PN ABR-952
89224

NRMP-IEA Input-Output Working Paper No. 5

CASE STUDY OF THE FORESTRY SECTOR

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Jakarta

February 1993

Preface

NRMP-IEA Technological Scenarios

The Natural Resources Management Project (NRMP) assisted by USAID in association with the Institute for Economic Analysis (IEA) at New York University is carrying out a modelling exercise to project the economic, employment and environmental consequences of different development paths for the Indonesian economy. The purpose is to provide advice to the Indonesian National Planning Agency (BAPPENAS) to assist in the development of the next five-year plan (Repelita VI) and the next Long-Term Development Plan. The first stage of this work has already been completed with the support of the Environmental Programming Support Services Project of CIDA.

The analysis, of which the present paper is a component, will provide advice on the trade-offs and complementarities between the growth of income and employment on the one hand, and the levels of natural resource depletion and degradation of the natural environment on the other, that are likely to be associated with alternative patterns of structural change. For instance, it is important for policy makers to know how the development of the pulp and cement industries over the next 20 years is likely to affect air and water pollution and how costly or cost-saving it will be to adopt cleaner technologies than are being used now.

The analytical framework includes a dynamic input-output model covering all economic activities. The model is dynamic in two senses. First, it incorporates a representation of investment in which levels of sectoral investment depend on expected growth of output, the technology in use and levels of capacity utilisation. Secondly, the model is dynamic in that it explicitly incorporates projections of changes in technology for a range of sectors in the economy, including agricultural sectors, forestry, energy sectors and key manufacturing sectors.

Technological scenarios are developed for each of these sectors using detailed information about likely technological and institutional changes obtained from technical experts. They include expected changes in intermediate inputs, notably energy and raw materials, capital stocks and human resources of different skill types as well as expected changes in natural resource usage and environmental degradation associated with current and alternative future technologies.

This paper is one of a series of working papers prepared by NRMP and IEA researchers in collaboration with industry experts. The papers will form a vital part of the data base for the numerical computations. In addition, it is hoped that they will be valuable as stand-alone analyses of technological futures for a range of important industries in Indonesia.

I Introduction[1]

This scenario paper describes current and future technologies in the Indonesian logging industry (Sector 5 in the NRMP-IEA 30-sector classification system). This sector covers the process of extracting logs from forests and delivering them to the 'mill door'. It does not describe technologies or production methods in the timber processing industries. By 'technologies' we mean the ways in which intermediate inputs, capital equipment, labour of various skill types and knowledge are combined to produce and extract logs. The technologies described here also include some of the impacts on the natural environment of different logging methods.

Three log production and extraction methods are defined:

1. current logging practice in natural forests;

2. a more sustainable system of logging in natural forests; and

3. the establishment of plantations on degraded land using mechanical techniques.

In this paper, these logging methods are described in terms of both their economic inputs -- intermediate, capital and labour inputs -- and their impacts on the natural environment. These three logging methods are used to define three 'technological scenarios' for the logging industry:

S0 the current situation in which there is heavy reliance on logs from natural forests using unsustainable practices;

S1 a shift to more sustainable logging in natural forests and reliance on plantation timber for 40 per cent of log supply; and

S2 a shift to more sustainable logging in natural forests and reliance on plantation timber for 68 per cent of log supply.

Although the principal purpose of the paper is to develop numerical estimates for the technologies, the paper reaches some policy conclusions as well. Broadly, the analysis indicates that a significant amelioration of current environmental damage and a sustained supply of timber require an urgent shift to:

1. more sustainable logging practices in natural forests including improved planning and implementation of roading, felling and transportation, the introduction of directional felling, the use of wheeled skidders and extensive use of winches for log extraction; and

2. a much larger share of logs coming from plantations. These sawlog and pulp log plantations should be established on the plentiful supply of alang-alang and belukar land, and will require government subsidies financed by increased stumpages on natural forest logging.

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1 I am grateful for comments from Faye Duchin, Jim Douglas, Jerry Bisson and David Ostermeier.

It must be stressed that the success of the transition to a system of sustainable logging with plantations depends critically on effective implementation of government policy. In particular, policies on use of forest land need to be strictly enforced to prevent further environmental damage. In the case of plantations it is especially important for the government to ensure that they are established on genuinely degraded land so that existing forests are not cleared for plantations.

II Forest types and technologies

In Indonesia there are several different forest types each with its own logging technology. Technologies can also differ within a forest type. The principal forest types that are now or will be the main sources of logs are as follows:

Natural forests
mixed hill forests
peat swamp forests

Plantations
tropical hardwoods and softwoods
estate crops (coconut wood, rubber wood, oil palm wood).

Each of these has a different logging technology. Peat swamp logging, for example, often involves the construction of small-gauge railways in the swamps for log extraction. For the purposes of this study, only three technologies will be defined, two for natural mixed hill forests (current practice and a more sustainable technology) and one for timber plantations.

Natural mixed hill forests and plantations now provide and will continue to provide the great bulk of commercial timber in Indonesia. The proportion of timber supply from plantations is expected to increase sharply over the next decades as output from natural forests declines and plantations come on stream. The FAO and the Ministry of Forestry have made log output projections based on an optimistic scenario specifying investments in plantations and improved log recovery from natural forests. Their estimates appear in Table 1. Between 1990 and 2020 (the period of this study) the proportion of logs supplied by plantations is expected to rise from 28 per cent to 68 per cent. The projected decline in total log volume from natural forests reflects high rates of deforestation and forest degradation as well as declining yields as the more productive forests are logged out.

In this scenario analysis, projected changes in the technology for producing logs will take two forms:

> a shift to more sustainable methods of harvesting natural forests involving more environmentally sensitive roading and felling practices; and
>
> a shift in the composition of total log supply away from logs extracted from natural forests and towards logs grown in plantations (using mechanised techniques).

Table 1 Potential industrial wood supply by source (million cubic metres)

	1990	1995	2000	2005	2010
Natural forests[a]	33.02	29.80	24.98	24.59	24.43
Plantations[b]	13.16	17.60	23.17	31.96	33.56
Proportion from plantations	0.28	0.37	0.48	0.57	0.58

2015	2020	2025	2030
23.99	23.19	22.74	21.49
44.18	48.39	65.57	68.03
0.65	0.68	0.74	0.76

a. Includes conversion forests.
b. Includes estate crops.

Source: FAO-MoFr, 1990, Volume 2, Table 9.13, p230

It is first necessary to define the current production technology for logs derived from natural forests and logs from plantations. These are very different. In the former case, where the trees are already standing, the principal input costs are those of labour and machinery for road building, harvesting and haulage. In the case of plantations, the principal costs are the establishment costs of plantations, covering machinery and labour for land preparation, planting and weeding as well as labour for harvesting and haulage. There is a crucial difference relating to the timing of inputs and outputs. In the case of natural forest logging, investments in equipment begin to be repaid more or less immediately because the trees are already standing. In the case of plantations, there are large initial investments followed by a delay of between 9 and 50 years. The latter makes the calculation of 'input coefficients' awkward.

III Natural forest logging technology

There are four main stages to logging: taking an inventory and laying out of roads, road building, felling and transporting logs. The values of inputs into the 'Wood' sector (Sector 21 in the 1985 BPS input-output table, Sector 5 in the NRMP-IEA classification) appear in Table 2 below as do BPS estimates of the capital stocks in that sector. We calculate input coefficients per unit of output value and per 1000 m of logs. Note that the 1985 log output was 24,082,000m^3 and the value of output in 1985 was Rp 1,482,206 million implying a unit price of Rp 61,548 (US$ 54.4) per m^3

In this section we check the input-output data against other input data. In some cases it will prove necessary to revise the BPS capital stock data.

It is worth noting the very large share of total intermediate inputs accounted for by 'operating surplus' in the BPS input-output tables, a share not explained by imputed wages. While this may reflect very high rents being accumulated by concession holders, it may also reflect inaccuracies in the input values.

Capital stock coefficients have been calculated by dividing the value of capital stock (in millions of rupiah) by the value of output of Sector 5 (Sector 21 in the BPS classification) in 1985 (i.e. Rp 1 482 206 million).

Table 2 Intermediate inputs to Sector 5 from the 1985 input-output table

Sector			Values (Rp m)	Coefficients[a] .Rp/Rp	Rpm/1000m^3
Sector number and name[b]					
5	(21)	Wood	7429	.005012	0.31
13	(38)	Paper & products	5136	.003465	0.21
17.7	(47)	Fab metal	7220	.004871	0.30
17.8	(48)	Machinery	33439	.022560	1.39
18	(41)	Petroleum refin	35273	.023798	1.46
23	(52)	Construction	12623	.008516	0.52
24	(53)	Trade	15983	.010783	0.66
26.2	(56)	Road transport	6612	.004461	0.27
27	(61)	Finance	12039	.008122	0.50
29	(65)	Other services	33412	.022542	1.39
Total intermediate			189417	.127794	7.87
Wages and salaries			219160	.147861	8.13
Operating surplus			967790	.648216	40.19
TOTAL INPUTS			1482206	1.000000	61.54
Capital stocks					
12.4	(37.4)	Wooden furniture and fixtures	40.0	.000027	0.02
17.7	(47)	Fabricated metal	39.0	.000026	0.02
17.9	(49)	Transport equip	53.0	.000035	0.02
23	(52)	Construction	55,810.0	.037653	2.32
30	(66)	Unspecified	70.0	.000047	0.03

a. The first column of coefficients measures input value per unit output value (Rp per Rp) and the second measures input value per unit output volume (Rp million per 1000 m)3

b. See Appendix for sectoral classification. Numbers in brackets indicate the sector code from the standard BPS 66-sector input-output classification.

Sources: BPS (1989); BPS capital stock estimates for 1985, pers. comm.

It is apparent from Table 2 that the principal intermediate inputs are from the petroleum sector, machinery (repairs and maintenance) and other services. In the BPS

estimates, the principal capital stocks are from the construction sector (mainly logging roads). These capital stock figures are not consistent with more direct sources of information and we will attempt to improve on them.

Scattered information is available on equipment and other costs in a number of logging concessions. These data are summarised in Table 3.

Table 3 Input coefficients in logging activities

Intermediate inputs (Rp million/1000 cubic metres of logs)		
Fuel	12.67	Petroleum refining (47)
Maintenance	13.00	Machinery (55)
IHH/DR	22.89	Reforestation & other fees
O'heads & others	6.88	Other services (74)
Capital stocks (units/1000 cubic metres of logs)		
Chainsaws	0.12	Fabricated metal products (54)
Tractors & skidders	0.23	Transport equipment (56)
Trucks	0.20	Transport equipment (56)
Employees (person years/1000 cubic metres of logs)		
Supervisors	0.36	
Drivers	0.34	
Labourers	2.28	
TOTAL	2.98	

Source: NRMP survey of concessions in West Kalimantan. Note that the volumes of logs may have been understated so that the per unit costs reported here are too high.

The data of Table 3 will be used to develop estimates of unit labour inputs and capital stocks for natural forest logging and to help estimate changes in other coefficients to reflect the new technology.

It is possible to make an estimate of capital stocks in logging from these and other figures. Each 1000 m^3 of logs requires .43 tractors, skidders and trucks (supplied by Sector 17.9, Transport equipment). To produce the 1985 output of 24,082,000 m^3 of logs would require 10,355 units of transport equipment. Valuing these at a new price of US$60,000 (an approximation only), converting at the 1985 exchange rate of US$1 = Rp1131 and applying a depreciation factor of .6 gives a value of capital stock of Rp 422,000 million. Similar calculations allow us to estimate the value of stock of

chainsaws and similar equipment from Sector 17.7 (Fabricated metal products): 0.12 units per 1000 m^3 at $1,000 each and depreciation of .5 gives a stock value of Rp 1634 million. We make a rough guess for wooden furniture and fixtures. These are summarised in Table 4.

Table 4 Capital stock estimates for natural forest logging 1985 (Rp million)

Sector		*Capital stock (Rp m)*
41	Wooden furniture & fixtures	10,000
47	Fabricated metal products	1,634
56	Transport equipment	422,000

The total estimated capital stock (Rp 433,634 million) represents around Rp 18,000 per m^3. Each cubic metre of logs is valued at Rp 61,548. These estimates will be used in the input-output analysis.

Note that the FAO-MoFr (1990, Volume 2 p76) estimates that the commercial yield of production forests is 37 m^3/ha.

The current system of natural forest logging has various negative environmental impacts including:

- deforestation:
- erosion and siltation;
- changes in water flow rates and water quality;
- pollution of forest lands from fuel oils, chemicals and human wastes; and
- impacts on wildlife including habitat fragmentation, depletion of food sources and loss of biodiversity.

It is possible to make reasonable numerical estimates for only two of these, deforestation and erosion.

Deforestation

The FAO-MoFr (1990, Volume 2, Table 3.3 p61) estimates that between 1982 and 1990 236,000 ha of *production forest* were deforested each year. [2] (This figure rises to 407,000 ha per annum if the East Kalimantan fires of 1982-83 are included.) This deforestation is due to roading, forest degradation as a result of poor logging practices and shifting

2 The estimates of deforestation made here exclude clearing of conversion forests.

cultivation. The FAO also reports that in recent years around 900,000 ha of production forest have been logged each year (FAO-MoFr 1990 Volume 2, p61). Therefore, around 26 per cent of logged over production forests are deforested as a result of logging. In other words, under the current system, for every 4 ha of production logged, one ha is left deforested. Several studies confirm these figures. One indicates that around 20 per cent of land area is deforested because it is covered with roads, and if skid trails are included the percentage rises to 30 (Hendrison, 1992, p23).

Unlike deforestation on land designated as conversion forest, this deforestation of production forests is undesired. It not only reduces the ability of the forest to replace the biomass lost through logging, it also interferes with the ecological processes of the forests including water flows, risks of fire, habitat loss, disturbance to wildlife corridors and soil degradation. Some of this deforestation is avoidable; the extent to which it is avoidable will be discussed in the next section.

Soil erosion

According to the FAO-MoFr (1990, Volume 4, p80):

> The increased soil erosion rates caused by commercial forest harvesting are mainly attributable to the disturbance of the soil by logging techniques, mainly from log landings, skid trails, and roads. On steep slopes and with high intensity rain patterns, the erosion can be quite serious and persist for many years.

The FAO suggests that the quality and planning of logging roads is inadequate.

Estimation of the rates of erosion as a result of logging in mixed species hill forests is difficult and only order-of-magnitude estimates are possible. While soil loss from undisturbed forests is almost nil, one study of Indonesian forests (Hamilton and Pearce 1988) measured soil loss from a newly constructed and used skid road at 12.9 tonnes per hectare per month. Three years after the road had been abandoned soil losses persisted at 3.2 tonnes per hectare per month. The figure of 12.9 tonnes/ha/month converts to 154.8 tonnes/ha/yr from roads. Repetto *et al.* (1989, Table II.7, p45) report a series of studies in Java which indicate rates of soil erosion on degraded forested land (both under roads and not under roads) of 88.3 tonnes/ha/yr.

It was reported above that around 26 per cent of logged over production forest is left deforested and that a large proportion of this is due to roads and log landings. Hamilton and Pearce (1988) report that the percentage of a logging concession under track and trail can range from 16 to 30 per cent. [3] We take 16 per cent as a conservative estimate of area under roads and landings. We assume soil loss from roads to begin at 154.8 tonnes/ha in the first year and to fall asymptotically through 38.4 tonnes/ha/an (i.e. 3.2 tonnes/ha/month) in year four until year ten. In recent years around 900,000 ha of production forest have been logged annually.

Using these estimates, we can calculate that each year 70.8 million tonnes of soil are eroded from roads built over the previous 10 years. In other words, erosion occurs at an average rate of 79 tonnes/ha/an (i.e. 70.8 million tonnes divided by 900,000 ha.).

To help picture this total amount, tonnes of soil can be converted to cubic metres by dividing by 1.8, giving around 39 million cubic metres as the total annual volume of soil

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3 Weir and Manan (1989, p66) report studies that indicate that selective logging leaves up to 50 per cent of the ground surface affected by machinery.

erosion from production forests. This can be thought of as an annual mound of soil one metre high covering an area of 1 kilometre by 39 kilometres.

Note that these estimates cover only erosion due to roads and landings and exclude erosion from soil disturbance off roads and landings. Nor do these estimates include soil erosion from conversion forests.

IV Logging technology in plantations

According to the FAO-MoFr (1990, Volume 2, Chapter 7), a major program of forest plantation establishment is necessary to meet the deficit in timber supply from natural forests that will occur in the next few years. Plantations are also necessary to rehabilitate critical watersheds that have been extensively degraded by increasing population pressure. The Government's ambitious plan is to establish about 6 million hectares of industrial timber estates by the year 2000.

The FAO argues that the social returns from the establishment of industrial timber estates are higher than private returns (because of the environmental benefits and the shorter investment horizons of private logging companies) and that therefore subsidies are justified to encourage plantation establishment. Under such a system plantations producing pulpwood alone, saw/veneer logs alone and mixed saw/veneer logs plus pulpwood are all profitable. Later in this paper, it will be stressed that, in order to avoid major environmental disturbance to natural forests, new plantations must be established on land that is already degraded.

The key difference in logging technology between natural forests and plantations is that in the latter a large part of the input costs are devoted to establishing the plantation (in addition to the costs of harvesting and transportation) and that investors must wait several years before they see a return on their investments.

Data on physical inputs into plantations are difficult to obtain. Moreover, there are many feasible types of plantations varying according to species planted, the planned rotation, the site quality and the size of the plantation. Each has a different cost structure. Table 5 provides cost estimates for a hectare of representative plantation of Acacia Mangium, a fast-growing exotic hardwood that is suitable for pulpwood, sawlogs and veneer logs. The division between 'purchases' and 'labour' is a rough one only. In this example, taken from an FAO report, it is assumed that the plantation is established on alang-alang land using mechanical land preparation and weeding (but not planting). The plantation is aimed at producing pulpwood, sawlogs and veneer logs and has a rotation of 15 years, with pulp thinnings harvested in year 9. The figures of Table 5 will be translated into our input-output classification.

Table 5 Plantation costs, Acacia Mangium (Rp 000/ha)[a]

Period	Years							Total
Cost item	1	2	3	4	5	6-10	11-15	
Purchases								
Roads	124	0	0	0	0	0	0	124
Road maint'nce	0	5	5	5	5	25	25	70
Buildings	23	0	0	0	0	0	0	23
Building maint'nce	0	12	12	12	12	60	60	168
Vehicles & mach'ry	20	0	0	0	0	0	0	20
Vehicle maint'nce	31	31	31	31	31	155	155	465
Overheads	51	51	51	51	51	255	255	765
Labour								
Planning	18	17	17	17	17	85	85	256
Nursery	75	0	0	0	0	0	74	149
Estab'nt/weeding	465	0	0	0	0	0	243	708
Stand improvement	0	0	3	10	0	13	0	26
Fire & protection	0	3	3	8	25	48	41	128
Harvesting	0	0	0	0	0	645	1902	2547
Haulage	0	0	0	0	0	390	1170	1560
Total labour	558	20	23	35	42	1181	3515	5374
TOTAL COSTS	807	119	122	134	141	1676	4010	7009

a. Using an exchange rate for 1986 of US$1 = Rp1655.

Source: Davis, 1989, Field Document No. I-3, Appendix XVII, p203; harvesting and haulage costs are from Appendix XXII p226.

The yields for this regime are reported as follows:

Table 6 Yields from Acacia Mangium plantation

Age	Product	Yield (m^3/ha)
Year 9	Pulpwood	60
Year 15	Veneer logs	50
Year 15	Sawlogs	125
Year 15	Pulpwood	75
TOTAL		310

Source: as for Table 5

Over a fifteen-year rotation each hectare produces 310 m3 of logs. These figures imply a mean annual increment of a little under 21 m3/ha/an, a fast growth rate which is apparently achievable with this species. (PT Indah Kiat reports an achieved MAI of 40 m3/ha/an for Acacia Mangium in its Riau plantations (Pk Soebardjo, pers. comm.).) The yield of 310 m3/ha from this plantation compares to a yield of 37 m3/ha from natural production forests (with a 35-year rotation).

Mechanised establishment and maintenance of plantations offers several advantages over manual systems including better suppression of alang-alang grass and other noxious weeds, increased ploughing volume and depth of soil for rooting, full benefit of applied fertiliser and faster growth in the first year. Overall, mechanised systems use about half of the labour of manual ones and have lower costs. In the mechanised system described in Table 5 establishment of each hectare of plantation requires over the first four years the following days of labour: 6 supervisors, 4 operators and 114 labourers. Using the total cost data of Table 5 to allocate these days to each of the first four years gives the results in Table 7. Note that the total days of labour convert to 400 person days/1000 m^3 for establishment of mechanised plantations compared to around 894 person days/1000 m^3 for logging in natural forests.

Table 7 Labour inputs to mechanised Acacia Mangium plantation

	Year				Total
	1	2	3	4	
Days/ha					
Supervisors	4.09	0.60	0.62	0.68	6
Operators	2.73	0.40	0.41	0.45	4
Labourers	77.86	11.46	11.78	12.90	114
TOTAL	84.69	12.46	12.81	14.03	124

Source: Davis, 1989, Volume I-3, p54 and Table 5 above.

From Table 5 it can be seen that only 12 per cent of total labour costs per ha occur in the first four years of the 15-year cycle. Most of the costs (76 per cent) are incurred at the times of harvest in years 9 and 15. This implies that 1048 days of labour are required per ha over 15 years or 11.27 person years (3381 person days) per 1000m^3.

Plantations of the future may use around 150kg of fertiliser (mainly TSP and urea) per hectare (Davis, 1989, Volume I-3, p 213). In 1985, the cost of a kilo of fertiliser was around Rp200. A tractor (with appropriate attachments) takes around 3 hours per hectare to carry out ripping, clearing, ploughing and weeding on alang-alang land. This suggests that (allowing for downtime) each tractor could prepare around 600 ha each year (FAO, 1992, Volume I-3, pp73-74).

The environmental impacts of plantation logging must now be assessed. The impacts will depend crucially on what sort of land is used to establish plantations. If naturally forested lands are cleared for plantations then the environmental consequences -- in

terms of erosion, siltation, changes in water flows and impacts on biodiversity -- will be very severe. If alang-alang and belukar (scrubby) sites are used, the environmental impacts are likely to be less severe because the impact of initial deforestation has already been absorbed. In terms of environmental impact, then, decisions regarding location of future plantations are critical.

Land availability

Mechanised plantations require reasonably flat terrain with minimal stumps; 'a high proportion of such land will be belukar or alang-alang sites' (see Davis, 1989, Volume I-3, p85). Consequently, and at the risk of underestimating the ecological impact of plantations, it is assumed that they are developed on alang-alang or belukar sites.

To generate 68 million m3 of plantation logs by the year 2030 (see Table 1) at an average growth rate of, say, 15 m3/ha/an, will require around 4.5 million ha to be planted. Davis estimates (1989, Appendix XXIV, p247) that in the Outer Islands there are about 5.2 million ha of dry grassland and 14.6 million ha of shrubland suitable for plantation establishment, a total of 19.8 million ha.

Soil erosion

On alang-alang and belukar land, the principal ecological impact is likely to be erosion and siltation due to road building (especially on slopes of more than 5 degrees) and ripping and ploughing in preparation for planting. It is likely that after high rates of erosion in the first years, once the plantations are established soil loss will be less than it was when the land was under alang-alang or belukar. No quantitative information appears to be available on the impact of plantation establishment on soil erosion. Basing our estimates on the sources cited above, Repetto *et al.* (1989) and FAO-MoFr (1990, Volume 4), we postulate the impacts specified in Table 8.

Table 8 Postulated erosion impact of plantation establishment on alang-alang land

	Soil loss (tonnes/ha)
Before plantation	15
Due to plantation	
- first year	40
- years 2-4	20
- subsequent years[a]	5

a. Note that Repetto et al. (1989) report an erosion rate of 6 tonnes/ha for forested land on Java. That land is liable to be steeper than the plantation land in question.

If the figures in Table 8 are approximately correct then in the longer term plantations will have a net positive impact on erosion as long as natural forests are not cleared to establish plantations. (A further environmental problem from plantations may be a small amount of pollution of waterways from fertilizer runoff.)

V Future logging technology

Although it is assumed that the mechanical plantation technology will apply over the whole of the study time horizon (i.e. to the year 2020), the influence of plantation technology on timber extraction will increase as a rising proportion of the total volume of timber is sourced from plantations. If plantations are established on alang-alang and belukar land then the substitution of plantation timber for naturally grown timber will have a major positive impact on the environment including:

- a sharp reduction in the rate of soil loss and associated siltation;
- a reduction in flooding and ecological damage to waterways; and
- a declining rate of deforestation, and a marked reduction in threats to wildlife habitat and biodiversity.

We turn our attention then to potential changes in logging technology in natural forests. Hendrison (1992, pp 22-23) has proposed a series of improvements to current practices aimed at reduction in vegetation damage, soil damage and erosion. His scheme 'C' has the following characteristics, all of which can be achieved with only minor alterations to the existing system of natural forest logging:

- improved planning and organisation of roading, felling and transportation;
- the introduction of directional felling and controlled skidding;
- partial replacement of branch roads by trails for wheeled skidders; and
- log extraction by winching.

Hendrison estimates that these changes would reduce the total area of forest affected by logging from about 52 per cent to 30 per cent. They would increase felling costs by around 10 per cent but reduce transport costs by 15 per cent and skidding costs by 5 per cent. Jonsson and Lindgren (1990, p51) report that trials in Sarawak using similar methods and emphasising careful planning reduced logging costs by 20 per cent compared to a conventional operation.

In addition, we extend Hendrison's changes by requiring road construction that is more sensitive to the risks of erosion (only on side slopes of less than 25 degrees, allowing for adequate drainage, siting of landings on level ground and requiring roads and landings to be at least 100 metres from streams). This system we call the More Sustainable System of natural forest logging.

We postulate that the impact of these changes will be to:

- reduce the affected area from 52 to 30 per cent;
- reduce annual average erosion from 79 tonnes/ha to 30 tonnes/ha;
- reduce the incidence of damage to remaining stems from around 60/ha to 40/ha (Jonsson & Lindgren 1990, p53); and
- reduce the rate of deforestation due to roading and careless logging from 26 to 15 per cent of the area subject to logging.

The reduction in impact on biodiversity and wildlife numbers will be small because the proposed changes still involve intensive logging. An additional step would involve reducing the average number of stems cut so that the yield declines from around 37 m^3/ha to 20 m /ha. Such a system would not only reduce structural damage to the forest (by minimising the extent of canopy opening with consequent protection of soils, nutrients and microfauna) but would contribute significantly to regeneration and sustained yields. Note that the reduction in the volume cut per hectare would mean that the number of workers per hectare would fall, but that the number of workers per cubic metre of timber extracted would increase slightly.

The above system involves the following changes in the input structure in the shift from the current system of natural forest logging to the More Sustainable System:

> in view of the evidence of Hendrison (1992) and Jonsson and Lindgren (1990), we assume that unskilled labour costs fall by 10 per cent;
>
> training in road building, felling techniques and extraction methods is represented by a 50 per cent increase in the costs of 'supervisors';
>
> upgrading of management skills is required in addition to more supervision of forest operations and this is represented by another 50 per cent increase in the costs of supervisors; and
>
> machinery requirements may change a little with greater use of wheeled skidders. These could be introduced gradually and are represented by a 10 per cent increase in the stock of capital drawn from the transport equipment sector.

These changes are reported in Table 9 below.

VI Summary and scenarios

According to the 1985 input-output tables Rp 514,416 million of intermediate inputs (including wages but excluding operating surplus) were required to produce 24,082,000 m^3 of logs, mostly from natural forests, i.e. Rp 21.4 million for each 1000 m3. According to our estimates of the costs of plantations, the cost of producing 1000 m3 of logs from plantations is almost the same, Rp 22.6 million (although the costs per ha are much higher). The difference is that there is a long wait before investments in plantations return a profit.

Table 9 summarises the information presented in this paper in the way that it will be used in the input-output model. The first column of the table shows the values of intermediate and capital inputs (in 1985 constant prices) used in the production of 1000 m3 of logs from natural mixed hill forests under the current system. It also shows the amount of labour in person days per 1000 m3 of logs and the impacts of logging on deforestation and soil erosion. The second column shows changes in inputs and changes in impacts on deforestation and erosion using the More Sustainable System of logging natural forests. The third column shows the inputs and natural resource effects of plantations, also measured per 1000 m 3of logs.

Table 9 Inputs and natural resource impacts of various log-production technologies

Sector	Natural forests: Current practice	Natural forests: More sust.	Mech. plant'n
Intermediate inputs (Rp/Rp of output)[a]			
14 Fertiliser & pesticides	0	0	.0016
17.8 Machinery	.0226	.0226	.0244
18 Petroleum refinery	.0238	.0238	.0238
24 Trade	.0108	.0108	.0108
29 Other services	.0225	.0225	.0400
Labour (person years/Rp million of output)[b]			
Supervisors	.0058	.0116	.0116
Operators	.0055	.0050	.0058
Labourers	.0370	.0333	.1681
Total labour	.0492	.0499	.1855
Capital stocks (Rp/Rp of output)[a]			
12.4 Wooden furniture etc	.0067	.0067	.0067
17.7 Fabricated metal prod	.0011	.0011	.0011
17.9 Transport equipment	.2847	.3132	.5556
Total capital stocks	.2925	.3210	.5634
Environmental impacts			
Deforestation (prop. of land area)	.26	.15	0
Soil erosion (tonnes/ha)			
- before logging/establishment	0	0	15
- after logging/establishment	79	30	10
Other parameters			
No. a/1000m^3 logs	26.5	26.5	3.22

a. Coefficients can be converted into million Rp of input/1000 m3 of log output by multiplying by 61.548 (= 1985 value of output, Rp 1482206 million, divided by 1985 volume of output, 24082,000 m3).
b. Coefficients can be converted into person years/1000 m3 of log output by multiplying by 61.548.

Sources: Tables 2, 3, 4, 8 and text of this paper.

It only remains to define the technological scenarios themselves. This is done in Table 10 below where the scenarios are represented by mixes of the current system of natural forest logging, the More Sustainable System of natural forest logging and mechanised plantations. The percentage distribution between logs from natural forests and plantations are based on the forecasts of Table 1.

Table 10 Technological scenarios for model analysis

Scenario	S0	S1	S2
Percentage of logs from:			
Natural forests			
. current practice	72	0	0
. more sustainable	0	60	32
Plantations	28	40	68

The shift to supplying logs from plantations and more sustainable natural forest logging will cause a very marked fall in erosion and deforestation, and thus of all the associated environmental problems. The negative impacts of current logging on biodiversity and carbon fixation will be significantly alleviated. However, these conclusions depend heavily on where plantations are established. If natural forests are cleared for plantations then the environmental problems will still be severe.

Achievement of these results will require government policies to:

encourage the establishment of plantations on alang-alang and belukar land; and

enforce more sustainable logging practices in natural forests.

An effective general policy to achieve these changes would be to provide subsidies to the establishment of plantations by private investors. The subsidies could be financed by the imposition of substantially higher stumpages on logs harvested from natural forests. This would discourage the current high levels of waste in natural forest logging. At present, natural forest logging is highly profitable while plantations are marginally profitable in some circumstances and unprofitable in most. Many investors are unwilling to make the large financial commitment when the waiting time is so long. However, anticipating the end of the supply of logs from natural forests, some large pulp and paper companies now have active programmes of plantation establishment. To the extent that it is needed, financial support for plantations should subsidise early establishment costs; once plantations are well established investors have an incentive to protect them.

There are several specific measures the government could take to encourage plantations, including:

granting of long leases on government-owned land;

provision of free technical advice;

provision of low-interest loans;

subsidies on imported capital equipment; and

rebates on wages of plantation workers.

The success of any scheme to encourage plantations will depend heavily on effective implementation by the relevant government agencies to ensure that the scheme is not undermined or abused.

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