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GREENHOUSE GAS INVENTORY AND ABATEMENT STRATEGY FOR FORESTRY AND LAND USE CHANGE SECTOR

Inventarisasi Gas Rumah Kaca dan Strategi Penurunan Emisinya untuk Sektor Kehutanan dan Perubahan Tata Guna Lahan

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ABSTRACT

In the last ten years, rate of deforestation in Indonesia tended to increase and this leads to the increase in carbon emission from forestry sector. In 1990, it was estimated that Indonesian forest emitted 339 Tg of CO_2 and removed 686 Tg of CO_2. Thus in 1990, Indonesian was considered as net sinket country. However, improvement of these estimates need to be done since many of activity data and emissioin factors used were assumed data and default values provided by IPCC. Methodology to estimate the carbon emissions and removals also need to refined. Efforts to reduce emission from forestry sector have been implemented by Indonesian Government through reforestation (Rf) and afforestation (Af) programs, timber estate (TE), social forestry (SF) and private forest (PF) developments (called as mitigation options). Carbon mitigation potential and cost effectiveness of these options have been evaluated. Carbon mitigation potential of these options varied, i.e. from 94 to 165 tonne C/ha. Life cycle cost of these options also varied from 4.4 to 15.4 US$/tonne C. The investment required to implement the options ranged between 67 and 311 US$/ha. In order to offset 25% of carbon emission from energy sector, rate of planting for the five options need to be increased by about 23% of the baseline rate in the period of 2000-2005 and by about 30% in the period of 2006-2020. Total additional waste land required to implement the options (2000-2020) were about three million hectares.
Keywords: Greenhouse gases, carbon emissions, carbon mitigation, forest and land use change.

ASBTRAK

Dalam sepuluh tahun terakhir, laju deforestasi cenderung meningkat dan berakibat pada meningkatnya emisi gas rumah kaca dari sektor kehutanan. Pada tahun 1990 tingkat emisi dari sektor kehutanan diperkirakan mencapai 339 Tg CO_2 dan tingkat penyerapannya 686 Tg CO_2. Jadi pada tahun 1990, Indonesia merupakan negara penyerap CO_2 (*net sinker*). Namun demikian, perbaikan terhadap hasil pendugaan ini perlu dilakukan karena sebagian data aktivitas dan faktor emisi yang digunakan merupakan data asumsi dan data default dari IPCC. Selain itu, metode perhitungannya juga perlu untuk diperbaiki. Upaya untuk menurunkan emisi dari sektor ini sudah dilakukan oleh pemerintah Indonesia melalui program penanaman lahan kosong dengan tanaman pohon baik melalui program reforestasi dan afforestasi ataupun program pembangunan hutan kemasyarakatan, hutan rakyat dan hutan tanaman (disebut sebagai teknologi mitigasi). Potensi masing-masing teknologi ini dalam mengambil CO_2 dari atmosfir sudah dievaluasi demikian juga analisis ekonominya. Hasil analisis menunjukkan bahwa potensi mitigasi dari teknologi tersebut bervariasi mulai dari 94 sampai 165 ton C/ha. Biaya yang diperlukan untuk satu siklus hidup dari teknologi tersebut juga beragam mulai dari 4.4 sampai 15.4 US$/ton C. Investasi yang diperlukan untuk melaksanakan kegiatan berkisar antara 67 dan 311 US$/ha. Dengan menggunakan skenario menekan emisi dari sektor energi sebesar 25% melalui kegiatan kehutanan, maka laju penanaman pohon pada masing-masing teknologi tersebut harus ditingkatkan sebesar 23% dari *baseline* (laju penanaman menurut program pemerintah) untuk periode 2000-2005 dan sebesar 30% untuk periode 2006-2020. Total tambahan lahan yang diperlukan untuk melaksanakan kegiatan tersebut (2000-2020) ialah sebesar tiga juga hektar.
Kata kunci: Gas rumah kaca, emisi karbon, penekanan emisi, hutan dan perubahan tata guna lahan.

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INTRODUCTION AND BACKGROUND

Indonesia is a tropical country that has a land area of about 193 million hectares. It is located within latitude 6° North and 11° South and longitudes 94° West and 141° East. Through a consensus among agencies related to the use of forest lands, about 140.4 million hectares has been planned as forest area. This is known as Forest Land Use Plan by Consensus (TGHK). The main objective of the plan were to provide a basis for implementing sound forest management and to avoid misuse of forest lands. Subsequently, this directive provided a framework to monitor and control the depletion of forest resources and to re-establish forest wherever necessary.

It was estimated that the Indonesian forest has a growing stock of about 19 billion m^3. With this stock, the forestry sector plays an important role in the Indonesian economy. In 1993, timber commodity export value was about US$6.15 billion. It is the second only to oil for that year. However, high rate of deforestation due to shifting cultivation, transmigration development, agricultural plantation development, wasteful logging, the practice high grading, and fire are likely to affect the growing stock adversely. MoF (1995) stated that if Indonesia continues to maintain its market dominance and industrial pace and if concession management efficiency does not improve, log shortages are likely to occur in many areas by the year 2000 (MoF, 1995).

The high rate of deforestation is responsible for high green house gases (GHGs) emissions. In the early 1970s, the rate of deforestation in Indonesia was estimated to be about 300,000 ha. The early 1980s estimate was about 600,000 ha (MoF and FAO, 1990), and in the early 1990s deforestation has been estimated to be about 1 million ha (Sorensen, 1993). However, based on the forest database (MoF, 1996), the area of deforestation in early 1990s was about 700 thousand hectares. Due to government regulation, the improvement of the control system, and eco-labeling, the rate of deforestation in the future may not increase significantly from the current rate.

To compensate forest loss and to reduce the GHG emission from the forestry sector, the sink capacity of forest should be increased, particularly through reforestation and afforestation. The main target area for the two programs is critical land. The total area that has been afforested and reforested during Pelita V were about 2.57 and 0.32 million hectares respectively and the remaining critical land at the beginning of Pelita VI was about 10.96 million hectares (Center for Forest Inventory, 1996).

This paper discussed the inventory of GHG emission and uptake from the forestry sector. Technological options that could be considered to reduce forestry emissions as well as their economic assessment were also described.

GHG INVENTORY

Inventory of 1990. Emission and uptake of GHG was estimated using IPCC methodology. There are three main activities in forestry sectors that result in CO_2 emissions and removals. These activities include change in forest and other woody biomass stocks, forest and grassland conversion, and abandonment of croplands, pastures, plantation forests or other managed lands. From the analysis, it was indicated that Indonesian forest was a potential sink for CO_2. The forest can uptake about 686 Mt of CO_2 (Table 1). In comparison with other studies, this value is lower. Total CO_2 uptake by natural regeneration and forest plantation estimated by JEA (1992) was about 965 million tonnes CO_2. The US Country study estimated at 1,237 million tonnes CO_2 (SME, 1996). The methodology used in the ALGAS study and US-Country Study (US-CS) was the same. The differences in estimates between the two studies are primarily due to the difference in mean annual growth rate of production and conversion forest used. US-CS used a value of 9 t/ha/yr, while ALGAS used a lower value. Many studies showed that the annual growth rate of production forest was about 2.5 t/ha. In the Malay Peninsula a forest of *Shorea leprosula* has an increment of 5.4 m^3/ha/year or a productivity of 2.808 t/ha/year (Landon, 1957), while forests of *Shorea*, *Dryobalanops*, and *Dipterocarpus* have an increment of 4.2 m^3/ha/year or a productivity of about 2.9 t/ha/yr (Danhof, 1946). Natural forest has an increment of about 5 m^3/ha (Lattunen *et al.*, 1995). Based on the available data, the productivity of the Indonesian tropical lowland rainforest is around 5.8 t/ha/yr. and that of the tropical montane rainforest is about 12.4 t/ha/yr (Soerianegara, 1996)

Table 1. CO_2Balance and Emissions of non-CO_2 GHG from Indonesian Forests

	CO_2	CO_2	Emission			
	Uptake Gg	Released Gg	CH_4 Gg	CO Gg	N_2O Gg	NOx Gg
Change in forest and other woody biomass stock	575,390.64	26,846.60				
Forest and grassland conversion	-	312,601.48	524.74	4,591.51	3.61	130.39
Abandonment of managed land	111,100.00	-	-	-	-	-
Total	**686,490.64**	**339,448.08**	**524.74**	**4,591.51**	**3.61**	**130.39**

In this study, annual growth rate (MAI) used for the production and conversion forest was 2 t/ha. The lower value was used since some of the production and conversion forest may be at a climax stage. As most of the area of Indonesian forest is under the category of production and conversion forest, a slight change of the MAI will affect greatly the sink capacity of Indonesian forest. For example, if the mean annual increment used is 3 t/ha, the sink capacity of Indonesian forest will increase from 686 Tg to 810 Tg (about 15 percent). Therefore, the improvement of the forest inventory will much depend on the accuracy of the MAI and the availability of data on area of production and conversion forests that are already at climax stage and at growing stage.

Projection of GHG Emission and Uptake. From the analysis, it was found that by the year 2020, the total emission from Indonesian forests reaches 456 Mt, increases by 29 percent from the 1990's emissions. Similarly, CO_2 uptake also increases from 686 Mt. in year 1990 to 844 Mt. in year 2020 (Table 2).

Table 2. Projected GHG Emission and Uptake from Forestry Sector (Gg)

Activity		GHG	1990	2000	2010	2020
Change in forest and other woody Biomass stock	Uptake	CO_2	575,390.63	649,007.28	707,100.09	732,846.90
	Emission	CO_2	26,846.59	111,599.20	144,075.82	176,793.49
Forest and grassland conversion	Emission	CO_2	312,601.47	277,149.02	262,534.09	271,014.04
On-site burning	Emission	CH_4	524.74	422.91	371.99	364.72
		CO	4,591.51	3,700.47	3,254.95	3,191.30
		N_2O	3.61	2.91	2.56	2.51
		NO_x	130.39	105.09	92.43	90.63
Abandonment of managed land	Uptake	CO_2	111,100.00	111,100.00	111,100.00	111,100.00
Total CO_2-eq. Emission			351,586.70	398,531.43	415,215.30	456,244.75
Total CO_2-eq. Uptake			686,490.63	760,107.28	818,200.09	843,946.90
Total net CO_2-eq. Uptake			334,903.93	361,575.85	402,984.79	387,702.15

Note: CO and NO_x are excluded.

This result shows that Indonesian forest in year 2020 will be able to uptake the CO_2 emissions from other sectors by about 388 Mt. In developing the projection, several assumption were used namely:

1. Rate of the deforestation is 1.1 million ha/yr from 1990 to 1995 and 0.7 million ha/yr from 1996-2000.
2. Area of forest and grassland converted into agricultural land was assumed to be 465,000 ha/yr.
3. Rate of timber estate development is 250,000 ha/yr until year 2006.
4. Rate of reforestation and afforestation is assumed to be 65,000 and 350,000 ha/yr, respectively.
5. MAI of tree species after year 2000 increase by 5 percent as result of using high yield species and reducing the impact of logging.
6. Wood demand (industrial wood and fuelwood) follows the scenario given by MoF and FAO (1990).
7. Total area that is naturally generated is assumed to be 7,000,000 ha.

GHG ABATEMENT ASSESSMENTS

GHG Mitigation Options. Technical control options involving forestry can sequester carbon through the growth of woody plants, reduce anthropogenic production of CO_2, and complement other strategies for reducing the accumulation of greenhouse gases. Forestry sector strategies for responding to the threat of global warming fall into two major categories from an economic standpoint: those technical and policy options that reduce the demand for forest land and forest products, and those that increase the supply of forested land and forest products. From a greenhouse gas accounting perspective, these can be divided into fourth classes (Houghton, 1993):

1. reduce sources of GHG,
2. maintain sinks of GHG,
3. expand sinks of GHG,
4. fossil fuel substitution to reduce GHG.

Two important programs dealing with mitigation options in forestry are forest management and rehabilitation and forest protection. Forest management includes the activities that are related to efficiency and implementation of management of forest protection and forest conservation. Several activities of the Government of Indonesia that could be used as mitigation options in the forestry sector especially relating to rehabilitation and protection are:

1. Rehabilitate protection forest—social forestry,
2. Reduce shifting cultivation by introducing permanent agriculture system to shifting cultivators, resettling forest squatters in transmigration areas and villages surrounding forests developed by forest concessionaire holders (*HPH Bina Desa*),
3. Reforestation program—target 1 million ha/5 years,
4. Timber estate—total targets 6.2 million ha,
5. Regreening program (afforestation)—target 1.25 million ha/5 years,
6. Social forestry—target 250 thousand ha/5 years,
7. Private forest—target 250 thousand ha/5 years.

In this study, only five mitigation options being examined namely reforestation, timber estate development, social forestry, afforestation, and private forest. Features of each option was described in Table 3 while area available for the implementation of the options was in Table 4.

GHG Mitigation Options Assessment. Assessment of each mitigation option was carried out using the COMAP Model (Sathaye and Meyers, 1995). It was indicated that the mitigation potential of Af, PF and SF are relatively lower than that of the other three options (Table 5). The highest mitigation potential is Rf, and followed by TE. The mitigation potential of Rf is about two times of that of Af, PF and SF while TE and BE are about 1.75 of that of Af, PF and SF.

In term of investment cost, SF and Af required lower cost, whereas TE and PF required higher cost (Table 5). The highest investment cost was for TE. Considering the cost and total carbon abated, Rf and Af appear to be the options to promote (Fig. 1). TE has a relatively high cost; however, TE can also be considered as an option to be promoted as it has considerable capacity to abate carbon and it is also expected to be the main source of log production.

Table 3: Features of the Mitigation Options

Category Option	Purpose/Description	Remarks
Reforestation (Rf)	Rehabilitation program, i.e. planting trees mainly in critical land and grassland of forest area	Mean annual increment of species is normally 9-15 m^3/ha/yr. Specific gravity 0.5 ton/m^3. Production 50-100 m^3/ha/rotation. Rotation 20-40 years. Most trees planted in critical areas under this program will not be harvested but left for protection and soil conservation.
Timber Estate (TE)	Planting trees in forest area mainly for timber production, and managed by companies	Types of plantations are long rotation timber plantation, short rotation timber plantation, and nontimber product plantations. Long rotation mainly in Java. Log production from the plantation is expected to be 200-250 m^3/ha/rotation.
Social Forestry (SF)	Planting trees mainly in transmigration area or in buffer zones (between forest and community land)	Trees species used have growth rate of 5-15 m^3/ha/yr. Log production from this plantation is expected to be 30-40 m^3/ha/rotation. However, the main products from this plantation are fruits and other nonforest products.
Afforestation (Af)	Rehabilitation program, i.e. planting trees mainly in critical land, grassland, and community land of non-forest area.	Trees species used have growth rate of12-23 m^3/ha/yr. Rotation is 10-20 years and it is expected to produce wood at about 100-150 m^3/ha/rotation. Some of trees in afforested land are left for protection and soil conservation (non-coppice species). The ones that are harvested are coppice species.
Private forest (PF)	The program takes place in community land (non-forest land) and mainly in Java.	In general, species used in this program are fast growing species. The mean annual increment of species is 9-20 m^3/ha/yr.

Table 4: Forestry Mitigation Options and Area Available.

No.	Land Category	Total Areas (million ha)	Mitigation options	Available area for the option (million ha)
1	Forest Area -*Production Forest*	63.0	1. Reforestation (Rf) 2. Enhance natural regeneration 3. Estate timber plantation (TE) 4. Social Forestry (SF)	14.9[a]
2	Conversion Forest	30.0	1. Non-forest plantation	6.8[b]
3	Non-Forest Area	8.8	1. Afforestation (Af) 2. Private forest (PF)	8.8[c]

a Summation of area which has been exploited by Forest Concession Estate up to 1995 (BPS 1997), critical land in forest area (MoF, 1996) and 0.3 of area of grassland.
b Summation of area of critical land in forest area (MoF, 1996) and 30 % of area of grassland.
c Summation of area of critical land in non-forest area (MoF, 1996) and 70 % of area of grassland.

Table 5: Comparison of the Five Mitigation Options

	TE	SF	Rf	PF	Af
Mitigation potential					
- tonne C/ha	165	94	214	99	106
- tonne CO_2/ha	605	344	785	363	389
Life cycle costs					
- $/tonne C	15.46	4.44	5.43	14.48	9.81
- $/tonne CO_2	4.22	1.21	1.48	3.95	2.68
- $/ha	1,600	418	759	979	776
NPV of benefit					
- $/tonne C	4.40	2.02	3.52	12.82	12.05
- $/tonne CO_2	1.20	0.55	0.96	3.50	3.29
- $/ha	767	190	614	1,367	1,023
Investment cost ($/ha)	311	107	186	205	67

Figure 1 shows that the lifecycle cost for social forestry (SF) and reforestation (Rf) are not very different, similarly for private forest (PF) and timber estate (TE). The first two options have a lower cost than the latter two options; i.e., the cost of PF and TE is 3 times that of SF and Rf. The life-cycle cost of afforestation (Af) lies between the other two groups. This cost is very sensitive to the change of rotation, mean annual growth rate of trees, and type of product produced. The use of trees with longer rotation, higher growth rate, and longer product life may result in lower life cycle cost as its capacity in sequestering carbon increases. Therefore, the type of trees used in the five programs will determine this cost. If the trees species used in each program are changed, the analysis should be reviewed.

In terms of benefit gained per tonne carbon abated, private forest (PF) and afforestation (Af) gave higher benefit compared to other options, while the other three options are relatively similar (Figure 1). The benefit gained by the first two options is between 2 and 5 times that of the last three options. However, all the forestry mitigation options are profitable.

Baseline and Least-Cost Abatement Scenarios to 2020. For forestry, the baseline scenario is assumed to be "business as usual". Hitherto, there are five activities conducted in the forestry sector, namely timber estate, social forestry, reforestation, private forest, and afforestation. Rates of afforestation and reforestation were assumed to be the same as that occurring in Pelita V (1989-1994), while the rate of timber estate plantation is the same as government target. Rates of social forestry development and private forest were about 50 thousand hectares per annum. This rate is considered as rational, since the availability of labor in the rural areas is very limited. The survival rates for the programs varied. However in the COMAP analysis, it was assumed that the survival rates were 100 % so that the area data that were used in the model were the same as those of government targets. The survival rate variation was accommodated by varying the growth rate of the tree species.

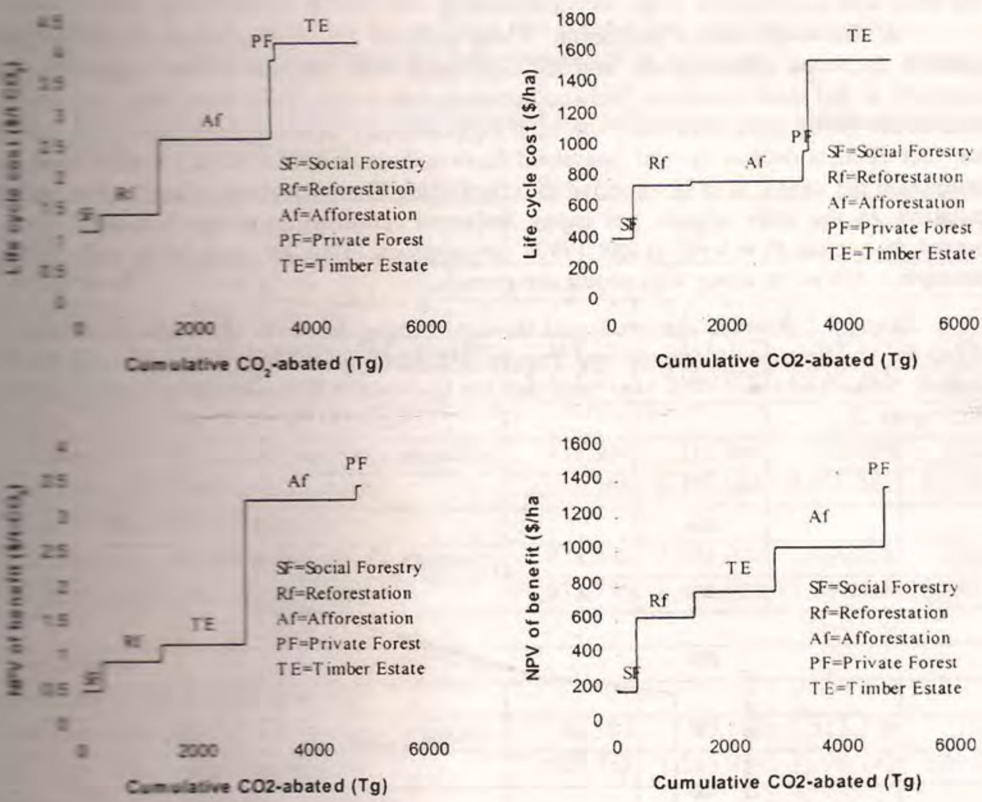

Figure 1. Comparison of the Five Mitigation Options.

Abatement scenarios/options in the forestry sector were developed using four strategies: (i) biomass demand based scenario (Scenario-0), (ii) reduction of 25 percent of net emission (Scenario-1), (iii) reduction of 25 percent of energy sector emissions (Scenario-2), and (iv) forestry technical potential scenario (Scenario-3). The emissions factor from the energy sector used is the baseline scenario emission. The latter strategy is carried out with the assumption of no financial constraint so that all available area is used for the mitigation options.

Assumptions used for development of wood demand projection followed the FAO study (MoF and FAO, 1990). Projection of industrial wood domestic consumption was based on the relationship between GDP and consumption level reflected in income elasticity. The income elasticity is assumed to decline over time, to reflect the commonly observed fact that income elasticity is lower at higher incomes per capita (Table 4-19). The GDP growth rate was assumed to be 5 percent per annum until the year 2000, and the GDP grows by 4 percent per annum after that year. For other industrial wood it is assumed that the estimated constant per capita consumption of

0.0155 m^3 per year will continue to take care of the requirements of other small industries as well as the poles and rough timber needs for rural housing.

For fuelwood demand projection, it was assumed that Java accounts for 57 percent of household fuelwood consumption, and its importance will continue in the future. The other assumption is that total household fuelwood consumption in the island until 2000 is predicted to remain at the 1990s level, thus there will be a slight decrease in average per capita consumption. After year 2000, a decline in total household fuelwood consumption, with a further decrease in consumption per capita, is to be expected to reflect rising living standards of both urban and rural population. In the outer islands, per capita fuelwood consumption of the household sector is expected to remain at a level of the 1990s consumption. Thus an increase in total fuelwood consumption will occur along with population growth.

Strategy 1. Biomass demand based scenario. Using the above assumptions, in year 2020 demand for sawn timber (domestic and export) will reach 35.4 Mm^3, while demand for other industrial wood will reach 40.6 Mm^3 and that for fuelwood will be 164 Mm^3 (MoF and FAO, 1990; Figure 2).

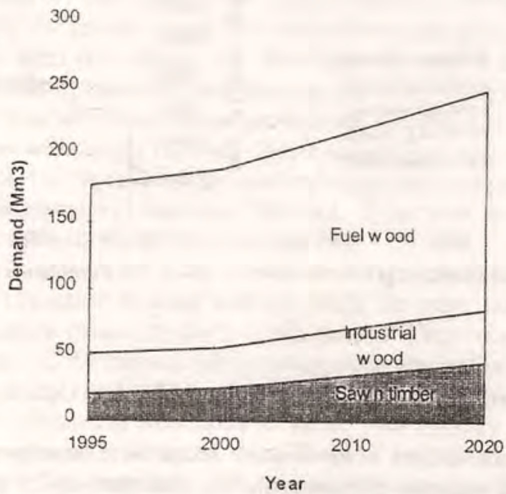

Figure 2. Projection of Demand for Wood (estimation based on GDP growth rate; MoF and FAO, 1990).

If it is assumed that sawn wood demand given in Figure 2 is fulfilled from timber estate using long rotation species with mean annual increment of 7.83 t/ha and 15 years rotation, as well as industrial and fuelwood demand but using short rotation species with mean annual increment of 10 t/ha and 7 years rotation, in 2020 the total area should be planted annually under long and short rotation species would be about 290 thousand ha and 23.55 million ha respectively (Table 6). In total, area under long and short rotation species need to be planted to fulfill sawn wood and industrial wood demand is 8.99 million ha and area under short rotation species to fulfill fuelwood demand is about 18.89 million ha. In the long-term development planning, the government target for timber estate development is only 6.2 million hectares. Thus, using this scenario the wood demand may not be met. However, by selecting tree species that have higher growth rates and longer rotation, the wood produced from the timber estate can be increased.

Table 6 Estimated Area to be Planted and Harvested Annually under Long and Short Rotation to Fulfill All Wood Demand.

	1995	2000	2010	2020
A. Scenario-1a				
Sawn Wood (Long rotation species)				
- Total area to be planted and harvested annually	169,562	212,332	289,339	288,490
- Total area to be under long rotation	2,543,431	3,184,979	4,340,083	4,327,357
Industrial Wood (Short rotation species)				
- Total area to be planted and harvested annually	235,840	233,206	275,899	311,988
- Total area to be under short rotation	3,537,595	3,498,088	4,138,481	4,679,821
Fuelwood (Short rotation species)				
- Total area to be planted and harvested annually	978,250	1,032,000	1,140,268	1,259,286
- Total area to be under short rotation	14,673,750	15,480,000	17,104,018	18,889,286
B. Scenario-1b				
Sawn Wood (Long rotation species)				
- Total area to be planted and harvested annually	66,383	83,128	113,276	112,944
- Total area to be under long rotation	995,753	1,246,919	1,699,142	1,694,160
Industrial Wood (Short rotation species)				
- Total area to be planted and harvested annually	110,058	108,829	128,753	145,594
- Total area to be under short rotation	1,650,878	1,632,441	1,931,291	2,183,916
Fuelwood (Short rotation species)				
- Total area to be planted and harvested annually	456,516	481,600	532,125	587,666
- Total area to be under short rotation	6,847,750	7,224,000	7,981,875	8,815,000

A = Mean annual increment of long rotation (15 years) species is assumed to be 7.8 t/ha/yr. and for short rotation (7 years) species 10.0 t/ha/yr.

B = Mean annual increment of long rotation (30 years) species is assumed to be 10 t/ha/yr. and for short rotation (10 years) species 15.0 t/ha/yr.

It was assumed that the fuelwood supply from timber estate, home garden trees and trees in non forest land was zero.

By using long rotation species with mean annual increments of 10 t/ha and 30 years rotation, and short rotation species with mean annual increments of 15 t/ha and 10 years rotation, the total area required under long rotation species in 2020 to fulfill the sawn wood demand is 1.7 million ha with a rate of planting of 113 thousand hectare per annum. For industrial wood the required area is 2.2 million hectares with a rate of planting of 146 thousand ha per year, and for fuelwood the required area is 8.8 million hectares with a rate of planting of 590 thousand hectare per year. As mentioned above, the government target for timber estate plantation is 6.2 million ha.

Since the required area for sawn timber and other industrial wood is only 3.9 million ha, the government target can meet the demand. Furthermore, FAO and MoF (1990) stated that the role of timber estate in supplying fuelwood demand was not dominant. Most of fuelwood demand is fulfilled from non-forest sources such as home garden, private forest, and agricultural plantation. This indicates that the baseline scenario can meet the biomass demand based scenario. Further analysis in the strategy is therefore not carried out.

Strategy 2. Emission Reduction Scenario. Using the baseline scenario, it was estimated that the emissions of CO_2-equivalent from the energy sector increase very sharply after year 2000 (Fig. 3). In year 1990, the energy emissions were about 8.54 Tg while in 2000, 2010, and 2020, the emissions are about 18.71, 36.9 and 62.26 Tg, respectively. Cumulatively, total emission from energy sector from 1990-2020 was about 13860 Tg (equivalent to 3780 Tg C). However, before year 2000, Indonesian forest is able to offset the CO_2 emission from the energy sector. Thus in year 2000, it is estimated that Indonesia will emit about 8.8 Tg of CO_2-eq, and in year 2020, the net emission becomes 648.8 Tg. Cumulatively, the net total emission from 1990-2020 was about 6086 Tg (equivalent to 1660 Tg C). In this study, three scenarios have been developed, i.e. reduction of 25 percent of the net emissions (Scenario-1), reduction of 25 percent of the energy emissions (Scenario-2), and forestry technical potential scenario (Scenario-3).

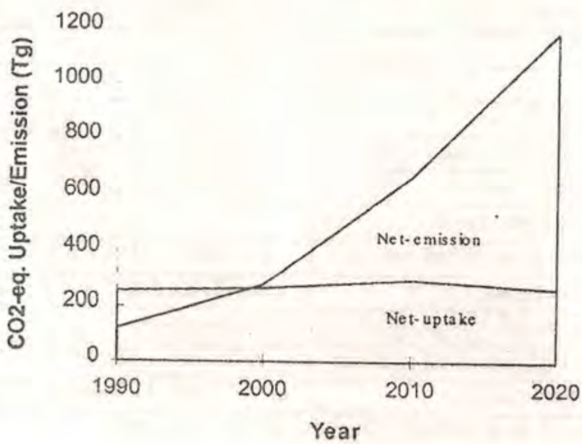

Figure 3: Net Uptake and Net Emission of CO_2.

The selection of mitigation options for each of the scenarios is based on cost-effectiveness, potential of the option to reduce carbon, labor, and land availability. As discussed earlier, the options that are to be promoted are TE, Af and Rf. For PF and SF the baseline rate is already optimal and it is unlikely to be increased due to labor and land limitations. For Scenario-1 and Scenario-2 the analysis was carried out by determining the allocated area for each option, considering the capability of the government to implement the option. In this analysis, about 30 percent of the carbon emission reduction will be carried out through the reforestation program, 55 percent through afforestation, and 15 percent through timber estate plantation. For Scenario-3, all available area for afforestation will be used for this option (8.8 million ha), whereas the available area of 14.9 million ha allocated for the reforestation program was divided into two, i.e. 11.2 million ha for reforestation and 3.7 million ha for timber estate plantation. The area available for non-forest plantation is not used.

Impact of the Baseline and Abatement Scenarios. As it is mentioned previously, there are three abatement scenarios in the forestry sector, i.e. the forestry sector abates 25% of net emission (Scenario-1), the forestry sector abates 25% of emission from energy sector (Scenario-2) and forestry technical potential abatement (Scenario-3). The 25 percent of cumulative net emission in the period of 1990 to 2020 is estimated to be about 415 Tg C (Scenario-1), while the 25 % of cumulative energy sector emissions is about 945 Tg C (Scenario-2). In order to offset the emission of 415 Tg C and 945 Tg C, the area that needs to be planted is about 3.1 Mha and 7.1 Mha, respectively (Table 7). Furthermore, if all feasible areas are planted (i.e. 23.7 Mha), the total carbon that can be abated is about 3938.8 M tonnes (Table 7). It is indicated that the technical potential for abatement through forestry activities is larger than the total cumulative energy sector emissions (Scenario-3). The relationships between cumulative carbon uptake and cumulative life cycle cost, between cumulative carbon uptake and NPV of benefit and between cumulative carbon uptake and investment cost for the three scenarios are presented in Figure 4.

Table 7: Mitigation Potential, investment cost, life cycle cost and benefit of the three scenarios

Mitigation options	Area to be dedicated (million ha)	Cumulative abated (millio tonne	Cumulative investment cost (US$ million)	Cumulative PV of life cycle cost (US$ million)	Cumulative NPV of benefit (US$ million)
		Scenario-1			
Timber Estate (TE)	0.407	67.1	126.6	1,037	295
Reforestation (Rf)	0.563	187.6	231.3	1,692	719
Afforestation (Af)	2.144	414,9	374.9	3,921	3,458
		Scenario-2			
Timber Estate (TE)	0.916	151.2	284.9	2,338	665
Reforestation (Rf)	1.281	425.3	523.2	3,826	1,630
Afforestation (Af)	4.903	945.0	851.7	8,924	7,892
		Scenario-3			
Timber Estate (TE)	3.725	614.6	1158.5	9,502	2,704
Afforestation (Af)	8.800	1546.4	1748.1	18,652	13,944
Reforestation (Rf)	11.175	3938.8	3826.7	31,638	22,362

Furthermore, the cumulative life-cycle cost required for abating 415 Mt of carbon (Scenario-1), is about US$3,921 million while the benefit is about US$3,458 million (Figure 4). Thus, using this scenario, the cost required to abate one tonne of carbon is about US$9.45 with a benefit of US$8.33. While in Scenario-2, the cost required to abate one tonne of carbon is about US$9.44 with a benefit of US$8.35, and in Scenario-3, the cost will be US$8.03 per tonne carbon and the benefit is US$5.68 per tonne carbon.

Furthermore, the implementation of the abatement scenario has a positive impact on socioeconomic activities. It can increase potential absorption of labor. Labor required to implement timber estate development, afforestation, and reforestation are about 945, 832, and 890 man-days per hectare per year respectively. Therefore, the total amount of labor absorbed by mitigation Scenario-1, 2 and 3 in the period of 2000-2020 are about 2670; 6085 and 20787 million man-days. This implies that these scenarios can generate income for the poor, particularly for rural women and forest dwellers. In addition, they can also resettle forest dwellers, thereby reducing shifting cultivation practices.

Forestry activities also have positive impacts on the balance of trade. This is because, on the one hand, almost 80 percent of input required for forestry activities originate from domestic resources. The foreign resources required in this sector are only processing of final products. On the other hand, almost all forestry products can be exported. Therefore, if mitigation options are implemented, it will enhance a surplus of balance of trade.

Reforestation and afforestation will also have positive impacts on conservation of water resources. In addition, they can create favorable conditions for natural regeneration by decreasing forest fire, providing shelter and suitable microclimate to flora and fauna, and by improving soil condition.

Timber plantation system may not have positive impact on biodiversity, particularly if single-species plantation is applied. Diversification of tree species and canopy structure is therefore suggested in the plantation system. Increasing diversity of plantation can be done by the introduction of native tree species, agroforestry systems, or assisted natural regeneration (Tampubolon *et al.*, 1995).

Sector Least-Cost GHG Abatement Strategy. Options that could be used in the forestry sector for mitigating GHG emissions are reforestation, afforestation, timber estate, social forestry, and private forest. In addition, resettlement of forest squatters, natural regeneration, and agroforestry are also other potential options, but they are not included in this analysis. The Government has targeted to rehabilitate the critical land/unproductive land at a rate of 500 thousand hectares per annum, where 300 thousand hectares will be rehabilitated via an afforestation program and 200 thousand hectares via a reforestation program. However, during Pelita V (1989/90-1993/94), this target could not be achieved, particularly for reforestation. The realization for reforestation during this period was 338,760 ha (about 65 thousand ha per annum) and during 1994/95 the realization was only 39,653 ha. In fact, among the three options, this option has been found to be the least-cost option.

PPLH IPB (1997) stated that the problems faced in the implementation of the reforestation program are: (1) difficulties in accessing the location of reforestation area as this area is mostly widely distributed and undulating, (2) limited labor, (3) low maintenance, and (4) low survival rate. Therefore, the strategies implemented in reforestation are (1) to use trees species that do not require intensive maintenance, (2) not to allow farming activities in the reforestation area, and (3) to give villagers an opportunity to maintain the reforested area and allow them to harvest the non-forest products.

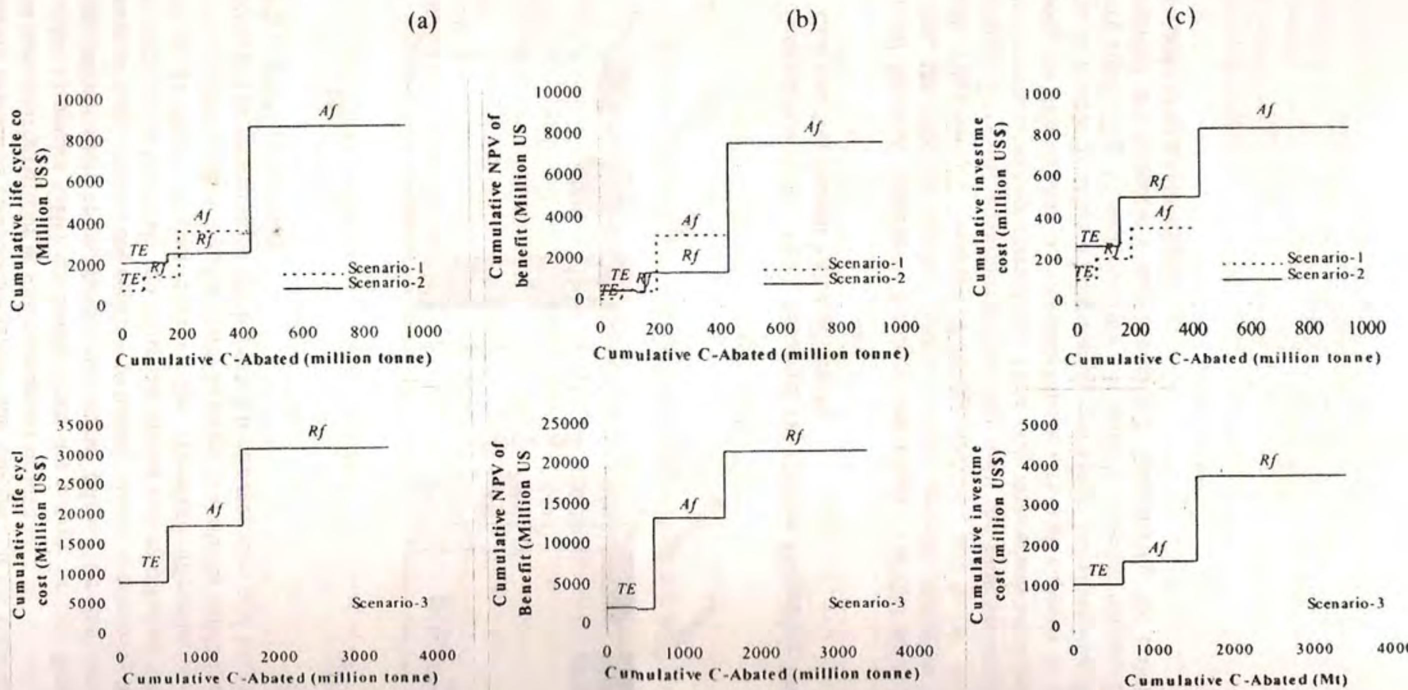

Figure 4:. (a) Cumulative Lifecycle cost (vs.) Cumulative C-abated, (b) Cumulative PV of Benefit (vs.) Cumulative C-abated, (c) Cumulative Investment Cost (vs) Cumulative C-abated by Reforestation, Afforestation and Timber Estate.

In timber estate development, the agroforestry system is also practiced. Food crops are introduced during plantation establishment until the canopies of the trees overshadow the crops. This system is particularly popular in teak plantations in Java.

In order to uptake GHG emissions from the energy sector, three options have been chosen, namely afforestation, reforestation, and timber estate. The first two options are selected, because for each of these options the capacity to uptake carbon is relatively higher than the others, while the cost required is relatively low. The last option was selected on a basis of its mitigation potential only, as its abatement cost is quite high. Therefore, afforestation and reforestation are suggested to be implemented in the short-term strategy, and timber estate along with afforestation and reforestation are suggested to be implemented in the medium- and long-term strategies, when the economy is at a better condition.

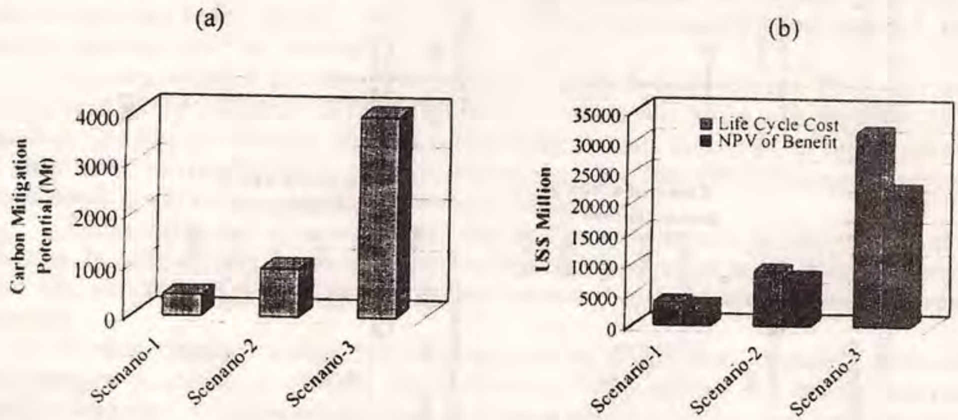

Figure 5: Comparison of the Three Scenarios (a) Carbon Mitigation Potential (b) Life-cycle Cost and Net Present Value of Benefit.

General Sectoral Abatement Strategy and Goals. In this study, four strategies were considered: first, the biomass demand based scenario, second, reduction of 25 percent of net emission, third, reduction of 25 percent of energy emission, and fourth, the technical mitigation potential scenario. Since the government plan can meet the biomass demand scenario, further analysis for this scenario was not carried out. Thus, only three scenarios were studied.

Among the three scenarios, Scenario-3 has a very high capacity to reduce carbon (Figure 4). This scenario is able to offset all the energy emissions. However, the implementation of the scenario is very costly (Fig. 5), and therefore it is unlikely to be carried out. The possible scenarios to be implemented are Scenario-1 and Scenario-2. Considering the economic condition, only Scenario-1 is viable to be implemented.

PROPOSED TIMELINE FOR IMPLEMENTATION OF STRATEGY

Implementation of the GHG abatement initiative follows three timelines, i.e. short-term (1998-2005), medium-term (2005-2015) and long-term (2015-2020) (Table 8). In the short –term, the total additional land required for afforestation, reforestation, and timber estate development is about 128,000 ha per year, while in the medium and long terms the land requirements are about 162,350 ha and 170,100 ha per year, respectively. Thus, for uptaking 25 percent of net carbon emission, the rate of planting needs to be increased by about 23 percent of the baseline rate in the period of 2000-2005, by about 30 percent of the baseline rate in the period of 2006-2020.

As stated in Pelita V, the government target for the rehabilitation of critical land is 500,000 ha/year (40 percent for reforestation and 60 percent for afforestation) and for timber estate is about 250,000 ha/year. This implies that the Indonesian government is able to implement the rate of planting of 750,000 ha/year. As the total rate of planting (baseline + initiatives) required is between 690,000 and 735,000 ha/year, the implementation of this scenario is very possible.

Referring to Table 7, in Scenario-2, the area dedicated for timber estate development, reforestation and afforestation is about 7.1 million ha, two times of that of Scenario-1. Thus, the total rate of planting (baseline+initiative) required will be between 820,000 and 905,000 ha/yr, a bit higher than that of the baseline. Therefore, economic conditions may become a constraint in implementing the initiatives. Another constraint is labor availability. However, with the successfulness of the transmigration program, more labor will be available outside Java where the three programs will be implemented. When labor is not sufficient, options which require less labor will be the priority options, for example, enhancement of natural regeneration.

Table 8: Proposed Timeline for the Implementation of GHG Abatement Initiatives for Scenario-1

Programs		2000-2005	2005-2015	2015-2020
Afforestation	Baseline (ha/year)	250,000	250,000	250,000
	Initiative (ha/year)	100,000	107,200	114,400
SUBTOTAL		**350,000**	**357,200**	**364,400**
Reforestation	Baseline (ha/year)	65,000	65,000	65,000
	Initiative (ha/year)	28,000	28,150	28,300
SUBTOTAL		**93,000**	**93,150**	**93,300**
Timber estate	Baseline (ha/year)	250,000	250,000	250,000
	Initiative (ha/year)	0	27,000	27,400
SUBTOTAL		**250,000**	**277,000**	**277,400**
Social Forest	Baseline (ha/year)	50,000	50,000	50,000
	Initiative (ha/year)	0	0	0
SUBTOTAL		**50,000**	**50,000**	**50,000**
Private forest	Baseline (ha/year)	50,000	50,000	50,000
	Initiative (ha/year)	0	0	0
SUBTOTAL		**50,000**	**50,000**	**50,000**
Total Baseline (ha/year)		**565,000**	**565,000**	**565,000**
Total Initiatives (ha/year)		**128,000**	**162,350**	**170,100**
Total (Baseline + Initiative)		**693,000**	**727,350**	**735,100**

CONCLUSION AND RECOMMENDATION

In 1990, Indonesian forest was able to uptake 686.5 Tg of CO_2-eq, while the emission was about 556.7 Tg. Therefore, during this period Indonesia was a negative emitter. However, in the near future, Indonesia is becoming a GHG emitter due to a rapid increase in GHG emissions from the energy sector. It was estimated that net CO_2-eq. emissions will be about 8.8 Tg in year 2000, 246.3 Tg in year 2010, and 648.8 Tg in year 2020. In order to reduce 25 percent of the cumulative net emission (2000-2020), additional efforts to enhance the capacity of forest to sequester carbon is needed. It is suggested that the rate of afforestation and reforestation should be increased by about 40 percent from the baseline rate, and the rate of timber estate development be increased by about 11 percent.

Implementation of the forestry mitigation options may have positive impacts on socioeconomic and environmental conditions. It was estimated that GHG abatement initiative could absorb about 133, 304, and 1039 million man-days per year for Scenario-1, 2 and 3 respectively. The impacts on environmental conditions include conservation of water resources, creating favorable conditions for natural regeneration by decreasing forest fire, providing shelter and suitable microclimate to flora and fauna, and improving soil condition.

The problems that might be faced in the implementation of the abatement initiative options are economic conditions and labor shortage. With the success of the transmigration program, the labor constraint may be overcome. Nevertheless, the implementation of the options should be promoted when they are socially, economically, and environmentally justified.

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