Chapter VI

Analyzing the Three Coffee Production Systems

The ecological and economic/productivity advantages of intercropping systems over monocropping are many. Perhaps one of the most significant advantages of intercropping in comparison with monoculture ones is that intercropping suitable trees with coffee may increase the total yield per hectare, due to decreased competition, and moderated microclimate in the farms.

In this chapter, some ecological factors, which play quite important roles in the way those affect the trees, are analyzed. In addition, the productivity aspects are also to determine for evaluating the performance of individual system.

6.1 Some ecological factors of three coffee-based systems

The trees are grown together on the same land with various strata and components that have closely interrelationships among the species in the farm. There are usually both ecological and economic interactions between the trees and other components of the system. The ecological interactions that are the most distinctive feature may be positive or negative effects and take place above ground (e.g. shading, evapotranspiration, windbreak) and below ground such as root interactions with respect to water and nutrients (Young, 1997). In the following section, only some ecological factors, taking place above ground are mentioned.

6.1.1 Moderating microclimate inside the intercropping farms

In order to identify the influences of air temperature and wind speed as the limiting factors on growth, development and yield of the crop trees, in a 15-day period of March 2002 these factors were simultaneously measured their dynamic in three coffee systems. There were so large differences of the daily air temperature and wind speed among the coffee systems. The temperature ranged from 22.4 to 31.4^{o}C, an average of 25.6^{o}C in the farm of P1. This varied from 22.1 to 28.7^{o}C, an average of

24.4°C in P2 farms, and from 22.0 to 26.4°C, with an average of 23.5°C that were found in the farms under coffee - black pepper system (P3). Meanwhile, the wind speed recorded at the same time indicated that under intercropping systems the monsoon wind blowing from the southeast moved through the farms with slower speed in comparison with that of mono-system. For the three systems of P1, P2 and P3 respectively, the maximum wind speeds measured in this time were 5.7 m/s, 4.9 m/s and 4.1 m/s. The minimums were 2.8 m/s, 2.3 m/s and 2.0 m/s, with means of 4.0 m/s, 3.3 m/s and 2.4 m/s (Table 43). There was significant difference between air temperature means of P1 and P3. While the means of wind speed of three systems were differences at 5 percent level of significance.

As indicated in the climate of DakLak province and the study site as well, dry season was a period of positive and negative impacts on forming yield of the trees in the systems. Firstly, positive one because the coffee trees, durian and black pepper need a short drought period to develop flowers for even opening (Nghi *et al*., 1996; Nhan *et al*., 1999; Nghiep, 1985; Tan, 2001; Chuong, 1999 and Sung, 2001). This period coincides with dry season in the region. Therefore, under this condition, the yields of trees will be greater than that of other places without drought time. Some regions where without or too short dry season (one month), the coffee yield was very low in comparison with the areas of distinct drought season. Secondly, the negative effect was high air temperature associated with strong wind caused so many damages for the trees. Air temperature over 26°C the photosynthesis process is reduced, and leaf damage occurs through continuous exposure to temperature above 30°C (Nghi *et al*., 1996 and Nghiep, 1985). The process of evapotranspiration from the trees and soil surface caused severe water loss in the trees, leading to destroy branches, flowers sometimes trunks, if no or insufficient water was supplied. Particularly, high temperature negatively affects on the process of pollination due to pollen burnt.

Coffee was very sensitive to strong persistent wind. Strong wind caused structural damage, for instance defoliation, branches breaking, exposure of roots in light soils and even uproot (Cambrony, 1992). In the study site, strong wind was accompanied by high temperature and without rainfall that was a serious problem of crops, especially coffee tree.

To reduce these adverse impacts to coffee cultivation in the Ea Ktur village as well in the whole province, the intercropping farms with various canopies were one of the key alternatives for coffee based farming systems. That played very essential roles not only in preventing so much water loss from evapotranspiration process but also creating an advantage environment for cross-pollination of coffee. Because robusta coffee and durian could not be self-pollinated, pollination process depends on insects such as bees, ants or the wind bringing the pollens from tree to tree (Nhan *et al.*, 1999 and Phong *et al.*, 1994). So slow wind moving through farm was an ideal condition for pollens to be brought to others for pollinating, otherwise the pollinating process was not able to be completed, even the flowers were dropped before pollinating. Therefore, the trees under intercropping farms in some serious conditions often could withstand and maintain their productivity better than those of monocropping system.

Table 43. The air temperature and wind speed in the systems (16-30 March, 2002)

Factor	Statistics	P1	P2	P3
Air temperature (°C)	Max.	31.4	28.7	26.4
	Min.	22.4	22.1	22.0
	Mean	25.6	24.4	23.5
Wind speed (m/s)	Max.	5.7	4.9	4.1
	Min.	2.8	2.3	2.0
	Mean	4.0	3.3	2.4

Source: Survey, 2002.

Note: P1(n=46): mono-coffee system, P2 (n=46): coffee-durian intercropping system, P3 (n=46): coffee-black pepper intercropping system.

6.1.2 Reducing water requirement in intercropping farms

Water is continually flowing through the body of a plant: leaving the stomata via transpiration and entering through the roots. For this reason, plants depend on having a certain amount of water available to their roots in the soil. Inadequate soil moisture, they quickly wilt and die (Gliessman, 1998) Thus maintaining sufficient moisture in the soil is a crucial part of coffee production in dry season. According to Bau (1999) the permanent wilting point of robusta coffee planted on basaltic soil (Rohdic Ferralsols) is 25 percent of soil moisture. So the management of soil moisture or water irrigation in dry season is very important work to gain stable yield in seasonal production.

Table 44. Soil moisture level in the layer of 0 to 40 cm depth at a given time

Point of time	**P1**	**P2**	**P3**
	--- Percentage of soil moisture ---		
2 days before irrigation	25.9	25.7	25.7
25 days after irrigation	25.3	26.1	26.7

Source: Survey, 2002.

Note: P1 (n=46): mono-coffee system, P2 (n=46): coffee-durian intercropping system, P3 (n=46): coffee-black pepper intercropping system.

The dynamic of soil moisture was measured after watering 600 m^3 per hectare in different coffee systems (3 farms for each system). The results showed that 25 days after irrigation, soil moisture in the layer of 0 to 40 cm depth reduced to close level of the permanent wilting point (25 percent) in the farms belonging to mono-coffee system. While at the same time, soil moisture of the P_2 farms was 0.6 percent lower than that of P_3, at the level of 26.1 percent and 26.7 percent for P_2 and P_3 farms, respectively (Table 44). The significant differences of soil moisture of the systems were found at 5 percent level. Therefore in the dry season, in order to guarantee for the performances in the body of the trees, it was necessary to add more water in the farms of P_1 than P_2 and P_3 due to greater amount of water loss in P_1 farms. On other hand, the farm of the P_2 and P_3 was applied less water than P_1 farm because of less water loss from evaporation and longer interval between two times of irrigation. Because the farmers had applied the methods of mulching the soil surface to maintain soil moisture in dry season, in one hand. On the other hand, intercropping trees in coffee farms could be considered as the shades for coffee. It was an essential component of the farm, and the mixed layers of communities created a favorable microclimate inside the plantation for crops in different stories. Coffee in the lowest layer avoided serious damage from direct sun light in dry season that reduced evapotranspiration from the tree and soil surface. Hence, under dry conditions, the soil dried more slowly than soil exposed to dry wind and the sun of the mono-farms.

Irrigation in dry season is one of the most important factors influencing not only on the tree yields but also on the survival of the farms. As having discussed, no water for irrigation means that without coffee grown in the study area. But the matter here does not discuss about whether or not available water for irrigation to the farms, but importantly, the potential systems of coffee-based farming systems with high water use efficiency should be looked for. Measuring the total amount of water irrigated for one hectare per year was one of the criteria to compare the system efficiency. There were very large differences from maximum total water with minimum one used in one dry season. In fact, some farmers have irrigated their farms with double amount of water in comparison with others. The maximum amounts of water of P_1, P_2 and P_3 were 3,420 m^3, 3,069 m^3 and 3,600 m^3 respectively. The minimums were 1,914 m^3, 1,706 m^3 and 1,530 m^3, with the average amounts of 2,467.1 m^3, 2,150.3 m^3 and 1,961.6 m^3 per hectare per year (only in dry season). Therefore, coffee planted under intercroppimg of coffee-durian and coffee-black pepper systems were provided amount of water of 316.8 m^3 and 505.5 m^3 less than farms under monoculture system (P_1) respectively. If the exceeded-water was only calculated in a small scale of one or two hectares of the farm, that is not significant to affect on the water resources of the local. But these figure multiplied with the total area of 260,000 hectares of coffee, a huge amount water of at least 80 millions m^3 exceeded per one dry season, approximately VND 65,000 millions (about US$ 4.25 millions) in value, was exceeded. In other word, the farmers in the province would have saved this amount of money if they have designed the coffee farms in the form of intercropping systems. In addition the exceeded-volume (80 millions m^3) of water will be an important source to supply to other crops or activities. It is also a vital factor contributing to reduce the problem of water scarcity for living and producing of the province in dry season. Testing for difference between the means of two independent populations of P_1 and P_2, P_1 and P_3, P_2 and P_3, there was a significant difference between two means of each given pair at the 5 percent level. Therefore, in the circumstance of the study area the total amount of water irrigated for one hectare of coffee per year under mono-farms (P_1) was higher than that of P_2, and P_3 (Table 45). So cultivation of coffee under intercropping system not only reduced cost of production, due to less cost of irrigation, but also protected the water resource from degradation.

Table 45. The amount of water irrigated in dry season (m^3/ ha)

Statistics	P1	P2	P3
Max.	3,420.0	3,069	3,600.0
Min.	1,914.0	1,706.0	1,530.0
Mean	2,467.1	2,150.3	1,961.6
SD	387.7	251.5	362.5

Source: Survey, 2002.

Note: P_1(n=46): mono-coffee system, P_2 (n=46): coffee-durian intercropping system, P_3 (n=46): coffee-black pepper intercropping system

In short, coffee cultivation under intercropping coffee-based system has brought some advantages in the forms of ecological factor like moderating microclimate by reducing high air and surface temperature, and wind speed inside the farms. In this condition the crop trees, especially coffee trees, might avoid the destroys such as collapsing flowers, breaking branches, falling leaves and so on that are the agents causing yield loss in coffee production. On the other hand, the process of cross-pollination of coffee and others in intercropping farms could be taken place better than that of monocultural farms, which often suffered from fluctuation of yield, due to affecting of bad weather in flowering stage of coffee. But one of the most important factors contributed to sustainable coffee production in study area, maybe, was low requirement of the amount of water irrigation compared to mono-farms. Normally, the total mount of water irrigated for one hectare of mono-coffee farms in the normal weather condition ranged from 2,600 to 3,200 m^3 and annually the whole province needed at least 676 millions m^3 of water to irrigate for coffee farms only (Sung, 1999). So it was also warned that the problem of water shortage for irrigation have been taking place in the large scale of the province. Hence, it was necessary to develop the solutions for restraining risk above and raising water use efficiency of the coffee. Probably, intercropping coffee-based farming systems were one of the best choices of the solutions that were proved by the results presented in the Table 45.

6.1.3 Increasing natural enemies and reducing insecticide use in intercropping systems

At present, there are not many literatures of reduced pest incidence in intercropping systems as opposes to monocropping systems. Each kind of cropping system of a particular local/region has some certain beneficial insect species existing inside as the agents to keep insect pest under the damage threshold. For coffee-based systems in DakLak, the issue of identification of how many natural enemy species of coffee insect pests existing in the whole province or even in smaller levels as districts or villages has not been studied specifically. However, there were 12 coffee beneficial insect species identified, belonging to 6 orders of (1) Araneidae, (2) Hymenoptera, (3) Hemiptera, (4) Coleoptera, (5) Diptera, and (6) Neuroptera in the province-wide. They are the enemies of almost insect pests of coffee trees (Phat, 2002).

To identify the number of natural enemy species occurring in the three coffee systems for the last three years, the farmers were asked about the natural enemies, whether or not they could identify and recognize the beneficial insects on their farms. Firstly, the respondents were encouraged to name all the insects that they thought those were natural enemies. And then, 20 color photographs of 12 beneficial insect species (*Ectrychotes* sp., *Rodolia* sp., *Scymnus* sp., *Chrysopa* sp., *Ischiodon Scutellaris, Leptomastix* sp., *Gasteracantha* sp., *Phidyppus* sp., *Oxyopes javanu thorell, Argiope, Atypena formosana, Lycosa pseudoannulata*) and 8 insect pests classified by the plant protection scientists were given the farmers to identify the insects that frequently occur in their farms. Surprisingly, the numbers of natural enemies listed were equal to those recognized through looking photographs. The farmers interviewed also agreed that there were many beneficial insects co-existing with the harmful insects on farms. And the survey result presented in the Table 46 did not indicate exactly how many species as well as the number of individuals of the certain species present in each system. But it gave us an overview of the relationship between coffee system with diversity of natural enemy species.

Table 46. Farmers' recognition about number of natural enemy species on farms

Number of natural enemy species	P1	P2	P3
	--- Number of farmers ---		
0	13	1	0
1	15	2	2
2	11	13	3
3	4	10	15
4	3	13	11
5	0	7	10
6	0	0	5

Source: Survey, 2002.

Note: P1(n=46): mono-coffee system, P2 (n=46): coffee-durian intercropping system, P3 (n=46): coffee-black pepper intercropping system

As mentioned, the farmers reported total 8 beneficial pest species, namely *Ectrychotes* sp., *Rodolia* sp., *Scymnus* sp., *Chrysopa* sp., *Ischiodon Scutellaris, Leptomastix* sp., *Gasteracantha* sp., *Phidyppus* sp. present in the study area. Farmers of P1 could define only six of eight species, while farmers of P2 and P3 indicated a maximum of 8 species. They could only point out the species, which they have ever seen, otherwise they did not know. Although 8 species of natural enemies could be recognized, not at all those resided on the farms. Comparing the farms of P1 and P2, the number of species present in the farms of P3 were quite diverse with maximum of 6 species occurred in 5 of 46 P3 farms and minimum of one species reported by two farmers. One (1) farmer of P2 and 13 farmers of P1 said they have never seen any species of the given beneficial insects on their farms, but complained about a problem of insect pests outbreak only one to two months after insecticides applied. For P1 farmers, these natural enemies seemed to be present with fewer species on their farms with maximum 4 species in individual farm of 3 farmers. 15 and 11 others of the group pointed out only one and two species respectively occurring on their farms. Meantime, 5 species were regularly seen in each farm of 7 farmers of P2 (Table 46). Most of the farmers agreed with opinion of the higher population of natural enemies were present on-farm the less damage from pests attacked to crops. In spite of this recognition, annually the farmers still used insecticides to control coffee insect pests. Yet the frequency and the amount were different among the systems.

In order to measure the amount of insecticide used, the farmers interviewed were encouraged to recall how much amount of insecticide was used in the past three years. The results were presented in Table 47. The P1 farmers mainly relied on the insecticides to control insect pests. Some growers used insecticide amount with 3 times higher than others did (8.9 liter versus 3.1 liters). The amount averaged 5.2 liters. So much insecticides were applied that negatively affected not only the harmless insects but also surrounding environment and farmers. However, in this case, it was important to follow all labels and others regulation closely in order to minimize possible hazards to non-target groups, said P1 farmers. For the P2 farmers, maybe, those were not faced with the serious problem of pest outbreak, and the abundance of natural enemies as the agents kept insect pests under damage threshold on their farms. Therefore, the insecticides used were lower than P1. The maximum amount was 5.1 liters, minimum of 1.7 liters, and an average of 3.2 liters in the farms of P2. Ranging from 0.9 to 4.6 liters per hectare a year, with an average of 2.0 liters that was the amount used on the farms of P3. The significant differences were found in means of amount of insecticide use.

Reducing insecticides used, including chemical and biological ones, and increasing the methods of integrated pest management in coffee production have been encouraged for the past decade in DakLak (Loang, 1999). But the yields obtained were very low, because of lack of both specific studies and less participation of farmers in farming system research. However, the survey result indicated that the farmers of P_2 and P_3 applied less insecticide than ones in P_1 did, due to not facing with serious problem of pest outbreak. This was as a result of the application of several methods such as regular monitoring pest situation, manual controlling, and protecting natural enemies. Controlling pests by these methods was labor-intensive, but keeping the farmers and environment were beyond danger. And the coffee growers get economic benefit from investment in labor instead of paying for insecticides. But a significant thing of the coffee intercroping system in reducing in insecticide applied contributed to protect human health, to prevent environment degradation from insecticide residues in the air, soil, water and crops. This was one of the factors of sustainable coffee production in the farm level as well as in larger scale.

Table 47. The amount of insecticide used (l/ha/year)

Statistics	P_1	P_2	P_3
Max.	8.9	5.1	4.6

Min.	3.1	1.7	0.9
Mean	5.2	3.2	2.0
SD	1.2	0.9	0.9

Source: Survey, 2002.

Note: P1(n=46): mono-coffee system, P2 (n=46): coffee-durian intercropping system, P3 (n=46): coffee-black pepper intercropping system

In summary, in intercropping systems, the overstory trees played a significant role in retaining moisture and soil nutrients, and moderating the heat and light reaching the coffee plants. Coffee is an understory plant in the farm, and grown well on farms that mimic forest conditions. Intercropping systems provided habitats for natural enemies of insects and microbes that attack coffee, as well as inhibit weeds, either from reduction of light, or from naturally occurring chemicals leaching from the trees or their litter.

6.2 Farm performance

Output is one of the most important indicators to assess the performance efficiency of any agro-ecological systems. It is a primary measure of the relative adaptability of a system or activity in a particular agro-ecological environment. On commercial farms it is an indicator of relative efficiency of resource use and management performance. On non-commercial farms productivity plays a very important role in achieving family sustainability. Production beyond what a family can consume or store or barter becomes irrational or may even be undesirable (McConnell *et al.*, 1997). In the study area, the farms with the cash trees of coffee, durian and black pepper were not large enough to be considered as large commercial family farms or commercial estates. But all main farm products were of for sale, not for family consumption. Type and source of family income were entire cash. Therefore, these farms could be classified as the small independent-specialized family farms as McConnell *et al.* did.

6.2.1 Productivity

Although, the farms were commercially-oriented types specialized on producing main product of coffee, but the secondary products were quite important in total farm income. For the P2 farm type, durian contributed a proportion up to one third of total yearly output value of farm. Meanwhile, black pepper product in coffee-pepper system occupied about 45 percent total outputs in value. The by-products, in spite of with small values, should not be ignored in measuring the productivity of an agricultural system. They contributed to significantly reduce family expenditure for fuel, and organic residue of *leucaena* trees (P3) as the free sources of nutrients. However, in this case the farmers could not estimate the weight of by-products such as firewood, crop residues, and coffee pulp/husk, which were annually harvested. Despite, recognizing a positive role of these products in total family farm income, but the data in form of weight of each was not available for evaluation. Therefore, only yields of main crops in the systems - coffee yield of sole farms, coffee and durian yields of coffee-durian systems, coffee and black pepper yields of coffee-pepper systems - were used to compare the productivity among the systems.

Fortunately, all of the farmers interviewed had recorded almost all the inputs and outputs, particularly yields of the crop trees, of their farms in past five years. The coffee yield in intercropping farms was lower than that of mono-coffee farm. The average of the five- year coffee yields among the systems were found to be 16,082.3 kg of fresh weight per hectare of P1 farms, 13,622.7 kg of P2 farms and 12,347.5 kg of P3 farms. Comparing the coffee yields of P2 and P3 with P1 one showed that those were equivalent to 84.7 percent and 76.8 percent, respectively. This did not mean that the productivity of P2 and P3 were completely lower than P1 one, because besides coffee yield P2 and P3, other products such as durian (P2) and black pepper (P3) contributed a considerable yield to total outputs of the farm. In term of money value, durian and pepper some years contributed higher revenue to total farm income compared to coffee value. That has taken place in the years of poor coffee harvest, or low coffee price, while yield and price of durian and black pepper were quite stable in the past five years.

Table 48. The yield of coffee, durian and black pepper (kg/ha)

Statistics	P1	P2		P3	
	Coffee	Coffee	Durian	Coffee	Pepper
Max.	17,632.0	15,735.0	3,741.3	15,062.3	939.7
Min.	14,242.8	11,067.0	3,372.5	10,270.3	707.3
Mean	16,082.3	13,622.7	3,609.1	12,347.5	911.2
SD	979.8	1,264.6	79.9	1,065.7	32.6

Source: Farmer interview, 2002.

Note: Coffee and durian are fresh weight, pepper is dry weight.

P_1(n=46): mono-coffee system, P_2 (n=46): coffee-durian intercropping system, P_3 (n=46): coffee-black pepper intercropping system

There was a large gap in yield among the P_1 farms, with maximum of 17,632.0 kg and minimum of 14,242.8 kg, or 3,389.2 kg in difference. In the P_2 farms, the grower annually harvested not only coffee but also durian yield. The yield ranged from 11,067.0 to 15,735.0 kg of coffee berries and from 3,372.5 to 3,741.3 kg, with an average of 3,609.1 kg of durian fruits per hectare (approximately 52 kg per tree). The differences of yields amongst the farms in P3 were 4,792.0 kg per hectare for coffee, and 232.4 kg for pepper. The five-year-mean yields of the 46 farms of P3 were identified to be 12,347.5 kg and 911.2 kg per hectare for coffee and black pepper respectively. Those were equal to 11.1 kg per coffee tree and 3.3 kg of dry pepper weight per vine (Table 48).

6.2.2 Stability

Yields of systems indicated the ability of resource use and management among the farms in each coffee system, but those did not show whether there were the significant differences of productivity among the three systems due to having two products in each farm of P2 and P3. Analyzing the stability of each system in terms of yields of the trees was a necessary tool to define the absence or minimization of year to year fluctuation of family income from the farms. The yield stability of the coffee systems had a close relationship with income of the farmers. The farmers interviewed were the smallholders with the family income mainly relied on the farm yields that contributed over 70 percent of total family income of 125 surveyed households (over 90 percent of total). It was said that the instabilization had no adverse impact on the life of the growers, because of an annual surplus to be retained in good year be able to cover deficiencies in poor year. This was generally possible right with farmers of some large commercial family farms or estates. For the small farmholders of the study area, large magnitude of year to year variation in yield might be synonymous with the farmers incurring a debt.

The yield/income fluctuation or stability was most conveniently measured in terms of coefficient of variation, denoted by CV percent. The larger the value of CV percent, the higher the degree of instability of the system (McConnell *et al*., 1997). The Table 49 gives an annual-series set of data of the yield per hectare on each coffee-based farming systems, P1, P2 and P3, for the 5 years 1998 to 2002 of coffee yield, and for the 4 years 1999 to 2002 of durian and black pepper yields. The CV of coffee yield of the P1 farms was calculated as 6.7 percent, of 2.6 times and 3.1 times as high as that of P2 and P3 respectively. This implied that income from coffee yield of the farmers in P1, ignoring the total value of income, was less stable than income of ones in P2 and P3. Likewise, comparison of the CV values for the coffee yield of the farms of P2 and P3 indicated that yield was high as unstable on P2 farms with a CV of 2.6 percent as on P3 farms with a CV of 2.1 percent. Apart from the stable coffee yield, the magnitude of year to year fluctuation in yield varied widely among the trees (crops). The data presented yield of two secondary tree crops, durian and black pepper, in P2 and P3 farms respectively illustrated a higher magnitude of yield fluctuation of durian in comparison with black pepper. The CV values were computed to durian of 2.1 percent and to pepper of 1.8 percent.

Table 49. Measuring yield stability of different coffee systems (kg/ha)

Years and statistic	Average yield				
	P1	P2		P3	
	Coffee	Coffee	Durian	Coffee	Pepper
1998	15,248.5	13,602.3	-	12,213.5	-
1999	17,272.5	13,567.0	3,667.8	12,012.2	901.4
2000	15,720.6	14,142.4	3,627.7	12,548.9	916.8
2001	17,175.4	13,142.4	3,642.5	12,291.0	895.0
2002	14,994.5	13,659.5	3,498.3	12,671.9	931.6
Mean	16,082.3	13,622.7	3,609.1	12,347.5	911.2
SD	1,074.8	355.5	75.7	264.3	16.0
CV%	6.7	2.6	2.1	2.1	1.8

Source: Farmer interview, 2002.

Note: P_1(n=46): mono-coffee system, P_2 (n=46): coffee-durian intercropping system, P_3 (n=46): coffee-black pepper intercropping system

In short, the income on coffee farm of the intercropping coffee was more stable than that of on full sun coffee. And the yield stability might be ranked as follows: $P_3 > P_2 > P_1$. Although the system stability referred to the absence or minimization of year to year fluctuation in yield of tree crops or family income, it could neither show the monthly distribution of family income from the farm, nor how much the family income in a seasonal production. These issues will be mentioned in the following discussions. On the other hand, the stability measure based on CV was unsatisfactory because it ignored information about the structure of data samples and was potentially inefficient or misleading (Mead, 1986).

6.2.3 Time-dispersion

Other property of the system is the time-dispersion. It refers to the degree to which a given production/income is predictably dispersed over time and measures the uniformity of within-year production/income flow (McConnell *et al.*, 1997). For the surveyed farms, a higher level of time-dispersion (or low level of time-concentration) of income was usually desirable for the reasons: (1) indebtedness of small-farm families to the moneylenders or shopkeepers was the serious problem throughout much of the study area. Therefore, the coffee systems, which generated a uniform flow or nearly uniform flow of cash income throughout the year, played an important role in eliminating or reducing such indebtedness of the farmers. (2) The income from farms had a close relationship with yields of the tree crops on farm. The labor requirement for harvesting and other activities related to the supply-flow of family labor. Total labor demand in an annual basis could almost be met by the family labor that was a vital factor of increase in family income of the households.

In order to obtain the data for this calculation, the farmers involved were encouraged to estimate the weight (yield) of each tree crop kind, which was monthly-harvested during the seasonal production (a year). And then the value of family monthly income from the farm production for particular system was computed by multiplying monthly yields with relevant unit prices. The data presented in Table 50 shows the percentage of family income through the farm products, which were different from the systems. With one product (coffee), the P1 monthly income distributed in last quarter of the year. Two outcomes (coffee and durian yields) of P2 farms, the farmers had a 6 month income per year. The durian contributed 34 percent in three months of May, June and July. And 66 percent for the last three-month income came from coffee yield. While in the coffee-black pepper system, coffee yield contributed about 55 percent of income in four months of October, November, December and January. Black pepper provided 45 percent in March and early April.

Table 50. Relative monthly income, relative time-concentration and relative time-dispersion of three coffee systems

Month and statistics	Family monthly income from the farm		
	P_1	P_2	P_3
	--- Percentage of annual total income ---		
January	0	0	7
February	0	0	0
March	0	0	13
April	0	0	32
May	0	5	0
June	0	19	0
July	0	10	0
August	0	0	0
September	0	0	0
October	11	6	7
November	32	20	14
December	57	40	27
Monthly mean	8.3	8.3	8.3
SD	18.0	12.4	11.2
CV %	216.0	148.7	134.6
RTC = CV_{Pi}/CV_{P_1}	1.0	0.7	0.6
RTD = (1-RTC)	0.0	0.3	0.4

Source: Survey, 2002.

Note: i receives a value of 1, 2 and 3

P_1(n=46): mono-coffee system, P_2 (n=46): coffee-durian intercropping system, P_3 (n=46): coffee-black pepper intercropping system

For each system, the coefficient of variation (CV) of its monthly income was shown. The P_1 with only one product, coffee yield, distributed in last three months (last quarter) of a year had the highest coefficient of variation value of 216.0 percent. With income measured on a monthly basis, an relative time-concentration (RTC) index of P1 system and others could be obtained as the ratio of its coefficient of variation (CV) to the coefficient of variation (CV) of 216.0 percent. This resulted in a relative time-concentration (RTC) index of 1.0, and 0.7, and 0.6 for P1, P2 and P3 respectively. It was easy to infer the relative time-dispersion (RTD) of the P1, P2 and P3 as one (1) minus its relative time-concentration (RTC), giving the relative time-dispersion (RTD) values of zero for P1, 0.3 for P2 and 0.4 for P3 (Table 50). Hence, the distribution of income of farm product among the months of a year was quite even in P3 compared to P2, and of course P1 was the lowest monthly income dispersion. This meant that farmers who owned their coffee farms under intercroping systems of coffee-durain, and coffee-black pepper might be freer of indebtedness than farmers of monoculture system. Because P2 and P3 farmers had more chances to get income from other farm products than P1 farmers did.

6.2.4 Performance efficiency or profitability

In order to compare performance efficiency among the systems throughout the economic returns, the inputs and outputs were calculated to identify the money profit of each system during a year production. As addressed, all the study farms are the small independent-specialized family farms with the objective of obtaining high return in terns of money from the products of their farms. So money profit was the most important criterion for measuring the performance of the coffee-based farming systems.

The data demonstrated in the Table 51 was the average numbers in terms of economical values of 46 farms for each system. Those were computed by multiplying all inputs and outputs (yields of coffee, durian, and pepper) with relevant price units, which were the three-year average units (1999-2002) coming from source of an office, namely, DakLak Trade and Tourist Department (2002). The price units of coffee and durian were identified at the farm gate, because of without data of processing to be collected from the respondents. Meanwhile the price of pepper was based on the local market price applied for raw-processed pepper. According to the respondents, the prices of all kinds of inputs and outputs were quite stable. Except the coffee price that sharply dropped to US$ 0.0656 (or VND 1,000) per kilogram of fresh weight in 2002, but averaged US$ 0.118 (or VND 1,800) per kilogram for the past three years.

To better understand about the production efficiency of three groups of farmers in different coffee-based farming systems, farm gross margin (GM), farm net return (NR) and family farm sustainable income were performed. Farm gross margin was computed by simply subtracting total revenue (TR) of each system, which is the sum of all yields of tree crops times their relevant price, with the total variable cost (TVC), including cost of fertilizers, insecticides, fuel for machine, and hired labor.

For farm net return was obtained as farm total revenue subtracted the sum of total variable cost and total fixed cost (TFC) or equal to gross margin (GM) less total fixed cost (TFC), which included the payments for annual land-use tax, machine depreciation and equipment (tool) depreciation.

And family farm sustainable income was calculated by minus the total revenue with total cost, including total variable cost, total fixed cost and total family labor cost.

For a seasonal production (or one year), the average total variable costs were not so much difference among the systems, ranging from US$ 479.7 (P2) to US$ 518.3 (P1). Although, the machines and tools were used to cultivate in various conditions of the certain coffee based-farming system, and relying on the reports of the respondents and direct observation, the depreciation cost of those tools was calculated to every farm in each system. Yet there was too less difference value among the farms as well as the systems. So in order to avoid complex in computation process, and relying on the standard of investment for coffee production (Sung, 1997), the same depreciation value of US$ 229.5 per year has given to all of the farms with size of one hectare (other farm sizes were converted to equivalent unit). It included the machine and other equipment deprecations. Therefore, the total fixed cost (depreciation cots and land use tax) of the three systems paid a similar value of US$ 295.1 per ha per year. And the total cost (TC) consisted of US$ 1,126.8 per hectare per year for P1 farms, US$ 1,094.8 for P2 farms and US$ 1,146.0 for P3 farms.

Table 51. Assessing performance efficiency of each system (US$/ha)

	Item	P1	P2	P3
A	Return			
	Coffee	1,898.2	1,607.9	1,457.4
	Durian	-	828.3	-
	Black pepper	-	-	1,195.8
	Total gross return	1,898.2	2,436.2	2,653.2
B	Total cost = ($B_1 + B_2 + B_3$)			
B_1	Variable costs	518.3	479.7	490.3
B_2	Fixed cost	295.1	295.1	295.1
B_3	Family labor cost	313.4	320.0	360.6
	Sum of costs = (**B_1** + **B_2** + **B_3**)	1,126.8	1,094.8	1,146.0
C	Gross margin (A - B_1)	1,379.9	1,956.5	2,162.9
D	Farm net return (C - B_2)	1,084.8	1,661.4	1,867.8
E	Family farm sustainable income (A - B)*	771.4	1,341.4	1,507.2

Source: Survey, 2002.

* Excluding family labor cost

Note: US$ 1 = VND 15,250 in 2002

P_1 (n=46): mono-coffee system, P_2 (n=46): coffee-durian intercropping system, P_3 (n=46): coffee-black pepper intercropping system

Average gross margin of the 46 farms, belonging to mono-coffee system (P1), was US$ 1,379.9 per hectare per year. This value calculated to the farms of P2 was US$ 576.6 higher than that of P1 and US$ 206.4 lower than that of P3. Alternatively, in the certain condition of the study area in the recent years, cultivation of coffee under intercropping systems of coffee - durian, and coffee - black pepper have given higher gross margins, or financial profit, than mono-coffee farms. But this level of income was not yet stable over the long term because it made no provision for replacing capital equipment as this wore out. So it is better to measure the farm net return, which would be more stable over long time than gross margin, due to eliminating depreciation charge from gross margin value. The farm net returns among the systems ranged from US$ 1,084.8 to US$ 1,867.8 per hectare per year. The farm net return of P3 was US$ 783.0 and US$ 206.4 per hectare higher than P1 and P2 respectively, and P2 farm net return of US$ 1,661.4 compared to US$ 1,084.8 per hectare of P1. Finally, concern should be paid with family farm sustainable income from the farm in which subtracted the family labor cost from the income. For this, if a farmer owns one hectare of 10 year-old coffee farm, he or she will earn approximately US$ 771.4 a year in net profit after investing about US$ 1,126.8 (case of mono-coffee farm: P1) for one-year production. Data in row E in the Table 51 shows that income of P3 farmers was higher than that of P2 and P1, with the value of US$ 771.4 and US$ 1,341.4 and US$ 1,507.2 per hectare for P1, P2 and P3 respectively (Table 51). Note that this is clearly a narrow use of the word "sustainable". It said nothing about the possible loss of sustainability due to degradation of land, environment, falling terms of trade.

In general, coffee cultivation under intercropping systems generated several benefits to the growers in terms of ecological aspect and economic aspect. For the ecological angle, intercropping reduced the damage of extreme factors of climate on the performance and yield of tree crops in the system. Moderating microclimate such as air temperature, and wind speed on farm to create a favorable condition for processes of cross-pollination and photosynthesis that was one of the several advantages of the P2 and P3 farms brought to the tree crops in severe condition of the study area. In addition soil surface underneath of the canopies of coffee and others was dried more slowly than soil exposed to the sun and harsh wind in the mono-farms. This was clearly manifested by the data of soil moisture measured and total water supply for the farms in dry season. Therefore, the coffee intercropping systems in the forms of coffee-durian, and coffee-black pepper played very significant roles in properly using and protecting the water resources for sustainable agriculture production, especially for coffee production, of the province. Other element of ecological aspect that intercropping farm was able to generate was habitat diversity for many species of natural enemies that kept pest insects of farm in check. So it was not necessary to use so much insecticide to prevent the tree crops from hand of insects, that protected the health of farmers as well as environment.

For the economic aspect, coffee production in the forms of coffee-durian system, and coffee-black pepper system brought income diversity to the farmers, because of more farm products harvested. Besides main product, coffee yield, the secondary products such as durian fruit in P2 farms and black pepper yield of P3 farms were the sources of the considerable incomes contributed to the total farm income of farmers. On the other hand, the diversity and wide range of income in the months of a year from farm products have brought free of debt to the producers, particularly small farm-holders who were often suffered from credit shortage in the lean period. Apart from that, the intercropping farms had a crucial role to play in reducing risk for the farmers in the case of bad harvest of coffee or low price of main product in the market. Because the loss of one product was compensated by other in the system, so it kept the farmers in safety from falling down to the bottom. One more important element, which intercropping coffee farms given the producers was the total farm income (gross return) from the farms. Although, it was said that income from inter-coffee farms was often lower than that of from mono-farms, but in the certain condition of the study area indicated that intercropping coffee with durian or black pepper got higher return than one from farm product in momo-farms.

6.3 Selecting the best coffee farms

With the purpose of identifying some best farm practices, which are economically viable and good in farm management, and using these farms as the demonstration farms for learning process of farmers, the farm management practices and gross margin (GM) of individual farm were integrated and computed. Firstly, the gross margins of the farms in certain system were grouped into small groups.

Secondly, t-test was used to test the significant differences of the means of each pair among the groups. If there was significant difference between groups, the group, which contained the highest mean of gross margin value, was used to select the best farm practices in term of money value. However, in order to sustain coffee production, the farms, which did not heavily depend on the chemical inputs, were prioritized for choosing. In addition, the inputs and outputs of the selected farm were compared with the results of previous studies carried out in the province and region in order to make sure that the selected farms have the potential for sustainable production.

6.3.1 Some standards and results of previous studies in coffee production

As stated in the rationale of study, there were so many studies on coffee cultivation in Vietnam and the central highlands' provinces of DakLak, Gia Lai, Kon Tum and Lam Dong as well. They have come up with the results and built up the standards for coffee cultivation in the central highlands' condition. But all of the studies had been implemented in the mono-coffee farms at the research stations and focused on increase in coffee yield as high as possible without concerning to the sustainable production of the system.

Following is the results of some previous researches. For robusta coffee farm should be designed with density of 1,110 trees per hectare or 3 m x 3 m in spacing, 2.0 to 2.4 meters in tree height, and pruned two times at after harvesting and in April of the yearly production. The terraces and basin in each coffee tree were made to anti-soil surface erosion in rainy season. Yearly irrigation should be started in January/February, with water amount of surrounding 600 m^3 per time per hectare, and 20-25 days in interval between two applications. The basin irrigation (under tree irrigation) was better than overhead one (sprinkler) because of less amount of water need (Bau, 1999 and Sung, 2001).

For fertilizers, the application of 379.8 kg N, 172.7 kg P_2O_5 and 415.2 kg K_2O to one hectare of coffee monoculture farm were the best dosages to obtain high economic return. And these amounts should be divided to apply 5 times for N, 2 times for P_2O_5, and 4 times for K_2O in different months of year (Y Kanin *et al.* 2001 and

Tu, 1998). Nam (1999) stated that application of at least 250 kg N,100 kg P_2O_5 and 230 kg K_2O for one hectare of coffee has got 13,000 kg of fresh yield. Increasing every 4,300 kg of coffee yield should add more 70 kg N, 20 kg P_2O_5 and 70 kg K_2O to meet the nutrient demand of the trees. And she also suggested that nitrogen application was 4 times in February, May, June/July and September/October, phosphorus: 2 times of application in May and September/October and potassium: 3 times of application in May, June/July and September/October should be done. This schedule of fertilizer application has also been proposed by Lich since1997. But phosphorus was suggested providing to farms in May and August with the same dosage of 50 percent of total for each time. Meanwhile, NAFED (1998) generally suggested to use the optimal amount of fertilizers of 300 kg N, 120 kg P_2O_5 and 300 kg K_2O to apply for one hectare of sole coffee farm with yield of about 13,000 kg of fresh beans. Increasing every 4,300 kg of yield should be plus of 70 kg N, 20 kg P_2O_5 and 90 kg K_2O to total amount above. Truc *et al.* (1997) has come up with a conclusion of bio-fertilizer research for coffee that application of 2,667kg bio-fertilizers in combination with 193 kg N, 20 kg P_2O_5 and117 kg K_2O per year obtained coffee yield higher than 300 kg N, 100 kg P_2O_5 and 250 kg K_2O applied (16,290 kg of coffee compared to 13,630 kg). All the authors suggested that nitrogen fertilizers should be extracted about 20 percent of total to apply in dry season, the rest was combined with potassium to apply in the wet season with the same dosage for each time. For phosphorus should be divided into two equal parts to add in the months indicated above.

Many coffee researchers have agreed that organic fertilizers, crop residues and coffee pulp/husk should be applied as much amount as possible in order to provide more nutrients for the trees, maintain soil productivity and mulch soil surface in dry season (Loan *et al.*, 1995). So designing the organic matter based-systems played very important role in sustaining coffee production in the local. Because much of the modern coffee systems were based on the design of agricultural eco-systems that subsidize the external inputs of insecticides and synthetic fertilizers, which may bring potential risks in forms of destroying soil properties, environment, and loosing income when prices of these inputs increase.

6.3.2 Analyzing gross margin, inputs and outputs of farm in each system

The another factor related to economic aspect was analyzed farm gross margin to look for the farms with the highest gross margin during seasonal productions. For the all systems, the gross return was calculated by multiplying the crop yields of each farm with the relevant price unit. The total variable cost comprised of costs of irrigation water, all types of fertilizers, insecticide and hired labor invested in one year. The gross margin resulted from the gross return less the variable cost.

The mono-coffee system

The gross margins of the 46 farms of the mono- coffee system were grouped into 5 groups of (i) less than US$ 1,255; (ii) from US$ 1,255 to 1,335; (iii) from US$ 1,335 to 1,415, (iv) ranging from US$ 1,415 to US$ 1,495; (v) and over US$ 1,495. The data in the Table 52 shows that 27 of 46 farms of the coffee monoculture system gave the gross margin less than US$ 1,415 per hectare per year. Of which 9 farms had gross return from US$ 1,335 to 1,415. The value of US$ 1,415 to 1,495 with an average of US$ 1,452.4 was found out in 14 farms. Meanwhile the gross margin of over US$ 1,495 (an average of US$ 1,546.2) was found out only in 5 farms of the system (Table 52). The differences between means of each pair of groups were found out at 1 percent significant level. That means that the performances of 5 farms obtained the gross margin over US$ 1,495 were more efficiency than farms of other groups. So these farms were prioritized for selecting the best farm practices.

Table 52. Gross margin groups and statistics results among the farms in the mono-coffee system (P1)

Gross margin groups (US$)	Number of farms	Mean (US$)	SD
< 1,255	8	1,185.9	105.7
1,255-1,335	10	1,287.1	29.0
1,335-1,415	9	1,387.1	24.9
1,415-1,495	14	1,452.4	24.4
> 1,495	5	1,546.2	13.5

Table 53. Gross margins of five selected farms of mono-coffee system (P1)

Farm number	Gross return	Total variable cost	Gross margin
		--- US$ per hectare ---	
8	2,081.5	502.8	1,578.4
28	2,073.7	499.5	1,574.1
14	2,074.9	524.0	1,550.9
11	2,071.0	532.8	1,538.2
38	2,019.0	489.8	1,529.2
P1 mean	1,898.2	518.3	1,379.9

Table 53 shows that all the farms selected as the best farms in terms of money value income. Because those brought the highest gross margins to the growers, while the variable costs in the level of the whole system average. However, for the farmers the best alternative was always the farms, which could produce the greatest returns. If ignoring other aspects such as sustainability, environmental health, social aspect, technology, etc., the attention only pays to farm productivity in term of money value. The farm number 8, 28, 14, 11 and 38 with gross margins of US$ 1,578.4; US$ 1,574.1; US$ 1,550.9; US$ 1,538.2 and US$ 1,529.2 respectively should be ranked in the top of priority for selections.

As indicated in previous parts, the three systems, in general, were heavily depended on the input sources, especially on external inputs, to achieve the high yield of tree crops. But in this part, the individual farm within the system will be compared together in terms of inputs used and outputs obtained.

The data in the Table 54 indicates the characteristics and management practices of the five selected-farms of 46 surveyed farms of the mono-coffee system. Looking at the farm size of the five farms, it was easy to recognize that there was no significant correlation between farm size with coffee yield or gross margin at 10 percent level. That means that the coffee yield or gross margin did not depend on farm size, but depended on the farm management practices. Therefore, to gain high coffee yield, the farms were sufficiently provided not only water in dry season, but also nutrients in the form of synthetic and organic fertilizers. Particularly, looking at all farms in this group, it was easy to realize that the amounts of chemical fertilizers applied were less than that of the whole system (46 farms) in average. In contrast, the organic substances were over. If analyzing these farms in the aspect of input levels, they can be qualified as the best farms for coffee monoculture system. However, based on the viewpoint of sustainable production, the farm-number 11 had high potential for selecting, due to lower dependence on chemical fertilizers applied than others.

One main problem of the farms of P1 was the use of so much insecticide, with an average of 5.2 liters per hectare per year, to control insect pests on farm. These chemical agents had the appeal of offering the farmers a way to rid their fields once and for all organisms that continually threatened crops and literally ate up their profit (Gliessman, 1998). But this promise has proved to be completely false. Insecticides can dramatically kill pest populations in short term, but for long term this solution is not a good way for controlling pests. So the solution of management rather than control pests on farm is possible application in coffee production, and only using insecticides in the necessary cases.

In short, relying on the results from analyzed input and output levels in the relationship with gross margin of each farm in the system, the farm number 11 should be the first choice of the coffee growers. The reason for this selection is that this farm could meet the two basic requirements: low dependence upon external inputs and high gross margin. Nevertheless, the other farms of this group are also the potential alternatives in order to meet the various alternatives of the farmers, due to the farm management practices of the five farms met the standards and suit with the previous study results of coffee production in DakLak. An attention should be paid is development the methods to manage insect pests on farm to reduce the amount of insecticide use for securing the health of farmers, tree crops and environment involved.

Table 54. Characteristics and farm management practices in a production year of five selected farms of monoculture system

Indicator	Farm number				
	8	28	14	11	38
Farm size (ha)	0.9	1.3	2.2	1.0	1.8
Density (tree/ha)	1,110	1,110	1,110	1,110	1,110
Water irrigation (m^3/ha/time)	610	590	590	620	600
Irrigation interval (day)	23	22	22	23	23
N application (kg/ha/yr.)	321	309	312	290	300
Month of N application*	2; 5; 7; 9; 10	2; 5; 7; 9; 10	3; 5; 7; 9; 10	2; 5; 7; 9; 10	3; 5; 7; 9; 10
P_2O_5 application (kg/ha/yr.)	118	91	120	95	102
Month of P_2O_5 application*	5; 8	5; 8	5; 8	5; 8	5; 8
K_2O application (kg/ha/yr.)	315	310	345	290	302
Month of K_2O application*	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10
FYM (kg/ha/yr.)	900	1,800	1,200	1,000	600
Coffee pulp (kg/ha/yr.)	1,600	1,900	1,500	2,000	1,300
Bio-fertilizer (kg/ha/yr.)	500	900	600	1,000	500
Insecticide use (l/ha/yr.)	6.1	4.0	6.4	3.1	4.8
Month of pruning*	1; 4	1; 4	1; 4	1; 4	1; 4

Note: * refers to month of year: 1=January, 2=Febuary, 3=March, 4=April, 5= May, 6=June, 7=July, 8=August, 9=September and 10= October

FYM and bio-fertilizer were applied in May; Coffee pulp was returned to farm in February

The coffee-durian intercropping system

As the coffee monoculture system, the gross margins of the 46 farms of the coffee-durian intercropping system were divided into 6 groups of (i) less than US$ 1,860; (ii) from US$ 1,860 to 1,920; (iii) from US$ 1,920 to 1,980; (iv) ranging from 1,980 to 2,040; (v) from 2,040 to 2,100; (vi) and over US$ 2,100. Of which 19 of 46 farms yielded the annual gross margin of less than US$ 1,920 per hectare. 9 farms obtained gross margin from US$ 1,920 to 1,980 per hectare with an average of US$ 1,947.8 per hectare. 4 farms gave the value raging from US$ 1,980 to 2,040. Meanwhile the yearly gross margin of over US$ 2,100 (an average of US$ 2,146.8) was found out only in 6 farms of the system (Table 55). The differences between means of each pair of groups were identified at 1 percent significant level. That means that the performances of 6 farms in the group obtained the gross margin over US$ 2,100 were more efficiency than other groups. So these farms should be prioritized for selecting the best farm practices of its system.

Table 55. Gross margin groups and statistics results among the farms in the coffee-durian system (P2)

Gross margin groups (US$)	Number of farms	Mean (US$)	SD
<1,860	12	1,779.8	55.3
1,860-1,920	7	1,887.6	16.4
1,920-1,980	9	1,947.8	18.8
1,980-2,040	4	2,017.1	22.7
2,040-2,100	8	2,074.0	21.5
>2,100	6	2,146.8	31.3

In terms of farm profit returned to the farmer, the gross margin is one of the important indicators to measure the performance efficiency of the farm in a year production. With the annual gross margins were US$ 2,190.0; US$ 2,175.9; US$ 2,168.2; US$ 2,148.1; US$ 2,137.4 and US$ 2,113.7 for farms number 1, number 25, number 15, number 36, number 11 and number 30 respectively. These farms attained the highest gross margins in comparison with the rest farms and with the gross margin value average (US$ 1,956.5) of the whole system (Table 56). So those should be the potential farms for selecting the best farm practices of its system.

Table 56. Gross margins of six selected farms of coffee-durian intercropping system

Farm number	Return			Total variable cost	Gross margin
	Coffee	Durian	Gross		
	--- US$ per hectare ---				
1	1,826.3	839.1	2,665.4	475.4	2,190.0
25	1,802.4	850.4	2,652.8	476.9	2,175.9
15	1,851.8	820.3	2,672.1	503.9	2,168.2
36	1,775.5	853.1	2,628.6	480.5	2,148.1
11	1,846.8	855.9	2,702.7	565.3	2,137.4
30	1,857.2	823.0	2,680.2	566.5	2,113.7
P2 mean	1,607.9	828.3	2,436.2	479.7	1,956.5

Similarly, the mono-coffee system, the vital inputs of the intercropping system also included water, insecticides and fertilizers, the key outputs of the system were the yields of coffee and durian. As noted, the main goal of this section is to look for the farms with appropriate input applied, but high output and profit obtained. In any cropping systems, fertilizers, not only inorganic types but organic ones also, are always the effective tools to maintain the high productivity, and soil fertility of the system for long term production. But how fertilizers to be used in order to meet crop nutrient requirement and to prevent environmental degradation, including soil environment that are always the questions of the agronomists, environmentalists and farmers involved. The coffee - based farming system also needs so much nutrient in the forms of fertilizer types and organic materials, to satisfy the crop nutrient demand

and to compensate the amount to be lost by leaching, volatilizing, and removing of harvested yields. And other elements of water and insecticide applied that are the tools can not be ignored in coffee cultivation.

Looking on farm management practices of the six farms in Table 57, all of them could be used as the demonstration farms for learning process of the farmers in the local. In the individual farm, which produced quite high yields of coffee (over 15,00 kg) and durian (grater than 3,500 kg) compared to the average ones of the whole system. The chemical materials applied to one hectare per year at the level of others. Meanwhile the organic materials paid more attention, with the large amounts of FYM, coffee pulp/husk and bio-fertilizer. Those contributed important roles in maintaining and improving soil structure, soil fertility, and soil water holding capacity, and increasing chemical fertilizer-use efficiency of the tree crops. The appropriate application of the external input keeps the farmer beyond vulnerability to supply shortages, market fluctuations and price increases.

Water has been the potential constraint and a main yield-limiting factor of coffee production. So the question of how to use reasonably water in order to meet the trees demand as well as to protect the water resources for long term production that is a concern not only of coffee producers but also of the provincial authorities. Looking at the farm number 11, it is easy to realize that the farmer has oversupplied water of 300 m^3 in comparison with others. Meanwhile, the outputs were not higher that that of others. Therefore, if the amounts of water irrigation and insecticide application are adjusted to the levels of the whole system mean (Table 57). The farm should also be selected as the potential farms for meeting the diversification of farmers' practices (farmers' choices).

In short, combining the selective standards of inputs, and gross margin of individual farm in the system. Relying upon some indicators of sustainable agricultural production- do not or less depend on external, purchased inputs (non-renewable inputs), make intensive use of locally available and renewable resources, and have benefit (Gliessman, 2001) - the six farms are the best choice because of meeting these criteria.

Table 57. Characteristics and farm management practices in a production year of six selected farms of coffee-durian system

Indicator	Farm number					
	1	25	15	36	11	30
Farm size (ha)	1.2	0.8	1.5	2.4	1.3	1.0
Coffee density (tree/ha)	1,110	1,110	1,110	1,110	1,110	1,110
Durian density (tree/ha)	69	69	69	69	69	69
Water irrigation (m^3/ha/time)	590	600	600	590	930	610
Irrigation interval (day)	24	24	24	24	25	25
N application (kg/ha/yr.)	312	298	285	280	240	288
Month of N application*	2; 5; 7; 9; 10	2; 5; 7; 9; 10	2; 5; 7; 9; 10	3; 5; 7; 9; 10	3; 5; 7; 9; 10	2; 5; 7; 9; 10
P_2O_5 application (kg/ha/yr.)	103	86	90	95	68	84
Month of P_2O_5 application*	5; 8	5; 8	5; 8	5; 8; 10	5; 8	5; 8
K_2O application (kg/ha/yr.)	280	284	302	300	245	297
Month of K_2O application*	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10
FYM (kg/ha/yr.)	800	500	1,000	500	3,200	3,000
Coffee pulp (kg/ha/yr.)	2,600	2,400	2,800	2,500	5,500	2,500
Bio-fertilizer (kg/ha/yr.)	450	400	1,000	700	600	1,000
Insecticide use (l/ha/yr.)	2.8	4.1	4.5	3.2	5.1	3.1
Month of pruning*	1; 6	1; 4	1; 6	1; 6	1; 4	1;4

Note: * refers to month of year: 1=January, 2=Febuary, 3=March, 4=April, 5= May, 6=June, 7=July, 8=August, 9=September and 10= October

FYM and bio-fertilizer were applied in May; Coffee pulp was returned to farm in February

The coffee-black pepper intercropping system

The gross margins of the 46 farms of the coffee-durian system were split into 5 groups of (i) less than US$ 2,090; (ii) from US$ 2,090 to 2,170; (iii) from US$ 2,170 to 2,250; (iv) from US$ 2,250 to 2,330; (v) and over US$ 2,330. Most of the farmers (25 of 46 farmers) said that they annually earned less than US$ 2,170 from their farms in terms of gross margin value. Meanwhile the yearly gross margin of over US$ 2,330 (an average of US$ 2,431) was found out only in 4 farmers of the system (Table 58). Two-tailed tests for differences between means of each pair of groups were found out at 1 percent significant level. That meant that the performances of 4 farms obtained the highest gross margin over US$ 2,330 were more efficiency than other groups. So the farms were prioritized for selecting the best farm practices.

Table 58. Gross margin groups and statistics results among the farms in the coffee-black pepper system (P3)

Gross margin groups (US$)	Number of farms	Mean (US$)	SD
< 2,090	11	2,026.6	74.6
2,090-2,170	14	2,131.0	21.9
2,170-2,250	12	2,196.0	20.1
2,250-2,330	5	2,281.5	30.1
> 2,330	4	2,431.0	59.3

In terms of economic return or gross margin of a farm in one-year production, the farms number 29, and 3 obtained the highest values with US$ 2,481.6 per hectare and US$ 2,461.8 respectively. While the total variable costs (US$ 475.0 and US$ 476.7) of the two farms were at the lower level of an average value (US$ 490.4) of the whole system. Only farm number 24 was invested total variable cost over average level of the 46 farms of the system. However, this farm brought so high return to the farmer in a year of production (Table 59). Therefore, relying on the economic aspect of gross margin, these farms of group were good enough in terms of farm profit return for selecting the best farm practices in the coffee-black pepper system.

Table 59. Gross margins of four-selected farms of coffee-black pepper intercropping system (P3)

Farm number	Return Coffee	Return Pepper	Return Gross	Total variable cost	Gross margin
	--- US$ per hectare ---				
29	1,755.9	1,200.7	2,956.6	475.0	2,481.6
3	1,731.2	1,207.3	2,938.5	476.7	2,461.8
24	1,777.8	1,209.3	2,987.1	571.6	2,415.5
39	1,670.0	1,178.3	2,848.3	492.9	2,355.4
P_3 mean	1,457.4	1,195.8	2,653.2	490.4	2,162.8

Likewise, the two systems stated above, in the four-selected farms, the farms number 29, and 3 and 24 could be considered to be the best farm practices in terms of gross margins obtained. Because those got the higher gross margin than that of farm number 39 did. For the input aspect, the amounts of water, insecticide and chemical fertilizers application were found out at surrounding level of the average amounts (574 m^3, 2 liters, 261 kg N, 76 kg P_2O_5, and 269 kg K_2O, respectively) of the whole system. On the other hand, the organic materials, consisting of farmyard manure, coffee pulp/husk, and bio-fertilizer, were paid attention to incorporate into the farms with quite large amount. This generated a good condition in conserving soil productivity for long term production (Table 60).

Therefore, the four farms above should be selected as the best farm practices and could be used them as the demonstration farms for learning process among the farmers in the studied village as well as others. However the priority should be given to the farms that brought the highest gross margins and used under the above category appropriate input levels, those were farm number 29, number 3 and number 24.

Table 60. Characteristics and farm management practices in a production year of four selected farms of coffee-black pepper system

Indicator	Farm number			
	29	3	24	39
Farm size (ha)	1.0	1.3	1.0	2.0
Coffee density (tree/ha)	1,110	1,110	1,110	1,110
Pepper density (tree/ha)	278	278	278	278
Water irrigation (m^3/ha/time)	590	570	570	590
Irrigation interval (day)	26	25	27	26
N application (kg/ha/yr.)	268	267	259	255
Month of N application*	2; 5; 7; 9; 10	2; 5; 7; 9; 10	3; 5; 7; 9; 10	2; 5; 7; 9; 10
P_2O_5 application (kg/ha/yr.)	95	78	69	92
Month of P_2O_5 application*	5; 7; 9	5; 7; 9	5; 8	5; 7; 9
K_2O application (kg/ha/yr.)	254	278	266	312
Month of K_2O application*	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10	5; 7; 9; 10
FYM (kg/ha/yr.)	1,000	800	1,400	1,000
Coffee pulp (kg/ha/yr.)	4,100	4,100	3,300	5,500
Bio-fertilizer (kg/ha/yr.)	700	800	2,200	900
Insecticide use (l/ha/yr.)	2.7	1.0	1.3	1.5
Month of pruning*	1; 4	1; 4	1; 4	1; 4

Note: * refers to month of year: 1=January, 2=Febuary, 3=March, 4=April, 5= May, 6=June, 7=July, 8=August, 9=September and 10= October

FYM and bio-fertilizer were applied in May; Coffee pulp was returned to farm in February

In brief, based on the discussions above, the 5 farms, namely, farm numbers 8, 28, 14, 11 and 38 should be considered as the potential farms for sustainable coffee production under monoculture system. The 6 farms with the manes of farm numbers 1, 25, 15, 36, 11 and 30, which belong to the coffee-durian intercropping system, could be used as the demonstration farms for learning process of the farmers. However, farm number 11 of this system should be adjusted at the level of an average of 46 farms of the system. For 4 farms of coffee-black pepper intercropping system named farm numbers 29, 3, 24 and 39 should be selected as the best farm practices of this system. Therefore, depending upon the certain condition of farm and family that the farmers can choose the demonstration farms, which suit with their circumstances, to apply in production.