of CTL is 5.81 higher than CCL (4.87) and CL (5.65).

The strength of CTL was in economic aspect with total score 1.98. First, the normalized value of land productivity indicator shows that CTL is more advantageous compared to other two systems in terms of the intercropping system. Second, the normalized value of profitability indicator in CTL also shows the highest score among others. This is indicated that either NPV or IRR results, CTL is more profitable compared to CCL and CL. Third, in terms of income stability indicator, the normalized value of CTL is averagely the same as CL, which specified that these two systems remain more sustainable compared with CCL. The reason is due to the high fluctuation of clove in CCL. Farmers were doing the integrated coffee-based farming systems in order to reduce the price-risk caused by the coffee-price fluctuation. The price of clove in CCL was also fluctuated, so this resulted in high CV which explained low income stability. In other word, this can bring a higher risk to the farmers' income stability in CCL in the future. In terms of social aspect assessment, the overall score of CTL (2.03) shows that CTL is more acceptable compared with CCL and CL. The strong point of CTL was in employment generation indicator, where averagely the normalized value of CTL was better than CCL and CL. In farmers' awareness indicator, CTL normalized value was better than CL but less than CCL. Also, in input self sufficiency indicator, CTL normalized value was better than CCL but less than CL. So, from these two values, CTL was in the middle-rank among the three systems.

Nevertheless, CTL has some weaknesses especially in terms of ecological suitability aspect. Overall score of CTL normalized value for ecological aspect is 1.80, which is less than CL (2.45) but more than CCL (1.62). The result of organic input used indicator showing that there is no significant different among the three systems, but the weakness of CTL that should be highlighted was in soil fertility (SF) indicator, which showed that the normalized value of CTL was less than CL even it was better than CCL. Also, in terms of water saving, where CTL normalized value is less than CL but better than CCL. The decline of soil fertility caused by crop production and crops water requirement in CTL was higher compared with CL. So, to make the CTL more sustain, more concern on improving soil fertility is necessary, especially to maintain the organic farming that farmers have been applying since 2007.

For CCL, this system has some strong points to sustain the system. Firstly, the highlight was in ecological aspect especially in terms of organic input used indicator (OU). Secondly, in social aspect, based on farmers' perception, CCL was valued as the most useful intercropping system to maintain farmers' livelihood. Thirdly, in term of economic aspect, the average normalized value of profitability indicator of CCL acknowledged the same with CL.

The weak points of CCL were observed in soil fertility, where the cost of land use in CCL remains highest compared to CTL and CL. Also, in water required indicator, where the crops companion required more water compared with CTL and CL. In terms of social acceptability, the weakness of CCL founded at input self sufficiency indicator. Even though it is already more than 50%, but it is the lowest compared with CTL and CL. In economic viability, weakness was focused in income stability indicator where coefficient of variation of CCL remained highest among the other two systems. So, these three weakness points should be considered to improve and sustain the system.

The emphasized of CL system were observed in the case of soil fertility indicator where the decline of soil fertility caused by crop production system in this system is the lowest compared with CTL and CCL. Another highlight was in input self sufficiency indicator, where ISS percentage of CL was the highest compared with CTL and CCL, which means most farmers in CL system were having self sufficiency better than those in CTL and CCL. Another emphasized of CL was in income stability indicator where averagely the normalized value in this system was more than CCL and the same as CTL. This is the result of the price-fluctuation of clove in CCL. The aim of integrated coffee-based farming systems was to reduce the risk from coffee-price fluctuation. But, the study found that when the integrated crops also have high-fluctuated price, it affected the income stability of farmers and brought a higher risk to their livelihood.

The weaknesses of CL system that can be highlighted were in terms of employment generation indicator, where CL system employed less labor compared with CTL. Also, based on farmers' perception, CL is the least useful intercropping systems compared with the other two systems. In addition, weak point of CL system also observed in land productivity and profitability indicator. So, these four indicators should be highlighted to improve the sustainability of CL system.

6.2.2 Overall sustainability by AMOEBA diagram

Finally, the overall sustainability of the three systems was illustrated by the area of polygon, with crest points are the average normalized values of nine indicators of sustainability being used (see figure 6.2). The crest point which close to or reach 1.00 was the sign of more sustainable, and in opposite, crest point close to or reach 0.00 indicated less sustainable. CTL has strong points (crest point close to 1.00) in economic aspect, defined by land productivity (LP), profitability (Pt), and income stability (IS) which indicated this system is economically viable compared to other systems. For CCL, the weak point located at income stability (IS), while for CL the weak point was in land productivity (LP). In terms of social aspect, for employment generation (EG) and farmers' awareness (FA) the crest point of CTL and CCL are mostly equal, but the strong point of CCL located at FA indicator. The strong point of

CL located at input self sufficiency (ISS). Overall, in social aspect, CTL and CCL have a medium sustainability compared to CL. In ecological aspect, CL has strong points in all indicators (soil fertility, water saving, and organic input use) which indicated this system is ecologically suitable compared to other systems.

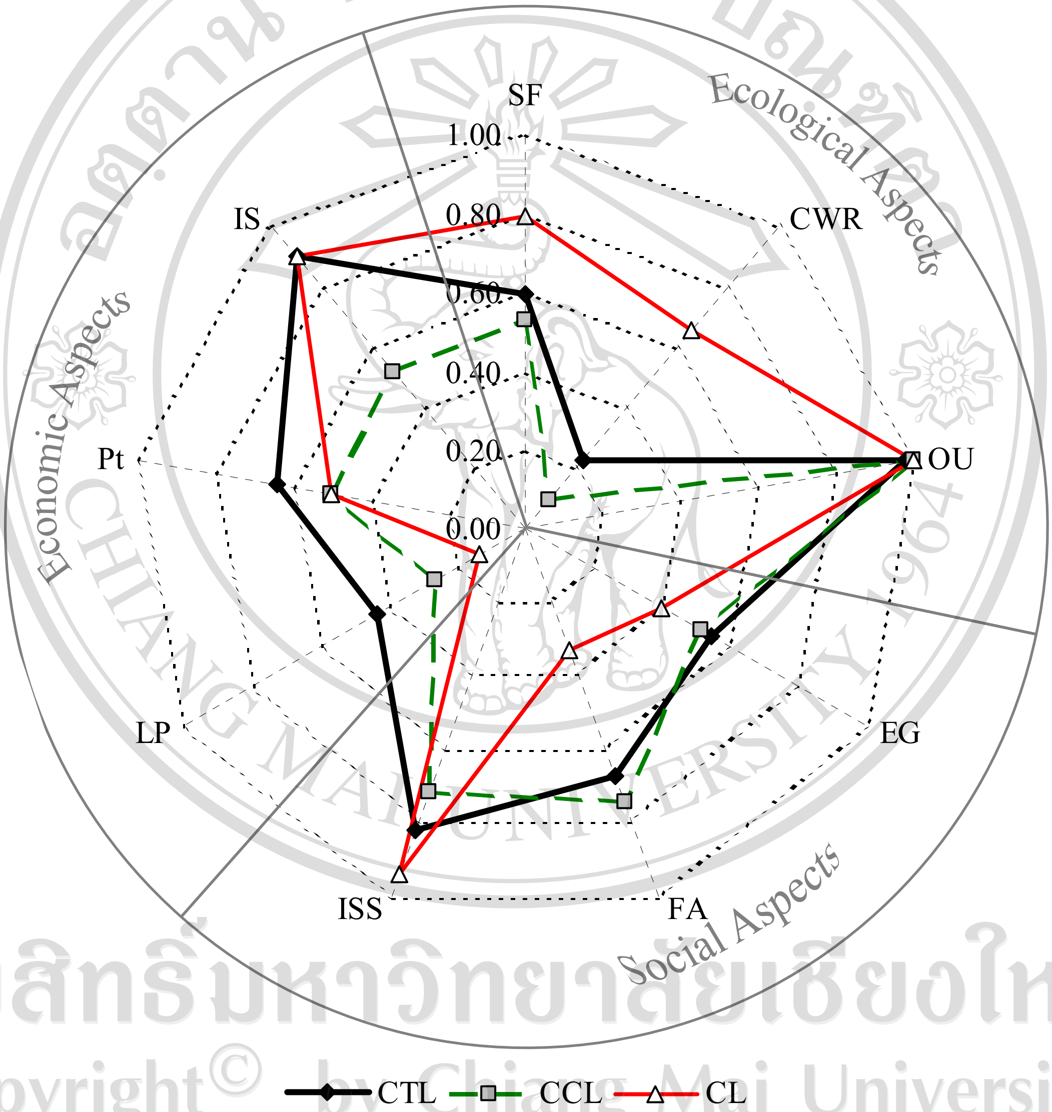

Figure 6.2 Overall sustainability with AMOEBA

6.2.3 Indicators assumed having un-equal weight

When indicators of sustainability are assumed having un-equal weight, it is quite difficult to assess the sustainability only with Sustainability Indicator Analysis (SIA) method since the weight much more depend on the decision makers, in this case, farmers themselves. Analytical Hierarchy Process (AHP) is acknowledged as one method that able to identify and take into consideration the decision maker's personal inconsistencies (Alphonce, 1997). Decision makers are rarely consistent in their judgements with respect to qualitative aspects. The AHP method incorporates such inconsistencies into the model and provides the decision maker with a measure of these inconsistencies.

Similar like in SIA, the overall sustainability score in this method also using the average normalized value of nine indicators to compare among the three systems. But, the indicators here assumed to have un-equal weight, which mean that the weight of indicators was defined by the subject or stakeholder, in this case, farmers themselves. So that, the result is strongly depend on the choices or weight given by farmers. One workshop on AHP was done to achieve the weight of indicators and the weight result is presented in the Table 6.17.

From the table 6.17 below, it is observed that farmer concerned on economic aspect more than social and ecology aspect as the weight for economic aspect was highest at 0.72 and followed by social and ecologic aspects. Mostly in other sustainability research findings found that economic aspect has been the first priority to the small-scale farmers in continuing their farming systems.

After getting the weight of three aspects of sustainability, farmers were asked to weight for each indicator in each aspect and the weight results are presented in. Table 6.18. So, based on those weights, the overall weight of sustainability was calculated from multiplication of the weight that farmer awarded to each aspect of sustainability with the mean weight of indicators that given on the workshop (see table 6.19). From overall weight in Table 6.19 below, it is explained that based on the weight given by farmers in the workshop, land productivity (LP) is the most essential indicator for farmer (0.518), followed by profitability (Pt) (0.144), employment generation (EG) (0.13), farmer awareness (FA) (0.060), income stability (IS) (0.058), soil fertility (SI) (0.052), Water saving (CWR) (0.023), input self sufficiency (ISS) (0.010), and chemical use (CU) (0.005).

Table 6.17 Result of AHP workshop for the three aspects of sustainability

Sustainability	**Ecological aspect**	**Economic aspect**	**Social aspect**	**Mean**
Ecological aspect	1	1/7	1/3	**0.08**
Economic aspect	7	1	5	**0.72**
Social aspect	3	1/5	1	**0.20**
Consistency ratio*	**0.063**			

*Source: AHP workshop, 2008. *CR < 0.1 meaning that there is no serious inconsistency*

Table 6.18 Result of AHP workshop for indicators of sustainability

Ecological aspect	Water saving	Organic input used	Soil fertility	**Mean**
Water saving	1	7	1/3	**0.29**
Organic input used	1/7	1	1/9	**0.06**
Soil fertility	3	9	1	**0.65**
Consistency ratio*		**0.078**		

Table 6.18 (Continued)

Social aspect	input self sufficiency	farmer awareness	Employment generation	**Mean**
Input self sufficiency	1	1/5	1/7	**0.07**
Farmer awareness	5	1	1/3	**0.28**
Employment generation	7	3	1	**0.65**
Consistency ratio*		**0.063**		
Economic aspect	profitability	land productivity	Income stability	**Mean**
Profitability	1	1/5	3	**0.20**
Land productivity	5	1	7	**0.72**
Income stability	1/3	1/7	1	**0.08**
Consistency ratio*		**0.063**		

Source: AHP workshop, 2008. * *CR < 0.1, meaning that no serious inconsistency*

Afterward, to determine the overall sustainability score of the three systems, the multiplication of overall weight of AHP with the average normalized value of SIA results is shown in Table 6.20. In the Figure 6.3 below, the score of each indicator is differed extremely from SIA score due to the weight that farmers have been given. Soil fertility has been the most important indicator that influences sustainability, which farmers should maintain it in order to sustain the integrated coffee-based farming systems. The outcomes of sustainability assessment by AHP resulted that the CTL is the most sustain systems with overall score of 0.531, which is higher than CCL (0.392), and CCL (0.335).

Table 6.19 Measurement of overall weight of sustainability by AHP

Sustainability aspect	Mean	Indicators	Mean	Overall weight
Ecological aspect	0.08	SI	0.65	**0.052**
		CWR	0.29	**0.023**
		CU	0.06	**0.005**
Social aspect	0.2	EG	0.65	**0.130**
		FA	0.28	**0.060**
		ISS	0.07	**0.010**
Economic aspect	0.72	LP	0.72	**0.518**
		Pt	0.2	**0.144**
		IS	0.08	**0.058**

Source: calculated from AHP workshop, 2008

In comparison, the values of overall sustainability when indicators were assumed to have un-equal weight were less than those results of assuming equal weight. This is due to the weight given by the decision makers in each indicator to determine the priority of indicator. In which indicator decision makers concerned the most make its sustainability weight higher.

Table 6.20 Overall sustainability score by using AHP

			CTL		CCL		CL	
Indicator	**Initial**	**AHP weight**	**normalized value**	**AHP weighted value**	**normalized value**	**AHP weighted value**	**normalized value**	**AHP weighted value**
Soil fertility	SF	**0.052**	0.59	0.031	0.53	0.027	0.79	0.041
Water saving	CWR	**0.023**	0.23	0.005	0.09	0.002	0.66	0.015
Amount of organic input used	OU	**0.005**	0.98	0.005	1.00	0.005	1.00	0.005
Employment generation	EG	**0.130**	0.54	0.070	0.52	0.067	0.40	0.052
Farmer awareness	FA	**0.060**	0.67	0.040	0.74	0.044	0.33	0.020

Source: calculated from AHP workshop, 2008

Table 6.20 (Continued)

Indicator	Initial	AHP weight	CTL normalized value	CTL AHP weighted value	CCL normalized value	CCL AHP weighted value	CL normalized value	CL AHP weighted value
Input self sufficiency	ISS	**0.010**	0.82	0.008	0.71	0.007	0.93	0.009
Land productivity	LP	**0.518**	0.44	0.227	0.26	0.137	0.13	0.069
Profitability	Pt	**0.144**	0.64	0.092	0.50	0.072	0.50	0.072
Income stability	IS	**0.058**	0.90	0.052	0.52	0.030	0.90	0.052
Total sustainability score				**0.531**		**0.392**		**0.335**

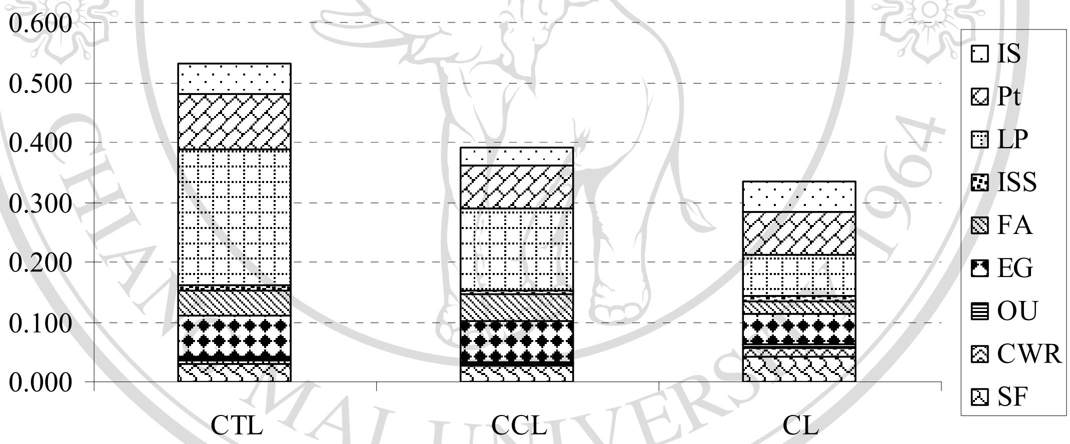

Figure 6.3 Overall sustainability score by using AHP

6.3 Potential and constraints of integrated coffee-based farming systems

Farmers were asked about potential and constraints of the integrated coffee-based farming system. The information regarding potential and constraint of integrated coffee-based farming systems were gathered from a group discussion, which is consist of 13 farmers' representatives from three villages under the study area and 5 extension officers' assistances in the study area.

Farmers stated the potential of integrated coffee-based farming system and it can be summarized as follows:

1. 100% of samples in this study have been applying organic agriculture in their integrated coffee-based farming systems, which should be enlarged and maintained to sustain the systems in the future.
2. Most farmers are member of a farmer group (*subak abian*) in their respective villages which actively held a group meeting once a month in order to share the knowledge or problems occurred among the members related with their farming systems activities.
3. *Subak abian* is well-organized and well-coordinated with plantation crops agency in Bali province especially in agricultural extension activities. There is extension office located in Catur village which covered nine villages nearby. Once a month, they usually held a meeting to deliver information, problem discussion, and technology dissemination which is related with their farming activities, such as introducing red-cherry harvesting for coffee, cattle vaccination, crops-waste compost practicing, etc. These activities should be delivered continuously.
4. Farmers are eager to get better income from their farming activities, but since they only have small size of land, so that, they were increasing the quality of their crops and livestock. They are also market-oriented, so they are aware to the quality standard based on market demand
5. The crops and livestock in the integrated coffee-based farming systems in the study area are mostly having a high value, like arabica coffee, clove, and Bali

cattle. Local government should improve the processing and marketing systems so farmers can enjoy better income.

6. Bali is a well-known destination for tourism in Indonesia. Moreover, there is a potential to develop a community-based agro-tourism especially in the study area, since farmers applying organic farming to their integrated coffee-based farming systems, and it is located in mountainous area. Also, arabica coffee produced in the study area is having unique flavor: tangerine, even that it was integrated with clove or cultivated in monoculture.

Farmers also mentioned about some constraints of integrated coffee-based farming system as summarized as follows:

1. As a mountainous area, most of irrigation of integrated coffee-based farming systems were highly depends on the rainfall, which can be a barrier for farmer to continue the systems. Farmers were worried with the changing of climate, where recently, the dry season was longer than rainy season, which affected the yield of crops. Therefore, to anticipate this, local government has to have accurate climate forecast annually, that can help farmers to persist their farming systems. Also, local government should introduce alternatives crops which required less water and companion with arabica coffee to diversify the farming systems.
2. In term of crops fluctuating price, especially arabica coffee, the international coffee price remains unstable. This affects the motivation of farmers to do farming systems based on coffee. And sometimes farmers are not convinced

that local trader could guarantee better prices even the quality improved. So, in term of marketing, some of them still practicing the traditional systems, such as: selling the green-cherry coffee bean, storing raw crops in the house without processed it and only sells when they need cash. Local government and private institution should set some inter-related cooperation with *Subak abian* to absorb the surplus product with standard price, held extension program of product diversification, etc.

3. The involvement of farmer groups in coffee marketing is limited by the lack of knowledge and capital, such as costly equipment, technical problems. So, workers who operate the coffee processing must be proficiently trained

4. In the study area, there is a need to improve the infrastructure, such as transportation access, market, roads to support the integrated coffee-based farming systems. Among the three villages under this study, only in Catur village, there is a market to sell crops and livestock, and it is only open in certain days. In terms of coffee processing, in Belantih village, they already have the machine to process, but in small scale operation. For Catur and Pengejaran village, they have to go 10 km to the processing factory. It is costly, and time-consumed. In terms of cattle's breeding center, the closest were in Denpasar city, 80 km from the study area.

As a summary, this chapter has reviewed and discussed about the assessment of sustainability of three integrated coffee-based farming systems with two different conditions: equal and un-equal weight. When sustainability indicators were assumed to have equal weight, the assessment of sustainability at household level seemed to be more simple compared when indicators of sustainability were assumed un-equal weight. In the case where sustainability indicators were assumed un-equal, it involved a complex decision-making process and requires more comprehensive framework to acquire the most favorable solution. The sustainability score from SIA and AHP showing different outcome. This indicates that stakeholders opinion or decision makers' opinion is quiet important in influencing the sustainability (ecological-social-economic) decision making process.

Furthermore, this chapter also discussed some potential of integrated coffee-based farming systems observed from the study that should be maintained more, such as: organic agriculture practices, well-incorporated between farmer organization (*subak abian*) and plantation crops agency in Bali province especially in agricultural extension activities, and enthusiasm of farmers to get better income from their high value crops. Nevertheless, there are some general constraints highlighted from the study, such as water availability, climate change, crops fluctuating price, lack of knowledge and capital in crops processing and marketing, and infrastructure.