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ANNEX 1

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REPORT ON PROJECT PD 107/90 (i)

Strategies for Sustainable Wood Industries in Sarawak

FOREST RESOURCES STATUS AND TIMBER SUPPLY PLANNING FOR THE FUTURE

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STRATEGIES FOR SUSTAINABLE WOOD INDUSTRIES IN SARAWAK

FOREST RESOURCE STATUS AND TIMBER SUPPLY PLANNING FOR THE FUTURE

CURRENT FOREST STATUS

1. The current status of forests in Sarawak's 9 administrative Divisions is summarized in Table 1-A. Based on interpretation of 1985 LANDSAT imagery, updated to the end of 1991 there were approximately 8.5 million ha of forest[1] - including 7 million ha of Mixed Dipterocarp forest; 1.3 million ha of peat swamp forest; and 0.2 million ha of Mangrove forest in coastal/riverine areas.

2. Administratively, Sarawak's forests consist of 4.4 million ha (55%) of Permanent Forests (PF)[2]; 3.8 million ha (45%) of State Land Forest (SF); and Totally Protected Areas (TPAs) (300,000 ha) such as National Parks and Wildlife Sanctuaries. Additional areas have been identified for inclusion in TPAs (0.7 million ha) and in PF (0.9 million ha). A further 0.5 million ha is proposed for inclusion in PF in the future. On completion of the proposed additions, the expanded PF would equal 5.1 million ha; while the TPAs would cover about 1 million ha. The remaining Stateland forests will continue to serve as a source of land for expansion of Sarawak's agricultural sector.

3. Based on interpretation of 1985 LANDSAT and 1990 SPOT satellite imagery, by the recently completed Sarawak Integrated Agricultural Development Project, summarized in Table 1-B, Sarawak's forest land area is 8.4 million ha - 1.4 million ha of peat swamp and mangrove forest, and 7 million ha of mixed dipterocarp, or "hill" forest. Approximately 6.5 million ha of forest is licenced for timber production under long-term (F-30) forest licences. Unlicenced forest account for an additional 1.8 million ha - about 1 million ha in existing and proposed parks and wildlife sanctuaries and 0.8 million ha in steep areas near the south-eastern border with Kalimantan.

CONDITION AND DISTRIBUTION OF THE PERMANENT FOREST

4. Table 2 shows the results of a mid-1993 survey of areas licenced for timber harvesting. There are approximately 550 timber licences with a total area of about 9 million ha. According to the licence documents, the total forested area was 7.6 million ha, at the time of issue. However, only 6.5 million ha of forest remain. Approximately 2.5 million ha of the area under forest licence.[1]

5. Data on the current status of forest land was compiled in Table 2 for 28 districts. The data was further disaggregated into 8 Timber Supply Planning Units (Map 1), based on log transportation and usage patterns. Forest data for each timber supply unit is summarized in Table 3.

6. Three planning units account for 62%, (4 million ha) of the forest area licenced for timber harvesting. These are: upper Baram river basin (Marudi) - 20%; upper Rajang river basin (Belaga) - 23%; and middle Rajang river (Song-Kapit)- 19%.

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[1] For the purposes of this report, "**Forest**" consists of "in tact" natural forest - both logged and unlogged - which has not been clear-felled within recent times. **Secondary forest** - areas which have been cleared for agriculture (including shifting cultivation areas in fallow) and are recovering but have not yet reached climax species, are not included as **Forest** in this report.

[2] Permanent Forests (PF) are areas managed sustainably for timber production; including: 0.8 million ha of Forest Reserves; 3.6 million ha of Protected Forests; and about 5,000 ha of Communal Forests.

Table 1: STATUS OF SARAWAK's FOREST LANDS Hectares of PF and Stateland Forest

A: Based on F.D. Records as of 31/12/91

Division Name	Forest Reserves	Protection Forest	Protected Areas Existing	Protected Areas Exist&Prop.	Permanent Forest (PF) Existing	Permanent Forest (PF) Proposed	State Land Forest (SF)	Total Forest Area
Kuching	56,230	200	15,200	49,704	73,630		89,400	163,030
Sri Aman	29,960	62,796	71,400	157,070	164,178		190,300	354,478
Samarahan	52,946	36,556	0	0	89,502		109,800	199,302
Subtotal	141,156	99,554	86,600	206,774	327,310	107,322	389,500	716,810
					46%		54%	100%
Sarikei	28,992	83,423	28,900	29,040	141,315		122,700	264,015
Sibu	93,018	298,346	23,500	23,780	414,864		226,000	640,864
Subtotal	122,010	381,769	52,400	52,820	556,179		348,700	904,879
					61%		39%	100%
Kapit	53,299	2,439,189	69,000	538,023	2,561,486	360,940	736,200	3,297,686
Subtotal	53,299	2,439,189	69,000	538,023	2,561,486	360,940	736,200	3,297,686
					78%		22%	100%
Bintulu	131,461	386,484	7,100	26,739	535,104		371,800	906,904
Miri	266,487	264,463	61,700	166,320	612,650	250,470	1,468,000	2,080,650
Subtotal	397,948	670,947	68,800	193,059	1,147,754	250,470	1,839,800	2,987,554
					38%		62%	100%
Limbang	78,324	16,400	12,000	27,000	106,724	232,310	452,200	558,924
Subtotal	78,424	16,400	12,000	27,000	106,724	232,310	452,200	558,924
TOTAL	792,737	3,607,859	288,800	1,017,676	4,699,455	951,042	3,766,400	8,465,855
			(6%)	(12%)	56%	(11%)	45%	
				Exist.& Prop. PF – 5.6 mil.ha.				

Notes/Observations:

1. 55% of the total forest (4.7 million ha) is in Permanent Forests (PF)
2. 45% of the total forest (3.8 million ha) is State Land Forests (SF)
3. PF (4.7 mil.ha) includes: Forest Reserves (0.8 mil.ha); Protection Forest (3.6 mil.ha); & Protected areas (0.3 mil.ha)
4. Existing Protected Areas (0.3 million ha) account of 3.5% of the forest area.
5. Addition of proposed parks and wildlife sanctuaries would increase this to 12% of the forest area.
6. Addition of areas proposed for inclusion in PF would increase PF to 5.6 million ha and decrease SF to 2.8 million ha.
7. Inclusion of Proposed PF areas would increase PF to 66% of forest area and Reduce SF to 33% of Forest Area.
8. Forest Licences account for 6.5 million ha or 77% of forest area.
9. Non–Licenced Forested Areas – 1.8 million ha. (21% of Forest Area) includes existing and proposed national parks and Wildlife Sanctuaries (1 million ha.); plus Steep, Terrain Class IV areas in south–eastern Sarawak – 0.8 million ha.

B. Based on interpretation of LANDSAT (1985) & SPOT (1990) Satellite Imagery – SADP Project

District Name	Mangrove & Swamp For.	Hill (Dip) Forest	Total Forest
Lundu	13,622	81,724	95,346
Bau	0	15,697	15,697
Kuching	35,923	16,709	52,632
K.Smrahan	23,699	4,123	27,822
Serian	13,136	28,589	41,725
Simunjan	98,138	28,161	126,299
Sri Aman	139,190	41,033	180,223
Saratok	39,619	0	39,619
Betong	51,437	0	51,437
Lubk.Antu	103,062	72,731	175,793
Subtotal	517,826	288,767	806,593
Sarikei	95,663	0	95,663
Matu	42,303	0	42,303
Daro	48,705	0	48,705
Maradong	33,412	0	33,412
Sibu	40,967	2,448	43,415
Julau	0	54,687	54,687
Kanowit	0	55,464	55,464
Subtotal	261,050	112,799	373,849
Dalat	62,894	50,796	113,692
Mukah	175,210	112,987	288,197
Subtotal	238,104	163,785	401,889
Song	0	252,694	252,694
Kapit	0	1,246,304	1,246,304
Subtotal	0	1,498,998	1,498,998
Belaga	0	1,806,887	1,806,887
Tatau	46,925	338,992	385,917
Bintulu	59,970	430,324	490,294
Miri	97,110	173,075	270,185
Subtotal	204,005	942,391	1,146,396
Marudi	156,668	1,641,735	1,800,403
Limbang	5,633	267,980	273,613
Lawas	26,099	238,046	264,145
Subtotal	31,732	506,026	537,758
Sarawak	1,411,385	6,961,386	8,372,773
Licenced –	1,044,647	5,493,465	6,538,114
Unlicenced –	366,738	1,467,923	1,834,659

Source: Sarawak Integrated Agricultural Development Project (1991)

Based on 1991 Satellite Imagery

Table 2: STATUS OF F30 FOREST LICENCES AS OF JULY 1993
– Forest Area (Hectares) Converted, Forested, Logged, Unlogged by Hill and Swamp Forest Types

District Name		Forest Licence Area Total	Forest(91)	Converted Area	Logged Area	Unlogged Area	Remaining Swamp Forest (91) Forested	Logged	Unlogged	Remaining Hill Forest (91) Forested	Logged	Unlogged
1. Lundu –Sri Aman	Lundu	107,523	56,832	50,691	43,526	13,306	0	0	0	56,832	43,526	13,306
	Bau	3,884	2,944	940	1,472	1,472	0	0	0	2,944	1,472	1,472
	Kuching	11,284	1,991	9,293	459	1,532	0	0	0	1,991	459	1,532
	K.Smrahan	21,026	15,215	5,811	15,034	181	15,215	15,034	181			
	Serian	65,639	18,563	47,076	13,201	5,362	18,563	13,201	5,362			
	Simunjan	165,013	102,119	62,894	93,010	9,109	102,119	93,010	9,109			
	Sri Aman	201,338	117,918	83,420	98,827	19,091	117,918	98,827	19,091			
	Saratok	38,612	10,525	28,087	9,104	1,421	10,525	9,104	1,421			
	Betong	49,171	37,829	11,342	33,628	4,201	37,829	33,628	4,201			
	Lubk.Antu	50,358	9,253	41,105	5,493	3,760	0	0	0	9,253	5,493	3,760
	Subtotal	713,848	373,189	340,659	313,754	59,435	302,169	262,804	39,365	71,020	50,950	20,070
2. Sarikei –Sibu	Sarikei	39,715	13,087	26,628	8,006	5,081	13,087	8,006	5,081			
	Matu	56,694	50,409	6,285	50,359	50	50,409	50,359	50			
	Daro	55,767	41,514	14,253	40,808	706	41,514	40,808	706			
	Maradong	46,385	34,174	12,211	33,271	903	34,174	33,271	903			
	Sibu	130,809	100,114	30,695	92,086	8,028	100,114	92,086	8,028			
	Julau	79,526	22,840	56,686	21,702	1,138	0	0	0	22,840	21,702	1,138
	Kanowit	110,519	31,614	78,905	24,144	7,470	152	152	0	31,462	23,992	7,470
	Subtotal	519,415	293,752	225,663	270,376	23,374	239,450	224,682	14,768	54,302	45,694	8,606
3. Song –Kapit	Song	274,776	159,197	115,579	106,103	53,094	0	0	0	159,197	106,103	53,094
	Kapit	1,403,730	1,088,914	314,816	519,142	569,772	0	0	0	1,088,914	519,142	569,772
	Subtotal	1,678,506	1,248,111	430,395	625,245	622,866	0	0	0	1,248,111	625,245	622,866
4. Dalat –Mukah	Dalat	177,362	94,208	83,154	91,713	2,496	52,670	50,244	2,426	41538	41469	70
	Mukah	391,251	208,438	182,813	153,500	54,938	113,052	85,342	27,710	95,386	68,158	27,228
	Subtotal	568,613	302,647	265,966	245,213	57,434	165,722	135,586	30,136	136,925	109,627	27,298
5. Bintulu –Miri	Tatau	436,674	325,098	111,576	249,157	75,941	29,235	22,110	7,125	295,863	227,047	68,816
	Bintulu	687,526	412,667	274,859	319,441	93,226	39,982	28,237	11,745	372,685	291,204	81,481
	Miri	423,418	236,688	186,730	198,978	38,070	107,625	92,735	15,250	129,063	106,243	22,820
	Subtotal	1,547,618	974,813	572,805	767,576	207,237	177,202	143,082	34,120	797,611	624,494	173,117
6. Rajang	Belaga	1,640,985	1,499,824	141,161	599,731	900,093	0	0	0	1,499,824	599,731	900,093
7. Baram	Marudi	1,767,300	1,309,095	458,205	630,242	678,853	99,107	77,503	21,604	1,209,988	552,739	657,249
8. Limbang – Lawas	Limbang	307,129	220,359	86,770	71,592	148,767	0	0	0	220,359	71,592	148,767
	Lawas	356,423	219,305	137,118	128,089	99,053	16,406	15,278	1,128	210,736	112,811	97,925
	Subtotal	663,552	447,501	216,051	199,681	247,820	16,406	15,278	1,128	431,095	184,403	246,692
Other (H/S) Area		163,051	89,180	73,869	71,852	17,330	44,591	35,926	8,665	44,591	35,926	8,665
TOTAL –	Sarawak	9,262,888	6,538,112	2,724,774	3,723,670	2,814,442	1,044,647	894,861	149,786	5,493,467	2,828,809	2,664,656

7. From Tables 2 and 3, it can be seen that the area of logged PF is 3.7 Million ha; while that of the unlogged PF is 2.8 million ha. Mixed dipterocarp, or hill forests contain the majority of the logged area, accounting for 2.8 million ha (76%), while logged swamp forests account for 0.9 million ha (24%).

8. The remaining unlogged forest area is concentrated in three planning units - all in hill forest. These are the middle Rajang (Song-Kapit), with 22% of the remaining unlogged forest; the upper Rajang (Belaga), with 32%; and the upper Baram (Marudi) with 24%.

IMPORTANCE AND CHARACTERISTICS OF LOGGED FOREST AREA

9. Once old growth timber stocks have been liquidated - during the period 2005-10, at currently projected rates of harvest - the status, protection and management of Sarawak's logged-over forest area will be critical to the state's long-term timber supply. A survey of the logged forest area was conducted to characterize the area by: Forest Type - Swamp/Hill; Forest Land Classification - PF/SF; and Period of Harvest.

10. According to F.D. records, summarized in Table 4, the average annual area of "new" forest logged[3] during the past decade was 220,000 ha, yielding an average of 12 million m3 of timber. The Forest Department projects that, with slight annual variations, the average annual harvest area and timber production will continue at this level throughout the 1990s and into the next decade.[4]

11. **Forest Area by Status, Forest Type and Classification** A 1990 F.D. survey of forest land status, summarized in Table 5, shows forest area logged by forest type (swamp and hill forest) and land classification (PF and SF). This information was projected ahead to the end of 1994, based on a number of sources, including: Tables 4 and 5; F.D.'s 1991 Study of Forest Productivity,summarized in Table 6A; and F.D.'s mid-1993 survey of forest status on long-term timber licences. This projection of forest status at the end of 1994 is presented in Table 6, which shows that 62% of the 6.5 million ha of forest licenced for harvesting has been logged. The logged portion varies from 45% (1.6 million ha) in PF ; to 74% (2.2 million ha) in Stateland Forests; and from 56% (3.1 million ha) in hill forests - to 90% (900,000 ha) in swamp forests.

12. **Harvest of Remaining Unlogged PF** Harvesting the estimated 2.5 million ha of unlogged PF, remaining at the end of 1994, at present annual rates will result in depletion of swamp forest in 5 to 10 years and the hill forest in about 12 to 15 years. At the current rate of harvesting - 128,000 ha per year - in SF, the remaining 754,000 ha of unlogged PF will be harvested in 6 years.

13. Approximately 1 million ha of unlogged forest will remain in areas set aside for protection under National Parks, Wildlife Sanctuaries. In addition, 44% of the 1.2 million ha of steep, Terrain Class IV will remain unlogged due to the fact that the forests are not of commercial quality. It is proposed to use limited access, heli-logging to selectively harvest areas of Terrain Class IV which support forest of commercial quality.

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[3] This does not include relogging of previously logged forests, which in 1991 contributed one-third of annual log production.

[4] Forestry in Sarawak, Malaysia - F.D. Sarawak, 1991

Table 3: Summary of Current Status of F-30 Forest Licence Areas.
Million Hectares – Converted, Logged, Unlogged – Hill & Swamp Forest

Planning Unit	Forest Licence Area Total	Forest Licence Area Forest	Converted Area	Logged Forest Area Hill	Logged Forest Area Swamp	Logged Forest Area Total	%of Logged	Unlogged Forest Area Hill	Unlogged Forest Area Swamp	Unlogged Forest Area Total	% of Unlogg	Remaining Licenced Forested Area Hill	Remaining Licenced Forested Area Swamp	Remaining Licenced Forested Area Total
1. Lundu – Sri Aman	713,848	373,189	340,659	50,950	262,804	313,754	8%	20,070	39,365	59,435	2%	71,020	302,169	373,189
												19%	81%	100%
2. Sarikei – Sibu	519,415	293,752	225,663	45,694	224,682	270,376	7%	8,606	14,768	23,374	1%	54,300	239,450	293,750
												18%	82%	100%
3. Song – Kapit	1,678,506	1,248,111	430,395	625,245	0	625,245	17%	622,866	0	622,866	22%	1,248,111	0	1,248,111
												100%	0%	100%
4. Dalat – Mukah	568,613	302,647	265,966	109,627	135,586	245,213	7%	27,298	30,136	57,434	2%	136,925	165,722	302,647
												45%	55%	100%
5. Bintulu – Miri	1,547,618	974,813	572,805	624,494	143,082	767,576	21%	173,117	34,120	207,237	7%	797,611	177,202	974,813
												82%	18%	100%
6. U.Rajang – Belaga	1,640,985	1,499,824	141,161	599,731	0	599,731	16%	900,093	0	900,093	32%	1,499,824	0	1,499,824
												100%	0%	100%
7. U.Baram – Marudi	1,767,300	1,309,095	458,205	552,739	77,503	630,242	17%	657,249	21,604	678,853	24%	1,209,988	99,107	1,309,095
												92%	8%	100%
8. Limbang – Lawas	663,552	447,501	216,051	184,403	15,278	199,681	5%	246,692	1,128	247,820	9%	431,095	16,406	447,501
												96%	4%	100%
Other (H/S) Areas	163,049	89,180	73,869	35,926	35,926	71,852	2%	8,665	8,665	17,330	1%	44,591	44,591	89,182
TOTAL – Sarawak	9,262,886	6,538,112	2,724,774	2,828,809	894,861	3,723,670	100%	2,664,656	149,786	2,814,442	100%	5,493,471	1,044,649	6,538,120
Percent of Licence or Forest Area	100%	71%	29%	76%	24%	100%		95%	5%	100%		84%	16%	100%

Notes/Observations:

78% of Unlogged forest is in 3 Units – Belaga(22%); Kapit (32%) and Marudi (24%)
71% of logged forest is in 4 Units – Belaga(17%); Bintulu/Miri(16%); Baram(21%); and Kapit (17%)
86% of the remaining Swamp Forest Area Has been Logged (14% remains unlogged)
52% of the remaining Hill Forest Area Has been Logged (48% remains unlogged)
86% of the remaining (6.5 million ha) forest area is hill forest (14% swamp forest)
The total area of forest licences is 9.1 million ha.
Total Original Forest Area of These Licences was 7.6 million ha.
Total Present Forest Area of These Licences is 6.5 million ha.
55% of the total forest (4.7 million ha) is in Permanent Forest (PF)
45% of the total forest (3.8 million ha) is State Land Forests
The PF (4.7 million ha) consists of Forest Reserves (0.8 million ha); Protection Forest (3.6 million ha); and Protected areas (0.3 million ha)
Protected Areas (0.3 million ha) account of 6% of the forest area proposed additional protected areas would increase this to 1 million ha (12 %).

Table 4: Annual Area of Forest Harvested and Log Production From PF and SF Forests of Sarawak

Forest Type	Permanent Forests			Stateland Forests			Total Forest		
	Area(Ha)	Vol.(M3)	M3/ha	Area(Ha)	Vol.(M3)	M3/ha	Area(Ha)	Vol.(M3)	M3/ha
Swamp	22,000	1.82	83	15,000	0.76	51	37,000	2.58	70
Hill	74,000	4.56	62	110,000	4.62	42	184,000	9.18	50
Total	96,000	6.38	66	125,000	5.38	43	221,000	11.76	53

Source: Forestry In Sarawak, Forest Department, Kuching, Sarawak (1990)

Table 5: Forest Area (Total and Harvested) as of 1990 (000s Ha)

Forest Type	Permanent Forests (000 ha)		Stateland Forests (000 ha)		Total Forest Area (000 ha)	
	Total Area	Harvested	Total Area	Harvested	Total Area	Harvested
Swamp	762	575	484	328	1,246	903
%	61%	75%	39%	68%		72%
Hill	3,699	1,073	3,324	2,091	7,023	3,164
%	53%	29%	47%	63%		45%
Total	4,461	1,648	3,808	2,419	8,269	4,067
%	54%	37%	46%	64%	100%	49%

Source: Forestry In Sarawak, Forest Department, Kuching, Sarawak (1990)

Table 6: Estimated Forest Area and Area Harvested As of Dec.31, 1994

Forest Type	Forest Licences In Permanent Forests			Forest Licences In Permanent Forests			Total Forest In Forest Licences		
	Area	Harv.	Unharv.	Area	Harv.	Unharv.	Area	Harvested	Unharv.
Swamp	637	586	51	408	351	57	1,045	937	108
%	61%	92%	8%	39%	86%	14%	100%	90%	10%
Hill	2,966	1,038	1,928	2,527	1,963	564	5,493	3,091	2,402
%	54%	35%	65%	46%	78%	22%	100%	56%	44%
Total	3,604	1,624	1,979	2,934	2,180	754	6,538	4,028	2,510
%	55%	45%	55%	45%	74%	26%	100%	62%	38%

Source: ITTO Project – Strategies for Forest Industries – 1993

Table 6A: Annual Log Supply from Logging and Relogging of PFE and Stateland Forest

Units	PFE			SLF			TOTAL		
	Hill	Swamp	Total	Hill	Swamp	Total	Hill	Swamp	Total
				PRIMARY LOGGING – LIQUIDATION OF OLD GROWTH					
M3	7,450	980	8,430	4,731	500	5,231	12,181	1,480	13661
Ha	160	14	174	114	14	128	274	28	302
M3/Ha	47	70	48	42	36	41	44	53	45
				RELOGGING OF PREVIOUSLY LOGGED AREA					
M3	1,445	528	1,973	3,139	273	3,412	4,584	801	5385
Ha	33	12	45	76	7	83	109	19	128
M3/Ha	44	44	44	41	39	41	42	42	42
				TOTAL PRIMARY LOGGING PLUS RELOGGING					
M3	8895	1508	10403	7870	773	8643	16765	2281	19046
Ha	193	26	219	190	21	211	383	47	430
M3/Ha	46	58	48	41	37	41	44	49	44

Source: Based on 1991 Forest Productivity Study by Sarawak Forest Department

14. **Stateland Forest** Currently there are about 3.8 million ha of Stateland Forest. Of this, about 3 million ha is licenced for timber production. Approximately 1 million ha has been identified for inclusion in PF. An additional 0.5 million ha is proposed for inclusion in PF. The remaining 2.3 million ha of Stateland Forest is, in principle, destined for conversion to other uses - mainly agriculture and conservation. About 700,000 ha have been identified for new and expanded Parks and Wildlife Sanctuaries. This leaves about 1.6 million ha of Stateland Forests for conversion to agriculture. However, this far exceeds projected needs for agricultural land expansion, as illustrated in the following paragraph.

15. The recently completed: **Sarawak Agricultural Development Plan** (SADP) indicated that future growth in agriculture will be slow, constrained by labour availability, relatively poor soils and poor market access. Land currently under small-holder agriculture (350,000 ha) is forecast to expand at 2% (7,000 ha) per year; while land under large-scale government and private sector agricultural plantations (70,000 ha) will expand at 5% (3,500 ha) per year. Thus the annual amount of land conversion required meet this expansion will be 10,500 ha. Assuming a planning horizon equal to one (hill forest) cutting cycle of 25 years, a total of 262,000 ha of additional land will be required for agricultural expansion, between 1995 and 2020. Contrasting this with the 1.6 million ha of stateland forest available, it can be seen that there is abundent potential (1.3 million ha) for further expansion of areas dedicated to timber production (PF) and conservation (TPA).

Distribution of Logged Forest by Period of Logging

16. **Hill Forest** In the absence of detailed data on area logged by year, the area of forest logged, by 5-year periods, was estimated from log production records. As shown in Table 7, 85% of the 3 million ha of logged hill forest originated during the last 15 years - 1980-95[5]. The remaining unlogged forest will be logged during the next 15 years - 1995-2010. The majority of the logged forest area is scheduled for reharvesting[6] during the period 2005 to 2020. Commencement of this reharvest coincides with completion of harvesting in the remaining unlogged forest.

17. **Swamp Forest** Harvesting in the swamp forest commenced earlier than in the hill forests and was more evenly distributed through time. About 60% of the 900,000 ha of logged swamp forest was created during the 20 year period - 1960 to 1980; while 40% was created in last 15 years - 1980 to 1995. Swamp Forests are managed on a 45 year cutting cycle - therefore the 60% of the area harvested area between 1960 and 1980 is scheduled for reharvest commencing 10 years from now -during the period 2005-2025. This coincides with completion of logging of remaining unlogged swamp forest.

18. The fact that completion of harvesting of the remaining unlogged forest coincides, more or less, with commencement of relogging in both hill and swamp forest would appear to ensure timber supply continuity. However, uncertainties exist over the effect of relogging prior to expiry of prescribed cutting cycles[7], and the effect of logging damage on regrowth of the residual forest; both of which could influence timber supply from the second, and subsequent cutting cycles. These are discussed in the following section - Timber Supply Planning.

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[5] The 3 million ha includes only the area remaining as forest. Over the years a much larger area has been logged but much of this has been converted to other uses - mainly agriculture.

[6] According to the 25 year cutting cycle under which hill, dipterocarp forests are currently managed.

[7] The extent of relogging is difficult to assess, however, it is generally believed that significant areas have been relogged. Some indication of this is given in a FD productivity study, showing, 45,000 ha of PF and 83,000 ha of SF relogged in 1991.

Table 7: Area And Volume Harvested By Year for Hill And Swamp Forests of Sarawak

Year of	Hill Forest				Swamp Forest				Hill/Swamp		
Logging	000M3	000Ha	Ha/%	M3/Ha	000M3	000Ha	Ha/%	M3/Ha	000M3	000Ha	Ha/%
1960	58	2		30	1109	18		50	1167	20	
1961	60	2		30	1137	18		50	1197	20	
1962	134	4		30	1204	19		50	1338	24	
1963	170	6		30	1534	25		50	1704	30	
1964	276	9	23	30	1565	25	105	50	1841	34	128
			1%				11%				3%
1965	276	7		35	1565	21		60	1841	28	
1966	393	10		35	1918	26		60	2311	36	
1967	616	16		35	3006	40		60	3622	56	
1968	719	18		35	3511	41		60	4230	59	
1969	721	19	70	35	3519	41	169	60	4240	60	239
			2%				18%				6%
1970	938	24		35	3751	38		70	4689	62	
1971	825	21		35	3302	33		70	4127	54	
1972	988	25		35	2183	22		70	3171	47	
1973	815	21		35	2455	25		70	3270	46	
1974	774	20	112	35	2053	21	137	70	2827	40	249
			4%				15%				6%
1975	762	17		40	1750	18		70	2512	35	
1976	1388	31		40	3025	30		70	4413	61	
1977	2021	45		40	2863	29		70	4884	74	
1978	3141	71		40	2842	28		70	5983	99	
1979	4262	96	260	40	3257	32	136	70	7519	128	397
			8%				15%				10%
1980	5132	91		45	3267	30		70	8399	122	
1981	5850	104		45	2847	26		70	8697	130	
1982	7988	142		45	3256	30		70	11244	172	
1983	7950	141		45	2615	24		70	10565	166	
1984	8243	147	625	45	3159	29	141	70	11402	176	766
			20%				15%				19%
1985	9463	151		50	2822	26		70	12285	178	
1986	8538	137		50	2933	27		70	11471	164	
1987	10250	164		50	3405	32		70	13655	196	
1988	10756	172		50	3631	34		70	14387	206	
1989	14800	237	861	50	3363	31	150	70	18163	268	1011
			28%				16%				25%
1990	16158	242		50	2680	25		70	18838	267	
1991	16979	255		50	2432	23		70	19411	277	
1992	16544	248		50	2256	21		70	18800	269	
1993	14685	206		50	1815	17		70	16500	222	
1994	13500	189	1140	50	1500	14	99	70	15000	203	1239
			37%				11%				31%
1960–94	Logged	3091		1960–94	Logged	937			Logged	4028	
1994	Forest	5493	100%	1993	Forest	1045	100%		Forest	6538	100%
1994	Unlogged	2402		1994	Unlogged	108			Unlogged	2510	

19. Condition of Logged Forest Unlike the virgin forest, from which past (relatively homogeneous) timber harvests have come, the stocking and condition of logged forests are very variable. The quality, quantity and timing of future timber harvests from these forests depends on such factors as: original forest structure; intensity of initial harvest; care and control of harvesting operations; and incidence of relogging.

20. Except for a recent remote sensing survey, which identified the extent of logged and unlogged forest, a comprehensive inventory of Sarawak's logged forests has not been undertaken. Given the lack of detailed information of the condition of logged forest, it may be useful to identify some basic trends.

(a) In the early years of logging in Sarawak, yields were lower than at present due to market factors. These lower yields resulted in less residual forest damage. Logging damage in recent years, is agravated by higher yields and by a generally less skilled work force, brought on by rapid growth of the sector - demand for additional labour has exceeded the ability to train qualified loggers.

(b) Use of MAI's from growth and yield plots which have been more carefully treated and protected to predict growth on areas logged in the past, many of which were poorly controlled and executed, results in overestimation of future yields. (see para 28 - Mean Annual Increment)

(c) Areas of stateland forests relogged in recent years, particularly those in built-up areas, will likely be converted to agriculture, and should not be included in estimates of future timber availability. (see timber supply scenarios, Annex 2)

(d) The eventual contribution of logged forests to long-term timber supplies will depend on successful protection against further relogging prior to expiry of the prescribed cutting cycle intervals.

21. Relogging Relogging, with yields ranging from 20 to 60 m3 per ha, has played a significant role in Sarawak's log production since the mid-1980s, accounting for about 30 percent of annual log production - 5-6 million M3 - in both hill and swamp forests.[8] Although relogging in the hill forest has been concentrated (68%) in stateland forests; in 1991, 66% of timber originating from relogging of swamp forests was from PF.

22. F.D. regulations require annual coupes to be "closed" prior to granting permission to enter a new annual coupe. However, this regulation was relaxed due to poor market conditions in the early 1980s. Since that time, logging coupes have frequently been reentered, particuarly in times of favaorable log markets. As a result, it is estimated that in excess of 1 million ha of logged forest has been relogged at least once. In recent years, the practice of requiring operators to "close" one annual coupe before entering another has been renewed and relogging, at least in PF has declined. Relogging in both PF and SF is subject to a "Timber Assessment Report" being approved by the F.D. This report shows the volume of trees larger than the cutting diameter limit and the number of residual trees to be left. In future, consideration should be given to making approvals of relogging conditional upon use of less damaging logging systems such as heli-logging in order to avoid logging damage and excessive growing stock reduction.

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[8] Malaysian National Conservation Strategy - Towards Sustainable Development, Vol. 4, Natural Resource Accounting, P.69 Economic Planning Unit, Prime Minister's Department, 1993

23. Forests logged prior to expiration of the prescribed cutting cycles, a will not provide viable timber harvests until later than the planned 25 year (hill) and 45 year (swamp) cutting cycles. Adequacy of present cutting cycles is discussed in the following paragraphs.

24. **Cutting Cycles** The capability of both hill and swamp forests to regenerate tree sizes and volumes for a second, commercially viable harvest[9] at 25 year (hill) and 45 year (swamp) cutting cycles, must be questioned in light of growth rates recorded on yield plots in logged hill and swamp forests. Present cutting cycles may be too short to produce adequate volumes and sizes of timber for commercially viable tractor logging operations. Relogging prior to expiry of cutting cycle periods, as has been the case on much of the Stateland Forest, will also require longer cutting cycles to achieve financially viable future harvests.

25. **Hill Forest Cutting Cycles** The 1990 ITTO Mission[10] estimated that it requires 45 to 50 years to produce a commercially viable timber harvest[11] from logged, untreated, dipterocarp forest. The Mission added that this period could be reduced to 35-40 years by reducing the minumum felling diameter to 45 cm. Implicit in these projections is a harvestable MAI equivalent to 1 m3 per ha.

26. Conclusions of other studies of residual tree growth in logged dipterocarp forests, (Korsgaard, 1986), (Korsgaard, 1992) support the Mission's estimates. It can be concluded that diameter and volume increment of commercial tree species, as recorded on Growth and Yield plots in mixed dipterocarp forests[12], will produce 5 to 7 trees of the minimum felling size[13], in 40 to 50 years time.

27. One solution to insufficient length of cutting cycle would be to reduce the minimum cutting size. However, researchers (Chai,Kho,Chung, 1994) caution that present 60 cm cutting limit may be necessary, in order to ensure retention of dipterocarp species in residual forests. Reduction of the cutting limit may lead to elimination of these valuable species from future crops. Further study of the effects of varying minimum felling diameter limits on sustainable yields of different species groups should precede any decision to adjust the felling diameter limits. Such studies are being undertaken in the ITTO project: **Model Forest Management**, being implemented under the leadership of Mr. Stephanus Andel.

28. **Swamp Forest Cutting Cycles** Based on measurement of growth and yield plots in regenerating swamp forest[14], it is not possible to produce trees of the minimum felling size (50 cm DBH for Ramin and 40 cm DBH for other species) in the presently prescribed 45- year cutting cycle. Reasons

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[9] It is generally accepted that an average yield of 40 m3 per ha is required to justify the initial costs of roads, camps, log ponds, etc, for the first harvest. Many of these items will not have to be constructed for subsequent harvests and therefore yields of 25 to 40 m3 may suffice. Heli-logging may be viable at even lower yields due to reduced road requirements, higher productivity, and generally higher log values.

[10] Promotion of Sustainable Forest Management - A Case Study in Sarawak. ITTC; May 1990.

[11] Commercial timber yields from hill forests of 40 m3 per ha from trees of >60 cm (dipterocarps) and >45 cm (non-dipterocarps).

[12] Measurement of leading desirable crop trees in logged, untreated hill forests of Sarawak (Research Plots 54-65,66,90,106) resulted in a mean annual diameter increment of 0.66 cm.

[13] Miniumum Diameter at Breast Height (DBH) for dipterocarp tree species is 60 cm and for non-dipterocarp tree species 45 cm.

[14] Measurement of 33 growth and yield plots at 25 to 30 years after logging in swamp forest show an average diameter growth of leading desirable trees (those which will make up the future harvest) of 0.52 cm/yr for all species and 0.40 cm/yr for Ramin.

for this include: the relatively slow growth rate of one of the principal species - Ramin. Another important swamp species - Alan[15] - regenerates from seedlings, rather than advanced residuals. Relogging in recent years, has damaged or destroyed many of the advanced residual trees which would have made up the next harvest. Future harvests may have to rely on growth of seedlings, therefore requiring longer periods to produce trees of commercial size and adequate yields.

29. Projecting diameter growth rates (from yield plots measured at 12 to 28 years after harvest) to a 45 year cutting cycle, results in an average tree size of 23 cm (all species) and 18 cm (Ramin) - well below the 45cm minimum felling size. Projecting diameter increments forward in time, it was found that an average of 66 years is required to reach the minimum cutting size. In other words, financially viable subsequent harvests can be scheduled at 65 to 70 year intervals.

30. **Mean Annual Increment (MAI)** The 1990 ITTO mission assumed MAIs of 1.3 m3/ha/yr and 2.0 m3/ha/yr for untreated and treated logged forest areas, respectively. Growth and yield studies in Malaysia and other countries of the region, are reviewed in Annex 1. These studies show a large range in volume increment of mixed dipterocarp forests. Recognizing that future timber supply will come from a variety of sites and stand conditions throughout the state, a mean annual increment (MAI) of harvestable timber volume of 1 m3 per ha was adopted for predicting future timber supply in the current - **Strategies for Sustainable Wood Industries in Sarawak** - project. Although data from some yield plots indicates MAIs of 2 to 3 m3 per ha; data from other yield plots show MAIs of less than 1 m3 per ha.

31. The decision to use an average MAI of 1 m3 per ha for predicting future timber supply, was based on the following factors:

(a) Many of the earlier yield plots, are located in lowland dipterocarp forest, the majority of which has been converted to agriculture. The focus of forest harvesting, now and in the future, will be hill dipterocarp forests, often found on poorer sites, with lower growth rates than their lowland counterparts.

(b) Data derived from Growth and Yield plot data, are often based on gross volume increment of all species, and all diameters (>10cm). Yet is the growth of trees of commercial species and size that should be used to predice future timber supply.

(c) In summary, MAIs based on measurement of trees of all species and sizes, on yield plots located on productive, secure sites may not represent harvestable commercial timber volume from large areas of hill dipterocarp forests, on generally poorer sites, some of which have been relogged prior to exiry of the cutting cycle.

32. The 1990 ITTO Mission observed that MAI of logged forests can be increased, through more intensive forest management practices. Concepts for such yield-increasing practices are being for consideration by ITTO in the Project: **Sustainable Multiple Use of Hill Forests in Sarawak**, being prepared Dr. Hans Christian Seip.

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[15] Alan (Shorea albida) forest grow in almost pure stands in parts of the swamp forest and are harvested by clear felling.

Table 7A - Present and Projected Forest Plantations in Sarawak

1. Existing Plantations By Establishment Year

Year of Establishment	Area (Ha)	Cumulative Area Planted	Lundu to Sri Aman	Bintulu to Miri
1979	19			
1980	124			
1981	44			
1982	187			
1983	368	(1979–84)		
1984	548	1289		
1985	623			
1986	741			
1987	770			
1988	449	(1985–89)		
1989	776	3359		
1990	747			
1991	1217			
1992	1466			
1993	1030	(1990–95)		
1994	1200	5660		
Total Planted	10308	10308	6604	3704

2. PROJECTED FOREST PLANTATION DEVELOPMENT BY ESTABLISHMENT PERIOD & TIMBER SUPPLY UNIT

Past/Future Plantation	Ha.	Lundu to Sri Aman	Sarikei To Sibu	Dalat–Mukah	Miri to Bintulu	Limbang–Lawas	Total
1979–84	1289	64%	0%	0%	36%	0%	100%
1985–89	3359	50%	0%	0%	50%	0%	100%
1990–94	5660	30%	0%	0%	70%	0%	100%
1995–99	7500	20%	15%	15%	50%	0%	100%
2000–04	7500	10%	20%	15%	45%	10%	100%
2005–09	7500	10%	20%	15%	35%	20%	100%
2010–14	7500	10%	20%	15%	35%	20%	100%
2015–19	7500	10%	20%	15%	35%	20%	100%
2020–24	7500	10%	20%	15%	35%	20%	100%
Hectares	55308	8000	8000	7000	25000	7000	55000
Percent of Total		15%	15%	13%	45%	13%	100%

3. PLANTATION ESTABLISHMENT & HARVEST BY PERIOD

Establish. Period	Area Planted	Harvest Period	Periodic Harvest Ha per 5 Yr.Period
1979–84	1289	1990–94	1289
1985–89	3359	1995–99	3359
1990–94	5660	2000–04	6949
1995–99	7500	2005–09	10859
2000–04	7500	2010–14	14449
2005–09	7500	2015–19	18359
2010–14	7500	2020–24	21949
2015–19	7500	2025–29	25859
2020–24	7500	2030–34	29449
	55308		

4. PROJECTED FOREST PLANTATION YIELDS BY HARVEST PERIOD & TIMBER SUPPLY UNIT (M3/Yr)

Past/Future Plantation	Harvest Ha.	Lundu to Sri Aman	Sarikei To Sibu	Dalat–Mukah	Miri to Bintulu	Limbang–Lawas	Annual Volume
1990–94	1289	24749	0	0	13921	0	38670
1995–99	3359	50385	0	0	50385	0	100770
2000–04	6949	62541	0	0	145929	0	208470
2005–09	10859	65154	48866	48866	162885	0	325770
2010–14	14449	43347	86694	65021	195062	43347	433470
2015–19	18359	55077	110154	82616	192770	110154	550770
2020–24	21949	65847	131694	98771	230465	131694	658470
2025–29	25859	77577	155154	16366	271520	155154	775770
2030–34	29449	88347	176694	32521	309215	176694	883470

PREDICTING FUTURE TIMBER AVAILABILITY

33. Sarawak's future timber supply will come from three sources of supply:
(a) Short-term - Harvest of Remaining Primary Forest in PF and SF
(b) Long-term - Harvest of regrowth on logged forest areas
(c) Long-term - Forest Plantations (see Table 7A)

34. Timber yield from these 3 sources was estimated by 5 year periods for four alternative scenarios, reflecting some of the limitations and uncertainties described in previous sections. The scenarios project future timber supply based on assumptions related to the following factors:

(a) the forest land base;
(b) the rate at which remaining unlogged forest area is harvested;
(c) the cutting cycles under which the forest is managed, and;
(d) the degree of planning, control and care taken in harvesting.

35. In the following pages, the essential assumptions underlying each Timber Supply Scenario are described and the results are presented in Tables and Graphs. It should be noted that the graphs show the annual Timber Supply for both PF and SF. However, for reasons discussed earlier, it is probable that only about half of the SF area will be available for management as production forest. Therefore, the probable average long and short-term timber supply will be slightly less than shown in the graphs, as indicated in the lower right corners of Tables 8,9,10 and 10A, under the caption - **"PF plus 1/2 SF"**. Further discussion of the four Timber Supply Scenarios and factors influencing short and long-term timber supply from natural forest and forest plantations is included in Annex 2. The potential contribution of Forest plantations to long-term timber supply is discussed in Annex 7.

36. **Scenario #1** is summarized in Table 8 and Figure 1. In this **"base case"** scenario, it is assumed that: current cutting cycles are maintained at 25 years and 45 years for hill and swamp forest respectively; and that the remaining 2.5 million ha of unlogged forest is harvested at rates based on current F.D. policy. ie. PF harvest is restricted to 9.6 million m3 and SF harvests to about 4 million m3 per year, by imposing a quota. In summary, short-term annual harvests from natural forest management is 14 million m3.[16] An additional 2 to 2.5 million m3 of timber is generally available from clearing land for conversion to agriculture.

37. Expansion of the current 10,000 ha of forest plantations, is assumed to continue at present rates until it reaches 55,000 ha during the period 2020-24. (see Table 7A and Annexes 2 and 7) Average annual timber yield is estimated for both natural and plantation forests by 5 year periods. The projections cover a 70 year period ranging from 1990 through 2060. Timber supply is projected for three levels of forest land base: the first, assumes that all of the current PF and SF contribute to future timber supply; the second, asssumes PF and half of SF contribute to future timber supply; and the third assumes that only PF contributes to future timber supply. Average annual yield for these three levels of forest land base are calculated for short-term (1995-2910) and long-term (2010-2060) periods - representing the periods "before" and "after" harvest of remaining unlogged PF and SF.

38. **Scenario # 2** The second timber supply projection was developed by recalculating data in Table 8, using extended cutting cycles - 45 years for hill forests; and 70 years for swamp forests - which would be more certain to produce tree sizes meeting current minimum diameter limits and provide financially viable timber yields. Timber supply estimates based on these extended cutting cycles are summarized in Table 9 and Figure 2.

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[16] Timber supply is currently augmented by an additional 2 to 2.5 million m3 of timber from clearing of land for agriculture bringing annual timber supply to about 16 million m3.

Table 8: TIMBER SUPPLY SCENARIO #1 (000 M3/Yr) – PRESENT CUTTING CYCLES & RATE OF LOGGING REMAINING UNLOGGED FOREST.
Timber Supply Sources by 5 Year Period

1. LOGGED FOREST AREA BY HARVEST PERIOD

Year of Harvest	Hill (000 Ha as of Dec. 31, 1994)	Swamp	Total	Cuml. Resid.
Unlogged	5493	1045	6538	6538
1960–64	23	105	128	6410
1965–69	70	169	239	6171
1970–74	112	137	249	5922
1975–79	260	136	396	5526
1980–84	625	141	766	4760
1985–89	861	150	1011	3749
1990–94	1140	99	1239	2510
Subtotal	3091	937	4028	2510

2. UNLOGGED FOREST BY HARVEST PERIOD (ha)

@ End 1994	2402	108	2510	2510
1995–99	875	54	929	1581
2000–04	825	54	879	702
2005–09	702	0	702	0

3. PLANTATIONS ESTAB. & HARVEST BY PERIOD

Establish. Period	Area Planted	Harvest Period	Periodic Harvest (Ha/5)
1979–84	1289	1990–94	1289
1985–89	3359	1995–99	3359
1990–94	5660	2000–04	6949
1995–99	7500	2005–09	10859
2000–04	7500	2010–14	14449
2005–09	7500	2015–19	18359
2010–14	7500	2020–24	21949
2015–19	7500	2025–29	25859
2020–24	7500	2030–34	29449
Area Plant	55308		

1. YIELD FROM LOGGED FOREST @25 yr (hill); @45 yr (swamp) (MAI Commercial – 1 M3/Ha/Yr)

Period	Hill	Swamp	Total
1990–1994	350	0	350
1995–1999	560	0	560
2000–2004	1300	0	1300
2005–2009	3125	945	4070
2010–2014	4305	1521	5826
2015–2019	6385	1233	7618
2020–2024	4935	1224	6159
2025–2029	5425	1269	6694
2030–2034	6635	1350	7985
2035–2039	4305	891	5196
2040–2044	6385	891	7276
2045–2049	4935	0	4935
2050–2054	5425	945	6370
2055–2060	6635	1521	8156
Short–term (1995–2010)			
PFE –	897	192	1089
Percent –	54%	61%	55%
SLF –	764	123	887
Percent –	46%	39%	45%
PFE & SLF	1662	315	1977
Percent –	100%	100%	100%
Long–term (2010–2060)			
PFE –	3876	662	4537
Percent –	70%	61%	69%
SLF –	1661	423	2084
Percent –	30%	39%	31%
PFE & SLF	5537	1085	6622
Percent –	100%	100%	100%

2. YIELD – UNLOGGED Hill Forest Over 15 Years Swamp For. Over 10 Years

Hill	Swamp	Total
16286	1980	18266
12500	1080	13580
11786	1080	12866
10029	0	10029
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

3. FOREST PLANTATN. HARVESTS

Plantation
39
101
208
326
433
551
658
776
883
883
883
883
883
883

4. TOTAL ANNUAL YIELD (M M3)

Hill Forest	Swamp Forest	Planted Forest	Total Forest
16636	1980	39	18654
13060	1080	101	14241
13086	1080	208	14374
13154	945	326	14424
4305	1521	433	6259
6385	1233	551	8169
4935	1224	658	6817
5425	1269	776	7470
6635	1350	883	8868
4305	891	883	6079
6385	891	883	8159
4935	0	883	5818
5425	945	883	7259
6635	1521	883	9039
12335	912	212	13459
3876	662	772	5309
12718	974	212	13903
4706	873	772	6351
13100	1035	212	14346
5537	1085	772	7393

Short–term 1995–2010 PFE Only
Long–term 2010–2060 PFE Only
Short–term 1995–2010 PFE & 1/2 SLF
Long–term 2010–2060 PFE & 1/2 SLF
Short–term 1995–2010 PFE & All SLF
Long–term 2010–2060 PFE & All SLF

FIGURE 1: SCENARIO 1 – ANNUAL TIMBER SUPPLY
By Source Type (Hill,Swamp, Plantation)

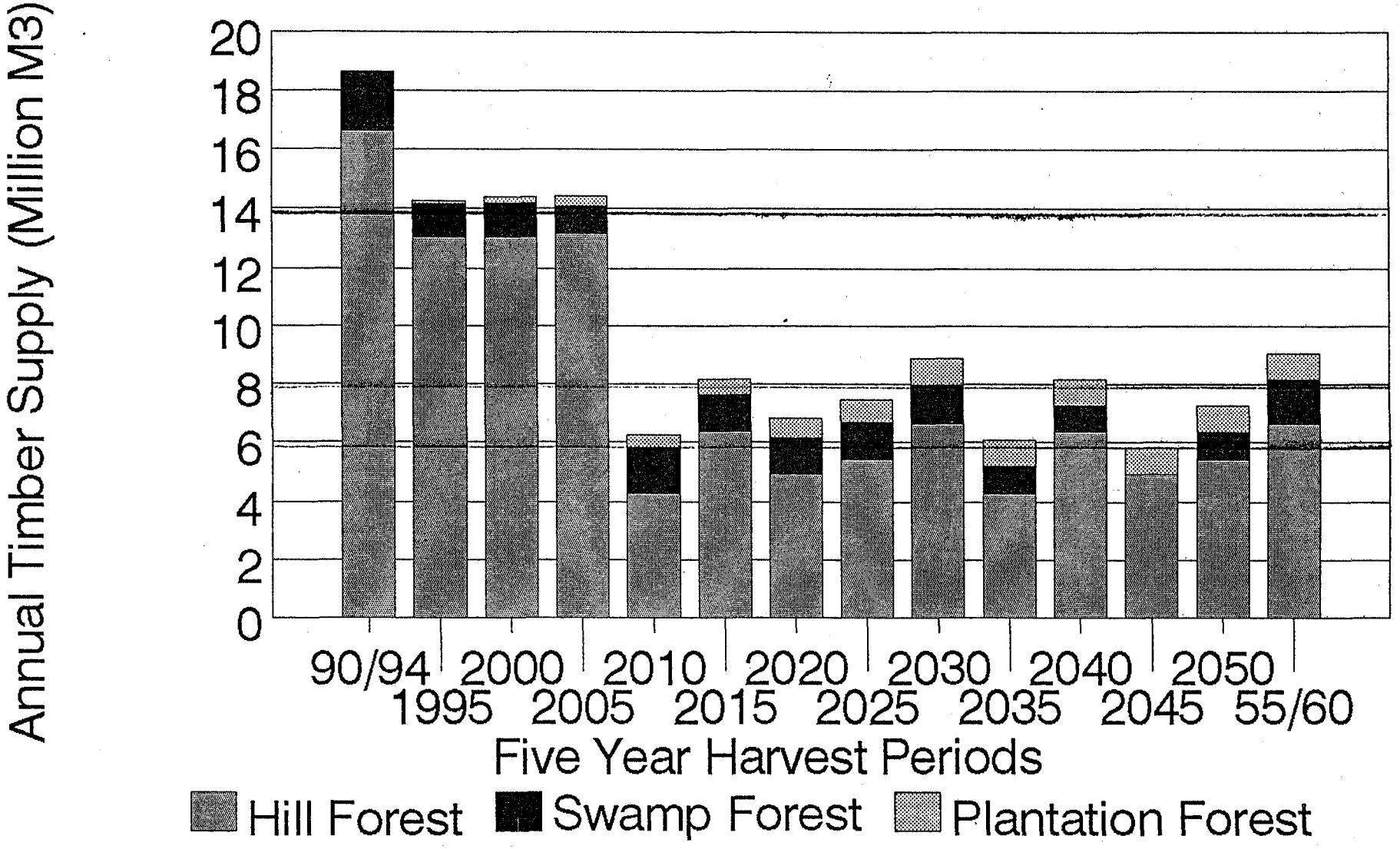


TABLE 9: TIMBER SUPPLY SCENARIO #2 (M M3/Yr) – EXTENDED CUTTING CYCLES AND PRESENT RATE OF LOGGING REMAINING UNLOGGED FOREST.

Timber Supply Sources by 5 Year Period

1. LOGGED FOREST AREA BY HARVEST PERIOD

Year of Harvest	Hill (000 Ha as of Jan. 1995)	Swamp	Total	Cuml. Resid.
Unlogged	5493	1045	6538	6538
1960–64	23	105	128	6410
1965–69	70	169	239	6171
1970–74	112	137	249	5922
1975–79	260	136	396	5526
1980–84	625	141	766	4760
1985–89	861	150	1011	3749
1990–94	1140	99	1239	2510
Subtotal	3091	937	4028	2510

2. UNLOGGED FOREST BY HARVEST PERIOD (ha

@ End 1994	2402	108	2510	2510
1995–99	875	54	929	1581
2000–04	825	54	879	702
2005–09	702	0	702	0

3. PLANTATION ESTAB. & HARVEST BY PERIOD (

Establish. Period	Area Planted	Harvest Period	Periodic Harvest
1979–84	1289	1990–94	1289
1985–89	3359	1995–99	3359
1990–94	5660	2000–04	6949
1995–99	7500	2005–09	10859
2000–04	7500	2010–14	14449
2005–09	7500	2015–19	18359
2010–14	7500	2020–24	21949
2015–19	7500	2025–29	25859
2020–24	7500	2030–34	29449
Total Planted	55308		

1. YIELD FROM LOGGED FOREST @45 yr (hill); @70 yr (swamp) (MAI Commercial – 1 M3/Ha/Yr)

Period	Hill	Swamp	Total
1990–1994	0	0	0
1995–1999	0	0	0
2000–2004	0	0	0
2005–2009	207	0	207
2010–2014	630	0	630
2015–2019	1008	0	1008
2020–2024	2340	0	2340
2025–2029	5625	0	5625
2030–2034	7749	1470	9219
2035–2039	10260	2366	12626
2040–2044	7875	1918	9793
2045–2049	7425	1904	9329
2050–2054	6525	1974	8499
2055–2060	630	2100	2730
Short–term (1995–2010)			
PFE –	37	0	37
Percent –	54%	61%	54%
SLF –	32	0	32
Percent –	46%	39%	46%
PFE & SLF	69	0	69
Percent –	100%	100%	100%
Long–term (2010–2060)			
PFE –	3505	716	4220
Percent –	70%	61%	68%
SLF –	1502	458	1960
Percent –	30%	39%	32%
PFE & SLF	5007	1173	6180
Percent –	100%	100%	100%

2. YIELD – UNLOGGED Hill Forest Over 15 Years Swamp For. Over 10 Years

Hill	Swamp	Total
16285.	1980	16265.
12500	1080	13580
11786	1080	12866
10029	0	10029
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0.
0	0	0
0	0	0

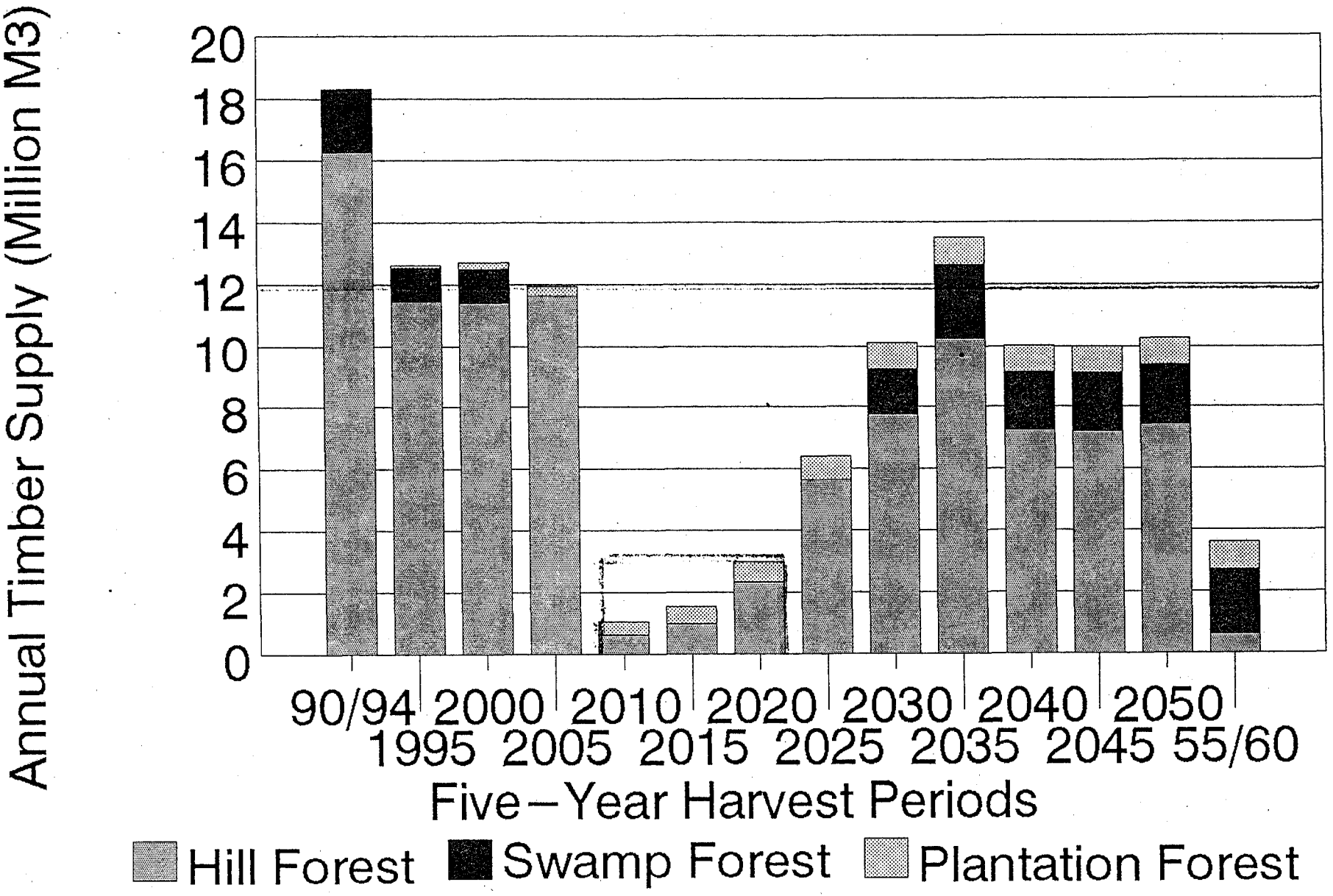
3. FOREST PLANTATN. HARVESTS

Plantation
39
101
208
326
433
551
658
776
883
883
883
883
883
883

4. TOTAL ANNUAL YIELD (M M3)

Hill Forest	Swamp Forest	Planted Forest	Total Forest
16286	1980	39	18304
12500	1080	101	13681
11786	1080	208	13074
10236	0	326	10561
630	0	433	1063
1008	0	551	1559
2340	0	658	2998
5625	0	776	6401
7749	1470	883	10102
10260	2366	883	13509
7875	1918	883	10676
7425	1904	883	10212
6525	1974	883	9382
630	2100	883	3613
Short–term 1995–2010 PFE Only	11475	720	212	12407
Long–term 2010–2060 PFE Only	3505	716	772	4992
Short–term 1995–2010 PFE & 1/2 SLF	11491	720	212	12423
Long–term 2010–2060 PFE & 1/2 SLF	4256	944	772	5972
Short–term 1995–2010 PFE & All SLF	11507	720	212	12439
Long–term 2010–2060 PFE & All SLF	5007	1173	772	6952

FIGURE 2: SCENARIO 2 – ANNUAL TIMBER SUPPLY
By Source Type (Hill,Swamp, Plantation)



39. In timber supply scenarios #1 and #2 (Tables 8 and 9), the remaining unlogged PF and SF is harvested over a 15 year period, 1995-2009, as shown in Table 11 and Figure 5 , at an annual rate of 160,000 to 170,000 ha. This results in abundent timber supplies in the short-term, followed by a sharp decline in timber supply (see Figures 1 and 2). This decline is due to the change in timber supply source - from liquidation of old-growth timber stocks (built up over many years) on a large land base (6.5 million ha of Forest in PF and SF); to a timber supply based on periodic harvest of timber increment[17] from regenerating PF plus SF, whose area has been reduced by conversion to agriculture and whose growing stock has, in many cases been reduced through relogging.

40. Negative impacts of declining timber supply can be reduced through a more gradual transition to a timber supply based on second-growth forest management by extending the period over which the remaining unlogged forest is harvested.

41. Scenario #3 - Table 10 and Figure 3 - explores the effect of extending the harvest of remaining unlogged PF and SF - from the currently projected, 15 years, to 30 years (1995-2025) - combined with the extended cutting cycles assumed in Scenario #2.

42. Scenario #4 - Table 10A and Figure 4 - is based on the same assumptions as Scenario #3, but explores the effects of improved timber harvesting methods on future timber yields from the remaining unlogged PF and SF. Increased timber yields accruing from improved harvest practices were projected into the future to examine their effect on long-term timber supply. The addition of 536,000 ha of Terrain Class IV which can logged by Helicopter is also included in Scenario #4. It should be noted that the extended harvest period for the remaining unlogged forests, implicit in Scenarios 3 and 4, provides time for the required training and implemention of improved logging practices.

43. Results Of Timber Supply Analysis for the four timber supply scenarios are included in Annex 2. Table 11 and Figure 5 show, assumed annual area (ha) of unlogged forest harvested by five-year period. Table 12 shows a summary the average annual timber supply volume (m3), in millions of M3, for each scenaro, by period and forest type - swamp, hill and plantations. At the bottem of Table 12, the portions of yield attributable to PF and SF are divided into 3 components: **PF only**; **PF plus 1/2 SF**; and **PF plus SF.** Average annual timber supply is shown separately for **short-term** - period over which remaining unlogged forest is harvested; and **long-term** - the period following logging of the remaining unlogged forest. Results summarized Table 12 show the following trends in Timber supply for each scenario:

Scenario 1 Short-term liquidation of old-growth timber stocks provides the majority of the annual timber supply of slightly over 14 million m3, between 1995 and 2010, after which timber supplies decline. Based on existing cutting cycles of 25 years for hill forest and 45 years for swamp forest, long-term annual timber supply from an expanded PF[18], averages **6.3 million m3** - ranging from 6 to 9 million m3 - for the 50 year period (2010 to 2060) following harvest of the remaining unlogged production forest.

Scenario 2 Extending cutting cycles for swamp and hill forest to permit trees to grow to the present minimum harvestable size, thus ensuring commercial timber yields capable of supporting viable logging operations, results in a short-term annual timber supply of 13 million m3; followed by a sharp decline in annual timber supply - to between 1 and 3 million m3 - for 15 years following logging of remaining unlogged forest in 2010. An imbalance of age classes, combined with longer cutting cycles, produces

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[17] Compared to the old-growth timber stocks, these timber increments have accumulated over relatively short cutting cycle periods since the previous harvest.

[18] Current PF plus 1/2 of SF.

wide fluctuations in timber supply from an expanded PF, ranging from 1 to 13 million m3 - average **6 million m3** - during the 50 years (2010-2060).

Scenario 3 The 15 year decline, in Scenario 2, (see Figure 2), and its severe negative effects on timber industries and regional economies, can be avoided by doubling the period over which the remaining unlogged forest is harvested - from 15 to 30 years, as shown in Figure 3. The resultant annual timber supply (expanded PF) declines from 18 million m3, to an average of **7 million m3**.

Scenario 4 Extending the harvest of the remaining unlogged forest allows time for implementation of a program of improved logging methods (RIL) resulting in less damage and faster regrowth in logged forests. It is estimated that this will result in an increase in MAI which will increase long-term timber supplies. Introduction of Heli-logging permits timber harvesting on 536,000 ha of previously unloggable, Terrain Class IV. This will increase both short and long-term timber supply. The combination of reduced impact tractor logging and helicopter logging have the potential to increase long-term annual timber supply to **8 million m3**.

TABLE 10: TIMBER SUPPLY SCENARIO #3 (M M3)– EXTENDED CUTTING CYCLES & EXTENDED PERIOD OF HARVESTING OF REMAINING UNLOGGED FOREST.

Timber Supply Sources by 5 Year Period

1.LOGGED FOREST AREA BY HARVEST PERIOD(ha)

Year of Harvest	Hill (000 Ha @ Dec.31/94)	Swamp	Total	Cumulat. Residual
Unlogged	5493	1045	6538	6538
1960–64	23	105	128	6410
1965–69	70	169	239	6171
1970–74	112	137	249	5922
1975–79	260	136	396	5526
1980–84	625	141	766	4760
1985–89	861	150	1011	3749
1990–94	1140	99	1239	2510
Subtotal	3091	937	4028	2510

2. UNLOGGED FOREST BY HARVEST PERIOD(ha)

@ End 1994	2402	108	2510	2510
1995–99	450	18	468	2042
2000–04	425	18	443	1599
2005–09	425	18	443	1156
2010–14	400	18	418	738
2015–19	400	18	418	320
2020–24	300	18	318	2

3.PLANTATION ESTAB.& HARVEST BY PERIOD(ha)

Establish. Period	Area Planted	Harvest Period	Periodic Harvest
1979–84	1289	1990–94	1289
1985–89	3359	1995–99	3359
1990–94	5660	2000–04	6949
1995–99	7500	2005–09	10859
2000–04	7500	2010–14	14449
2005–09	7500	2015–19	18359
2010–14	7500	2020–24	21949
2015–19	7500	2025–29	25859
2020–24	7500	2030–34	29449

1. YIELD FROM LOGGED FOREST @45 yr (hill); @70 yr (swamp) (MAI Commercial – 1 M3/Ha/Yr)

Year	Hill	Swamp	Total
1990–1994	0	0	0
1995–1999	0	0	0
2000–2004	0	0	0
2005–2009	207	0	207
2010–2014	630	0	630
2015–2019	1008	0	1008
2020–2024	2340	0	2340
2025–2029	5625	0	5625
2030–2034	7749	1470	9219
2035–2039	10260	2366	12626
2040–2044	4050	1918	5968
2045–2049	3825	1904	5729
2050–2054	4032	1974	6006
2055–2060	4230	2100	6330
Short–term (1995–2025)			
PFE –	377	0	377
Percent –	54%	61%	54%
SLF –	321	0	321
Percent –	46%	39%	46%
PFE & SLF	698	0	698
Percent –	100%	100%	100%
Long–term (2025–2060)			
PFE –	3977	1022	4999
Percent –	70%	61%	68%
SLF –	1704	654	2358
Percent –	30%	39%	32%
PFE & SLF	5682	1676	7358
Percent –	100%	100%	100%

2. YIELD – UNLOGGED

Hill 15 Years	Swamp 5 Years	Total
16286	1980	18266
6429	360	6789
6071	360	6431
6071	360	6431
5714	360	6074
5714	360	6074
4286	360	4646
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

3. FOREST PLANTATN HARVESTS

39
101
208
326
433
551
658
776
883
883
883
883
883
883

4. TOTAL ANNUAL YIELD (M M3)

Hill Forest	Swamp Forest	Planted Forest	Total Forest
Hill	Swamp	Plantatn.	Total
16286	1980	39	18304
6429	360	101	6889
6071	360	208	6640
6278	360	326	6964
6344	360	433	7138
6722	360	551	7633
6626	360	658	7644
5625	0	776	6401
7749	1470	883	10102
10260	2366	883	13509
4050	1918	883	6851
3825	1904	883	6612
4032	1974	883	6889
4230	2100	883	7213
Short–term 1995–2025 PFE Only	6091	360	380	6831
Long–term 2025–2060 PFE Only	3977	1022	868	5867
Short–term 1995–2025 PFE & 1/2 SLF	6251	360	380	6991
Long–term 2025–2060 PFE & 1/2 SLF	4829	1349	868	7046
Short–term 1995–2025 PFE & All SLF	6412	360	380	7151
Long–term 2025–2060 PFE & All SLF	5682	1676	868	7737

FIGURE 3:

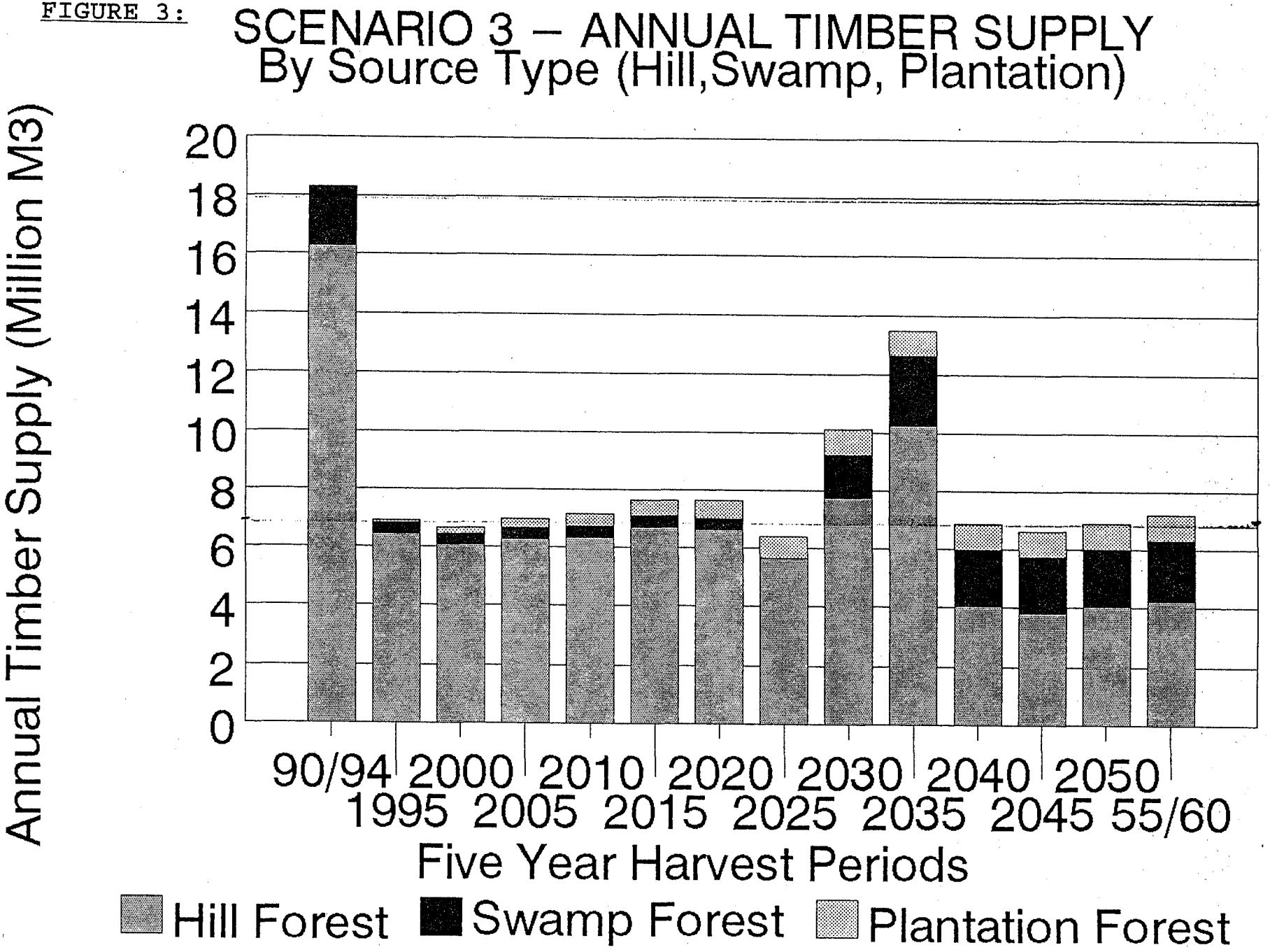

SCENARIO 3 – ANNUAL TIMBER SUPPLY
By Source Type (Hill,Swamp, Plantation)
Annual Timber Supply (Million M3)
20
18
16
14
12
10
8
6
4
2
0
90/94
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
55/60
Five Year Harvest Periods
Hill Forest
Swamp Forest
Plantation Forest

TABLE 10A: TIMBER SUPPLY SCENARIO #4 (M M3) – EXTENDED CUTTING CYCLES. EXTEND HARVEST OF UNLOGGED FOREST. REDUCED IMPACT TRACTOR & HELI-LOGGING.
Timber Supply Sources by 5 Year Period

1.LOGGED FOREST AREA BY HARVEST PERIOD(ha)

Year of Harvest	Hill (000 Ha @ Dec.31/94)	Swamp	Total	Cumulat. Residual
Unlogged	5493	1045	6538	6538
1960–64	23	105	128	6410
1965–69	70	169	239	6171
1970–74	112	137	249	5922
1975–79	260	136	396	5526
1980–84	625	141	766	4760
1985–89	861	150	1011	3749
1990–94	1140	99	1239	2510
Subtotal	3091	937	4028	2510

2. UNLOGGED FOREST BY HARVEST PERIOD(ha)

@ End 1994	2938	108	3046	3046
1995–99	550	18	568	2478
2000–04	525	18	543	1935
2005–09	500	18	518	1417
2010–14	450	18	468	949
2015–19	450	18	468	481
2020–24	463	18	481	0

3.PLANTATION ESTAB.& HARVEST BY PERIOD(ha)

Establish. Period	Area Planted	Harvest Period	Periodic Harvest
1979–84	1289	1990–94	1289
1985–89	3359	1995–99	3359
1990–94	5660	2000–04	6949
1995–99	7500	2005–09	10859
2000–04	7500	2010–14	14449
2005–09	7500	2015–19	18359
2010–14	7500	2020–24	21949
2015–19	7500	2025–29	25859
2020–24	7500	2030–34	29449

1. YIELD FROM LOGGED FOREST @45 yr (hill); @70 yr (swamp) (MAI Commercial – 1 M3/Ha/Yr)

Year	Hill	Swamp	Total
1990–1994	0	0	0
1995–1999	0	0	0
2000–2004	0	0	0
2005–2009	207	0	207
2010–2014	630	0	630
2015–2019	1008	0	1008
2020–2024	2340	0	2340
2025–2029	5625	0	5625
2030–2034	7749	1470	9219
2035–2039	10260	2366	12626
2040–2044	6435	1918	8353
2045–2049	6143	1904	8047
2050–2054	6057	1974	8031
2055–2060	5895	2100	7995
Short–term (1995–2025)			
PFE –	377	0	377
Percent –	54%	61%	54%
SLF –	321	0	321
Percent –	46%	39%	46%
PFE & SLF	698	0	698
Percent –	100%	100%	100%
Long–term (2025–2060)			
PFE –	4816	1022	5839
Percent –	70%	61%	68%
SLF –	2064	654	2718
Percent –	30%	39%	32%
PFE & SLF	6881	1676	8557
Percent –	100%	100%	100%

2. YIELD – UNLOGGED
Hill 15 Years
Swamp 5 Years

Hill	Swamp	Total
16286	1980	18266
7857	360	8217
7500	360	7860
7143	360	7503
6429	360	6789
6429	360	6789
6614	360	6974
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0
0	0	0

3. FOREST PLANTATN HARVESTS

39
101
208
326
433
551
658
776
883
883
883
883
883
883

4. TOTAL ANNUAL YIELD (M M3)

Hill Forest	Swamp Forest	Planted Forest	Total Forest
Hill	Swamp	Plantatn.	Total
16286	1980	39	18304
7857	360	101	8318
7500	360	208	8068
7350	360	326	8036
7059	360	433	7852
7437	360	551	8347
8954	360	658	9973
5625	0	776	6401
7749	1470	883	10102
10260	2366	883	13509
6435	1918	883	9236
6143	1904	883	8930
6057	1974	883	8914
5895	2100	883	8878
7372	360	380	8112
4816	1022	868	6706
7532	360	380	8272
5848	1349	868	8065
7693	360	380	8432
6881	1676	868	8936

Short–term 1995–2025 PFE Only
Long–term 2025–2060 PFE Only
Short–term 1995–2025 PFE & 1/2 SLF
Long–term 2025–2060 PFE & 1/2 SLF
Short–term 1995–2025 PFE & All SLF
Long–term 2025–2060 PFE & All SLF

FIGURE 4:

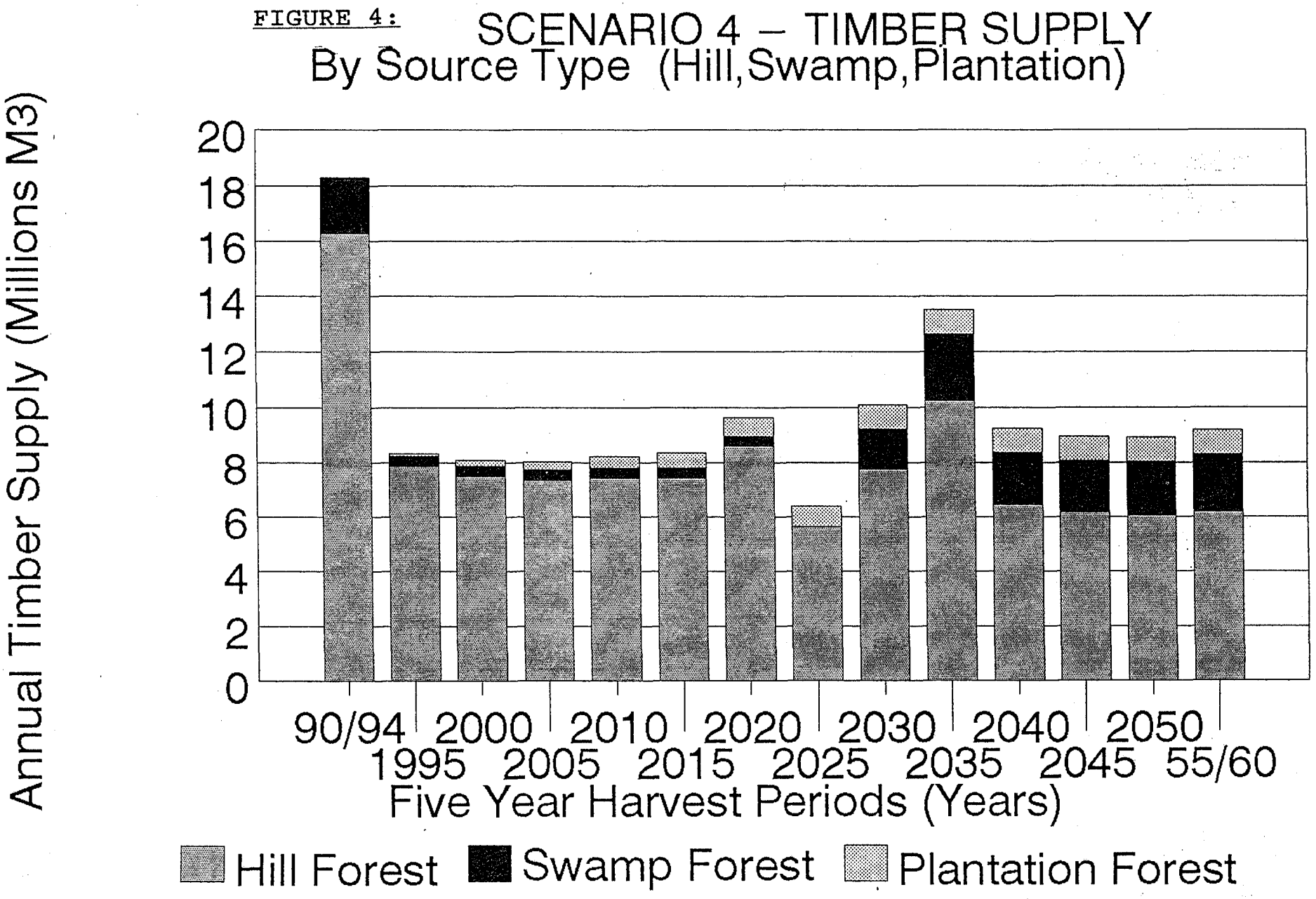
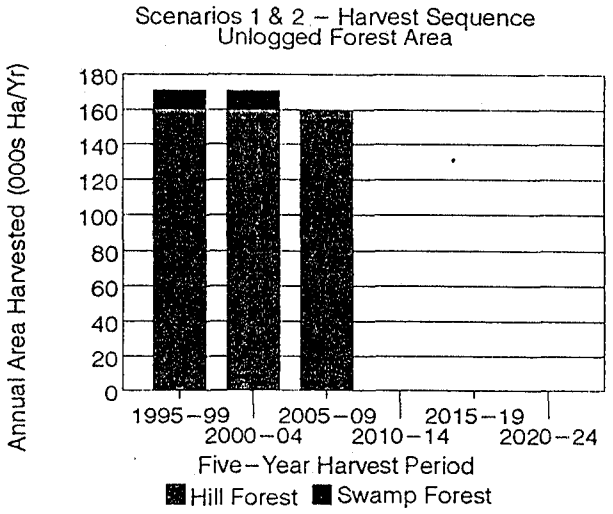
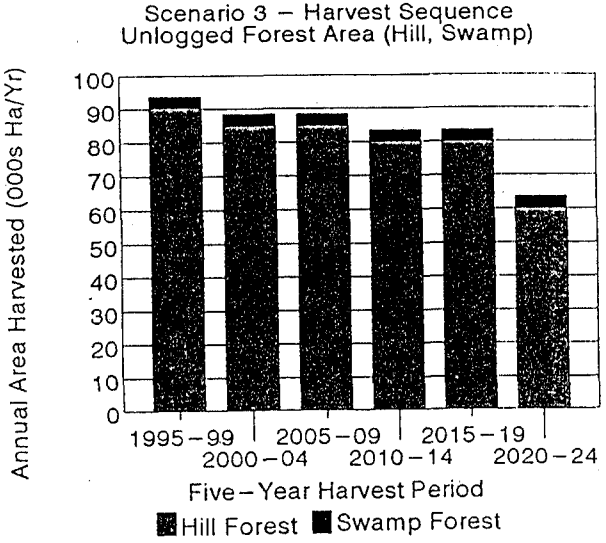

SCENARIO 4 – TIMBER SUPPLY
By Source Type (Hill,Swamp,Plantation)
Annual Timber Supply (Millions M3)
20
18
16
14
12
10
8
6
4
2
0
90/94
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
55/60
Five Year Harvest Periods (Years)
Hill Forest
Swamp Forest
Plantation Forest

Table 11: Proposed Harvesting Sequence of Unlogged Forest Area for 4 Timber Supply Scenarios.

Proposed Harvest Period 5–Yr. Periods	Scenarios 4: Extend Cut Cycle & Old Growth Harvest			Scenarios 3: Extend Cut Cycle & Old Growth Harvest			Scenario 1 & 2: Extend Cutting Cycle & Maintain O.G. Harvest		
	Hill	Swamp	Total	Hill	Swamp	Total	Hill	Swamp	Total
Unlogged Area At end 1994--->	2938	108	3046	2402	108	2510	2402	108	2510
Harvest of Remaining Unlogged Forest Area By 5–Year Period (000 ha)									
1995–99	550	18	568	452	18	470	802	54	856
2000–04	525	18	543	425	18	443	800	54	854
2005–09	500	18	518	425	18	443	800	0	800
2010–14	450	18	468	400	18	418	0	0	0
2015–19	450	18	468	400	18	418	0	0	0
2020–24	463	18	481	300	18	318	0	0	0
Average Annual Harvest of Remaining Unlogged Forest Area (000s Ha/Yr)									
1995–99	110	4	114	90	4	94	160	11	171
2000–04	105	4	109	85	4	89	160	11	171
2005–09	100	4	104	85	4	89	160	0	160
2010–14	90	4	94	80	4	84	0	0	0
2015–19	90	4	94	80	4	84	0	0	0
2020–24	93	4	96	60	4	64	0	0	0





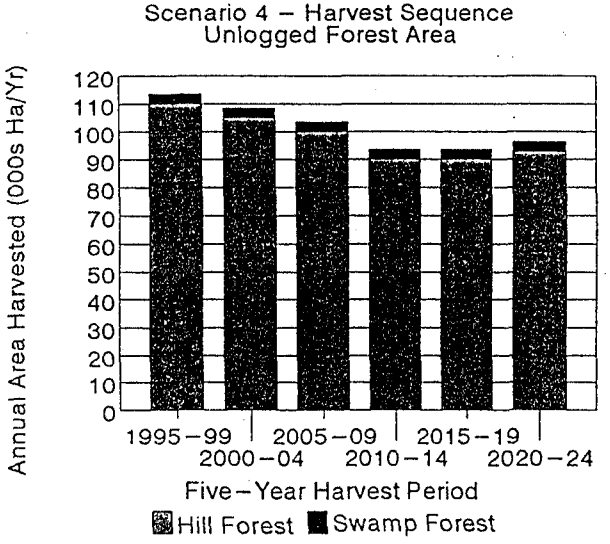


FIGURE 5: Proposed Harvesting Sequence of Unlogged Forest Area for 4 Timber Supply Scenarios.

COMPARISON OF RESULTS WITH ITTO MISSION FINDINGS AND F.D. POLICY

44. The 1990 ITTO Mission presented a range of estimates of Sustainable Annual Timber Yield. These were based on the forest area which could be brought into sustainable timber production under a range of assumptions. The annual yield estimates ranged from a low of 4.1 million m3, based on current practices and PF extent, to a high of 11 million m3, based on a number of future technical and policy conditions being met. These include: Stateland Forest not required for other purposes to be included in the PF; Environmentally sensitive harvesting methods to be developed for steep (Terrain Class IV) areas; Markets to be developed for presently non-marketable species groups 2 & 3; and Silvicultural treatment of harvested forests.

45. **Log Production Quota in PF** Since 1992, the F.D. has attempted to bring log harvests into line with ITTO estimates of Sustainable Annual Timber Yield through imposition of a log production quota on forest licences in the PF. The target annual yield for the PF has been set at 9.6 million m3[19]. This level of annual yield must be questioned, as many of the conditions upon which the original ITTO estimate were based have not been met. To better understand this, it is useful to review the conditions upon which the ITTO Mission's Prospective Sustainable Timber Yields were based:

(a) The report specifies a Sustainable Annual Yield from untreated forests of present PF areas with slopes less than 60% is 4.1 million m3.
(b) Inclusion of Stateland Forest with slopes <60%, not required for other purposes, increases Sustainable Annual Yield to 6.3 million m3.
(c) Inclusion of PF with Slopes >60% - appears feasible following the successful introduction helicopter logging - increases Sustainable Annual Yield to 7 million m3.
(d) Inclusion of PF & SF on Slopes >60%, increases Sustainable Annual Yield to 7.7 million m3.
(e) Yield is further increased, to 9.2 million m3, based on Liberation Thinning in areas <60% slope.
(f) Application of treatments on areas >60% slope increases Sustainable Annual Yield to 11 million m3.
(g) The above estimates, are based on inclusion of species groups 1,2 and 3 which result in Mean Annual Volume Increments (MAI) of 1.3 m3 for treated forest and 2.0 for treated forest.

46. The ITTO Mission's yield estimates generally exceed the estimates of Sustainable Annual Yield from Natural Forests, contained in this report (see Tables 8-11 and figures 1-5) which range from 5 to 8 million m3 per annum from an expanded PF. The main reasons for the difference are: the forest land base and volume increment upon which the estimates were based.

47. The differences in forest area available for long-term timber production are highlighted in Table 12A. The ITTO Mission estimate of 5.9 million ha of forest land exceeds the estimate of the current project (5.5 million ha) by 0.4 million ha. The main reason for this discrepancy is that forest land in the 1.2 million ha of Terrain Class IV which ITTO included in its estimates, is either in non-commercial forest types or in protected areas and therefore should not have been included as land available for timber production. The current project's long-term yield estimates are based on a MAI of 1 M3 per ha while those of the ITTO Mission are based on MAI of 1.3 M3/ha for untreated forests and 2 to 3 m3 per ha for treated forests. Differences in volume increment and yield are discussed below:

(a) ITTO Mission estimates for untreated forest are based on MAI of 1.3 m3/ha - 30% higher than the 1 m3/ha used in this report. One of the reasons for the ITTO Mission's higher MAI estimates is the inclusion of species groups 2 and 3. The current project's estimates

[19] The original ITTO Sustainable Annual Yield estimate of 9.2 million m3 based on: Expanded PFE, Marketing of Sp. groups 2 & 3 and Silvicultural treatment of logged forests; was adjusted upward following discussions between FD and the ITTO Project - Manpower Development of Sarawak's Forest Sector.

are based on species group 1 only. Species group 1 includes all species currently marketed in export and domestic markets. Species groups 2 and 3, cannot currently be sold, as there is no market for them.

(b) The ITTO Mission estimated a total of 1.2 million ha of Terrain Class IV[20] forest was available for timber production and the sustainable annual yield from this area to be 1.4 million m3. However, it should be noted that about 200,000 ha of this area is located in areas which are now proposed for National Parks or Wildlife Sanctuaries and which will be excluded from timber production. It should also be noted that a recent survey of forest licences indicate that of the Terrain Class IV in Forest Licences, only 56% is in commercial forest. The remaining 44% consists of remanent dipterocarp forests, kerangas, and other non-commercial forest. Applying these percentages to the 1.2 million ha of Terrain Class IV and deducting TPA areas, as shown in Table 17, there is an estimated 536,000 ha of Terrain Class IV in existing and potential forest licences. Inclusion of this area increases the Sustainable Annual Yield by 540,000 m3. The ITTO annual yield estimate of 1.4 million m3 for this component should be adjusted downward by 860,000 m3, to reflect this difference.

(c) Estimates by the ITTO Mission are based on the prospect of stand treatments such as liberation thinning being applied on all areas. Sustainable Annual Yield increases of 3 million m3 are attributed to applying these treatments. The prospective Sustainable Annual Yield of 9.2 m3 - from which the present 9.6 million m3 Annual Yield Target is derived - is based on Liberation Thinning of all logged areas. However, FD policy is one of "No Treatment", due to a lack of clear technical and economic justification, as well as difficulty in undertaking such treatments in isolated parts of the state where most forest harvesting takes place. Based on this inconsistancy, Sustainable Annual Yield should be revised downward by 3 million m3.

48. In conclusion, adoption of an annual timber harvest of 9.6 million m3 for the expanded PF is not justified, nor sustainable, given the forest resource base and realistic assumptions regarding markets and forest management practices. With the exception of the promising potential for helicopter harvesting in Terrain Class IV areas, the ITTO Mission's Sustainable Annual Yield estimate of 9.2 million m3 - upon which Sarawak's F.D. has based its current harvest - is based on conditions which are yet to be met.

49. Based on the ITTO Mission's findings, until these conditions are met, annual timber supply from the natural forests of an expanded PF, following harvest of the remaining unlogged forest, would be approximately 5.6 million m3[21]. Table 12A, shows the basis for both ITTO Mission and Current Project's estimates of forest land available for long-term timber production.

50. The following two sections explore opportunities for increasing annual timber supply through improvements in managing and harvesting forest resources.

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[20] ITTO estimates of Terrain Class IV forest area included 685,000 ha of PFE; plus 585,000 ha of Stateland Forest >60% slope.

[21] ITTO Mission's Sustainable Annual Yield estimate, reduced by 1 million m3 to reflect over-estimate of productive forest area in Terrain Class IV and by a further 3 million m3 to reflect absence of silvicultural treatment. These reductions reduce the harvest from 9.6 to 5.6 million m3.

Table 12: Annual Timber Supply by Period For Each Forest Management Scenario (M M3/Year)

Harvest Period	Scenario 4: Extend Cutting Cycles & O.G. Harvest & Adopt RIL				Scenario 3: Extend Cutting Cycles & Unlog. For. Harvest Period				Scenario 2: Extend Cutting Cycles & Harvest Unlog.@ Present Rate				Scenario 1: Present Cutting Cycles & Harvest Unlog.@ Present Rate			
	Hill	Swamp	Plant.	Total	Hill	Swamp	Plant.	Total	Hill	Swamp	Plant.	Total	Hill	Swamp	Plant.	Total
1990–1994	16286	1980	39	18304	16286	1980	39	18304	16286	1980	39	18304	16636	1980	39	18654
1995–2000	7857	360	101	8318	6429	360	101	6889	12500	1080	101	13681	13060	1080	101	14241
2000–2005	7500	360	208	8068	6071	360	208	6640	11786	1080	208	13074	13086	1080	208	14374
2005–2010	7350	360	326	8036	6278	360	326	6964	10236	0	326	10561	13154	945	326	14424
2010–2015	7059	360	433	7852	6344	360	433	7138	630	0	433	1063	4305	1521	433	6259
2015–2020	7437	360	551	8347	6722	360	551	7633	1008	0	551	1559	6385	1233	551	8169
2020–2025	8954	360	658	9973	6626	360	658	7644	2340	0	658	2998	4935	1224	658	6817
2025–2030	5625	0	776	6401	5625	0	776	6401	5625	0	776	6401	5425	1269	776	7470
2030–2035	7749	1470	883	10102	7749	1470	883	10102	7749	1470	883	10102	6635	1350	883	8868
2035–2040	10260	2366	883	13509	10260	2366	883	13509	10260	2366	883	13509	4305	891	883	6079
2040–2045	6435	1918	883	9236	4050	1918	883	6851	7875	1918	883	10676	6385	891	883	8159
2045–2050	6143	1904	883	8930	3825	1904	883	6612	7425	1904	883	10212	4935	0	883	5818
2050–2055	6057	1974	883	8914	4032	1974	883	6889	6525	1974	883	9382	5425	945	883	7253
2055–2060	5895	2100	883	8878	4230	2100	883	7213	630	2100	883	3613	6635	1521	883	9039
PFE AND STATELAND FOREST																
1995–2010									11507	720	212	12439	13100	1035	212	14346
2010–2060									5007	1173	772	6952	5537	1085	772	7393
1995–2025	7693	360	380	8432	6412	360	380	7151								
2025–2060	6881	1676	868	8936	5682	1676	868	7737								
PFE AND 1/2 STATELAND FOREST																
1995–2010									11491	720	212	12423	12718	974	212	13903
2010–2060									4256	944	772	5972	4706	873	772	6351
1995–2025	7532	360	380	8272	6251	360	380	6991								
2025–2060	5848	1349	868	8065	4829	1349	868	7046								
PFE ONLY																
1995–2010									11475	720	212	12407	12335	912	212	13459
2010–2060									3505	716	772	4992	3876	662	772	5309
1995–2025	7372	360	380	8112	6091	360	380	6831								
2025–2060	4816	1022	868	6706	3977	1022	868	5867								

NATURAL FOREST MANAGEMENT

51. Based on the wood quality limitations of forest plantations referred to in Annex 7, it appears that the only realistic approach to growing high quality timber for Sarawak's forest industries is effective management of natural forests. The technical and financial feasibility of ensuring adequate stocking of valuable species through a number of alternative forest management measures is examined in the following paragraphs.

(a) Reduced Impact Harvesting to ensure residual trees survive; (Annex 3)

(b) Silvicultural Treatments to encourage growth of the desired species, (Annex 4), and;

(c) Enrichment Planting of insufficiently restocked areas to ensured adequate stocking of desired species. (Annex 5)

52. **Reduced Impact Logging** (RIL) is defined as a collection of logging techniques[22] which, when implemented, results in lower levels of incidental damage to the residual forest and reduced compaction and displacement of soil, so that the residual forest after logging is both higher in volume of live timber and more productive than otherwise, leading to quicker recovery. Reduced Impact Logging using Tractors is currently being developed in a pilot project in Sabah to reduce negative logging impacts on moderate slopes. Reduced Impact Logging using Helicopters is being developed in Sarawak to reduce residual tree damage on steep slopes. Initial results of both Tractor and Helicopter RIL are favourable. Estimates of costs and benefits of RIL are included in Annex 3. Helicopter logging costs and benefits are included in Table 15 and Annex 6.

53. **Silvicultural Treatment** The area of forest treated in Sarawak is so small in comparison to the total area of logged forest[23] that the results of treatments applied to date would not influence the overall performance of the regenerating forest as a whole. A number of studies have been conducted on the benefits of post-harvest stand treatments aimed at improving growth performance of logged forests. Results have not shown a clear relationship between treatment and improved growth rates. Although individual trees show favorable increase in diameter growth, positive increases in stand volume increment due to treatment is more difficult to demonstrate.

54. Sarawak has not applied these treatments widely to harvested Hill Mixed Dipterocarp forests because research findings have indicated a **"no treatment"** option to be both ecologically and economically sound. This decision is supported by the findings of an Asian Development Bank study: **Rehabilitation of Natural Forest in Malaysia**, which concluded that investments in silvicultural treatment of logged forests were difficult to justify by conventional economic analysis. These analyses indicated that the **"cut and leave"** option provides a better economic return than silvicultural treatment.

55. Some note-worthy exceptions to this can be found; such as a 1989 study conducted in Sabah, which concluded that treatment of adequately stocked logged-over areas is financially attractive. (see Annex 4)

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[22] Reduction of skid trail area by advance survey and planning; reduction of soil compaction, erosion, and destruction of residual trees by directional felling and skidding; use of chokers to ensure maximum payload for each trip; use of logging arches to partially elevate skidded logs, thus reducing soil compaction; and climber cutting to reduce felling damage.

[23] A total of 255,000 ha of harvested forest (mainly Peat Swamp forests) have been treated - 9% of the logged forest area of 2.8 million ha.

56. **Enrichment Planting** attempted in Malaysia the past has met with limited success. Although, this treatment is theoretically justified, as illustrated in the cost-benefit analysis conducted in Annex 5; large areas must be treated in order to produce significant increase in timber volume. Due to the extent and remoteness of the areas requiring treatment, enrichment planting frequently fails to achieve its objectives due to a lack of attention and follow-up treatment, during the early years.

57. **Alternative Silvicultural Options** In forest areas occupied by rural communities, or those near population centres, where primary objectives are not necessarily timber production, silvicultural treatments such as liberation thinning and enrichment planting should be considered, along with agro-forestry, as a means of providing alternative livlihood and bringing degraded forests back into production. When stocking is clearly inadequate, replacement of degraded natural forests with forest plantations should be considered. (see Annex 7)

58. **Conclusions** Once an area becomes degraded (stocking becomes inadequate and/or weed invasion occurs) restoring it to productive forests is not practical under normal conditions. Based on experience to date, investment in planning and control of logging operations to ensure that logged-over sites are adequately stocked and that stands are not opened up by logging to the extent that weed species take over, is one of the most important aspects of sustainable forest management.

59. It follows therefore that an important function of natural forest management must be to prevent degradation so as to maintain as much as possible of the forest estate in a productive form. Since shifting cultivation is not expected to contribute significantly to future forest degradation, and the F.D. has adopted a policy of "no-treatment" of logged forests, emphasis must be placed on improved logging practices.

60. In this respect, the current trends toward helicopter logging and improved tractor logging practices, both of which will be further developed and demonstrated on the ITTO **Model Forest Management Area** project should be encouraged and supported. This subject is explored further in following section.

TIMBER HARVESTING METHODS AND COSTS

61. Timber harvesting costs for natural forests in Sarawak were analyzed to determine delivered cost and profitability for logs from Swamp and Hill forests, for four harvesting methods:

Swamp Forests

(a) Present Kuda-Kuda system; which combines manual skidding, rail transport and water transport.

Hill Forests

(b) Present Hill Logging System; which combines tractor skidding, truck transport and water transport;

(c) Improved Hill Logging System; which employs more planning and control of logging, to minimize damage to soil, water and residual forests;

(d) Helicopter logging; which employs helicopters, in place of tractors to selectively harvest high-value logs, minimizing damage to soil, water and residual forests.

62. The over-all cost and profitability of each logging system, was developed in Table 15. The average log sales prices and royalty rates, applicable to each system were developed from F.D. records. Log prices for hill and swamp species, weighted by their relative proportion of 1991 log production, are shown in Table 13. Royalty rates for each logging system, weighted by species, based on Rates of Royalty in Sarawak, Revision #14, 1993, are shown in Table 14.

TABLE 12A: COMPARISON OF ESTIMATES OF FOREST LAND BY SLOPE AND STATUS

1. 1990 ITTO MISSION REPORT

Status & Slope of Lands Available for Timber Production At 1990.

Millions of Hectares	Mixed Dipterocarp (Hill) <60%	>60%	Total	Swamp	Mangrove	Total
Primary Forest						
PFE (gazetted)	1721	614	2335	150	22	2507
Stateland (not needed For Other Uses)	824	588	1412	195	84	1691
Subtotal	2545	1202	3747	345	106	4198
Harvested Forest						
PFE	729	68	797	529	15	1341
Stateland	NA	NA	NA	242	2	244
Subtotal	729	68	797	771	17	1585
Deforested Land						
PFE	90	1	91	24	1	116
Stateland					31	31
Subtotal	90	1	91	24	32	147
All Forest Land						
PFE	2540	683	3223	703	38	3964
Stateland	824	588	1412	437	117	1966
Total	3364	1271	4635	1140	155	5930

Annual Timber Supply excluding Mangrove (Untreated MAI - 1.33 M3/Ha) = 7.7 Million M3
Annual Timber Supply excluding Mangrove (Liberated MAI - 1.9 M3/Ha) = 11 Million M3

2. 1994 ITTO PROJECT - STRATEGIES FOR SUSTAINABLE WOOD INDUSTRIES IN SARAWAK

Status & Slope of Lands Available for Timber Production At End of 1994

Millions of Hectares	Mixed Dipterocarp (Hill) <60%	>60%	Total	Swamp & Mangrove	Total Forest Area
Unlogged Forest in F-30 Forest Licences					
PFE	1647	292	1938	52	1990
Stateland	273	292	564	56	620
Subtotal	1819	583	2402	108	2510
Harvested Forest in F-30 Forest Licences					
PFE	1028	0	1028	586	1614
Stateland	1963	0	1963	351	2314
Subtotal	2829	0	3091	937	4028
Deforested Area of F-30 Forest Licences					2725
Total Area of F-30 Forest Licences					9263
Total Forested Area of F-30 Forest Licences					
PFE	2675	292	2966	638	3604
Stateland	2236	292	2527	407	2934
Total	4648	583	5493	1045	6538
Licenced and Unlicenced Area Available for Long-Term Timber Production					
Forested Area F-30 Licences			5493	1045	6538
Plus: Unlicenced (Stateland) Forest			766	106	832
Less: Stateland Forest for Other Use			1622	261	1883
Forested Area Available for Timber Production			4637	890	5487
PFE and Stateland Forest Area Available for Long-Term Timber Production					
PFE (Available PFE)	2675	292	2966	638	3604
Plus Stateland (1/2 Present Licenced and Unlicenced SLF)	1475	147	1622	261	1883
Total	4150	439	4588	899	5487

Indicated Annual Timber Supply (Untreated MAI - 1 M3/Ha) = 5.5 million M3

Notes/Assumptions:

1. Unlicenced Stateland Forest was derived by subtracting Licenced Stateland Forest (2.934 million ha), from the total Stateland Forest (3.766 million ha) = 832,000 ha.
2. Assume that 1/2 of Stateland Forest Area (3.766 million ha) is Available for long-term, sustainable timber production management - ie. inclusion in an expanded PFE.

63. **Conclusions on Harvesting Methods and Costs** Conclusions that can be drawn from the analysis conducted in Table 15 are:

(a) The Kuda-Kuda system of logging in Peat Swamp forests in spite of relatively low operating costs - MR 111 per m3 - provides relatively low returns to the state (MR 36 per m3 average royalty and other forest charges), and to the concession holder and logging contractor (MR 103 per m3). This is due to the relatively low log price (MR 250 per m3) received for the present mix of swamp logs, which is dominated by low value Alan (Shorea albida) and Mixed Light Hardwood species which account for 1.5 million m3 of the 2 million m3 annual log production from swamp forests.

(b) The present system of tractor logging in hill forests has high unit operating costs - MR 165 per m3 - however, returns to all parties are attractive, due to the high average log prices (MR 500 per m3). Estimated returns are as follows: to the state (MR 70 per m3); and concession holder/logging contractor (MR 265 per m3).

(c) Improved hill forest logging, through improved planning and control of operations, better roads, etc., is estimated to increase logging costs by about MR 45 per m3, to MR 210 per m3. There may be some savings in logging costs due to improved efficiencies related to better planning and organization of operations. However, these are difficult to estimate and have not been included in this analysis. In any case, additional costs incurred to reduce negative logging impacts are partially offset by a modest increase (10%) in log volume recovered per ha, but not by higher log prices. Therefore, although state revenues remain unchanged (MR 70 per m3), returns to concession holder and logging contractor (MR 220 per m3) decline by about decline by about 17% compared to the present system, due to increased costs, which they must bear. A cost benefit analysis (See Annex 3) of reduced impact logging (RIL) shows that an investment of MR 165 per ha in improved planning, control and execution of harvesting can lead to present benefits of MR 200 in harvesting cost savings; plus future benefits of MR 2,100 per ha in increased timber recovery. On a statewide basis, adoption of improved logging practices for the remainder of the 2.4 million ha of unlogged hill forests could provide an additional 700,000 m3 in future annual timber yield based on an assumed increase in MAI from 1 to 1.3 m3/ha.

(d) Helicopter logging costs 80% more than present tractor logging and 40% more than improved tractor logging. However, heli-logging provides equally attractive financial returns to Government[24] (RM 75 per m3); concession holder and logging contractor (MR 254 per m3) to those of the present tractor logging, and superior to improved tractor logging as illustrated in Table 15. Benefits to the state include an increase (700,000 m3) in annual timber supply from Terrain Class IV areas previously excluded from harvesting.

64. **Logging Costs by Timber Supply Unit** Average delivered log costs were developed for hill and swamp forest types in each of the eight timber supply units, by replacing the general values shown in Table 15 with specific values, representative of conditions in each timber supply unit. The resultant delivered log costs for each unit are shown in Table 16 along with the weighted average cost for swamp (RM113/m3) and hill (RM174/m3) forests. Trends include:

(a) Interior areas, with the highest concentrations of logged and unlogged forest, also have the highest delivered log costs.
(b) Delivered log costs from peat swamp forest range from a low of MR 113 per m3 in coastal areas, to over MR 120 per m3 in up-river swamp forests such as those along the Baram river between Miri and Marudi. Delivered costs of logs from hill forests range from MR 130 per m3 in coastal areas to MR 190 per m3 in up-river areas.

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[24] Includes royalty (RM 65) plus other forest charges (RM 10) but excludes income and other forms of corporate taxation.

Table 13: LOG SALES PRICES IN SARAWAK

Swamp Species – Kuda–Kuda Logging

Species	Log Price (US $/M3)	1991 Log Production (m3)
Ramin	145 (Local Sales)	400,000
Shorea (Alan)	100 (Local Sales)	700,000
Mixed Light Hardwood'	85 (Local Sales)	800,000
Sepitir	85 (Local Sales)	100,000
Jong Kong	85 (Local Sales)	200,000
Meranti (swamp)	90 (Local Sales)	200,000
Weighted Average	100 (RM 250/M3)	2,400,000

Hill species – Tractor Logging (assumes present species mix)

	Export Sales	Local Sale	M3 per Annum
Meranti	300	137	9,000,000
Kapur/Keruing	315	135	4,000,000
SB/Sepitir/Nyatoh	210	120	1,500,000
Other/MLH/Etc.	145	100	1,500,000
Weighted Average	281	131	16,000,000

Hill Species – Helicopter Logging (assumes only high value species)

Meranti	300 All Logs of	1,250,000
Kapur/Keruing/SB	315 Export Quality	750,000
Weighted Average	305	2,000,000

Source: STIDC Price Intelligence – FOB Log Price @ September 1993

Notes:
Log prices for 1993 were weighted by Species based on 1991 log production.
Log prices for 1993 were historically high and may not represent
Long–term market conditions. For profitablility estimates in Table 15,
log prices were reduced to RM 525/m3 for tractor logging and RM 660/m3
for Helicopter Logging.

Table 14: RATES OF ROYALTY IN SARAWAK (Revis.#14, 1993)

Swamp Species – Kuda–Kuda Logging

	Royalty	Product	1991 Vol.(m3)
Ramin	RM 35 per M3	Log	400,000
	RM 70 per M3	Sawn	
Shorea	RM 30 per M3	Log	800,000
	RM 60 per M3	Sawn	
Other	RM 30 per M3	Log	800,000
	RM 60 per M3	Sawn	
Weighted Average	RM 31 per M3	Log	2,000,000
All Forest Charges	RM 36 per M3		

Hill species – Tractor Logging (Species based on 1991 Log Production)

Meranti	RM 75 per M3	Log	9 million m3
Kapur	RM 53 per M3	Log	2 million m3
Keruing	RM 53 per M3	Log	2 million m3
Other	RM 30 per M3	Log	3 million m3
Weighted Average	RM 61 per M3	Log	16 million m3
All Forest Charges	RM 70 per M3		

Hill Species – Helicopter Logging (Assumes only High Value Species)

Meranti	RM 75 per M3	Log	1.25 Million m3
Kapur/Keruing	RM 53 per M3	Log	0.75 million m3
Weighted Average	RM 65 per M3	Log	2.0 million m3
All Forest Charges	RM 75 per M3		

Notes:

Royalty Rates Weighted by Species Distribution in 1991 Log Production.

"All Forest Charges" in above tables were derived by increasing Royalty by 15% to include all other Forest Charges Levied by Government.

TABLE 15: HARVESTING COSTS (RM) IN NATURAL FORESTS – SARAWAK

Logging Type & Location		Swamp Present	Hill Present	Hill Improved	Helicopter Logging
Log Production (m3/ha)		60	45	50	30
COST ITEM	UNITS				
Planning/Inventory Costs					
Mapping/Planning	RM/ha	5	5	15	10
Road/Rail Layout	RM/ha	3	3	10	5
Skid Trail Layout	RM/ha	NA	NA	5	0
Forest Inventory	RM/ha	3	3	10	10
Tree Marking	RM/ha	NA	NA	5	10
Climber Cutting	RM/ha	NA	NA	5	5
Planning/Inventory	RM/ha	11	11	50	40
Planning/Inventory	RM/M3	0.18	0.24	1.00	1.33
Road Construction & Maintenance					
Primary Road	m/ha	NA	3	3	3
Secondary Road	m/ha	5	3	3	2
Feeder Road	m/ha	15	5	5	0
Primary Road	RM/km	100000	100000	125000	100000
Secondary Road/Rail	RM/km	50000	75000	85000	75000
Feeder Road	RM/km	25000	50000	60000	50000
Bridge, Culvert	RM/km	25000	25000	25000	25000
Bridge, Culvert	RM/ha	500	250	275	125
Bridge, Culvert	RM/m3	8	6	6	4
Primary Road/Rail	RM/m3	0	6	8	10
Secondary Road/Rail	RM/m3	11	8	11	7
Feeder Road	RM/m3	6	6	6	0
Road Maintenance	RM/M3/km	0.20	0.20	0.20	0.20
Road Maintained	km/yr	25	50	75	35
Road Maintenance	RM/m3	5	10	15	7
Total Cost–Road/Rail	RM/m3	30	35	45	28
Felling/Debarking					
Felling Cost	RM/m3	4	4	8	12
Debarking Cost	RM/m3	1	1	1	1
Total Fell/Debark	RM/m3	5	5	9	13

TABLE 15: HARVESTING COSTS (RM/M3) .....continued.....

Extraction	RM/m3	25	40	60	150
Loading/Unloading					
Loading	RM/m3	2.50	5	5	5
Unloading	RM/m3	2.50	5	5	5
Total Load/Unload	RM/m3	5	10	10	10
Transportation					
Land (Truck/Rail) Cost	RM/m3/km	0.50	0.50	0.50	0.50
Land Transport Distance	km	25	50	50	50
Land Transport Cost	RM/m3	13	25	25	25
Water (barge/raft) Transport	RM/m3/km	0.25	0.20	0.20	0.20
Water Transport Distance	km	30	125	125	125
Water Transport Cost	RM/m3	8	25	25	25
Total Transport Cost	RM/m3	20	50	50	50
Other Costs					
Manage/Supervise	RM/m3	10	10	15	15
Crew/Goods Trans.	RM/m3	5	5	5	10
Camp, Room & Board	RM/m3	5	5	10	12
Head Office Overhead	RM/m3	5	5	5	7
Total Other Costs	RM/m3	25	25	35	44
Operating Costs	RM/m3	111	165	210	296
Royalty,other charges	RM/m3	36	70	75	75
Delivered Log Cost	RM/m3	147	235	285	371
Log Sales Price	RM/m3	250	525	525	660
Concessionaire & Contrator Profit	RM/m3	103	290	240	289

Notes:
Royalty Rates plus a 15% to cover other forest charges.
Log Sales Prices for 1993 were historically high and were therefore reduced to reflect a more representative long-term market situation.

Table 16: DELIVERED LOG COSTS BY TIMBER SUPPLY REGION
(RM/M3 for Hill and Swamp Forest)

Planning Unit	Logging Cost To Road		Transport Distance (Kilometers)			Transport Cost to Mill/Export			Total Delivered to Mill/Export		
	Hill	Swamp	Truck/Rail	Raft/Barge	Total	Truck/Rail	Raft/Barge	Total	Hill	Swamp	Weighted Avg.
1. Lundu – Sri Aman	110	90	25	20	45	13	6	19	129	109	113
2. Sarikei – Sibu	110	90	25	50	75	13	10	23	133	113	117
3. Song – Kapit	125	NA	35	125	160	15	25	40	165	NA	165
4. Dalat – Mukah	110	90	25	25	50	13	5	18	128	108	116
5. Bintulu – Miri	125	90	30	70	100	15	18	33	158	123	152
6. U.Rajang – Belaga	140	NA	60	125	185	30	25	55	195	NA	195
7. U.Baram – Marudi	140	100	50	125	175	30	25	55	195	115	189
8. Limbang – Lawas	125	90	75	25	100	38	5	43	168	108	166
TOTAL – Sarawak	128	92	44	94	138	23	20	42	176	113	168

65. **Future Role of Helicopter Logging** Initial experience with Helicopter logging trials in Sarawak has been positive. Operations are not only financially viable, they also reduce residual tree damage, expose less ground surface to erosion and decrease in stream turbidity, relative to conventional tractor harvesting.[25] It is proposed to utilize helicopters to selectively harvest high value species from steep, mountainous terrain with slopes >35 degrees (Terrain Class IV), previously excluded from harvesting. Future plans include extending heli-logging to Terrain Class III - steep, mountainous terrain with slopes <35 degrees (60%).

66. The 1990 ITTO Mission identified approximately 1.2 million ha of Terrain Class IV, approximately equally split between PF (614,000 ha) and SF (588,000 ha). Most of this area is located in the eastern part of the state, in the upper portions of the Rajang and Baram river drainages. A recent survey of Terrain Class IV land in current forest licences, as summarized in Table 17, shows that 9% of the forest area current forest licences (6.5 million ha) is in Terrain class IV (583,000 ha). The remaining 620,000 ha of terrain class IV is split between TPAs (approximately 200,000 ha) and unlicenced PF and SF (420,000 ha) which could be available for future timber production.

67. The survey of Terrain Class IV in licenced areas showed 44% to be in non-commercial forest types (remnant dipterocarp forests, kerangas, etc.), leaving 536,000 ha of forest which could support commercially viable helicopter harvesting. (see Table 17) Assuming a MAI of 1.3 m3 per ha - 30% greater than in Tractor logged areas, reflecting the generally healthier state of the residual forest - the additional annual timber supply from heli-logging in Terrain Class IV areas in about 700,000 m3.

68. As shown in Table 17, expansion of heli-logging to Terrain Class III would potentially include 2.6 million ha of forest land. Deducting 14% for non-commercial forest types and 10% for TPAs, and assuming that only 50% of the remainder is suitable for heli-logging, the net, potential area for helicopter logging in Terrain Class III is about 1 million ha. Assuming a MAI of 1.3 m3 per ha, this area would provide an annual harvest of about 1.3 million m3.

69. In summary, the area of productive forest potentially harvestable by helicopter from Terrain Classes III and IV is estimated at about 1.54 million ha. This area would provide an annual harvest of about 2 million m3. Based on an annual production per helicopter unit of 166,000 m3[26], a total of 12 helicopter logging units would be required to extract this volume.

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[25] Case Study on Helicopter Harvesting in Hill Dipterocarp forests of Sarawak, Danny Chua Kee Hui, Preliminary Research Report FE2/93, Sarawak Forest Department, August 1993.

[26] 600 m3/day * 23 days/month * 12 months per year.

Table 17: AREA OF TERRAIN CLASS III & IV IN EXISTING AND POTENTIAL FOREST LICENCES (HA)

		EXISTING FOREST LICENCE AREAS			POTENTIAL FOREST LICENCE AREAS	TOTAL TERRAIN IV FOREST AREA
Terrain Class IV	-- Mountanous Areas > 30 degrees slope					
	Productive Forest Area --	326,086 ha		56%	210,000	536,086
	Forest Type	Area (ha)	Cumulative	Percent		
Productive Forest Area	MD1 (20–50 m3/ha)	18,515	18,515	4%		
	MD2 (90–135 m3/ha)	105,508	124,023	23%	210,000	
	MD3 (170–230 m3/ha)	135,686	259,709	29%		536,086
Non – Productive Forest Area	MDR1	1,509	261,218	0%		
	MDR2	297	261,515	0%		
	Kerangas	141,007	402,522	30%	210,000	
	Other	61,996	464,518	13%		
	* Forest Area (Typed)	464,518		100%		
	* Total Forest Area	583,240			420,000	1,003,240
Protected Forest Area	Terrain Class IV in Proposed Parks and Wildlife Sanctuaries				200,000	200,000
TOTAL TERRAIN CLASS IV AREA		583,240			620,000	1,203,240
Terrain Class III	-- Mountanous Areas < 30 degrees slope					
	Estimated Prod. Forest	2,299,089 ha		86%		
	Forest Type	Area (ha)	Cumulative	Percent		
Productive Forest Area	MD1 (20–50 m3/ha)	104,025	104,025	5%		
	MD2 (90–135 m3/ha)	761,867	865,892	40%		
	MD3 (170–230 m3/ha)	796,098	1,661,990	41%		
Non – Productive Forest Area	MDR1	14,612	1,676,602	1%		
	MDR2	17,547	1,694,149	1%		
	Kerangas	228,227	1,922,376	12%		
	Other	1,467	1,923,843	0%		
	* Forest Area (Typed)	1,923,843		100%		
	* Total Forest Area	2,661,320				
Summary of Terrain Class III and IV						
	Total Forest Area in Licences	3,244,560 ha				
	* Forested Area Typed	2,368,361 ha				
	* Estimated Productive Forest Area	2,625,175 ha			420,000	3,045,175

Notes: * Forest types not available for all forest licences

MD1 – Mixed Dipterocarp (low Volume 30–50 m3/ha)
MD2 – Mixed Dipterocarp (med. Volume 90–135 m3/ha)
MD3 – Mixed Dipterocarp (high Volume 170–235 m3/ha)
MDR – Mixed Dipterocarp Remanent Fringes around agricultural areas. Commercial trees have been removed (low volume)

CONCLUSIONS

70. The extent of the logged production forest - as represented by the area of long-term Forest Licences - is 3.7 Million ha, while the remaining unlogged production forest area is 2.8 million ha. Mixed dipterocarp, or hill forests account for most of the logged area, accounting for 2.8 million ha (76%), while logged swamp forests account for 0.9 million ha (24%). The remaining unlogged forest area is concentrated in three planning units - all in hill forest. These are: middle Rajang (Song-Kapit) - 22% of remaining unlogged forest; upper Rajang (Belaga) - 32%; and upper Baram (Marudi) - 24%.

71. The permanent forest estate (PF) is presently 4.7 million ha. About 1 million ha is in existing and proposed parks and wildlife sanctuaries which are excluded from logging. This leaves a total of 3.7 million ha for production forestry. In addition to the PF, there are 3 million ha of Stateland Forest (SF), a portion of which is required for agriculture and other uses. The annual amount of land conversion required meet agricultural expansion between now and the year 2020, is estimated to be 262,000 ha. Allowing for other development (Bakun Dam, Mining, etc.) and conservation uses, the area of Stateland forest required for other uses, is not expected to exceed 1 million ha, leaving 2 million ha of Stateland Forest which could be included in the PF. Assuming that 1.5 million ha of the available Stateland forest can be added to the present production forest of the PF, the area of PF dedicated to timber production could be expanded to 5.2 million ha.

Timber Supply Scenario #1

72. Short-term liquidation of old-growth timber stocks on the remaining unlogged forest area can continue to supply between 12 and 14 million m3 of timber annually, for 15 years (1995-2010). Long-term timber supply projections indicate that given: the limited number of species currently accepted by the market; the uneven age class distribution of the logged forest area; current cutting cycles; relatively limited stand treatment; and current wasteful logging practices; the expanded PF could sustain an average annual timber harvest of about 5.5 million m3 - 4.5 million m3 from hill forests and 1 million m3 from swamp forests - over the 50 year period following harvesting of the remaining unlogged forest. An additional 800,000 m3 of timber from the Forest Department's current plantation establishment program would be available, increasing the total timber supply to 6.3 million m3.

Timber Supply Scenario #2

73. In the event that current cutting cycles are not sufficient to produce quantities and sizes of timber to support viable harvesting operations - a possibility which is indicated by growth and yield studies - and longer cutting cycles are required, the short-term timber supply situation could be quite critical. Assuming extended cutting cycles of 45 and 70 years for hill and swamp forests respectively, annual timber supply would decline to very low levels of 1 to 3 million m3, during the 15 year period following harvest of remaining unlogged production forests, and then fluctuate widely between 1 and 13 million m3 for the next 50 years. Although these periodic fluctuations could be evened out to an annual average of about 6 million m3, by adjusting the harvest rate between periods, the fact remains that short-term timber supplies may decline sharply to far below recent levels, with associated disruption in employment, government revenue and regional economic development.

Timber Supply Scenario #3

74. To avoid this situation, a more gradual transition from an forest sector based on liquidation of old-growth timber stocks, to one based on management of logged forest lands, is strongly recommended. A key element in such a transition would be the extension of the period over which the

remaining unlogged forest is logged. This would permit present logged forest areas to recover from harvesting and to regenerate sufficient volumes and sizes of timber to ensure a sustainable succession of commercially viable timber harvests into the future. In the timber supply projections conducted in this report, a transition period of 30 years (double the present rate) is adopted. This results in a relatively even annual flow of 7 million m3 of timber - 4.8 million m3 from hill forests; 1.3 million m3 from swamp forests and 0.9 million m3 from forest plantations.

Timber Supply Scenario #4

75. It is estimated that improved tractor logging on the remaining unlogged PF and SF could increase future annual timber yields by about 700,000 m3. The practice of helicopter logging on a portion of the steep, Terrain Class IV area, which is presently prohibited from logging due to the excessive damage which would result from tractor logging, can potentially increase the area available for timber production by about 536,000 ha, with a corresponding increase in annual timber production of 700,000 m3. Combining reduced impact tractor and helicopter logging can increase long-term annual timber supply to 8 million m3 - 5.8 million from hill forests; 1.3 million from swamp forests and 0.9 million from forest plantations.

RECOMMENDATIONS

76. To avoid potential disruptions in employment, government revenues and rural economic activity, a more gradual transition to second-growth forest management is recommended. The key to this is the rate at which the remaining unlogged forest area is harvested. It is strongly recommended that the present rate of harvesting the state's natural forests, which would result in liquidation of old-growth timber stocks over the next 15 years, be reduced to a sustainable level of 6 to 7 million m3. At this rate, remaining stocks of old-growth timber will be harvested over a period of 30 years (1995-2025). This extension of the period over which old-growth forests are harvested, will ensure that there is sufficient time for logged forests to regenerate commercially viable timber yields. In addition it will provide time for training and improved inspection and control systems related to Reduced Impact tractor and helicopter logging to be developed and implemented.

77. In light of the potential increases in both short and long-term timber supply which Reduced Impact Logging can bring about, it is recommended that quick and decisive action be taken to implement improved logging practices, including helicopter logging, to reduce logging damage to the remaining unlogged forest area.

78. The F.D. should tighten up inspection and control of logging operations to ensure that logging damage and premature relogging does not jeopardize the ability of forests to generate subsequent future timber harvests. The policy of Timber Assessment Survey be conducted prior to relogging of previously harvested coupes should precede all relogging cases.

79. Efforts to further develop methods for predicting growth and yield of forests recovering from both tractor and helicopter logged should be stepped up in order to provide more accurate definition of cutting cycles required to regenerate these forests.

80. Private sector forest plantations offer opportunities for increased timber supplies. For example, duplication of the present Sarawak Forest Department Plantation program by private sector investment in forest plantations has the potential to increase annual timber supply by an additional 1 million m3, bringing timber supplies to 9 million m3. It is recommended that the F.D. and other Government agencies provide the necessary incentives and policy instruments to encourage further development of forest plantations.

ANNEX 1: SUMMARY OF GROWTH AND YIELD PLOT DATA ON MEAN ANNUAL DIAMETER AND VOLUME INCREMENT

1. **Kalimantan, Indonesia - Forests are harvested on a 35 year cycle**
yield 50 m3 per ha - MAI - 1.43 m3/ha Source: US AID Jakarta, 1993

Pulau Laut, Indonesia Diameter Increment (DMAI) in treated & untreated logged forests
Untreated Dipterocarp Forest - Shorea spp. 0.5 cm/yr
All spp. 0.6 cm/yr
Treated Dipterocarp Forest - Shorea spp 1.1 cm/yr
All Spp. 0.9 cm/yr

Source: Growth Study on Logged Dipterocarp Forest; Soemarna & Parbagung, Division of Forest Mensuration, Bogor, Indonesia, 1983

2. **Sarawak, Malaysia - MAI (Volume of All Species > 30 cm DBH)**
Untreated 0.13 m3/ha - years 0 - 30
Forests 0.40 m3/ha - years 30 - 60

3. **MAI Estimates for Untreated Forests in Sarawak**

Pessimistic Mean Annual Harvestable Volume Increment -(0.17)m3/ha
Optimistic Mean annual Harvestable Volume increment - 0.82 m3/ha

4. **MAI Estimates for Treated Forests in Sarawak**

Pessimistic Mean Annual Harvestable Volume Increment - 0.27 m3/ha
Optimistic Mean annual Harvestable Volume increment - 1.07 m3/ha

Sources - Items 2,3&4: Korsgaard, 1992

5. Sarawak - Diameter Increment of Logged, Untreated Mixed Dipteropcarp Forest

Mean Annual Increment of Diameter - 0,25 cm/yr in low light intensity
to 0.6 cm/yr in higher light intensity. Average 0.4 cm/yr.

Source: Korsgaard, Interim Project Status Report,
Research Council for Development Research, 1986

6. **Summaries of Yield Plots for Swamp Forest in Sarawak**
23 yield Plots on 7 PFE Forest Areas - Simunjan, Sedilu, Triso, Sebuyau, Daro, Saribas and Tatau;
Net Industrial Stemwood Volume Increment Ranged from 0.54 to 3.47 m3/ha;
Average NIS MAI 1.72 m3/ha

Source: FAO/UNDP Forestry Development Project, Sarawak, W.P. 11, 1982

7. **Effect of Stand Treatments on Time to Next Harvest**

The time to next financially viable harvest in adequately stocked forest is 25 years; understocked - 40 years and unstocked - 80 years, assuming weed-free sites.

Source: MALAYSA -Natural Forest Rehabilitation Study, Silviconsult/ADB, 1989

8. **Simulated Yields for Hill Forest in Sarawak**

4 Research Plots - Untreated Hill Forest Average NIS MAI - 0.3 m3/ha
Net Industrial Stemwood Volume MAI Ranged from 0.0 in lightly logged forests to 0.4 m3/ha in intensively logged areas with improved logging techniques.

2 Research Plots - Treated Hill Forest Average NIS MAI - 3.1 m3/ha
Net Industrial Stemwood Volume MAI Ranged from 2.3 m3/ha in lightly logged forests to 4.0 m3/ha in intensively logged areas with improved logging

Source: Jonkers et al. FAO/UNDP Forestry Development Project, Sarawak, W.P. 11, 1982)

9. **Growth and Yield Of Logged Mixed Dipterocarp Forest In Sarawak**

Growth and Yield Plots Measured 16 years after harvest showed:
MAI (all species >15cm DBH) of Untreated Forest - 2.03 m3/ha
MAI (all species >15cm DBH) of Treated Forest - **3.39 m3/ha**

MAI (all species >30cm DBH) of Untreated Forest - 2.1 m3/ha
MAI (all species >30cm DBH) of Treated Forest - **2.6 m3/ha**

MAI (all species >45cm DBH) of Untreated Forest - 2.0 m3/ha
MAI (all species >45cm DBH) of Treated Forest - **2.0 m3/ha**

DMAI (all species >10 cm DBH) Untreated - **0.23 cm/yr**
DMAI " " Treated - **0.46 cm/yr**

Source: Francis Chai Yan Chiew, Kho Seng Yaw, Chung Kueh Shin, Forest Department Sarawak/ASEAN Insitute of Forest Management; January 1994.

10. **Growth and Yield Plot Studies in Yayasan Sabah Concession**

Average Diameter Increment - All trees > 10 cmDBH Unlogged 0.71 cm/yr
Logged 0.56 cm/yr
Trees on ridge Tops and mid-Slope grew faster (0.99 cm/yr) that those in valley bottem (0.59 cm/yr).

Source: Yong & Garcia, Forest Officers, Yayasan Sabah, IUFRO Growth and Yield Seminar, Kuala Lumpur, 1988.

11. **Productivity and Growth in Hill Dipterocarp Forest - Peninsular Malaysia**

Volume Increment MAI - 2 to 3 m3/ha/yr for all species, > 10 cm DBH
Diameter Increment DMAI (cm/year)
Meranti Dipt. - 0.26 cm Heavy Hdwds. - 0.37 cm
Nonmeranti Dipt. - 0.16 cm All Species - 0.33 cm
Light Hardwoods - 0.41 cm Medium Hdws. - 0.27 cm

Source: Borhan Bin Mohamad, FRIM, 1986

12. **Cost Effective Stand Treatment in Sabah's Dipterocarp Forest**

Measured Results - 19 Years After Logging

Diameter Increment in Untreated Logged Forest - 0.9 cm/yr
Diameter Increment in Light Treated Forest - 1.1 cm/yr
Diameter increment in Heavy Treated Forest - 1.4 cm/yr

Volume (MAI) Increment in Untreated Logged Forest - 0.9 m3/ha/yr
Volume (MAI) Increment in Light Treated Forest - 1.0 m3/ha/yr
Volume (MAI) increment in Heavy Treated Forest - 1.5 m3/ha/yr

Source: Lee, Matujau, Heuvedop, Forest Research Centre, Sandakan, Sabah
prepared for: IUFRO World Congress, Montreal, 1990

14. **Growth and Yield of Mixed Dipterocarp Forest in Peninsular Malaysia**

Diameter Increment - DMAI for 14 year regrowth period - 0.25 cm/yr for all trees > 5cm DBH
- 0.35 cm/yr for all trees >15cm DBH
- 0.39 cm/yr for all trees >30cm DBH

Volume Increment - VMAI for 14 year regrowth period - 0.94 m3/ha for all trees >15cm DBH
- 0.80 m3/ha for all trees >30cm DBH

Source: Yong, T.K., Fellowship Report, ASEAN Forest Management Inst., 1990

15. **Volume Increment** - MAI for 4 year regrowth period - 2.15 m3/ha for all trees >10 cm DBH
- 1.75 m3/ha for all trees >30 cm DBH

Source: FAO/UNDP, 1978

16. **Summary of Growth and Yield Studies in Malaysia's Forests** Diameter growth 25-45 years after harvest averages 0.5 cm/yr in Dipterocarps and 0.3 cm/yr for non-dipterocarps. MAI logged forest estimated at 2.5 m3/ha (all species, > 10 cm DBH). Source: Wan Razali Wan Mohd, FRIM/FAO,1988

17. **Annual Diameter Increments of Shorea Species - Sarawak - 15 Year Period**

Primary Forest (Untreated)	Improvement Felling
Red Meranti - 0.42 cm/yr	Red Meranti - 0.57 cm/yr
Yellow Meranti - 0.55 cm/yr	Yellow Meranti - 0.21-0.28 cm/yr
Selangan Batu - 0.32 cm/yr	Selangan Batu - 0.16-0.34 cm/yr
Six common spp.- 0.33 cm/yr	Kapur/Keruing - .65 cm/yr

Enkabang Plant.- 0.96 cm/yr

Source: Performance of Dipterocarps in Natural Forest of Sarawak, Primak, Chai, Tan, Lee, Sarawak Forest Department and Boston University, 1987

18. **Silviculture of Dipterocarp Trees in Sarawak** There are abundant seedlings in most logged over forests although the number of seedlings in logged forests is only about 10% that of the primary forest. Quite clearly, logging destroys most of the dipterocarp seedlings. Dipterocarp seedling counts 10 years after logging are still well below those of primary forests. Saplings are increasing in number over time showing that some seedlings are able to grow to the next size class. There is no obvious relationship between distribution of healthy adult trees and distribution of seedlings of those species within plots. There is no general relationship between open and shaded forest and the number of dipterocarp seedlings. In dipterocarp forests there are at least 5 times as many seedlings as adult trees; twice as many seedlings as saplings, and twice as many saplings as adults.

Source: Primack, Hall, Lee, Sarawak Forest Dept. Malaysian Forester, 50/1990

ANNEX 2: TIMBER SUPPLY ANALYSIS - FACTORS AFFECTING TIMBER SUPPLY

Short-Term Timber Supply - Harvest Remaining Primary Forest

1. As noted by the 1990 ITTO Mission, the main source of current timber harvests in Sarawak is the old-growth timber stocks of unlogged forest. When this source has been depleted - some time in the next decade - there will be an abrupt and significant decline in timber supply. Table 8 shows that annual timber supply from an expanded PF, declines from 14 million m3 to 5.6 million m3, (4.7 million m3 from hill forests and 900,000 m3 from swamp forest), following harvest of the remaining primary forest.

2. The 1990 ITTO Mission predicted this decline in yield, and associated losses in employment and government revenue. The Mission recommended that: ..**cutting rates[1] be reduced to allow for a gradual transition from harvesting primary forests to periodic harvests of logged forest**.....

3. Reviewing events since the ITTO Mission proposals were endorsed by the Sarawak Forest Department, it is encouraging to see that although steps are being taken to reduce the annual harvest from the PF to 9.6 million m3 by imposing a quota on PF forest licences. However, annual timber harvests, since the 1990 ITTO Mission have increased, rather than decreased[2]. This has come about through accelerated harvesting and relogging in SF areas.

4. **Alternatives to Harvesting Remaining Primary Forest** There are several alternatives harvesting remaining primary forest. For example: it could be harvested at rates which would sustain recent annual timber supplies, which, as shown in Table 7, have averaged between 15 and 20 million m3 over the past 6 years. This option, which involves harvesting remaining old-growth timber stocks in the Swamp and hill forests over the next 10 and 15 years respectively, is analyzed in Alternative Timber Supply Scenarios #1 and #2, which are summarized in Tables 8 and 9. The difference between these two alternatives, is that Table 8 is based on continued application of present, relatively short (25 and 45 year), cutting cycles for hill and swamp forest respectively; while Table 9 is based on adoption of extended cutting cycles (45 and 70 years) designed to ensure financially viable timber yields and minimum tree sizes of 45 cm.

5. Another example alternative for liquidating old-growth timber stocks would be to extend the harvest of the remaining primary forest area to - 30 years - to allow sufficient time for regenerating forests, the majority of which were logged during the past 15 years, to provide significant reharvest volumes, thus avoiding a sudden drop in timber supply following the harvest of the last primary forests. This alternative is explored in Table 10, which like in Table 9, involves extended (45 and 70 year) cutting cycles. In estimating timber supplies from the remaining primary forest, average yield of 50 cubic meters and 70 cubic meters per ha were assumed for hill forests and swamp forests, respectively.

Long-Term Timber Supply - Periodic Harvest of Logged-over PF & SF

6. If timber harvests in the PF are to be reduced to a level which can be sustained through management of a secure PF, as proposed by the ITTO Mission of 1990 and later endorsed by the Forest

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[1] Annual harvests from hill forests averaged 12 million m3 and from swamp forests 3.5 million m3 during the late 80s.

[2] Log production between 1990 and 1993 averaged 18 million m3.

Department, then long-term timber production, following harvest of the remaining unlogged forest, must be limited to the level of harvestable timber volume increment from the production forest area[3] of the present and proposed PF.

7. **Annual Harvest from Present and Future PF** There are currently 4.4 million ha of PF. Inclusive of additions from areas of SF not required for other purposes; and excisions for proposed future TPAs, the PF can realistically be expanded to about 5.1 million ha. An expanded PF, would provide a sustainable annual timber supply of 5.1 million m3 based on an MAI of 1 m3 per ha. Forest Plantations could increase this to 6 million m3, as described in the following section. The majority of the SF areas proposed for inclusion in PF are in interior areas (Baram and Rajang river basins and Limbang and Lawas), where SF forest licences are already being managed as in the PF. Table 1, shows 3 million ha of SF in the 3 eastern divisions of the state - 1.8 million ha in Miri Division; 0.45 million ha in Limbang division; and 0.74 million ha in Kapit division.

8. **Condition of the SF** Although the remaining hill forest area (5.5 million ha) is composed approximately equally of SF (2.5 million ha) and PF (3 million ha), the condition of these forests varies significantly. It is estimated that 78%, or 1.9 million ha, of Stateland hill forest have already been logged, leaving only 600,000 ha of unlogged hill SF. (see Table 6) Accelerated harvesting[4] from SF, which has accounted for almost half of Sarawak's timber supply in recent years[5] (see Table 4), cannot be sustained. At current harvest rates, remaining unlogged stateland forests will be harvested during the next 5 years (1995-99), after which timber supply will be limited to Primary Forests of the PF, plus limited[6] relogging of SF.

Forest Plantations

9. Forest Department Plantations Alternative Timber Supply scenarios explored in Tables 8,9,10 and 10A, include timber supply from forest plantations. During the 15 year period 1980-94, the F.D. established forest plantations covering about 10,000 ha. and plan to continue expansion of these plantations at an annual rate of about 1,500 ha per year. At this rate, as shown in Table 19, there will be 55,000 ha of forest plantations by about 2025.

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[3] Includes Forest Reserves (FR) and Protection Forests (PF) but does not include Existing and Proposed Protected Areas.

[4] Average annual area of stateland hill forest harvested in the past 10 years was 110,000 ha compared to 74,000 ha of PFE.

[5] Stateland Forests contributed 8.6 million m3 of the 19.1 million m3 harvested from Sarawak's forests in 1991. Of this, 3.5 million m3 were from relogging in Stateland Forests.

[6] Relogging has increased since the early 1980s. In 1991 alone, 45,000 ha of SLF and 83,000 ha of Stateland forest were relogged, producing 5.5 million m3 of timber. Soon relogging will no longer be viable due to depleted stocks of commercial timber on these areas, some of which have been relogged several times.

10. To date forest plantations have concentrated on reforestation of PF areas which have been encroached on by shifting agriculture. Most of the reforestation has been in the Lundu-Sri Aman area (6,600 ha) and Bintulu-Miri area (3,700 ha). Future forest plantation expansion will depend on land availability and markets. Reforestation will expand in to areas of degraded forest land where transportation infrastructure is available to move timber from the plantations to markets. These include: the Dalat-Mukah, Sarikei-Sibu and Limbang-Lawas Timber Supply Units. Assuming the above forecasts hold true, by 2025 there would be 25,000 ha of plantations in the Bintulu-Miri Timber Supply Unit; and another 30,000 ha divided approximately equally between the Lundu-Sri Aman (8,000 ha), Sarikei-Sibu (8,000 ha), Dalat-Mukah (7,000 ha) and Limbang-Lawas (7,000 ha).

11. Timber Supply from existing and planned forest plantations was estimated based on an assumed average (net commercial) MAI of 15 m3 per ha; yielding 150 m3 per ha at the end of a 10 year cycle. In the long-term, these plantations will supply 880,000 m3[7] per year, as shown in Table 7A. Some of this timber may be suitable for utility grade timber, but the majority will be destined for hardwood pulp chips. If combined with chips from mill residues, Sarawak could become a significant supplier to the growing Asian market for hardwood pulp chips.

12. The preceding estimates are based on modest expansion of F.D. forest plantation programs. However, potential also exists for private, industrial forest plantations, as recommended in the recently completed Sarawak Agricultural Development Project. Incentives for private sector forest plantations and other matters related to forest plantations are discussed in Annex 7.

TIMBER SUPPLY SCENARIO #1 - BASE CASE

- **Cutting cycles; Hill - 25 years; Swamp - 45 years**
- **All of PF and SF Area Contributes to long-term Timber Production**
- **Harvest Remaining Primary Forest Area Over 15 year period (1995-2009)**

13. Based on assumptions above, timber yield by 5 year periods was estimated for: Logging of remaining Old Growth Forests; relogging logged forests, and Forest Plantations. Results are summarized in Table 8.

14. The Next 15 Years 1995 - 2009. At currently planned harvest rates, annual timber supply from the three sources will decline from current level[8] of 18 million to about 14 million m3 per year for the next 15 years.

15. The Next 50 Years - 2010 to 2060. Commencing in the year 2010, timber supply declines sharply to an average of 7 million m3 per year for the next 50 years.(2010-2060) Annual timber suppy during the 50 year period ranges from a 6 to 9 million m3 per year. Annual harvest rates could be adjusted to minimize this variation.

16. Timber Supply Composition The yield from relogging of logged hill forests makes up the majority (76-84%) of short and long-term, future timber supply. Relogging of swamp forest will account

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[7] Lundu-Sri Aman (90,000 m3); Sarikei-Sibu (175,000 m3); Dalat-Mukah (130,000 m3); Miri-Bintulu (310,000 m3) and Limbang-Lawas (175,000 m3).

[8] Annual log production averaged 18 million m3 from 1989 through 1993.

for (10-12%); while forest plantation harvests could make up 6% of timber availability, in the short-term, increasing to 11% in the long-term.

17. On the assumption that the Forest Department is successful in reaching its goal of increasing the percentage of forest land in PF from the present 55% of forest land, to its stated objective of 75% of forest land, (or alternatively, 50% of present Stateland forests are managed for permanent timber production), annual timber supply would be 6 million m3 - 1 million m3 more than from the PF alone, and 1 million less than from managing the entire forest land area (PF and SF) for long-term timber production. As with the other two alternatives, hill forest yields dominate timber availability, accounting for 75% of the total; with swamp forest yields (12.5%) and plantation yields (12.5%) equally making up the remainder of the 6.4 million m3 per year.

ALTERNATIVE TIMBER SUPPLY SCENARIO #2

- **Liquidate Old Growth Timber Stocks Over 15 years;**
- **Increase existing PF by addition of One-half of SF;**
- **Extend Cutting Cycles to 45 yrs (Hill) and 70 yrs (Swamp)**

18. In this second set of timber supply alternatives the timber supply estimates in Table 8 were recalculated using extended cutting cycles - 45 years for hill forests; and 70 years for swamp forests - which are more certain to produce tree sizes meeting current minimum diameter limits. Timber supply estimates based on extended cutting cycles are summarized in Table 9.

19. The Next 15 Years - 1995 to 2009. In the short-term, timber availability will be less than under present cutting cycles. Average annual timber availability will be about 12.5 million m3 - about 1.5 million m3 per year less that under present cutting cycles, due to an absence of yield from periodic harvest of logged-over forests. This is caused by the fact that areas logged during earlier period have not yet grown through the extended cutting cycle periods. Plantation yields remain unchanged.

20. The Next 50 Years - 2010 to 2060. Once old-growth timber stocks are liquidated, in 2009, there will be a marked falldown in timber availability. Although some hill forests, logged during the 1960s, will have grown trees of the minimum harvest diameter, and can be harvested following liquidation of old-growth timber stocks, the areas involved are small, and therefore only modest timber volumes will be available. Areas of swamp forest logged during the 1960s will not be harvested until 2030-40. Annual timber availability will be between one and three million m3 for the 15 year period 2010-25. Only after 2025 will timber availability begin to increase, reaching 6 million m3 during 2025-29. Following this, annual timber availability increases to an average of 10 million m3. This increased timber supply is due to relogging of large areas of hill forest, logged during the 1970s and 1980s and, to a lesser extent, increasing forest plantation yields.

21. The average annual yield from an expanded PF over the 50 year period following liquidation of old growth timber stocks is 6 million m3. This long-term average is misleading, as it disguises large fluctuations in annual timber availability between periods, ranging from a low of 1 million m3 (2010-14) to a high of 13 million m3 (2035-39).

22. Timber Supply Composition Under the "Expanded PF" scenario, timber supply from relogging hill PF on a 45 year cutting cycle, continues to make up the majority of long-term, future timber supply, contributing an average annual volume of 4.3 million m3. Relogging of swamp PF at 70

year intervals contributes about 0.9 million m3, while forest plantation harvests contribute another 0.8 million m3; resulting in a long-term timber availability of 6 million m3 from the PF.

ALTERNATIVE TIMBER SUPPLY SCENARIO #3

- Reduce Harvest to Extend Period of Old Growth Timber Liquidation;
- Existing PF plus one-half of SF;
- Extended Cutting Cycles (45 years - hill; 70 years - swamp forest).

23. In timber supply scenarios #1 and #2, summarized in Table 8 and 9, old-growth timber stocks are liquidated over a 15 year period, 1995-2009, at an average rate of about 12 million m3 per year. This results in high levels of timber harvests, in the short-term, followed by a sharp decline timber availability, as timber supply source changes from liquidation of old-growth timber stocks (built up over many years) on a large land base (6.5 million ha of production PF and SF); to a timber supply based on periodic harvest of timber increment[9] from second-growth forests on a reduced land base represented by an expanded PF of 5.1 million ha, some of which has had its growing stock severely reduced through relogging.

24. The negative impacts of such a decline in timber availability can be reduced through a more smooth transition to second-growth forest management. This can be done by extending the period during which old-growth timber stocks are liquidated. The effect of doubling the period of old-growth liquidation to 30 years (1995-2025), is illustrated in Table 10.

25. The Next 15 Years - 1995 to 2025. In the short term, timber availability is significantly less than in the scenarios #1 and #2, with short-term annual timber harvests averaging about 7 million m3. Liquidation of the remaining unlogged forest will continue to provide the majority of timber supply - while short-term relogging of the SF areas will continue to provide yields until these areas have been depleted or converted. Plantation yields will remain unchanged.

26. The Next 35 Years - 2025 to 2060. In this scenario the timber supply from natural forest remains relatively constant once the remaining unlogged forest has been harvested. Long-term timber annual timber supply is approximately the same as short-term timber supply, averaging 7 million m3 per year from an expanded PF area and Plantations.

ALTERNATIVE TIMBER SUPPLY SCENARIO #4

- Reduce Harvest Rate to Extend Old Growth Forest Liquidation Period
- Existing PF plus one-half of SF;
- Extended Cutting Cycles (45 years - hill; 70 years - swamp forest).
- Implement Improved Harvesting Methods on all Remaining Unlogged Areas

27. In this scenario, extension of the harvest of remaining unlogged forest will allow time to implement improved logging methods which would result in less damage and faster regrowth in logged forests. This would, in the long-term, increase MAI to an estimated 1.3 m3 per ha, on the remaining unlogged forest area. The introductino of heli-logging on about 536,000 ha of Terrain Class IV, previously excluded from logging, will incrfease annual timber supply as well. The combined effect of improved tractor logging and heli-logging would be an increased annual timber supply of 8 million m3. Long-term timber supply sources would be: hill forest - 69%; swamp forest - 19% and Plantation forest - 12%.

[9] Compared to the old-growth timber stocks, these timber increments have accumulated over relatively short cutting cycle periods since the previous harvest.

ANNEX 3: REDUCED IMPACT LOGGING (RIL)[10]- COSTS AND BENEFITS

Introduction:

Current logging practices are a major cause of forest degradation. The degradation is made worse when:

(a) logging is done carelessly with little planning and excessive damage to the residual stand,

(b) excessive logging damage (frequently caused by relogging) results in high percentage of canopy opening, encouraging weed species and vines, which inhibit development of commercial (dipterocarp) species. Site rehabilitation is costly.

(c) logged-over areas are encroached upon by shifting cultivation. Becoming less critical with urbanization.

The following cost-benefit analysis shows that improved logging practices can be cost-effective and at the same time reduce logging damage significantly thus preserving more residual trees for future timber yields.

Objective:

Many studies have shown that the number of trees damaged during logging can be reduced significantly by careful planning, scheduling and control of logging operations. The objective of this analysis is to investigate the cost-effectiveness of such activities. The proposed activities include:

- pre-harvest coupe reconnaisance,
- planning logging operations on topograhic map; including location of cut block boundaries and skid trails according to topography
- surveying and marking boundries and skid trails in the field
- pre-construction of skidtrails,
- marking trees for directional felling toward skid trails,
- bucking of trees into log lengths,
- skidding to landings using chokers rather than the tractor mainline
- on site supervision and control of logging operations.
- post-harvest inspection of logged areas to assess compliance with regulations and levy penalties.

[10] RIL Consists of a Series of Actions Leading to Improved Planning, Control and Execution Of Timber Harvesting Operations.

Assumptions:

Average Annual Coupe size:	3,000 ha
Cutting Block Size:	100 ha
Annual Number of Cut Blocks:	30 blocks
Engineering:1	Forest Engineer
Survey and Engineering Crew 4-5 labourers	3 field crews, each consists of: forestry technician, draftsman &

Productivity:

1 crew require 1 month/block to complete the topographic mapping, alignment of skid trails on the ground and marking of trees for directional felling. To conduct the engineering planning for the 30 cut blocks will require the equivalent of 10 months for the 3 crews, leaving the equivalent of 2 months for monitoring & control inspections.

Costs: Engineering & Supervision: (MR/month)

Forest Engineer:	MR 4,000
Technician: 3 @ MR 2,50	MR 7,500
Topographic Mapper:	MR 2,500
Field Crew:12 men @ $1500	MR 12,000
Transport and subsistance	MR 15,000
Total Cost per month:	**MR 41,000**

Per Ha: (MR 41,000*12 mo./3000 hectares) MR 165/ha
Per M3: MR 165/40 m3/ha = MR 4/m3

Benefits

1. **Reduction in the amount of skid trails** required when the trails are planned and preconstructed rather than left to the descretion of the tractor operator to construct as he searches out trees of commercial species & size.

Skid trails Planned and Preconstructed: MR 1000/km * 0.2 km/ha = MR 200/ha
Per M3: MR 200/ha/40 M3/ha = MR 5/m3

Skid trails Built by Conventional Method: MR 1000/km * 0.25 km/h = MR 250/ha
MR 250/ha/40 M3/ha = MR 6.25/m3

Savings from Skid Trail	MR 50 /ha
Planning & Preconstruction	MR 1.25/m3

2. **Decrease in skidding costs** due to a 20% increase in skidding productivity attributable to rational planning and location of skid trails in relation to the trees to be removed will reduce skidding costs from MR 25/m3 to MR 20/m3, or a MR 5/m3 benefit to the logging contractor. Based on a volume of 40 m3/ha, this will result in a savings of MR 200 per hectare.

3. 25% less damage to residual future crop trees trees (>30 cm) (from 20 trees damaged to 15 trees damaged per hectare) will result in a saving of (5 trees @ an average of 1.5 m3/tree) 7.5 m3/ha of residual wood volume which at present delivered log costs of MR 250/m3 (including royalty) and log sales prices of MR 400/m3[11] represents an additional (MR 400 - MR 250/m3 * 7 m3/ha) = MR 1,050/ha in wood value.

4. Additional growth on these trees at an average rate of 0.5 cm of diameter and 0.3 m of height per annum for 25 years, will result in an additional 10 m3 of wood at the subsequent harvest. This represents another MR 1,050 in wood value, assuming 70% or o.7 m3 of this additional wood increment is recovered as commercial timber.

5. Effect on Future MAI and Sustainable Yield Although difficult value, RIL would have an added benefit increases MAI by about 0.3 m3 per ha[12], from the estimated current MAI of 1 m3/ha to 1.3 m3/ha. If RIL were adopted on all remainng unlogged production forest (2.5 million ha), future annual yield, (expanded PFE), would increase by 750,000 m3, bringing yield to 7 million m3 from natural forests and 7.7 million m3 from natural and plantation forests.

Relationship of Costs to Benefits

The additional cost of MR 165/ha spent on engineering planning is compensated for by a savings of MR 50/ha in skid trail construction and MR 200/ha in logging costs at the time of the first harvest. Future benefits at the subsequent harvest include additional wood recovery of 14 m3 per ha, which would have a net value (based on current logging costs and log prices of about MR 2,100 per ha. The relationship of benefit to cost is 14:1.

Labour Requirements

For the 250,000 ha to be harvested annually in Sarawak over the next 15 years until the remaining primary production forest has been depleted, a total of 75 to 80 crews each consisting of a forest engineer, 2 forestry technicians, draftsman, 10 labourers would be required for implementation of the engineering planning, supervision and control activities discussed in this analysis. The total labour requirement for implementing these proposed activities on all logging operations in Sarawak would be approximately 1,000.

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[11] Average of Export (MR 500/m3) and Local Sales (MR 300/m3)

[12] The additional increment of 10 m3, reduced by 30% for losses during harvesting, and divided by 25 years, gives increased mean annual increment (MAI) of 0.3 m3/ha of harvestable timber.

ANNEX 4: POST-LOGGING SILVICULTURAL TREATMENT - COSTS AND BENEFITS

Although existing silvicultural prescriptions appear to be adequate, their impementation clearly is not! There is a considerable backlog of areas for which post-logging inventory and silvicultural treatment have not been undertaken. Monitoring of logged areas which have been treated is also inadequate. The reason for this is that there is no conviction that silvicultural treatment of logged areas is economically justified.

A 1989 study conducted in Sabah shows that liberation thinning in adequately stocked logged over areas is an financially attractive investment. The degree of return on investment is proportional to the intensity of thinning undertaken. Heavy thinning costs are as follows:

COST OF POST-LOGGING LIBERATION THINNING

Item	MR/Ha
Chemicals	**5**
Travel Allow.	**5**
Transport,wages, labour,etc.	**75**
Staff/Wages	**5**
Administration	**10**
Total Cost	**100**

COSTS & BENEFITS

Item	Intensity of Liberation Treatment	
	Heavy Treatment (5 man-days/ha)	Light Treatment (3 man-days/ha)
Cost of Liberation Treatment (M$/Ha.)	MR 100	MR 60
Growth Rate Increase (cm/A)	0.9-1.5	0.7-1.0
Due to Treatment (M3/ha/A)	0.63	0.3
Increase In Merchantable[13] Timber Yield-30 yrs.(M3/ha)	10	5
Estimated Net Profit on the Additional Timber Extracted	MR 1,500	MR 750
Benefit/Cost Ratio	15 :1	12.5 : 1

[13] It was assumed that only one-half of the increment would be recoverable as commercial timber. The remainder of the increment would be lost due to natural mortality and logging waste.

ANNEX 5: ENRICHMENT PLANTING - COSTS AND BENEFITS

The following Cost Benefit Analysis demonstrates that enrichment planting of Enkabang, to produce a combination of nuts and timber can be an attractive alternative to natural forest management or fast growing plantations of exotic species. An investment of M$6,020 in plantation establishment and maintenance over a 50 year plantation cycle generates M$64,000 net revenue.

COST BENEFIT ANALYSIS OF LINE PLANTING OF ENKABANG (SHOREA) SPECIES FOR COMBINED PRODUCTION OF TIMBER AND ILLIPE NUTS(50 Year Rotation)

Assumptions:

- Average volume increment of 5 M3/Ha/A assumed for the plantation. (250 M3/Ha @ 50 years)
- Log sales prices for Enkabang wood was assumed @ $ 160/M3.
- Assume 100 of the 200 trees planted reach maturity. (average number of trees 150 trees/ha) Assume each tree will produce 10 kg. of dried kernal every 3 to 4 years from year 15 to year 50. (10 harvests of 10 kg/tree * 150 trees for a total production of 15,000 kg/ha (50 years)
- Illipe nut price - $1.10 to $2.50/kg. For this analysis it is assumed average price of $1.65/kg.

GROWING COSTS (MR/HA)

Plantation Establishment: 200 Trees/ha (5m*10m)

Line Clearing	200 MR/ha
Seedling Cost	50
Planting	100
Roads	50
Fertilizer, Chemicals	20
Post Planting Treatment (Up to year 5)	600
Total-Establishment Cost	1,020 MR/Ha

Plantation Maintenance:

Wages, Vehicles,Buildings, Equipment,Interest	100
Cost - 50 years	5,000

PRODUCTION COSTS (MR/HA)

Logging & Transport	15,000 (250 M3 @ MR 60/M3)
Illipe Nut Collection	15,000 (15,000 Kg @ MR1/kg)
Total Cost:	30,000

SALES REVENUES: (MR/HA)

Logs:	75,000 (250 M3 @ M$ 300 M3)
Illipe Nuts:	25,000 (15,000 kg @ $1.65/Kg)
Total Revenue:	100,000

NET REVENUE: 64,000

BENEFIT/COST RATIO: **11 : 1** **($64,000/$6,020)**

Assumptions and Additional Notes:

Heavy Treatment - (Initial Investment of MR 100/ha) includes climber cutting, poison girdling of all pioneer species and currently non-commercial species with sodium arsenate.

Light Treatment - (Initial Investment of MR 60/ha) includes climber cutting and poisoning of non comercial species leaving pioneer species alive.

Net Merchantable Timber Yield - An allowance of 30 percent was made between increased growth and net growth to allow for waste, breakage and leaving of pole and medium sized trees for next cutting cycle.

Net Profit on Additional Timber Yield - Assumed FOB Log price of MR 400/M3; logging costs & royalty of MR 250/M3 = net profit MR 150/m3

Labour Requirement - assuming that half of the 250,000 ha harvested annually in Sarawak (125,000 ha @ 3 mandays/ha) is light-treated, labour requirement would be 1250 on a year-round basis.

Growth Rates - based on 19 years of growth measured in permanent growth and yield sample plots.

ANNEX 6: HELICOPTER LOGGING - COSTS AND BENEFITS

Malaysian Ringit (MR)/M3

Assumptions on Helicopter Productivity and Cost:

Average load per cycle	5 tonnes (5.5 cubic metres)
Number of cycles per hour	15 (average 4 min./cycle)
Available Hours per day	10.0 hours
Fueling (0.25 hr./hr.)	1.5 hours
Maintenance (0.75 hr/4hr.	1.5 hours
Flying Time per day	6.0 hours (360 minutes)
Cycles per day	90 cycles
Volume per day	500 M3/day
Cost of Helicopter:	
Large Helicopter (Sikorsky)	MR 6500/hr
Small Helicopter (Bell 206)	MR 2000/hr

Analysis:

Total Cost of Helicopters:	MR 8500/hr
Daily Helicopter Cost:	MR 51,000/day
Helicopter Cost per M3:	MR 100/M3 (MR 51,000/500 M3)
Heli Operator Profit Margin	25/M3
Subtotal Helicopter Cost	MR 125/M3
Unit Cost of Other Phases:	
Inventory/survey/mapping	MR 2/M3
Felling/Bucking/Debark.	MR 13/M3
Main and Secondary Roads	MR 28/M3
Loading/Unloading	MR 10/M3
Land/Water Transport	MR 50/M3
Administration/overhead	MR 60/M3
Subtotal - Other Phases	MR 147/M3
Royalty Payments to Gov't.	MR 65/M3
Total Delivered Log Cost:	**MR 337/M3**
Delivered Log Cost by Conventional Operation:	MR 225/M3
Difference:	MR 112/M3

Conclusions and Additional Notes:

On the basis of cost alone, heli-logging is 1.5 times more than tractor logging. However, the additional cost of MR 112/M3 is compensaed for by higher prices for higher quality logs. Average log price for species and grades of logs normally harvested by tractor in Sarawak is about MR 625/M3; where as those extracted by Helicopter average MR 765/M3. The difference of 145 MR exceeds the MR 112/M3 additional cost. This leads to the conclusion that, when used to selectively extract high value timber, heli-logging can be more profitable than conventional tractor logging.

ANNEX 7 - FOREST PLANTATIONS IN SARAWAK - OPPORTUNITIES & CONSTRAINTS

1. **Wood Quality Constraints of Forest Plantations** Sarawak's forest plantations have concentrated on a single species - Acacia mangium, which is ideally suited to grow on degraded sites, such as those which have been subjected to repeated cycles of shifting cultivation. However, in addition to impressive growth rates on poor sites, it also suffers from poor form and a high incidence of heart rot.

2. **Potential For High Quality Timber From Forest Plantations** With few exceptions - Engkabang, Kapur being two Malaysian examples - it is extremely difficult and usually impossible to grow most high quality tropical hardwood species in plantations. Most of these species are components of late biological successions which have evolved in competitive, multi-species environments where there is a strong inter-relationship between a multitude of plants and animals. The majority of these species are ecologically unsuited to grow in pure stands or open environments when young. They usually suffer from chlorosis and lack of vigour and often succumb to fatal insect or pathogenic attack. It is therefore unrealistic to expect pure plantations of many of Sarawak's valuable tropical hardwoods to succeed on any scale.

3. **Potential for Forest Plantations of Native Species** Not withstanding previous comments on limitations of growing native tree species in plantations, there are promising examples of forest plantations of native Dipterocarp species, known locally under the collective name of Enkabang (Shorea macrophylla and other Shorea spp.) Enkabang has been planted on approximately 500 hectares in Sarawak and, on good sites, has a potential to be used both in forest plantations on cleared areas and in enrichment (line) plantings in cut-over forests. Advantages of Enkabang as a timber species is its relatively attractive growth rate (MAI of 5 M3/A, yielding 250 M3 at 50 years), and high quality timber. (Enkabang should command prices similar to other Shorea species). In addition to its timber value, this species produces a fruiting body, valued for its oil which is used in chocolate manufacture. Annex 5 includes a cost-benefit analysis of Enkabang enrichment planting.

4. Investors need to feel welcomed and encouraged by all levels of government before they can be expected to invest in high-risk forestry projects. Such tangiable incentives and benefits as tax deferals, repatriation of profits, tariff-free entry of equipment, work permits for foreign experts, and access to government funded research and development programs are all steps which cost little to the government but go a long way to encouraging private investors.

5. Some government policies have tended to discriminate against conversion of privately held land to forest plantations. Taxation benefits and soft credit are available for establishment of agricultural crops but forest plantations are not elegible for these benefits. If governments are sincere in wishing to expand forest plantations then these impediments should be removed.

6. **Financial Incentives** From a financial perspective, trees grown as wood crops are capital intensive and long-term and thus a relatively risky and uncertain investment. With costs concentrated in the early phases and returns in the late stages of the forest plantation cycle, the financial viability of investments in forest plantations is less attractive than alternatives such as oil palm and rubber which, although they involve higher initial investment, provide periodic returns at a relatively earlier stage of the plantation cycle.

7. **Minimum Requirement to Encourage Forest Plantations** In the absence of grant or soft-loan funds, the minimum requirements to encourage private sector forest plantation investment re either:

- current deductibility from taxable income of all growing and management costs (in the year they are incurred) or,
- accumulation of these costs, (indexed by an acceptable interest rate equal to or higher than inflation) and their deduction from taxable income received at the time of harvest.

8. The former system would suit companies who are already paying tax from other activities while the latter would be more attractive to the foreign investor who has no local taxation commitment.

9. This facility to choose whether to invest profits, which would have otherwise been paid in tax, on forestry projects is a powerful incentive. It has been used successfully to develop large forest plantations in Brazil, Argentina and Chile.

Other Factors to Promote Private Sector Investment in Forest Plantations in Sarawak

10. Climate, labour availability and cost, local management experitise, local industrial and transportation infrastructure, local markets, loading points for export and distance from markets are all important factors which will be considered by private investors before proceeding with forest plantations. The following are essential for promotion of Forest Plantations:

Private Sector Attitudes to Forest Plantation Development

11. Markets for traditional agricultural plantation products appear to be saturated and no new plantation areas are envisioned by large plantation companies on the Peninsula. In spite of rates of return on forest plantation investments being lower than the traditional agricultural crops, there has been interest by plantation companies in diversification into Forest Plantations. This interest has not yet been translated into reality for a number of reasons. Since labour now constrains agricultural plantation development, forest plantations may be more attractive in spite of their lower returns because they are less labour intensive than agricultural crops. Ratios of labour to land range from: 1 worker per 3 hectares for Rubber and Cocao; to 1 worker per 7 hectares for Oil Palm; to 1 worker per 10 to 15 hectares of Forest Plantations.

12. Private sector developers require large blocks (25,000+ ha) for forest plantations. However, in E. Malaysia potential areas are often subject to land tenure problems due to native customary rights (NCR) claims. This is the main impediment to private sector forest plantation development in E. Malaysia.

13. Forest plantations with species presently planted in Malaysia would be mainly destined for the Pulp Chip export market. The price for this product fluctuates considerably due to the fact that the pulp chips form a small portion of the total cost of the finished (paper) product. Increasing concern about environmental polution from pulp and paper mills has forced companies to use more recycled paper thus reducing demand for wood chips. The future demand and price for wood chips is uncertain, therefore could be a hesitancy on the part of private investors to enter the field of forest plantations.

Land Constraint to Sarawak's Forest Plantation Program

14. To date, forest plantations have been funded by the state government on Permanent Forest Estate lands which had been encroached upon by shifting cultivation. Difficulties have been encountered in solving Native Customary Rights (NCR) land claims, which have been a serious impediment to further plantation development by the private sector who seek large continguous blocks of land which can be managed efficiently as forest plantations.

15. In Sarawak, much of the potentially available land for forest plantations is difficult to consolidate into large blocks due to NCR claims on much of the shifting cultivation land in the western portion of the state.

16. **Wood Quality Constraints of Forest Plantations** Of all objectives of plantation forestry, the most difficult to achieve is improvement of wood quality. A combination of silvicultural management and genetic improvement is required for improvement of wood quality to meet end use requirements. Unfortunately it is difficult if not impossible to achieve high wood quality while at the same time achieving fast growth. Barbour and Kellog (1990) concluded that "accelerating growth rates and shortening rotation length will result in a decline in quality for almost all currently produced wood products".

17. **Potential For Forest Plantations of High Quality Timber** With few exceptions, Engkabang, and Kapur being two Malaysian examples, it is extremely difficult and usually impossible to grow most high quality rain forest species in plantations. Most of these species are components of late biological succession which have evolved in competetive, multi- species environments where there is a strong inter-relationship between a multitude of plants and animals.

18. Because the majority of these species are ecologically unsuited to grow in pure stands or open environments when young, they usually suffer from chlorosis and lack of vigor and often succum to fatal insect or pathogenic attack. It is therefore unrealistic to expect pure plantations of many of Malaysia's valuable tropical hardwoods to succeed on any scale.

19. With the foregoing in mind, it would appear that the only realistic approach to growing high quality timber for Sarawak's forest industries is effective management of natural forests in which the stocking of valuable species is ensured through silvicultural interventions including liberation thinning to encourage the growth of the desired species and enrichment planting where stocking levels of these species are insufficient.

20. Enrichment planting of cut-over forests has been attempted in Malaysia the past with limited success. Typically it suffers from the fact that areas required to produce significant timber volumes are extensive and therefore often do not receive the attention and treatment they require, especially during the early years. Therefore they often do not achieve the desired results.

21. **Forest Plantations of Native Species** Not withstanding the previous comments on the limitations of growing native species in plantations, there are promising examples of forest plantations of native Dipterocarp species, known locally under the collective name of Enkabang (Shorea macrophylla and other Shorea spp.) Enkabang has a good potential to be used both in forest plantations on cleared areas and in enrichment (line) plantings in cut-over forests. The advantages of Enkabang as a timber species is its relatively attractive growth rate (Enkabang plantations in Malaysia achieve annual volume increments of 5 M3/A), (250 M3 yield at 50 years), and high quality timber. (it is assumed that Enkabang wood would command a price similar to other commmercial Shorea species; about MR 400+/M3)

22. In addition to its timber value, this species produces a fruiting body - the Illipe Nut - which is valued for its oil which is used in chocolate manufacture. Unfortunately, irregular flowering and fruiting result in sporadic supplies of the nuts. As a consequence supplementary non-timber income is rather unpredictable as both supply and price fluctuate wildly from year to year. Short-term seed viablity and lack of regular seed years inhibit production of new planting stock. Perhaps vegetative propagation, as is currently being in East Kalimantan, Indonesia, may solve this problem. An additional impediment to widespread planting of Enkabang, is that it requires good sites. It is generally found in Rivirine belts associated with siliceous soils derived from sedimentary rock and does not tolerate degraded sites common in many areas under shifting cultivation.

23. In Sarawak there are approximately 500 hectares of Enkabang plantations and 40 hectares of Enrichment Planting. A sixty hectare Enkabang plantation was established by Sarawak Forest Department at Semengoh, near Kuching in 1925. The most recent plantings were in 1975. Although no records have been maintained of fruit production per tree or unit area, discussions with those involved indicated that signicant supplies of nuts occur every 3 to 4 years. It is estimated over a plantation cycle of 50 years, the production of nuts would average 300 kg. per ha. per year. (assuming initial fruiting at 15 years, and 10 fruiting years during the plantation cycle). A cost-benefit analysis of Engkabang Enrichment Planting in poorly stocked forest is included in Annex 5.