POTENTIAL OF AGROFORESTRY AND PLANTATION SYSTEMS IN INDONESIA FOR CARBON STOCKS: AN ECONOMIC PERSPECTIVE[1]

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ABSTRACT

This paper investigates the carbon sequestration potential of several alternative agroforestry and plantation systems in Indonesia. It is shown how different agroforestry systems vary in their attractiveness in terms of carbon sequestration, returns to land and labour and employment potential. A twenty-year life cycle of coffee multi-cropping systems is compared to short-rotation timber plantations and to a forty-year life cycle of fruit trees such as mango, duku and durian.

Keywords: Agroforestry, Indonesia, Carbon Sequestration, Economic Analysis.

INTRODUCTION

The recent Marrakech accord confirmed two types of activities which are eligible for inclusion in a carbon market within the Clean Development Mechanism (CDM) of the Kyoto Protocol (KP), namely afforestation (which includes activities such as agroforestry), and reforestation (including industrial plantations). This paper describes several common agroforestry systems in Sumatra, Indonesia, and pays particular attention to the benefits and costs of each system and their potential to sequester and store carbon for mitigation purposes.

An understanding of the viability (economic, social and biological) and carbon sequestration potential of the land-use systems currently being practiced in Indonesia is necessary for investors, decision makers and developers to choose and implement the most appropriate land-use systems to meet the social, environmental and economic objectives of the Indonesian government.

THE SYSTEMS STUDIED

The agroforestry systems analysed in this study include three different coffee-based (*Coffee robusta*) multi-stratum agroforestry systems: timber-based, fruit-based and shade-based systems. The coffee data are from Sumberjaya, which is north of the Lampung Province, and were collected by Wulan (2002). The other types of agroforestry systems studied are based on data provided by Hendri (Rizaldi Boer's staff) of Bogor Agricultural University (IPB) and include: durian (*Durio zibethinus*), macang (*Mangifera spp.*), mango (*Mangifera indica*), candle nut (*Aleurites moluccana*), pinang (*Areca catecu)* and rambutan (*Nephelium lappaceum*) agroforestry systems. In addition to these agroforestry systems, monoculture plantations such as *Paraserianthes falcataria* and meranti (*Shorea spp*) are evaluated. Most of these systems are located in the Jambi province of Sumatra.

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[1] Working Paper CC14, ACIAR Project ASEM 2002/066, http://www.une.edu.au/febl/Economics/carbon/

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Coffee (*Coffee robusta*) multi-stratum agroforestry systems

Most of the forested areas in Sumberjaya have been damaged or destroyed due to the expansion and encroachment of agricultural practices, primarily coffee gardens. The government's efforts to rehabilitate state forests have resulted in increasing conflict between government forestry officers and people living in the forest frontier. Therefore, to prevent these conflicts, land-use systems that can meet the needs of people while simultaneously maintaining the environmental and biological functions of forests are needed**.** One such land-use alternative is the coffee multi-stratum agroforestry garden. This system covers about 130,000 hectares of land in Lampung (Fadilasari, 2000), and produces 60 per cent of Indonesia's coffee exports. Coffee multi-stratum agroforestry systems are classified according to the tree species that dominates the system. For example, if the system is dominated by timber-producing tree species it is referred to as Timber-based multi-stratum system. If, however, the system is dominated by fruit-bearing species then the system is called a Fruit-based multi-stratum system. Finally, if the system is dominated by shade trees then it is referred to as a shade-based multi-stratum agroforestry system.

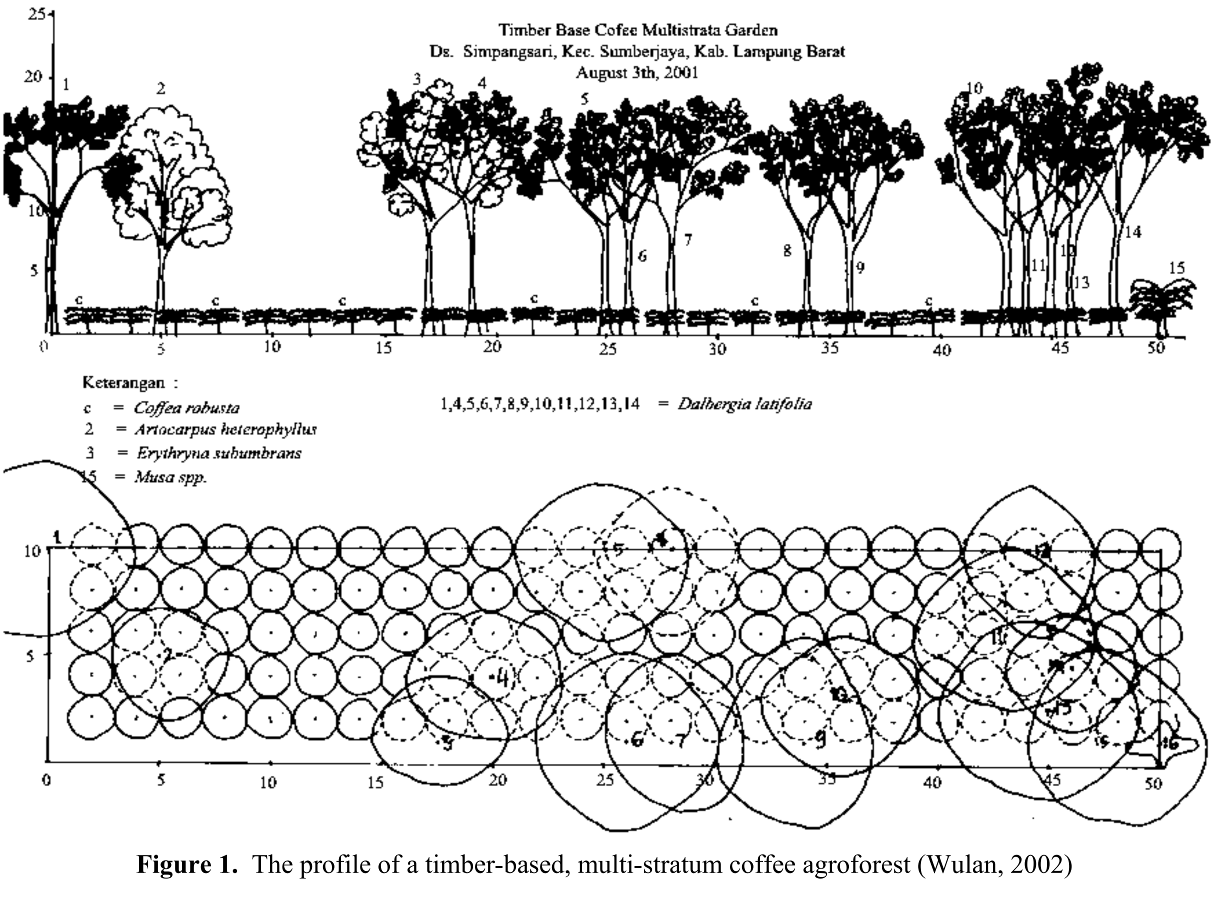

Figure 1. The profile of a timber-based, multi-stratum coffee agroforest (Wulan, 2002)

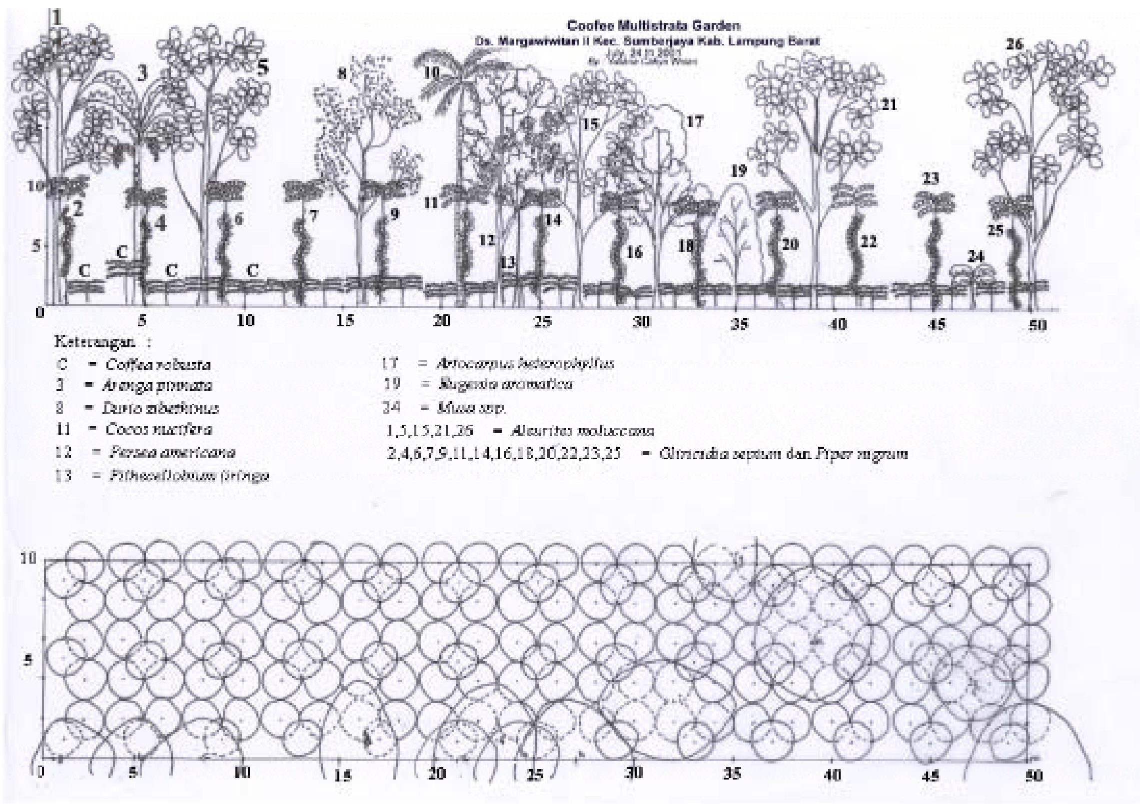

Figure 2. The profile of a fruit-based, multi-stratum coffee agroforest (Wulan, 2002)

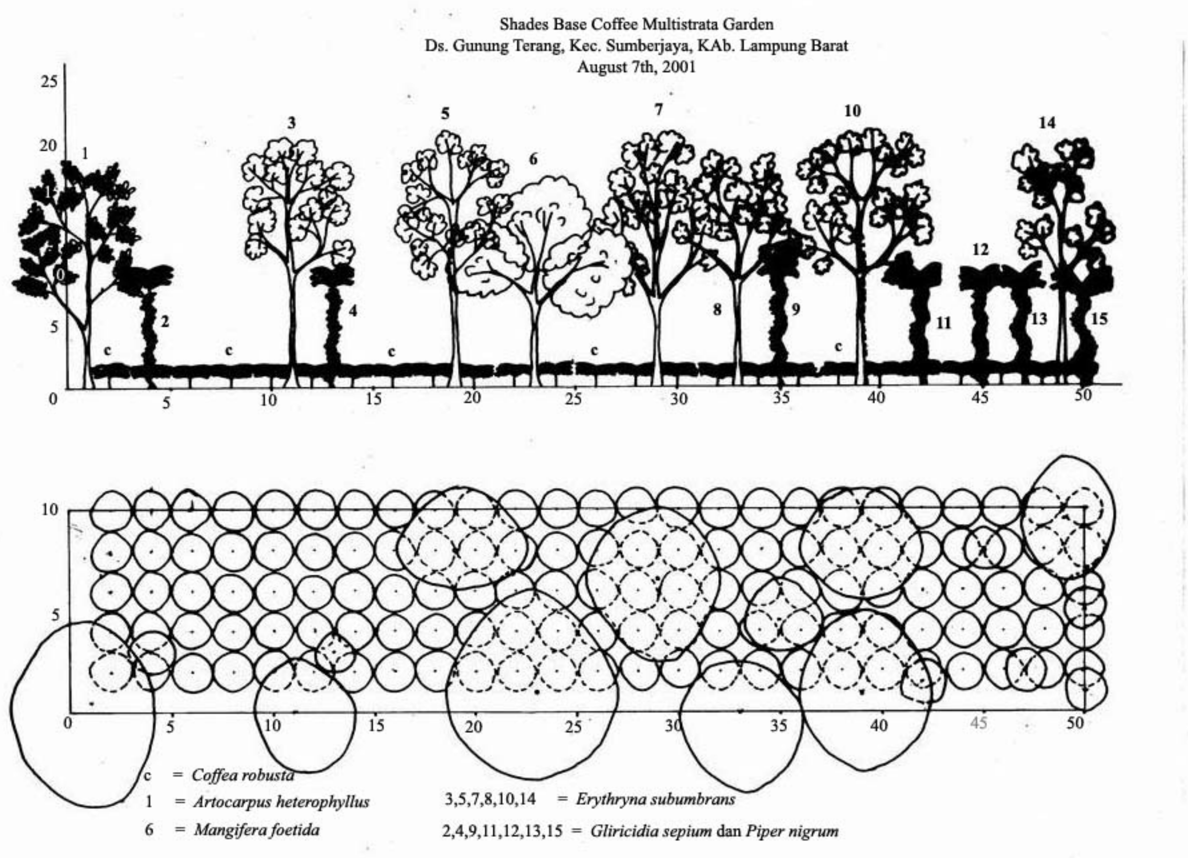

Figure 3. The profile of a shade-based, multi-stratum coffee agroforest (Wulan, 2002)

Timber-based, multi-stratum coffee agroforestry systems.

"Timber-based multi-stratum" refers to coffee agroforestry systems whose strata are dominated by timber-producing forest trees. In such cases most of the land is categorised as forest land. The dominant species found in these land-use systems include: sonokeling (*Dalbergia latifolia*) and sengon (*Paraserianthes falcataria*) which are species used for "regreening" by forest officers, and perennial trees such as jackfruit (*Arthocarpus heterophyllus), erythryna* and banana trees which cover other strata of the systems. Details of the species planted in this system are presented in Table 1.

Table 1. The species most commonly found in timber-based, multi-stratum coffee agroforests

No.	Species	Scientific names	Product	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*	Medicine	30 000	Rp / kg
23	Banana	*Musa spp.*	Fruit	250	Rp / kg

Fruit-based, multi-stratum coffee agroforestry systems.

"Fruit-based multi-stratum" refers to the strata of coffee agroforestry systems whose strata are dominated by fruit trees such as jack fruit, guava, and avocado. The trees species most commonly found in this system are shown in Table 2.

Table 2. The tree species most commonly found in fruit-based, multi-stratum coffee agroforests (Wulan, 2002)

No.	Species	Scientific names	Product	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, multi-stratum coffee agroforestry systems.

"Shade-based, multi-stratum" refers to coffee agroforests whose strata are dominated by shading trees such as *Gliricia sepium*, *Erythryna subumbrans* and *Leucaena leucocephala*. In such cases most of the garden is considered a young established garden rather than a forest. Trees found in this system are presented in Table 3.

Table 3. The tree species most commonly found in shade-based, multi-stratum coffee agroforests (Wulan, 2002)

No.	Species	Scientific names	Product	Price/cost	Unit
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	Pepper	*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

Sengon plantation (*Paraserianthes falcataria*)

Paraserianthes falcataria (sengon), is grown in both community forests and state timber plantations. Community forests comprising sengon were developed in 1950 (Saiban, Sylviani and Effendi, 1994). In 1989 the Ministry of Forestry, initiated a community-based afforestation program based primarily on sengon trees. In addition to increasing wood supply, this program also aimed to increase land productivity, provide additional wood for industry and generate employment. Sengon wood is usually used for packaging, furniture, and building construction. Sengon's leaves are sometimes also used as fodder for goats.

The sengon's life cycle is usually no longer than 15 years because this is when root rot sets in. In this system, sengon wood is harvested in year 8 and is managed as a monoculture timber plantation. The input requirements for a sengon plantation are presented in Table 4.

Table 4. The input requirements and outputs of an *Paraserianthes falcataria* plantation

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

Duku agroforestry *(Lansium domesticum)*

Lansium domesticum (Duku) is widely distributed in Indonesia and is usually referred to as a "fruit tree". Duku fruit is very popular in the province of South Sumatra because of its sweet taste and large size. The wood of the Duku tree is characterised as durable, strong, elastic and very suitable for building construction (ICRAF, 2000). In Indonesia Duku is grown in and around villages (*kampungs*). It does not require intensive cultivation and maintenance. In this analysis Duku is planted with other food crops (rice and vegetables) for the first three years. Detailed input requirements and outputs for a typical Duku agroforestry system are shown in Table 5.

Table 5. The input requirements and outputs of a *Lansium domesticum* plantation

INPUTS	Amount
Seedlings	
Duku seeds (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Materials (unit/ha)	
Machete	1
Labour (pd/ha)	
Sowing	16
Planting	32
Maintenance and monitoring	24
Harvesting	865
OUTPUTS	
Duku	
Fruit (kg/ha/yr) year 5-40	20,000
Wood (m^3/ha), year 40	407
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

Durian agroforestry *(Durio zibethinus)*

Durio zibethinus (durian) is one of most popular fruits in Indonesia. It is widely distributed in Indonesia and is mostly planted in drylands and gardens. Durian wood can be used for construction, furniture, cabinets, fittings, panelling, partitioning, plywood, chests, boxes, wooden slippers, low-quality coffins and ship building (Prosea, 1995). However, its use is generally limited to building construction and packaging. The inputs and outputs of an agroforestry system comprising durian, rice and vegetables are listed in Table 6.

Table 6. The inputs for, and outputs of, a hectare of *Durio zibethinus*

INPUTS	Amount
Seedlings	
Durian seeds (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	
Sowing	16
Planting	32
Maintenance and monitoring	24
Harvesting	641
OUTPUTS	
Durian	
Fruit (unit/ha/yr) year 5-40	20,000
Wood (m^3/ha), year 40	295
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

Candle-nut agroforestry *(Aleurites moluccana)*

Candle nut is a fast-growing tree species and is therefore often planted as the main tree species in reforestation programs. The advantages of Candle nut are that it has few input requirements, it is able to grow in arid land, and it is a good pioneer species for reclaiming land left fallow after shifting-cultivation practices (Kalima, 1990). Farmers grow candle-nut for its fruit, for spices and for traditional medicines.

The Indonesian Bio-diesel Institute is planning to use the candle-nut fruit as an alternative source of bio-diesel. This is because candle-nut fruit yields oil which has similar characteristics to petroleum oil. This and its ability to grow quickly (and hence capture and store carbon rapidly) make candle nut a very attractive species for inclusion in agroforestry systems. The inputs and outputs for a hectare of candle nut intercropped with rice and vegetables are present in Table 7.

Table 7. The inputs for, and outputs of, a hectare of candle-nut tree intercropped with rice and vegetables

INPUTS	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)	
Sowing	14
Planting	35
Maintenance	22
Monitoring	10
Harvesting fruit	281.5
OUTPUTS	
Candle nut	
Fruit (kg/ha/yr) year 5-40	2048
Wood (m^3/ha), year 40	132
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

Macang agroforestry *(Mangifera* spp.)

Macang is the generic word that includes a number of different fruit trees. The wood of these trees is generally used for light construction, ceilings, door panels, interior finishing, floor boards, moulds, crates, good quality charcoal, gunstocks, veneers and plywood (Prosea, 1995). The inputs and outputs of a Macang agroforestry system are listed in Table 8.

Table 8. The inputs for, and outputs of, a hectare of Macang agroforestry

INPUTS	Amount
Seedlings	
Macang seedlings (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)	
Sowing	16
Planting	32
Maintenance	24
Harvesting	532
OUTPUTS	
Macang Fruit (kg/ha/yr) year 5-40	20,000
Macang Wood (m^3/ha), year 40	248
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

Mango agroforestry *(Mangifera indica)*

The mango tree is a tall, evergreen tropical tree that typically grows between 30-100 feet and has a dense and heavy crown. This species is very popular in Indonesia and is grown in both drylands and homegardens. People plant this species primarily for its fruit but its wood can also be used for firewood. The inputs for, and outputs of, a hectare of a mango agroforestry system are shown in Table 9.

Table 9. The inputs for, and outputs of, a hectare of a mango agroforestry system

INPUTS	Amount
Seedlings	
Mangoes seeds (plants/ha)	120
Rice (plants/ha)	60
Vegetables (package/ha)	1
Materials (unit/ha/yr)	
Machete	1
Labour (pd/ha/yr)	
Sowing	16
Planting	43
Maintenance and monitoring	36
Harvesting	467
OUTPUTS	
Mango Fruit (kg/ha/yr) year 5-40	20,000
Mango Wood (m^3/ha), year 40	217
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

Plantation of Pinang (*Areca catecu*)

The Pinang tree is grown for its fruit (betel nut), which is chewed as a mild stimulant. It is also a beautiful palm tree used for garden accessories. Traditionally many people have used the betel nut for cosmetic and health purposes. The nut contains large quantities of tannin and also contains garlic acid, fixed oil gum, a little volatile oil, lignin, and various saline substances. The input and output data relating to a hectare of Pinang grown with rice and vegetables are listed in Table 10.

Table 10. The inputs for, and outputs of, a hectare of *Pinang* plantation

INPUTS	Amount
Seedlings	
Pinang seeds (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	
Sowing	14
Planting	35
Maintenance	32
Harvesting fruit	6.5
OUTPUTS	
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

Rambutan agroforestry *(Nephelium lappaceum)*

Rambutan is one of the most popular fruits in Indonesia. Rambutan is a medium-sized tree that produces a red or yellow fruit, round to oval in shape, with hairs or tubercles on its skin. The flesh or aril is translucent and sweet. Most rambutan trees that have been propagated from seed are not true-to-type and are usually sour. Rambutan produces a small crop in June and July and a large crop between November and January. The inputs and outputs of Rambutan intercropped with rice and vegetables are listed in Table 11.

Table 11. The inputs for, and outputs of, a hectare of Rambutan grown with rice and vegetable

INPUTS	Amount
Seedlings	
Rambutan (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)	
Sowing	16
Planting	32
Maintenance and monitoring	24
Harvesting	517
OUTPUTS	
Rambutan Fruit (kg/ha/yr) year 5-40	3000
Rambutan 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

MEASURES OF SYSTEM PERFORMANCE

In this section, the performances of the agroforestry and plantation systems reviewed above are 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 Tables 12 and 13.

Table 12 presents the inputs and costs for multi-stratum coffee agroforestry systems. In general the three systems used similar amounts of labour and non-labour inputs annually, although the fruit-based multi-stratum system used more hired labour and fertilisers. The transport required to deliver the outputs was calculated based on the amount of coffee produced by each system. The shade-based system produced the most coffee (dry weight) because the coffee trees have more space to grow larger and hence produce more coffee.

Table 12. Input and cost data for timber-based, fruit-based and shade-based multi-stratum coffee agroforestry systems

Item	Price/Cost	Quantity per Item		
		Timber-based	Fruit-based	Shade-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

Financial and economic analyses

Financial analyses are based on private prices (i.e prices experienced by producers) whereas economic analyses are 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 analyses measure profit as the farmer experiences it. Family labour is not paid a wage and the value of forestland cleared is not charged to the farmer. Hence the net present value (NPV) calculated in financial analyses represent the return to family labour, land, management and capital (Ginoga, et.al. 2002).

Economic analyses measure profit as it 'should be' in an ideal world with no price distortions. Family labour is paid the going market rate and the cost of cleared land is accounted for. Hence the NPV 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 (Ginoga, et. al. 2002).

Table 13. 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
Sengon 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
Mango 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			
Sengon 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
Mango fruit	Rp/kg	3,000	3,000
Mango 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

In financial terms, a system is feasible if its NPV is positive. The financial and economic analyses for the three different multi-stratum coffee agroforestry systems are presented in Table 14. Return to labour was calculated as the wage rate that makes NPV=0.

Overall the three coffee agroforestry systems yield positive returns both privately (Table 14) and socially (Table 15), so they are feasible under the assumptions of this study. Among the coffee systems, the most attractive is the shade-based multi-stratum system with a financial NPV of Rp 12,169,000/ha and an economic NPV of Rp 11,030,000/ha, while the least attractive is the timber-based multi-stratum system with a financial NPV of Rp 5,696,000/ha and an economic NPV of Rp 3,847,000/ha. The timber-based, multi-stratum system has the lowest net returns because a high proportion of the timber trees growing in such systems may not be harvested without the government's consent. This highlights the inefficiencies, uncertainties and risks that result from unclear or insecure property rights and land-tenure.

Establishment costs were estimated as the present value of costs incurred until the system reaches a positive cash flow. The timber-based, multi-stratum system has the highest establishment costs taking 10 years to reach positive cash flows. Compared with the NPV based on financial analysis, the NPV based on economic analysis of the three systems are all lower but remain positive. Therefore, even from an economic perspective, these land-use systems are attractive for investment. The best economic performance occurs in the shade-based, multi-stratum system with NPVs of Rp 12.2 M/ha.

In terms of employment potential, all of the systems provide similar prospects. In the case of establishment labour, the fruit-based coffee system provides the most employment (3,266 pd/ha) followed by the timber-based multi-strata system (2,954 pd/ha). In terms of economic analysis, the timber-based system provides the most employment (4,514 pd/ha) compared to the other two systems, due to high use of family labour and a longer period to obtain positive cash flow.

The financial and economic analyses of the other agroforestry systems studied are also presented in Tables 14 and 15. All these systems have positive NPVs both financially and economically, so they are feasible and attractive for investment. Mango agroforestry systems have the largest returns (Rp 143,265,000/ha and Rp 225,772,000/ha, financially and economically respectively) followed by duku agroforestry and then durian agroforestry (see Tables 15 and 16). This is because of the relatively high prices received by landowners for mango, duku and durian fruits. It is also indicated that agroforestry systems are more feasible than monoculture plantations because they have higher returns (both financially and economically) and have positive cash flows earlier than monoculture plantations do.

In terms of system financial and economic potential, mango and duku agroforestry systems provide the best prospects because they produce high NPV. Another interesting comparison can be obtained by evaluating the performance of each system in terms of returns to labour. Along with their high NPV, mango and duku agroforestry systems also have high returns to labour.

Table 14: Financial analysis for several agroforestry systems

	IRR (%)	NPV (Rp '000/ha)	Establishment costs (Rp '000/ha)	Return to labour (Rp'000/pd)	Years to positive cash flow	Labour requirements Establishment (pd/ha)	Labour requirements Operation (pd/ha/yr)	Labour requirements Total (pd/ha/yr)
Coffee systems:								
Timber-based	30.3	5,696	7,421	11.28	10	3,266	312	319
Fruit-based	32.1	7,209	7,271	12.69	9	2,954	312	319
Shade-based	51.0	12,169	5,703	17.29	4	1,394	312	319
Other systems:								
Sengon	51.0	6,683	1,816	99	8	208	211	47
Duku	133.8	71,045	4,180	310	5	269	38	41
Durian	133.5	70,487	4,180	281	5	269	41	44
Candle nut	107	18,217	4,140	108	5	277	34	38
Macang	100	23,135	3,980	119	5	287	29	33
Mango	164.0	143,265	4,180	610	5	269	27	31
Pinang	94.4	8,322	4,104	57	5	277	27	31
Rambutan	59.7	6,019	4,180	40	5	269	28	32

Table 15. Economic analysis for several agroforestry systems

	IRR (%)	NPV (Rp ‘000/ha)	Establishment costs (Rp '000/ha)	Return to labour (Rp'000/pd)	Years to positive cash flow	Labour requirements Establishment (pd/ha)	Operation (pd/ha/yr)	Total (pd/ha/yr)
Coffee systems:								
Timber-based	19.4	3,847	15,819	7.55	14	4,514	312	319
Fruit-based	21.7	6,230	15,040	8.50	12	3,890	312	319
Shade-based	34.3	11,030	9,481	10.43	5	1,706	312	319
Other systems:								
Sengon	51.0	9,979	1,967	125	8	208	211	47
Duku	133.8	112,251	4,439	423	5	269	38	41
Durian	133.5	111,379	4,439	272	5	269	41	44
Candle nut	90.9	27,816	4,996	105	5	277	34	38
Macang	92.4	36,225	4,614	141	5	287	29	33
Mango	164.0	225,772	4,439	841	5	269	27	31
Pinang	72.5	12,096	4,959	54	5	277	27	31
Rambutan	59.7	9,935	4,439	51	5	269	28	32

Carbon sequestration services

The amount of carbon sequestered by each system is presented in Table 16. Only carbon in the aboveground biomass of coffee trees is included in this analysis. The amount of carbon sequestered in coffee multi-stratum 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):

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

Were H is tree height (metres), ρ is wood density and D is diameter at breast height. Tree height and diameter were obtained from Wulan (2002) and ICRAF (2000).

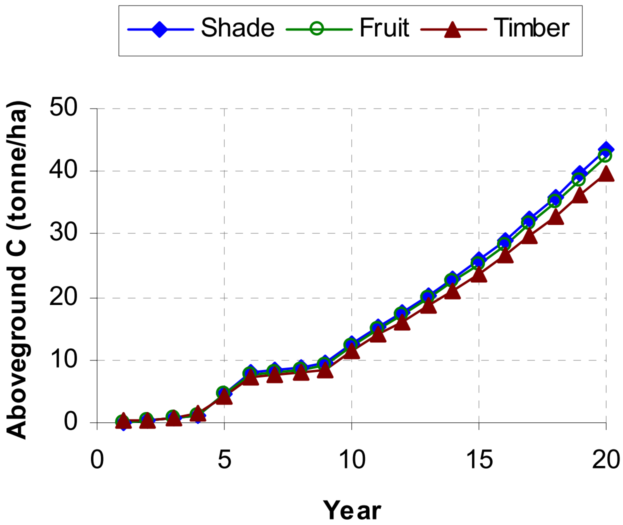

Figure 4. Carbon stocks for three coffee multi-stratum agroforestry systems (tC/ha)

These estimates exclude carbon in soil and litter, and hence underestimate actual carbon stocks. Based on research undertaken in the same area by Van Noordwijk, et al. (2002), it was assumed that the carbon content of non-coffee trees for the whole system were 29.6 tC/ha and that C accumulates in other trees at the same rate as it accumulates in coffee trees. In this case, the carbon stock is about 40 tC/ha by year 20.

Table 16 presents the costs of carbon sequestration for each system. These costs were calculated by dividing the establishment cost by the tonnes of carbon sequestered. It can be seen that carbon costs for the timber-based, multi-stratum systems were the highest.

Table 16 also shows the carbon stocks for the rest of the systems described in section 2. Among the non-coffee systems, the pinang system accumulates carbon at the highest cost (US$ 6.56 per tonne of C), while Durian accumulates carbon at the lowest cost ($3.14 per tonne of C) .

Table 16. Carbon sequestration of several agroforestry and plantation systems

	Average biomass C	C Cost (Rp '000/tC)		C Cost (US$/tC)	
	(tC/ha)	Financial	Economic	Financial	Economic
Coffee systems:					
Timber-based	39.7	187	399	18.69	39.85
Fruit-based	42.2	172	356	17.32	35.85
Shade- based	43.5	131	218	13.19	21.95
Other systems:					
Sengon	52.7	34.5	37.3	3.45	3.73
Duku	115.0	36.3	38.6	3.63	3.86
Durian	133.0	31.4	33.4	3.14	3.34
Candle nut	124.7	33.2	40.1	3.32	4.01
Macang	121.1	32.9	38.1	3.29	3.81
Mango	121.1	34.5	36.7	3.45	3.67
Pinang	62.6	65.6	79.2	6.56	7.92
Rambutan	118.0	35.4	37.6	3.54	3.76

An exchange rate of IDR 10,000 to US$1 was used.

Overall comparison of the systems

Different systems produce different social and environmental benefits. Social benefits are measured using indicators such as food security, income generation and poverty alleviation (Ginoga, et. al. 2002). None of the systems analysed provided any long term, direct food security because staple food-crops, such as rice and vegetables, were only produced during the first few years. However, steady employment can contribute indirectly to both food security and poverty alleviation. Poverty alleviation is also concerned with how the agroforestry systems can provide sustainable income, food, fuel and shelter to farmers and their families. For completeness, the analysis should also have considered the long-term physical impact that agroforestry has on soil erosion, soil fertility and hydrological balance, because these factors influence the systems’ capacity to generate income and other social benefits in the future. Such an assessment, however, is out of the scope of this study.

In this section we summarise our results by selecting the best agroforestry systems based on NPV at social prices, employment potential, return to labour and carbon sequestration services. The mango system is the most attractive in terms of NPV at social prices (Figure 5), and in terms of returns to labour (Figure 6B). The coffee systems provide the best employment potential, but have low returns to labour (Figure 6B).

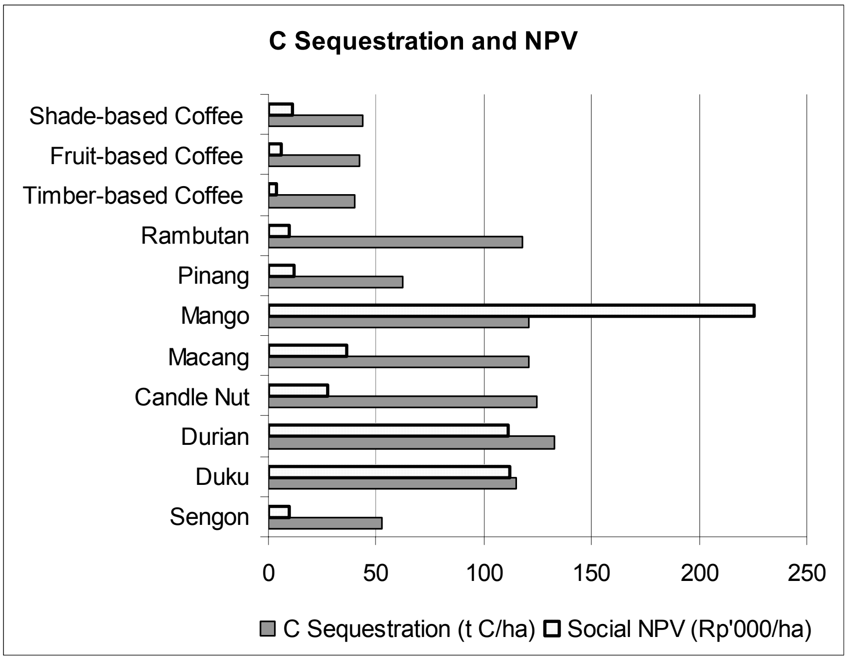

Figure 5. Comparison of agroforestry systems in terms of profitability and carbon sequestration, employment potential and carbon sequestration.

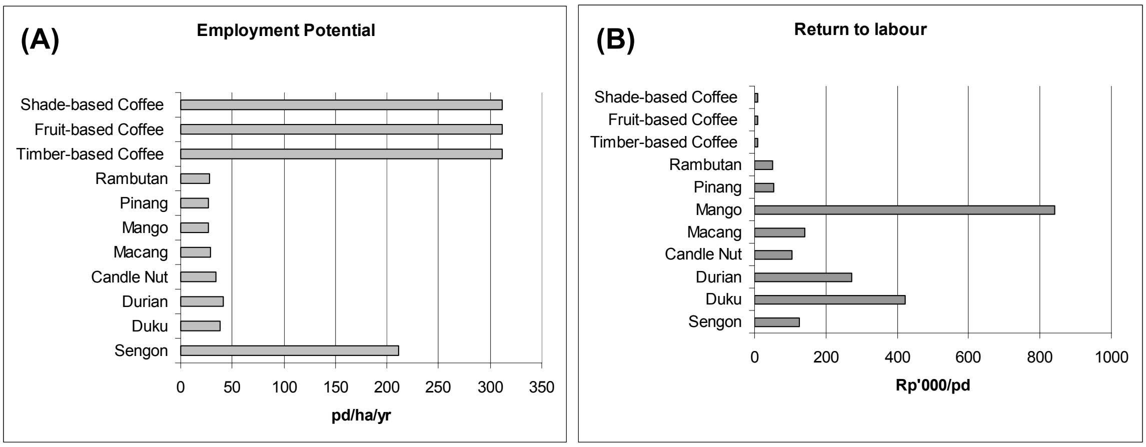

Figure 6. Comparison of agroforestry systems in terms of employment potential and return to labour.

SUMMARY AND CONCLUSIONS

This report provides a description of several important agroforestry and plantation systems, ranging from complex coffee agroforests to Sengon monocultures. In general, all the systems evaluated appear to be economically and financially attractive (they have positive NPV). The paper demonstrates how simple economic analysis can be used to evaluate the potential of agroforestry systems to provide both financial and economic profits while at the same time contributing to the mitigation of global warming.

However, other important aspects relating to the eligibility of land-use activities in the Kyoto Protocol, which are not analysed in this paper, include: insecure land ownership and property rights; the possibility of 'leakage' from land-use activities implemented as carbon-credit schemes, and the issue of 'permanence' of the carbon captured and stored in soils and vegetation.

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