

Agro-Forestry Systems in Dak Lak Province: Ecological Impacts and Economic Effects

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ABSTRACT

In 2001 and 2002, we surveyed, evaluated, and classified some coffee-based agroforestry systems in the Daklak province. These findings show:

In coffee-based agroforestry systems it includes other multi-purpose crops such as cashews, peppers, and muong den that are included with the coffee crop. This method is not only protect coffee crop, but also offer remarkable benefits for farmers.

This system is highly sustainable because, the average profits increased, over a three year period, (1999, 2000 and 2001), from 1.194 to 2.472. Although coffee prices in 2001 were low, the new coffee-based agroforestry method achieved higher profits than the old coffee monoculture system. For example the profits increased from 1.089 to 6.42, thus helping farmers overcome many difficulties and it increased their personal wealth.

In order to develop an effective coffee-based agroforestry system, we should develop a method to educate the farmers on new technologies, support their initial capital investments, developing new strategies in research, forecast new markets, and develop markets for agroforestry products.

1. Background

In both theory and practice, agro-forestry systems that allow for product diversification and support ecology have proved more socio-economically and environmentally sustainable compared to monoculture systems. Product diversification is a fundamental factor in improving the stability of farmers' incomes and for enhancing productivity even when agricultural product markets change unfavorably..

The research on “*Types of Agro-Forestry in Dak Lak Province and the Economic Effects of Coffee-Based Agro-Forestry Systems*” is meant to provide an overview of agro-forestry as practiced in Dak Lak province and a scientific framework for evaluating and suggesting effective agro-forestry types for dominant farming systems.

2. Research Objectives, Subjects and Scope

2.1. Research Objectives

- To identify and classify existing agro-forestry systems in Dak Lak province.
- To determine economically and environmentally sustainable agro-forestry systems.

2.2. Research Subjects and Scope

Research subjects: include all agro-forestry systems (both agriculture-based and forestry-based). In this research, coffee-based agro-forestry systems including (1) coffee and durian, (2) coffee and pepper, (3) coffee and cashew, and (4) coffee and *Crotalaria Striata* are paid much attention in order to evaluate economic effects and ecological impacts.

Study site: all agro-ecological zones in Dak Lak province

Research duration: from 1999 to 2001

3. Research Contents and Methods

3.1. Research Contents

- To survey all existing agro-forestry systems in Dak Lak province and to classify them.
- To evaluate the economic effects of coffee-based agro-forestry systems.
- To survey the impacts of agro-forestry systems under different agro-ecological conditions.

3.2. Research Methods

3.2.1. Survey and Data Collection Methods

- Taking sampling surveys and collecting data from related organizations, interviewing farm/garden owners, and making direct observations and measurements in the fields.

- Criteria for selected farms: the farm area is more than 0.5 hectare, the mature growth of trees is equal, and it is being well-maintained. The farms used for comparisons have the same soil conditions, climate, planting years, tree density, up-keep, etc.

- Sample size: Preliminarily surveyed all agro-forestry systems in Dak Lak province. Two standard and systematic agro-forestry types for each prevalent system of agro-forestry in

Dak Lak will be chosen to further evaluate the socio-economic effects and environmental impacts.

3.2.3. Research Index Group

- Soil nutrients: Determined using methods introduced by Institute of Soil and Fertilizer.
- Soil moisture: Measured from the 0 - 30 cm soil layer at two points of time: before watering and 10 days after watering. Soil moisture is calculated by the weigh method (%).
- Economic effects:
 - + Gross return = Yield/hectare x Price
 - + Total variable cost is the value of all inputs, including variable cost, fixed assets discount and opportunities cost.
 - + Net income = Gross return – Total variable cost

4. Research Results

4.1. Classification of Agro-Forestry Systems

Classification of agro-forestry systems is considered an important initial step in research on agro-forestry systems. Preferential groups are subsequently selected for surveys and put into practice.

Types of agro-forestry can be classified according to their components, their lay-out, or their purposes. In terms of system components, these can be seen as follows: trees with crops, trees with pastures and livestock, trees with insects or fish, and forestry with other subordinate components. According to this classification system there are eight types of agro-forestry practiced in DakLak province (Table 5.1).

Types of agro-forestry can also be categorized in terms of the spatial and temporal layouts of their components.

- + Temporal layouts: In these types of agro-forestry, trees and crops are rotated.

Table 1: Dominant Agro -Forestry Systems in Dak Lak Province

Type	Characteristics	Components	Advantages	Remarks
1. Traditional swidden	Plants grow naturally during the fallow period	- Cash crops, upland rice - Secondary forest	-Recover soil fertility -Increase secondary products like fire wood, non-timber forest products	Suitable for ethnic people farming in traditional ways
2. Improved Traditional swidden	Trees are planted before or during the fallow period, secondary forests are maintained instead of slashing and burning entirely	- Cash crops, upland rice, legumes - Fruit trees - Secondary forest	-Increase secondary products -Shorten fallow period - Strengthen the farming length of over ten years	Considered to be a dominant trend because of the soil limit
3. Taungya	Short-day crops and perennial trees are intercropped in the forest land	Cash crops or coffee are intercropped with trees	- Diversify products - Early income from the forest land	Require a large small investment
4. Planting in Rows	Mainly trees planted on slope land	Trees, <i>Crotalaria striata</i> (yellow flowers), <i>Tephrosia candida</i>	- Improve soil - Erosion control - Increase biomass	Applied to large areas, slope land and windy areas
5. Multi purpose timber, and various canopies	Various trees are planted everywhere	Coffee or cocoa and fruit trees, trees for timber	- Increase products - Soil protection - Shade - Block wind	Applied to the areas with intensive capital and significant farming activity; very popular
6. Garden	Various trees, cash crops	- Fruit trees - Cash crops	- Increase products - Soil protection - Shade - Block wind	Applied to the areas with high population density
7. Forest - Husbandry - Pasture	Animals raised under leaf canopies	Cows, goats, bees raised in the forest, rubber gardens or coffee gardens	- Diversify products - Shade	Require a large capital and labor investment; very popular
8. Garden - Pond - Husbandry	Animal husbandry can be carried out in this type of arrangement	Fruit trees, industrial trees, cash crops, livestock, and poultry	- Diversify products	Applied to farms

+ Spatial layouts: This is a combination of trees and crops planted in the same area.

Although the classification of agro-forestry systems is complex and diverse, based on the level of technological development, the main tree systems, and their contributions to the agriculture structure of the area, we may group the systems into the following three main types:

- + Perennial tree-based agro-forestry systems
- + Annual crop-based agro-forestry systems
- + Agro-forestry systems with livestock

In the diversified agro-forestry systems, the high-income generating systems most strongly developed by local farmers are coffee based systems; timbers with upper canopies are economic trees that bring direct income to farmers. Due to the reduction of land and the need to increase income from coffee monoculture systems, the introduction of multi-purpose timbers into these systems is becoming a prevalent trend and shows multifarious benefits in practice. Dominant timbers include fruit trees, high value trees such as cashew, pepper (clinging to *Black Cassia*, 'Long mut', *Leucaena Leucocephala*), cinnamon, timber trees such as *Black Cassia*.

4.2. The Economic Effect of Agro-Forestry Systems

Due to limited research time, we only focus on evaluating the economic effects of coffee-based agro-forestry systems. The results of surveys show that economic effects are a determinant for local farmers in selecting modes of investment.

4.2.1. Types of Coffee-Based Agro -Forestry

System	Space (m)
Coffee	3 x 3m
Coffee + Durian	Coffee: 3 x 3m Durian: 9 x 12m, 9 x 15 m, 9 x 9 m
Coffee + Pepper (clinging to <i>Black Cassia</i>)	Coffee: 3 x 3m Pepper: 3 x 6m, 6 x 6 m
Coffee + Pepper (clinging to <i>Leucaena Leucocephala</i>)	Coffee: 3 x 3m Pepper: 6 x 6m, 6 x 9 m
Coffee + Cashew	Coffee: 3 x 3m Cashew: 6 x 9m, 6 x 6 m
Coffee + muong den	Coffee: 3 x 3m Cashew: 6 x 12m, 9 x 12m

In general, economically valuable trees, such as those which provide shade and block wind are developed at the farm and household levels; meanwhile, some kinds of timber trees like *Black Cassia* are almost all planted in plantations.

4.2.2 The Investment into Coffee-Based Agro-Forestry Systems

Table 3. Levels of inorganic fertilizer and water for agro-forestry systems

System	Fertilizer (pure kilogram/hectare)			Water (m ³ /hectare)
	N	P ₂ O ₅	K ₂ O	
Coffee	400	150	350	3.000
Coffee + Durian	480	200	430	2.500
Coffee + Pepper	450	120	320	3.000
Coffee + Cashew	280	100	220	2.000

In some first years, coffee monoculture systems need a large amount of capital to invest seedlings, fertilizers, and the cost of labor planting. Intercropping with durian or pepper also requires another considerable amount of capital to buy seedlings and materials - therefore, these types of systems are often used by households with the large capital. In the yielding years, trees intercropped with coffee in agro-forestry systems mainly use fertilizers and water together. Correspondingly, the result of household surveys in Table 5 shows that the investment level of fertilizers and water in intercropped systems often approximate the standard level applied in coffee monoculture systems. In turn, the investment level into coffee-cashew systems is lower because of poor coffee productivity. These coffee-cashew systems are often selected by poor farmers. The additional capital for these systems is commonly used to pay labor costs.

4.2.3 Tree productivity of agro-forestry systems

Table 4. The Tree Productivity of Agro-Forestry Systems in the Yielding Period in Different Places

System	Location	Space (m)	Density (tree/ha)	Age (years)	Productivity	
					kg/tree	ton/ha
Coffee		3 x 3m	1111	8 - 14	3,4 - 4,0	3,8 - 4,4
Coffee + Durian	30 - 40 Plantation	Coffee: 3 x 3m	1111	10	2,7	3,0
		Durian: 9 x 12m	92	10	7,6	7,0
Coffee + Durian	Krong Pach	Coffee: 3 x 3m	1111	12	2,3	2,5
		Durian: 9 x 9m	123	12	7,2	8,8
Coffee + Pepper (long mut)	Eakpam	Coffee: 3 x 3m	1111	8	1,8	2,0
		Pepper: 3 x 6m	555	8	2,3	1,3
Coffee + Pepper (<i>Leucaena Leucocephala</i>)	Eapok	Coffee: 3 x 3m	1111	11	1,8	2,0
		Pepper: 6 x 6m	277	11	1,7	0,5
Coffee+ Cashew	Eatul	Coffee: 3 x 3m	1111	8	2,3	2,5
		Cashew: 6 x 9m	138	14	4,5	0,6
Coffee+ Cashew	Eatul	Coffee: 3 x 3m	1111	7	1,9	2,2
		Cashew: 6 x 6m	277	13	3,5	0,9

Note: Productivity unit: Coffee: ton of kernels per hectare

Tree productivity is an index reflecting the maturity of trees. Depending on the farm/garden owner or planting location, the productivity of each type of tree will be different and will influence the economic effect.

In general, the productivity of each type of tree differs from one agro-forestry system to another. These differences in productivity depend on differences in tree density, tree age, soil condition, and care-taking condition among farms/gardens. The productivity of coffee in coffee monoculture gardens fluctuates from 3.8 to 4.4 tons of kernels per hectare. The productivity of coffee in agro-forestry systems is less than that of coffee monoculture gardens and fluctuates from 2.0 to 3.5 tons of kernels per hectare. The productivity of coffee in coffee-cashew systems is the lowest.

In older agro-forestry systems, the competition for sunlight between yielding-period coffee trees and mature trees is undeniable; it is a main cause behind the great reduction of the coffee productivity. The higher the tree density is, the more the leaf canopies there are, and thus, the more quickly the coffee productivity decreases. However, the economic effect of systems is the most important index in this equation.

4.2.4. Economic Effects

- Production Costs:

Production costs consists of direct costs including those for seedlings, fertilizers, pesticides, labor (planting, care taking, harvesting), irrigation, and machines, and indirect costs such as those used for hired technicians, and administration. Depreciated costs include those for capital construction, the depreciation of garden assets, and taxes. In this research, we calculate the economic effect of a system according to its direct costs.

- Gross return:

+ The gross return of Coffee, Pepper, and Cashew, as well as Durian is based on real productivity, verified product value, and farmer interviews.

+ Unit price:

Table 5. The Economic Effects of Systems From 1999-2001

System	Tree density (tree/hectare)	Gross Expenditure (1.000VND)	Gross Return (1.000VND)	Profit (1.000®)	Compared to monoculture coffee gardens (%)
- Coffee	1111(3x3m)	16.779	28.805	12.026	100,0
- Agro-forestry systems					
- Coffee + Durian	92 (9x12m) *	19.879	49.609	29.730	247,2
- Coffee + <i>Black Cassia</i>	83 (6x20m) *	17.451	27.654	10.503	97,0
- Coffee + Pepper ('Long mut')	555 (6x3m) *	21.320	40.234	18.914	157,3
- Coffee + Pepper (<i>Leucaena Leucocephala</i>)	277 (6x6m) *	18.427	32.786	14.359	119,4
Coffee + Cashew	138 6x12m) *	18.270	30.323	12.053	100,2

Note: Coffee trees in agro-forestry systems have a tree density of 1111 trees per hectare

(*) The density of intercropped trees.

The following prices are the average prices of three years: 1999, 2000, and 2001.

- Coffee: 12.000 VND per kilogram of kernels
- Durian: 4.500 VND per kilogram
- Pepper: 20.000 VND per kilogram
- Cashew: 10.000 VND per kilogram

In general, during this three-year period, the economic effects of most agro-forestry systems are much higher than those of coffee monoculture systems. The coffee-durian systems gain the highest profit of 247 percent in comparison with the coffee monoculture systems. Meanwhile, the coffee-*Black Cassia* systems have the lowest economic effect regardless of timber capacity. It is estimated that 70 *Black Cassia* trees per hectare will supply 50 cubic metres of timber after a tree cycle of 25 to 30 years. As a result, each hectare will contribute 150 million VND from timber sales if they are sold at 3 million VND per cubic metre.

Table 6. The economic effect of systems in 2001

System	Tree density (tree/hectare)	Gross Expenditure (1.000VND)	Gross Return (1.000VND)	Profit (1.000®)	Compared to monoculture coffee gardens (%)
- Coffee	1111(3x3m)	14.432	18.000	3.568	100,0
- Agro-forestry systems					
Coffee + Durian	92 (9x12m)	20.320	43.250	22.930	642,4
Coffee + Pepper ('Long mut')	555 (6x3m)	20.620	35.400	14.780	414,2
Coffee + Pepper (<i>Leucaena Leucocephala</i>)	277 (6x6m)	14.560	20.465	5.905	165,5
Coffee + Cashew	138 (6x12m)	16.080	20.000	3.920	109,8

(* Coffee was sold at the lowest price of 4.500 VND per kilogram in 2001; other product prices fluctuated slightly).

In 2001, the economic effects of coffee-based agro-forestry systems were much higher than those of coffee monoculture systems. The coffee–durian systems gained the highest profit of 22,930 million, accounting for 642.4%. The coffee-pepper systems (clinging to 'Long mut' trees) were second highest, while the coffee-cashew systems had the lowest profit. The considerable disparity in the economic effects of agro-forestry systems and coffee monoculture systems was due to a strong reduction of the coffee price and to the stable prices of other agricultural products such as durian, pepper and cashew. Thus, these agro-forestry systems still brought economic effects regardless of a drop in the main product market prices. It is standard practice for scientists to continuously recommend farmers to diversify trees.

4.3. Impacts of Ecological factors on Agro-Forestry Systems

4.3.1. Soil Moisture:

Soil moisture is an important index to ensure the growth, development and productivity of trees. Water is considered a vital factor in coffee production during drought and strong wind conditions in Tay Nguyen's dry season. The maintenance of soil moisture and the appropriate reduction of water for trees in the dry season are necessary to farming systems in Tay Nguyen. Therefore, soil moisture is given a priority among many environmental indexes.

Table 7. Soil Moisture of Agro -Forestry Systems in the Dry Season (%)

System	Soil Moisture (%)		Compared with Coffee Monoculture Systems (%)	
	Before watering (first time)	After watering (10 days)	Before watering (first time)	After watering (10 days)
Coffee	28,5	31,2	0	0
Coffee + Durian	30,4	33,7	1,9	2,5
Coffee	-	31,1	-	0
Coffee + <i>Black Cassia</i>	-	34,5	-	3.4
Coffee	26,7	29,0	0	0
Coffee + Cashew	28,2	31,0	1,5	2,0

Before and after watering, the soil moisture of the 0– 30 cm soil layer in coffee-based agro-forestry systems is higher than that of coffee monoculture systems. It proves that agro-forestry systems can maintain soil moisture longer; hence, they can conserve water. Due to leaf canopies of trees, agro-forestry systems can limit evaporation. In addition, a layer of humus created from decaying debris dropped from trees also restrains evaporation and retains the moisture of top soil.

5. Conclusions and Recommendations

5.1. Conclusions

- Agro-forestry systems in Dak Lak are very abundant regarding their structures and functions. According to the criteria of the International Center for Research in Agro-forestry (ICRAF), there are eight types of agro-forestry practiced in Dak Lak.
- The diversification of trees in the same agro-forestry systems showed many more advantages in comparison with coffee monoculture systems.
- In the 1999-2001 period, most coffee-based agro-forestry systems achieved higher economic benefits than coffee monoculture systems. In particular, coffee-durian systems and coffee-pepper systems gained much higher economic effects in comparison with coffee-monoculture systems. Coffee-*Black Cassia* systems, however, brought lower economic effects than coffee monoculture systems. The economic

effects between other agro-forestry systems and coffee monoculture systems were different.

- Agro-forestry systems tend to improve soil moisture and to better limit water shortage in the dry season.
- These agro-forestry systems are mainly chosen by farmers depending on the economic effects they bring.

5.2. Recommendations

- Do 10-year experiments on agro-forestry systems in research centers; test different ways of combining coffee and durian, and coffee and pepper, depending on the conditions of soil, climate, slope, water, fertilizer investment, etc.
- Research the ability to supply high-value timbers from coffee-based agro-forestry systems.
- Issue policies encouraging farmers to apply agro-forestry systems, diversifying trees towards to commodity-oriented production in order to avoid the price risks.
- Conduct further research to locate the market for products from these farming systems.

Summary

Agro-forestry Systems in Dak Lak Province: Ecological Impacts and Economic Effects

This study is aimed at evaluating the ecological impacts and economic effects of the existing agro-forestry systems in Dak Lak province. The results showed that agro-forestry systems in Dak Lak are abundant regarding to their structures and functions. According to the criteria of the International Center for Research in Agro-forestry (ICRAF), there are eight types of agro-forestry currently practiced in Dak Lak. These essentially coffee-based systems showed many advantages regarding both ecological impacts and economic effects. However, due to limits of time and an uncontrollability of some external factors, more research needs to be continued to confirm this data.