ECONOMIC ASSESSMENT OF SOME AGROFORESTRY SYSTEMS AND ITS POTENTIAL FOR CARBON SEQUESTRATION SERVICE IN INDONESIA

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ABSTRACT

This paper provides several alternatives agroforestry and plantation systems to consider for carbon sequestration purposes. It is indicated that multicropping of coffee multistrata or fruit trees such as mango, duku and durian with timber or food and vegetable crops produces more benefits financially and economically compared to monoculture of tree plantation such as albizia. The former system is more attractive in terms of return to labour and land. However, the later system produce more carbon and low cost of carbon, which is more potential from the buyers point of view. So there is a trade-off from supply and demand side for choosing the best alternatives system. Implication of these are as follows: (i) amount and price of product is becoming a key factors in determining whether a system is more feasible for selling of product or carbon trade, and (ii) there is a need to create incentives system for land owners/producers if carbon trade is a priority.

Key words: Carbon sequestration, agroforestry, economic assessment

I. INTRODUCTION

Recent Marrakech accord confirmed two types of activity which are eligible for carbon market through CDM Kyoto Protocol, i.e., afforestation and reforestation, although there might be some opportunities over which other activities would be adopted, including agroforestry. This paper describes several types of common agroforestry systems in Sumatra, Indonesia, paying particular emphasize on cost benefit analysis and their mitigation potential for carbon sequestration. However, other aspects are not fully analysed including land ownership of the systems which may be the case if Kyoto eligibility is matter, because of its potential conflict for leakage and the issue of permanence.

Understanding the systems studied would provide alternatives toward which a system is more viable and sequestered more carbon.

II. THE SYSTEMS STUDIED

Several types of agroforestry system analysed include coffee *(Coffee robusta)* agroforestry multistrata, including timber base multistrata, fruit base multistrata and shades base multistrata. The coffee data is collected in Sumberjaya, in the northern part of Lampung Province, and obtained from Wulan (2002). The other types of agroforestry systems were adopted from Hendri (2000) using COMAP (Comprehensive Mitigation Assessment Process) approach and consists of agroforestry durian *(Durio zibethinus)*, agroforesty macang *(Mangifera* spp.), agroforestry mango (*Mangifera indica*), agroforestry candle nut *(Aleurites moluccana)*, agroforestry pinang *(Areca catecu)* and agroforestry rambutan *(Nephelium lappaceum)*. In addition, several types of monoculture plantations are evaluated including monoculture of *Albizia falcataria,* and meranti (*Shorea* spp).

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Most of these systems are located in the Province of Jambi.

A. Coffee (*Coffee robusta*) Agroforestry Multistrata

Most forest in Sumberjaya, Lampung province have been damaged due to encroachment. Most of state protected forests were converted into agricultural purposes, mainly coffee garden. Goverment's efforts to rehabilitate state forest resulted in more conflicts between goverments or forestry officers and people in forest frontier. Therefore, a type of land use system which can fulfill the needs of people while simultaneously maintain the forest function are needed to solve the conflicts. One of the alternatives is coffee agroforestry multistrata garden. This system covered about 130,000 hectare (Fadilasari, 2000), and resulted in 60 per cent of exported coffee were from the province of Lampung. Based on its dominant tree species in the coffee garden, the patterns of agroforestry system are classified as timber-base multistrata, fruit-base multistrata and shade-base multistrata.

Timber Based Multistrata. Timber based multistrata of coffee system refers to coffee agroforestry multistrata dominated by forest tree. Most of the land is categorised as forest land. The dominant species includes sonokeling *(Dalbergia latifolia)* and sengon *(Paraserianthes falcataria)* which is a species used for regreening by forest office. Other species include perennial trees such as jackfruit *(Arthocarpus heterophyllus)*, erythryna and banana cover the stratum of the systems. Details of species planted in this system is presented in Table 1 and illustrated in Figure 1.

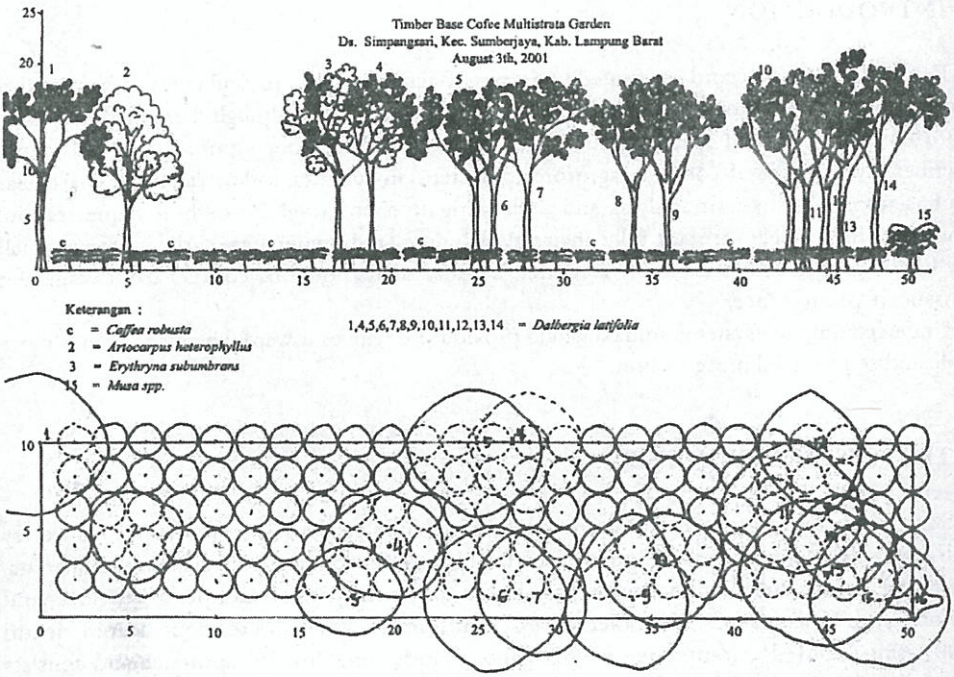

Figure 1. Profile of timber-based multistrata agroforestry of coffee

Fruit Based Multistrata. Fruit Based Multistrata refers to agroforestry multistrata of coffee dominated by fruit trees such as jack fruit, guava, and avocado. Species of trees planted in this system can be seen in Table 2 and illustrated in Figure 2.

Table 1. Species of trees planted in timber based multistrata of coffee

No.	Species	Scientific Names	Used of Products	Price/cost	unit
1	Coffee	*Coffea robusta*	Fruit (dry)	2,500	Rp / kg
2	Sonokeling	*Dalbergia latifolia*	Timber	60,000	Rp / pole
3	Sengon	*Paraserianthes falcataria*	Timber	10,000	Rp / pole
4	Durian	*Durio zibethinus*	Fruit	2,500	Rp / pcs
5	Mangos	*Mangifera indica*	Fruit	1,500	Rp / kg
6	Kapok	*Ceiba pentandra*	Pillow, mattress	3,500	Rp / kg
7	Guava	*Psidium guajava*	Fruit	100	Rp / kg
8	Jack fruit	*Artocarpus heterophyllus*	Fruit, Vegetable	3,000	Rp / pcs
9	Orange	*Citrus nobilis*	Fruit	4,000	Rp / kg
10	Avocado	*Persea americana*	Fruit	500	Rp / kg
11	Cinnamon	*Cinnamomum burmanii*	Bark (dry)	2,000	Rp / kg
12	Gliricidia	*Gliricidia sepium*	Fuel wood	250	Rp / bundle
13	Erythryna	*Erythryna subumbrans*	Fuel wood	250	Rp / bundle
14	Cengkeh	*Eugenia aromatica*	Spice	60,000	Rp / kg
15	Jambu bol	*Eugenia mallacencis*	Fruit	1,000	Rp / kg
16	Jengkol	*Pithecelobium jiringa*	Fruit	10,000	Rp / sack
17	Candle nut	*Aleurites moluccana*	Spice	2,000	Rp / kg
18	Rambutan	*Nephelium lappaceum*	Fruit	500	Rp / kg
19	Pisang	*Quercus sundaica*	Timber	15,000	Rp / pole
20	Bamboo	*Bambusoideae* spp.	Bamboo	3,000	Rp / pole
21	Kunyit	*Curcuma longa*	Spice	4,000	Rp / kg
22	Kapulaga	*Amomum compactum*	Traditional medicine	30,000	Rp / kg
23	Banana	*Musa* spp.	Fruit	250	Rp / kg

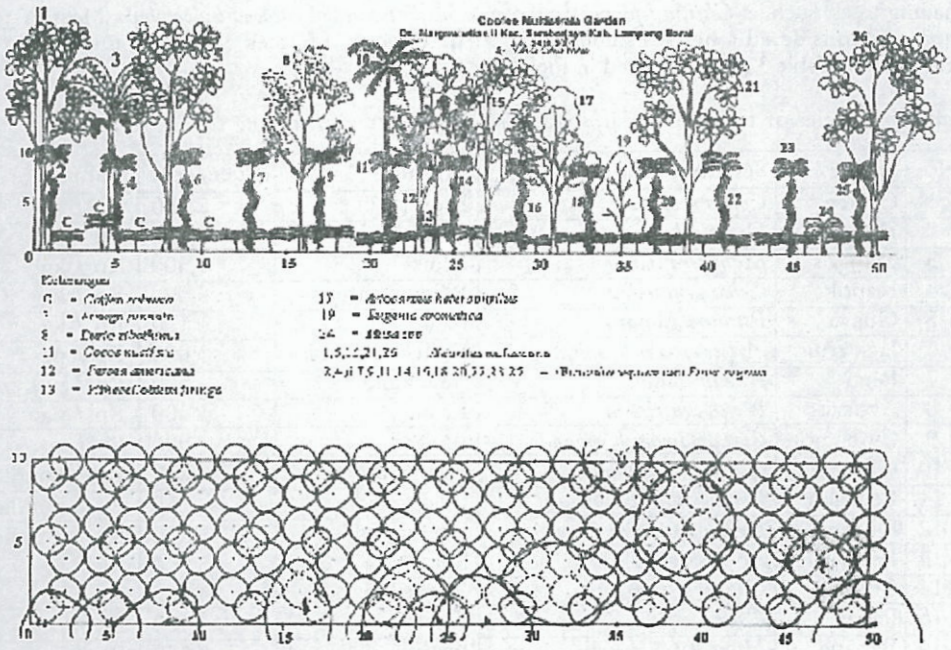

Figure 2. Profile of pattern agroforestry fruit base multistrata

Table 2. Species of trees planted in fruit based multistrata of coffee

No.	Species	Scientific Name	Used of Products	price/cost	Unit
1	Coffee	*Coffea robusta*	Fruit (dry)	2,500	Rp / kg
2	Durian	*Durio zibethinus*	Fruit	2,500	Rp / pcs
3	Rambutan	*Nephellium lappaceum*	Fruit	500	Rp / kg
4	Jengkol	*Pithecellobium jiringa*	Vegetable	10,000	Rp / sack
5	Jack Fruit	*Artocarpus heterophyllus*	Fruit	3,000	Rp / pcs
6	Kapok	*Ceiba pentandra*	Pillow, mattress	3,500	Rp / kg
7	Guava	*Psidium guajava*	Fruit	100	Rp / kg
8	Limus	*Mangifera foetida*	Fruit	1,500	Rp / kg
9	Mangos	*Mangifera indica*	Fruit	1,500	Rp / kg
10	Petai	*Persea americana*	Vegetable	500	Rp / pcs
11	Jambu air	*Syzigium aqueum*	Fruit	100	Rp / kg
12	Avocado	*Persea americana*	Fruit	500	Rp / kg
13	Tangkil	*Gnetum gnemon*	Vegetable	2,500	Rp / kg
14	Candle nut	*Aleurites moluccana*	Spice	2,000	Rp / kg
15	Gliricidia	*Gliricidia sepium*	Fuelwood	250	Rp / bundle
16	Erythryna	*Erythryna subumbrans*	Fuelwood	250	Rp / bundle
17	Cinnamon	*Cinnamomum burmanii*	Bark (dry)	2,000	Rp / kg
18	Cengkeh	*Eugenia aromatica*	Spice	60,000	Rp / kg
19	Aren	*Arenga pinnata*	Sugar Palm	500	Rp / pcs
20	Bamboo	*Bambusoideae* spp.	Bamboo	3,000	Rp / pole
21	Coconut	*Cocos nucifera*	Fruit, vegetable	750	Rp / pcs
22	Banana	*Musa* spp.	Fruit	250	Rp / kg
23	Pineapple	*Ananas comosus*	Fruit	150	Rp / pcs

Shade-Based Multistrata. Shade-Based Multistrata refer to agroforestry multistrata dominated by shading trees, such as *Gliricia sepium, Erythryna subumbrans* and *Leucaena leucocephala.* Most of the garden is considered a newly established garden. Species of trees planted in this system is presented in Table 3 and illustrated in Figure 3.

Table 3. Species of trees planted in shades based multistrata of coffee

No.	Species	Scientific Names	Products	price/cost	satuan
1	Coffee	*Coffea robusta*	Fruit (dry)	2,500	Rp / kg
2	Durian	*Durio zibethinus*	Fruit	2,500	Rp / pcs
3	Mangos	*Mangifera indica*	Fruit	1,500	Rp / kg
4	Kapok	*Ceiba pentandra*	Pillow, mattress	3,500	Rp / kg
5	Guava	*Psidium guajava*	Fruit	100	Rp / kg
6	Jack fruit	*Artocarpus heterophyllus*	Fruit, Vegetable	3,000	Rp / pcs
7	Petai	*Parkia speciosa*	Vegetable	500	Rp / pcs
8	Avocado	*Persea americana*	Fruit	500	Rp / kg
9	Cinnamon	*Cinnamomum burmanii*	Bark (dry)	2,000	Rp / kg
10	Gliricidia	*Gliricidia sepium*	Fuel wood	250	Rp / bundle
11	Leucaena	*Leucaena leucocephala*	Fuel wood	250	Rp / bundle
12	Dadap	*Erythryna subumbrans*	Fuel wood	250	Rp / bundle
13	Repper	*Pepper nigrum*	Spice	15,000	Rp / kg
14	Chilli	*Capsium frutescens*	Vegetable	4,500	Rp / kg
15	Papaya	*Carica papaya*	Fruit	100	Rp / pcs
16	Banana	*Musa* spp.	Fruit	250	Rp / kg

Source: Wulan (2002)

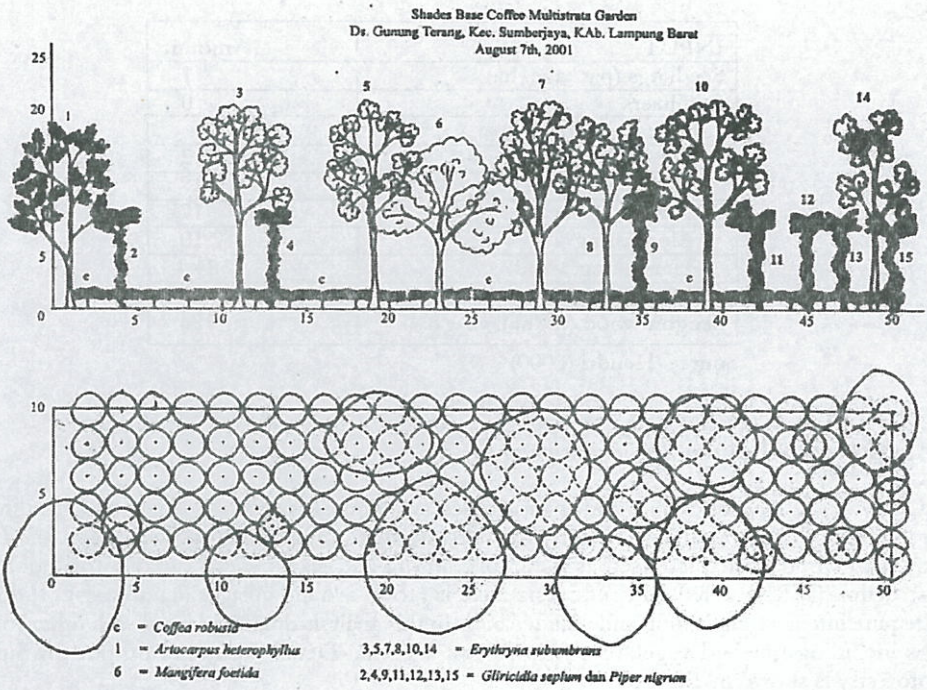

Figure 3. Profile of shades based multistrata agroforestry

B. Plantation of Sengon (*Albizia falcataria/ Paraserianthes falcataria*)

Albizia falcataria which is known as sengon in Indonesia, is commonly planted by many people both in community forest and timber plantation area. Community forest for sengon species has been traditionally developed since 1950 (Saiban *et al.*, 1994). In 1989 the Ministry of Forestry issued an afforestation program involving local people with sengon as the main tree. In addition to increase wood supply, this program was also intended to increase land productivity, provide additional wood for industry and generate employment. Sengon wood is usually used for packing, furniture, and light building construction. Sengon's leaves also produced fodder for goats.

Sengon's biological rotation is usually less than 15 year because beyond that age, the root usually starts to rott. In this system, sengon wood harvested at age 8 year and managed as a monoculture timber plantation. Inputs used for sengon plantations are presented in Table 4.

Table 4. Input Output for *Albizia falcataria* per year

INPUT	Amount
Seedlings (package/ha)	1
Fertilizers	0
Labour (pd/ha/year) ·	
Seedling	2
Planting	17
Maintenance	17
Monitoring	10
Harvesting wood	384.4
OUTPUT	
Sengon wood (m^3/ha), year 8	184

Source: Hendri (2000)

C. Agroforestry of Duku (*Lansium domesticum*)

Lansium domesticum or duku is widely distributed in Indonesia and usually known as fruit tree. The Province of South Sumatra is very popular with duku because of its' sweet taste and big size. Duku wood is characterised as a durable, strong and elastic, very suitable for building construction (ICRAF, 2000). In Indonesia duku is grown around villages (kampungs). It does not require intensive cultivation and maintenance. In this analysis duku is planted with other food crops including rice and vegetables for the first 3 years. Detail input and output for duku agroforestry is shown in Table 5.

Table 5. Input Output for *Landium Domesticum* per year

INPUT	Amount
Seedlings	
Duku seed (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Materials (unit/ha)	
Machete	1
Labour (pd/ha)	
Seedling	16
Planting	32
Maintenance and monitoring	24
Harvesting	865
OUTPUT	
Duku	
Fruit (kg/ha/yr) year 5-40	20,000
Wood (m^3/ha), year 40	407.1
Rice(yr 1 and 2)	405
Chilli (kg/ha/yr)	50
Tomato (kg/ha/yr)	60
Spinach (kg/ha/yr)	40
Snake bean (kg/ha/yr)	60
Egg plant (kg/ha/yr)	70
Cucumber (kg/ha/yr)	80

Source: Hendri (2000)

D. Agroforestry of Durian (*Durio zibethinus*)

Durio zibethinus or durian is one of most popular species among Indonesian fruit trees because of its particular flavoured and odor. It is found in many places of Indonesia, and most of them is planted in dryland or garden. Durian wood can be used for construction, furniture, cabinets, light traffic flooring, fittings, panelling, partitioning, plywood, chests, boxes, wooden slippers, low-quality coffins and ship building (Prosea, 1995). In reality the use of durian wood is still limited for building construction and packing. Multicropping of durian with rice and vegetables use input and produce output as shown in Table 6.

Table 6. Input and output for a hectare of durian plantation

INPUT	Amount
Seedlings	
Durian seed (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Materials	0
Machete (unit/ha/yr)	1
Rope (roll/ha/yr)	100
Labour (pd/ha/yr)	
Durian	
Seedling	16
Planting	32
Maintenance and monitoring	24
Harvesting	641
OUTPUT	
Durian	
Fruit (unit/ha/yr) year 5 - 40	20,000
Wood (m^3/ha), year 40	295.8
Rice (yr 1 and 2)	405
Chilli (kg)	50
Tomato(kg)	60
Spinach (kg)	40
Snake bean (kg)	60
Egg plant (kg)	70
Cucumber (kg)	80

Source: Hendri (2000)

E. Agroforestry of candle nut (*Aleurites moluccana*)

As one of fast growing species, candle nut are also planted as a main tree in reforestation program. The advantages of this tree include minimal requirements to live, able to grow in arid land and able to grow in shifting cultivated area (Kalima, 1990). Candle nut trees are planted by farmer mostly for its fruit which is used for spice and traditional medicine.

At present, Indonesian Bio Diesel Institute is planning to prepare candle nut plant as an alternative source of bio diesel. This is because candle nut fruit yields oil having similar characteristics with petroleum oil. For this reason, as a fast growing species, candle nut is highly potential for alternative petroleum oil in the next future. While the tree can be left growing to absorb carbon. Input used and output produced for a hectare of candle nut multicropping with rice and vegetables is presented in Table 7.

Table 7. Input and output for a hectare of candle nut plantation

INPUT	Amount
Seedlings	
Candle nut seed (plants/ha)	256
Rice (plants/ha)	60
Vegetables (package/ha)	1
Fertiliser (kg/ha)	54
Pesticide (ltr/ha)	1
Materials (unit/ha/yr)	
Machete	1
Labour (pd/ha/yr)	
Seedling	14
Planting	35
Maintenance	22
Monitoring	10
Harvesting fruit	281.5
OUTPUT	
Candle nut	
Fruit (kg/ha/yr) year 5-40	2048
Wood (m^3/ha), year 40	131.81
Rice (yr 1 and 2)	405
Chilli (kg)	50
Tomato (kg)	60
Spinach (kg)	40
Snake bean (kg)	60
Egg plant (kg)	70
Cucumber (kg)	80

Source: Hendri (2000)

F. Agroforestry of Macang (*Mangifera* spp.)

Macang is a species of fruit trees. Macang wood is used for light construction, planking, ceiling, door panels, interior finish, flooring, mouldings, packing boxes, gunstocks, veneer and plywood (Prosea, 1995). Input used for macang agroforestry is shown in Table 8.

Table 8. Input and output for a hectare of macang plantation

INPUT	Amount
Seedlings	
Macang seed (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Fertiliser (kg/ha)	0
Pesticide (ltr/ha)	0
Materials (unit/ha/yr)	
Machete	1
Labour (pd/ha/yr)	
Seedling	16
Planting	32
Maintenance	24
Harvesting	532
OUTPUT	
Macang	
Fruit (kg/ha/yr) year 5-40	20,000
Wood (m^3/ha), year 40	248.7
Rice(yr 1 and 2)	405
Chilli (kg)	50
Tomato (kg)	60
Spinach (kg)	40
Snake bean (kg)	60
Egg plant (kg)	70
Cucumber (kg)	80

Source: Hendri (2000)

G. Agroforestry of Mangoes (*Mangifera indica*)

Mangoes is a tall evergreen tropical tree growing up to 30-100 feet with a dense and heavy crown. This species has been planted by many people in Indonesia, both in dryland or backyard. People plant this species is to take advantage from fruit they bear even though they also can use mango wood for several uses like firewood. Input and output of a hectare of mangoes agroforestry is shown in Table 9.

Table 9. Input and output for a hectare of mangoes plantation

INPUT	Amount
Seedlings	
Mangoes seed (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Materials (unit/ha/yr)	
Machete	1
Labour (pd/ha/yr)	
Seedling	16
Planting	43
Maintenance and monitoring	36
Harvesting	467
OUTPUT	
Mangoes	
Fruit (kg/ha/yr) year 5-40	20,000
Wood (m^3/ha), year 40	217.4
Rice (yr 1 and 2)	405
Chilli (kg)	50
Tomato (kg)	60
Spinach (kg)	40
Snake bean (kg)	60
Egg plant (kg)	70
Cucumber (kg)	80

Source: Hendri (2000)

H. Plantation of Pinang (*Areca catecu*)

Pinang tree is planted for their fruit, the betel nut, which is chewed as a mild stimulant. It is also a beautiful palm tree used for garden accessories. Many people uses pinang for traditional cosmetics and health. Areca nut contains a large quantity of tannin, also garlic acid, a fixed oil gum, a little volatile oil, lignin, and various saline substances (Prosea, 1995). Four alkaloids have been found in Areca nut, i.e., arecoline, arecain, guracine, and a fourth existing in very small quantity. Arecaine is the active principle of the areca nut. Multicropping of a hectare pinang with rice and vegetables requires inputs and produces output as shown in Table 10.

Table 10. Input and output for a hectare of pinang plantation

INPUT	Amount
Seedlings	
Pinang seed (plants/ha)	284
Rice (plants/ha)	60
Vegetables (package/ha)	1
Fertiliser (kg/ha)	54
Pesticide (ltr/ha)	1
Materials (unit/ha/yr)	
Machete	1
Labour (pd/ha/yr)	
Pinang	
Seedling	14
Planting	35
Maintenance	32
Harvesting fruit	6.5
OUTPUT	
Pinang	
Fruit (kg/ha/yr) year 5-40	1136
Rice (yr 1 and 2)	405
Chilli (kg)	50
Tomato (kg)	60
Spinach (kg)	40
Snake bean (kg)	60
Egg plant (kg)	70
Cucumber (kg)	80

Source: Hendri (2000)

I. Agroforestry of Rambutan (*Nephelium lappaceum*)

Rambutan is a popular fruit for Indonesian people and can be found everywhere as a fresh or canned fruit. Rambutan is a medium- sized tree producing a red or yellow fruit round to oval in shape with hair or tubercles on its skin. The flesh or aril is translucent and sweet. Rambutan produces a small crop in June - July and a heavy crop in November to January. Agroforestry of rambutan with rice and vegetable is shown in Table 11.

Table 11. Input and output for a hectare of rambutan plantation

INPUT	Amount
Establishment inputs:	
Seedlings	
Rambutan seed (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Fertiliser (kg/ha)	0
Pesticide (ltr/ha)	0
Materials (unit/ha/yr)	
Machete	1
Labour (pd/ha/yr)	
Seedling	16
Planting	32
Maintenance and monitoring	24
Harvesting	517
OUTPUT	
Rambutan	
Fruit (kg/ha/yr) year5-40	3000
Wood (m^3/ha), year 40	241.6
Rice (yr 1 and 2)	405
Chilli (kg)	50
Tomato (kg)	60
Spinach (kg)	40
Snake bean (kg)	60
Egg plant (kg)	70
Cucumber (kg)	80

Source: Hendri (2000)

III. THE SYSTEM PERFORMANCE

In this section, the performance of the agroforestry and plantation systems reviewed above is examined in financial and economic terms. The analysis undertaken follows the guidelines established by the Alternatives to Slash and Burn (ASB) program (ICRAF, 1998; Budidarsono *et al.*, 2001). The private discount rate is set at 20% and the social discount rate at 15%. The prices of the major inputs and outputs used in the analyses are presented in Table 12 and Table 13, respectively. It can be seen that in general all of the systems use moderate and nearly similar amount of labour and input per year, except for fruit based multisrata which use more input of hired labour and fertiliser. Transportation of output delivery is counted based on the amount of coffee produced per systems. It can be seen that shade-based multistrata produces highest dry coffee, because of its highest output delivery costs, amounting to Rp 2,058,795 during the entire life cycle year (20 years).

Table 12. Input and costs of timber, fruit and shades based multistrata of coffee

Item	Price/cost	Timber Based	Fruit Based	Shades Based
Labour (Rp/pd/yr)				
Family	6,000	236	236	236
Hired	6,000	79	189	79
Fertilizer (Rp/kg/yr)				
Urea (N)	1,200	100	160	100
KCl	3,600	25	25	25
Pesticides (Rp/ltr/yr)				
Sprak	25,000	2	2	2
Pastak	120,000	0.2	2.0	0.2
Materials				
Hoe (Rp/unit/cycle)	20,000	5	5	5
Axe (Rp/unit/cycle)	30,000	3	3	3
Machete (Rp/unit/cycle)	10,000	5	5	5
Sickle (Rp/unit/cycle)	10,000	5	5	5
Sack (Rp/unit/cycle)	1,500	1679	1679	1679
Transportation				
Output delivery (Rp/kg/cycle)	100	1,502,024	1,870,846	2,058,795

Appendix 1 presents inputs and outputs used in other agroforestry systems, including duku, mangga, durian, candle nut, macang, pinang and rambutan, as well as plantation of sengon and meranti

A. Financial and Economic Analysis

Financial analysis is based on private prices, i.e. prices experienced by producers, while economic analysis is based on social prices, where the actual prices are adjusted to eliminate distortions caused by market imperfections. Policies that may cause such distortions include input and output price subsidies, tariffs and quotas. Financial analysis measures profit as the farmer experiences it. Family labour is not paid and the value of forestland cleared is not charged to the farmer. Hence the net private returns calculated in financial analysis represent the return to family labour, land, management and capital.

Economic analysis measures profit as it 'should be' in an ideal world with no price distortions. Family labour is paid at the market rate and the cost of cleared land is accounted for. Hence the net social returns calculated in the economic analysis represent the returns to management and capital, in an ideal world where 'true' prices are paid for inputs and outputs.

In financial terms, a system is feasible if its net present value (NPV) is positive. For clarity of exposition, the financial NPV is hereafter referred to as net private return (NPR). The financial and economic analysis for coffee multistrata are presented in Table 13.

Table 13. Financial and economic analysis of coffee agroforestry multistrata

	Financial Analysis			Economic Analysis		
	Timber Base Multistrata	Fruit Base Multistrata	Shades Base Multistrata	Timber Base Multistrata	Fruit Base Multistrata	Shades Base Multistrata
Economic performance :						
IRR (%)	30.90%	32.12%	51.00%	19.40%	21.70%	34.27%
NPV (Rp '000/ha)	5,696	7,209	12,169	3,847	6,230	11,030
Establishment cost ('000/ha)	7,421	7,271	5,703	15,819	15,040	9,481
Return to Labour (Rp/pd)	11,282	12,685	17,285	7,546	8,504	10,433
Years to positive cash flow	10	9	4	12	14	5
Labour requirements :						
Establishment (pd/ha)	3,266	2,954	1,394	4,514	3,890	1,706
Operation (pd/ha/yr)	312	312	312	312	312	312
Total (pd/ha/yr)	319	319	319	319	319	319

Overall coffee agroforestry multistrata systems yield a high return both private and social, so they are feasible under the assumptions of this study. The most attractive system is shade-based multistrata, with an NPR of Rp12,169,000/ha (Table 13). While the lowest one is timber-base multistrata. The later system also produced the lowest return. This is due to high proportion of timber trees that could not be harvested without government's consent, due to forest land ownership. Establishment costs were estimated as the present value of costs until the system reaches a positive cash flow. The highest establishment costs accrue to the timber based multistrata system, which take eight years to reach positive cash flows. The economic of NPV is referred to as net social return (NSR) to distinguish it from the private analysis. The profitability of the coffee agroforestry multistrata decrease, but they remain quite attractive. The best economic performance is produced by shades based multistrata, with NSRs of Rp 11,030,000/ha. In terms of employment potential, all of the systems provide similar prospects. In the case of labour establishment, fruit-based multistrata provides the most employment (2,954 pd/ha).

Financial and economic analysis of several other agroforestry systems studied is presented in Table 14 and 15. The systems all have positive NPVs, so they are feasible. It can be seen that mango agroforestry produced the highest NPVs and return financially and economically. Followed by agroforestry of duku and durian, with an NPVs of Rp 71,045,000 and Rp 70,458,000 per ha, respectively. This is due to good price of mango, duku and durian received by land owners. It is also indicated that agroforestry systems were more feasible compared to monoculture plantation, in terms of their higher return and NPVs, and sooner in having positive cash flows.

In terms of system potential, agroforestry of mango and duku/lansium provide the best prospects, since they produce high NPV and returns. Another interesting comparison can be obtained by evaluating the performance of each system in terms of return to labour, as it provides a measure on how beneficial the activity in relation to the labour. It was evident that agroforestry mango and duku provide the highest return to labour. This provides good insights into the attractiveness of mango an duku agroforestry systems.

Different systems produce different social and environmental benefits. Social benefits may be measured by indicators such as food security, income generation and poverty alleviation. None of the systems considered provided food security directly in the long term; because staple foods, such as rice and vegetables, are produced only during the first few years. However, steady employment can contribute to both food security and poverty alleviation. Poverty alleviation is also concerned on how the agroforestry plot can provide sustainable income, food, fuel and shelter to farmers and their families. For completeness, the analysis should have also considered the long-term physical impact that agroforestry has on soil erosion, soil fertility, and hydrological balance, because these factors influence the plot's capacity to generate income in the future, as well as overall benefits to society. Such assessment, however, is out of the scope of this study.

Table 14. Financial analysis for several agroforestry systems

	Financial Analysis							
	Albizia	Duku	Durian	Kemiri	Macang	Mango	Pinang	Rambutan
Economic performance :								
IRR (%)	51	133.8	133.5	107	100	164.0	94.4	59.7
NPV (Rp '000/ha)	6,683	71,045	70,487	18,217	23,135	143,265	8,322	6,019
Establishment cost ('000/ha)	1,816	4,180	4,180	4,140	3,980	4,180	4,104	4,180
Return to Labour (Rp/pd)	99	310	281	108	119	610	57	40
Years to positive cash flow	8	5	5	5	5	5	5	5
Labour requirements :								
Establishment (pd/ha)	208	269	269	277	287	269	277	269
Operation (pd/ha/yr)	211	38	41	34	29	27	27	28
Total (pd/ha/yr)	47	41	44	38	33	31	31	32

Table 15. Economic analysis for several agroforestry systems

	Financial Analysis							
	Albizia	Duku	Durian	Kemiri	Macang	Mango	Pinang	Rambutan
Economic performance :								
IRR (%)	51%	133.8%	133.5%	90.9%	92.4%	164.0%	72.5%	59.7%
NPV (Rp '000/ha)	9,979	112,251	111,379	27,816	36,225	225,772	12,096	9,935
Establishment cost ('000/ha)	1,967	4,439	4,439	4,996	4,614	4,439	4,959	4,439
Return to Labour (Rp/pd)	125	423	272	105	141	841	54	51
Years to positive cash flow	8	5	5	5	5	5	5	5
Labour requirements :								
Establishment (pd/ha)	208	269	269	277	287	269	277	269
Operation (pd/ha/yr)	211	38	41	34	29	27	27	28
Total (pd/ha/yr)	47	41	44	38	33	31	31	32

B. Carbon Sequestration Services

The amount of carbon sequestrated by each system is presented in Table 17 and 18. The amount of carbon sequestered in coffee multistrata was estimated by assuming a coffee wood density of 0.3 kg/m^3 and a carbon content of 45 percent of biomass. Tree biomass was estimated using the allometric equation of Brown (1997):

$$W = 0.049.\rho.D^2H$$

here: H = tree height (m), ρ= wood density, D = diameter at breast height

Tree height and diameter were obtained from Wulan (2001) and ICRAF (2000). These estimates (Figure 4) exclude carbon in soil and litter, and hence underestimate actual carbon stocks. Also, the carbon content of crops and trees plants was ignored. It is expected that the carbon stock in the cinnamon-coffee system will be higher, hence these figures should be taken only as rough approximations.

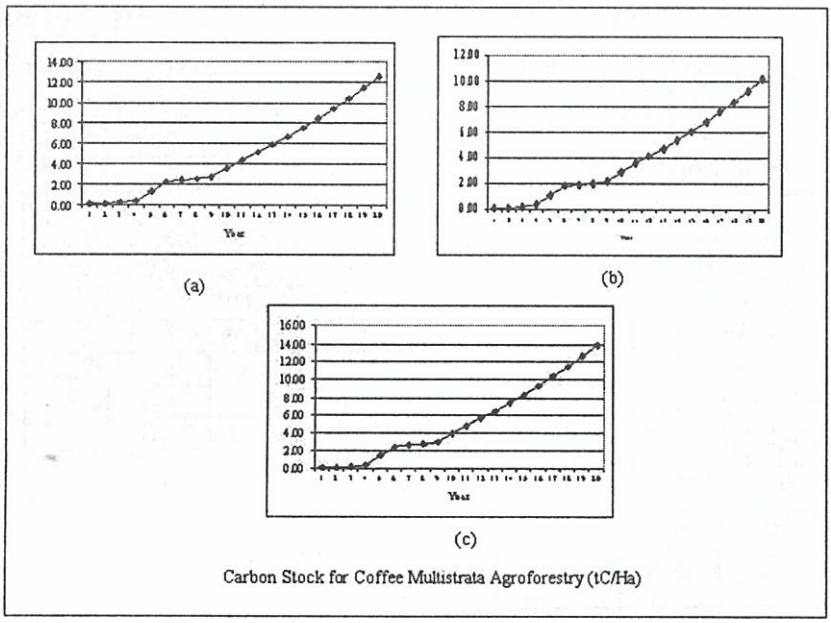

Figure 4. Carbon stock for coffee based multistrata (t C/ha)
Remarks: (a) fruit based multistrata, (b) timber based multistrata, and (c) shades based multistrata

Table 16 present carbon cost for each systems. It can be seen that carbon costs for timber based multistrata was the highest. It might not be the case, however, if carbon stock from other crops and tree species was included.

Table 16. Carbon sequestration of coffee multistrata

Carbon sequestration :	Financial Analysis			Economic Analysis		
	Timber Base Multistrata	Fruit Base Multistrata	Shades Base Multistrata	Timber Base Multistrata	Fruit Base Multistrata	Shades Base Multistrata
Average biomass carbon (t C/ha)	10.13	12.62	13.88	10.13	12.62	13.88
Carbon cost (Rp '000/t C)	731	576	418	1,658	1,192	718
Carbon cost $/t C	73	58	42	166	119	72

Table 17 shows the carbon stocks for others systems. It can be seen that meranti plantation has the highest potential for carbon sequestration, and produced the least cost of carbon, amounting to US 0.9 per ton of carbon. While pinang produces the highest costs, followed by agroforestry of kemiri, amounting to US $ 7.4 per t of carbon and US $ 3.7 per t of carbon, respectively.

Table 17. Carbon sequestration of several agroforestry and plantation systems

Description	Albizia	Duku	Durian	Kemiri	Macang	Mango	Meranti	Pinang	Rambutan
Average biomass carbon (t C/ha)	52.690	115.010	133.030	124.680	121.050	121.050	254.460	62.570	117.950
Carbon cost (Rp '000/t C)	34,466	36,345	31,421	37,223	35,803	34,531	8,893	73,598	35,439
Carbon cost $ /t C	3,447	3,634	3,142	3,722	3,580	3,453	0,889	7,360	3,544

IV. CONCLUSION

This report provides a description of several important agroforestry and plantation systems, ranging from a complex coffee agroforestry to a monoculture of albizia. In general, all the systems evaluated appear to be attractive except from meranti from an economic standpoint. The paper also demonstrates on how economic analysis can be combined with simulation of carbon sequestration to evaluate the potential of agroforestry systems to provide profits and contribute to mitigation of global warming.

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REFERENCES

Budidarsono, S., M.S. Delos Angeles and G. Wibawa. 2001. A profitability assessment of smallholder rubber agroforestry systems in Jambi, Sumatra, Indonesia. Manuscript prepared for the workshop "Complex Agroforests: Farmers Knowledge, Management, Profitability and Conservation", Muara Bungo, Jambi, 3-6 September 2001.

Brown, S. 1997. Estimating Biomass and Biomass Change of Tropical Forest: a Primer. FAO Forestry Paper-134. Food and Agriculture Organisation of The United Nation, Rome.

Fadilasari. 2000. Soal Embargo Kopi Lampung: Sonny Sarankan Cari Alternatif Lain. Tempo, 4 Agustus.

Hendri. 2000. Comap Data on Several Systems. Bogor Agriculture University, Bogor.

ICRAF, 1998. Alternatives to Slash and Burn in Indonesia. Summary Report and Synthesis of Phase II. ASB Indonesia Report No. 8, Bogor. Indonesia.

ICRAF. 2000. A Profitability Assessment of Robusta Coffee Systems in Sumberjaya Watershed, Lampung, Sumatra Indonesia. Southeast Asia Policy Research Working Paper, No.16.

ICRAF, 2000. *Ketika Kebun Berupa Hutan, Agroforest Khas Indonesia, Sebuah Sumbangan Masyarakat.*

Kalima, T. 1990. The kemiri plant in relation to its regreening plant in Indonesia. Journal of Forest Research and Development, VI (2): 20-25.

Prosea, 1995. Plant Resources of South-East Asia 5 (1) Timber Trees: Major Commercial Timbers.

Prosea, 1995. Plant Resources of South-East Asia 5 (2) Timber Trees: Minor Commercial Timbers.

Saiban, Sylviani and R. Effendi. 1994. Analysis of private sengon forest institution in West Java. Journal of Forest Research and Development, IX (1): 13-18

Wulan, Y. C. 2002. Nilai Ekonomi Sistem Agroforestry Kebun Kopi Multistrata (Studi Kasus Kebun Kopi Multistrata di Kecamatan Sumberjaya, Kabupaten Lampung Barat). Unpublished Thesis. Bogor Agricultural University. SB Indonesia Report No. 8, Bogor. Indonesia.

Appendix 1. Prices of major inputs and outputs used in financial and economic analyses

Item	Unit	Private Price	Social Price
Discount rate	%	20	15
INPUTS			
Fertilisers	Rp/kg	1,500	1,500
Fertiliser for palm oil	Rp/kg	2,500	2,500
Pesticides	Rp/ltr	55,000	55,000
Family labour	Rp/pd	0	15,000
Hired labour	Rp/pd	15,000	15,000
Albizia seedling	Rp/package	220,000	220,000
Duku seedling	Rp/seedling	1,000	1,000
Durian seedling	Rp/seedling	1,000	1,000
Candle nut seedling	Rp/seedling	1,000	1,000
Macang seedling	Rp/seedling	1,000	1,000
Mangga seedling	Rp/seedling	1,000	1,000
Meranti seedling	Rp/seedling	2,500	2,500
Pinang seedling	Rp/seedling	750	750
Rambutan seedling	Rp/seedling	1,000	1,000
Rice seedling	Rp/kg	3,000	3,000
Vegetables	Rp/package	270,000	270,000
OUTPUTS			
Albizia wood	Rp/m^3	200,000	200,000
Duku fruit	Rp/kg	1,500	1,500
Duku wood	Rp/m^3	150,000	150,000
Durian fruit	Rp/kg	1,500	1,500
Durian wood	Rp/m^3	200,000	200,000
Candle nut fruit	Rp/kg	4,000	4,000
Candle nut wood	Rp/m^3	100,000	100,000
Macang fruit	Rp/kg	500	500
Macang wood	Rp/m^3	150,000	150,000
Mangga fruit	Rp/kg	3,000	3,000
Mangga wood	Rp/m^3	150,000	150,000
Meranti wood	Rp/m^3	350,000	350,000
Pinang fruit	Rp/kg	3,500	3,500
Rambutan fruit	Rp/kg	1,000	1,000
Rambutan wood	Rp/m^3	150,000	150,000
Rice	Rp/kg	2,200	2,200
Vegetables			
Chilli	Rp/kg	10,000	10,000
Tomato	Rp/kg	3,000	3,000
Spinach	Rp/kg	2,000	2,000
Snake bean	Rp/kg	2,000	2,000
Egg plant	Rp/kg	2,000	2,000
Cucumber	Rp/kg	1,000	1,000