Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Andaman and Nicobar Islands				Volume of timber remaining in the forest in the form of buttressed stumps was 8.2 m^3/ha for hardwoods and 5.89 m^3/ha for softwoods Removal of the buttress before felling would minimize timber damage, increase timber yield and keep the forest floor in a more hygienic condition				Balachandra, L. 1988
Africa	Tropical moist forests · well planned and carefully controlled harvesting systems are superior economically, environmentally and silviculturally Such harvesting systems should be fully integrated with the management system, but has been an elusive goal in the tropics		Total bole volume in Francophone African countries average 111 m^3/ha, of which 61 m^3/ha (11.5 trees/ha) is of commercial size (>70 cm dbh), and of which 15 m^3/ha (2.3 trees/ha) is commercial volume of preferred species In polycyclic silviculture, systems must use RIL, in which case on a 30 year cycle and 1 cm/a dbh growth logging will be sustainable In Côte d'Ivoire they are confident that the majority of stems in the 20-40 and 40-60 cm dbh classes will move up to the next class with a 40-year logging cycle		Soil disturbance on 20-25% of logged area Every felled mature tree destroys 200-400 m^2 of forest			FAO 1989a
Africa	Successive felling at a very short interval associated with poor forest inventory is not compatible with sustainable management.		Logging intensity 1-2 trees/ha or 15-20 m^3/ha		Generally less than 10% of the original tree population damaged during logging			Sist, P. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Africa (central)	• The main objective of the "ECOFAC" project was to determine the relation between harvesting intensity and damage to the residual stand.		• Minimum harvesting diameter 80cm dbh (few trees <90cm dbh were cut) • The harvesting from 0.4 - 4 trees/ha		• Most of the damage was caused during skidding operations • 0.8% of the surface was affected by roads and landings.			Durrieu de Madron, L., Fontez, B., Dipapoundji, B. 2000
Africa, Anglophone west			Felling cycles • Cameroon 30-60 years • Nigeria 50 years • Ghana 40 years • Optimum felling cycle is one that ensures complete forest recovery and sufficient stem recruitment into the exploitable diameter class • Felling limits vary between 50-110 cm dbh depending on country and species	• In S.E. Asia 33-67% of the residual trees are damaged by logging	• In S.E. Asia 33% of the total area is damaged during logging			Dykstra *et al.* 1996
Amazonia	• In this study, the effects of logging intensity, time after logging, and skidder tracks, on the composition and diversity of the ground-level herb community of a terra-firme forest in central Amazonia were examined. • We conclude that forest managed with logging intensities similar to those used in this experiment could be compatible with conservation of understory herbs. • Skidder tracks should be minimised, as they have the greatest long-term impact and allow species from other habitats to invade the forest.		• Logging was carried out at varying intensities in eight 4-ha experimental plots in 1987, three plots in 1993, and five plots were controls.		• Results indicate that the herb ground community is not severely affected by selective logging at the intensities used in this experiment. • The alterations in composition are mainly local, and restricted to the most disturbed patches.			Costa, F. & Magnusson W. 2001
Amazonia (Brazil & Bolivia)	• Forest owners and operators in Brazil and Bolivia were interviewed in order to assess the level of implementation of RIL in the two countries. • In Bolivia the companies making the most progress towards RIL implementation are large, well organized and vertically integrated; whilst in Brazil those						• Two of the main obstacles facing RIL implementation in both countries is the perception that RIL is prohibitively expensive and the lack of trained people at all levels.	Blate, G.M., Putz, F.E. & Zweede, J.C. 2001

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	companies making most progress towards RIL adoption are those with enough capital to invest in appropriate technology and training of personnel. • Companies in Brazil and Bolivia have adopted the RIL elements that increase efficiency, reduce costs, enable them to comply with the law, and help them improve marketing. • In Bolivia, improving market access through certification is probably the most important reason for RIL adoption whilst in Brazil, increased operational efficiency and consequent cost savings.							
Asia-Pacific	• A necessary condition for implementing RIL is that personnel have the qualifications to perform their tasks and responsibilities effectively and efficiently. • Personnel need to know and understand the nature and scope of the work to be done, why it has to be done and how best to do it. In combination, these skills enable them to carry out complex tasks efficiently. Thus, greater efficiency and higher productivity in timber extraction under RIL is achieved through training. • RIL training often concentrates on felling/bucking and skidding operations simply because their negative impacts on the residual stands and the forest ecosystem as a whole are highly visible, and readily measurable in physical and monetary terms. • This approach often fails to recognize that other key stakeholders, such as policy-makers, planners and supervisors also need to undergo training because their decisions have significant and long-term impacts on the productivity and sustainability of the forest resources.							Vergara, N.T. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Asia-Pacific	• A basic attraction of RIL is that forests continue to provide economic potential through timber production while improving the environmental value • 50% of the green-house-gas-benefits are realised over the first few years.						• Increasing interest in using carbon offset financing to carry out more environmentally sound forest management • RIL provides little monetary incentives for forest concessionaires to invest in these techniques.	FAO 1998
Asia (South East)			• Logging intensity 8 trees/ha or 80-100 m^3/ha		• >50% of the original tree population are damaged during logging			Sist, P. 2000
Asia, Southeast	• Elephants are a low cost, low impact means of hauling logs in the forest. • However no studies comparing the damage level caused by elephant and conventional machine-based logging appear to have been carried out, but some general observations can be made.				• When elephants are used, skid trails in the logging area are not required, greatly reducing the amount of mineral soil exposed. • Elephants can also be used to float logs down shallow streams, reducing the need for access roads. • They can however cause soil compaction over defined trails through the forest, although the area affected is much less than under conventional tractor logging.			Grace, K.T. & Adnan, A. 1996
Asia, Southeast	• A model was constructed to simulate changes in biomass and carbon pools following logging of primary dipterocarp forests in southeast Asia. • A physiologically driven tree-based model of natural forest gap dynamics (FORMIX) to simulate forest recovery following logging.				• The relationship between fatal stand damage and ecosystem carbon storage was not linear, with biomass recovery following logging severely			Pinard, M.A. & Cropper, W.P. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• Following selective logging, simulated ecosystem carbon storage declined from prelogging levels (213 Mg C ha-1) to a low of 97 Mg C ha-1, 7 years after logging. • Carbon storage in biomass approached prelogging levels about 120 years after logging.				limited by 50-60% stand damage. • Results suggest that when 20-50% of the stand is killed during logging, replacing persistent forest species with pioneer tree species can reduce the site's potential for carbon storage by 15-26% over 40-60 years.			
Asia, Southeast	• The integration of silvicultural principles and guidelines is essential for improving RIL techniques towards sustainable harvesting practices. • Four of these silvicultural principles are: (a) minimum diameter cutting limit based on stand structure (b) Minimum spacing distance of 35 m between harvested trees (c) Single-tree felling gaps and (d) maximum diameter cutting limit. • These principles aim at keeping extraction rates below set thresholds; limit the impact of harvesting on the stand and maintain timber species populations.							Sist, P. 2001
Australasia	• Tasmania has pioneered improvements in forest operations within the Australian forest industry, with the introduction of the Forest Practices Act in 1985, of which the Forest Practices Code (FPC) is an integral part. • The code outlines minimal environmental standards that must be achieved for all forest operations, including guidelines to reduce the impact of logging. • The Vanuatu Code of Logging Practice (VCOLP) was introduced in 1998, using the existing Forestry Act as the basis for legislation (Vanuatu Department of Forests, 1997a).							Andrewartha, R. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• Full compliance with all operating standards was to be achieved by 31 December 2000. • Complementary to the code, reduced impact logging (RIL) guidelines were formulated designed to assist field supervisory staff and industry operators in executing forest-harvesting plans (as required by the VCOLP).							
Australia, Queensland	• Queensland selective logging system studied most important to further reduce damage is to enhance the skills, sensibilities and cooperation of field personnel		• Average logging intensity 6.6 stems/ha, 4.9 m^2/ha, 37 m^3/ha	• 146.7 stems/ha killed during logging amounting to 12 m^2/ha of basal area • Damage less than in other studies done in SE Asia · more fibre from crowns could have been utilized	• Machine trails occupy 5% of area • Canopy loss was 19.5% of area • 18 months after logging casual observations indicated there was little regeneration on the major logging tracks • Logging did not result in the loss of any tree species from the sample sites nor was there any change in the total plant species list after logging			Crome *et al.* 1992
Australia, Queensland	• Tropical forests • 14 species comprised 95% of volume removed, and 4 species comprised 50% of volume		• Logging intensity 8-10 trees/ha or 50-55 m^3/ha in 1987-1990 • In 1979-1980 logged areas, the logging intensity was 34 m^3/ha					Laurance, W. & Laurance, S. 1996
Australia, Queensland	• Harvesting model which enables estimation of selection logging yields and quantification of impact on the residual stand • Residual stem prediction equations derived from a series of 9 logging damage studies from 1977 to 1980 • Amount of basal area logged was one of the major variables		• Minimum cutting limit for defective trees 40 cm, but otherwise 60-100 cm dbh depending on species • In the logging damage studies 13.8% of the original stand stems were marked for removal and extracted, while 1.2% were marked, felled and left as		• From the logging damage studies 10% of original stand stems were destroyed, while 11.5% were damaged but would probably survive			Vanclay, J. 1989

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			unmerchantable • 38 years after logging, tree marking in a previously logged stand reached the same selection intensity as in a virgin stand					
Belize	• The stands on this site were logged 10 or more years ago and had an intact canopy • The harvest rate for mahogany far exceeded the regeneration and recruitment capacity of the forest.			• Because similar numbers of commercial and non-commercial species were damaged, loggers did not appear to make an effort to avoid damaging species of commercial value.	• Skid roads covered 3.8% and affected another 6.3% and thus accounted for 78% of the disturbed area • Logging gaps covered 2.28% and accounted for the remaining 22% of the disturbed area • The soil was significantly compacted on 3.8% of the study area • The soil was twice as compacted on skid roads than in adjacent forest • Soil compaction was over 200% greater on roads where more than one tree had been skidded			Whitman, A.A., Brokaw, N.V.L & Hagan, J.M. 1997
Bhutan	• Natural forests of the Himalayan range in Bhutan • The study was focussing on "environmentally friendly forest engineering"				• Focussing on environmental impacts of road construction, the superiority of excavator technique in difficult and/or steep terrain over bulldozer techniques becomes obvious although the short-term benefits might favour the use of bulldozers		• A productivity of 3.88 m^3/h was found for cable logging in CL and 5.01 m^3/h in RIL • The costs of timber extracted by long-distance cable crane amounts to US$ 25.53/m^3 for CL and US$ 20.13/m^3 for RIL • The total costs for roads were US$ 9.28/m for excavator	FAO 1999

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							construction and US$ 6.07/m for bulldozer construction	
Bhutan	• Prior to the early 1970s, logging was carried out manually and impacts on the soil, the residual stand and hydrology were high. • Bhutan has endeavoured to achieve high standards of environmental protection by adopting more appropriate management, road construction and harvesting techniques. • Bhutan's development policies are aimed also at maintaining cultural values for its population, which is heavily dependent on the forests. • The pursuit of these policies has required a limited amount of commercial forest exploitation in order to create revenues for national development. • Generally, Bhutan has been successful in achieving its environmental and social development goals, partly through the adoption of appropriate technology and techniques and partly due to a clear vision that has allowed decision-makers to follow a consistent course of action.							Thinley, U. 2002
Bolivia	• Bosque Chimanes • The value of previously logged forests for future timber production, and the contributions of these forests to the conservation of biodiversity will depend to a large degree on how much damage is done to the forest during the initial log extraction		• First pass is 95% mahogany in 602 ha study area 74 commercial mahogany trees extracted (= 0.12 trees/ha)		• Area under roads 6.31 ha or 1.05% (main road 4993 m long and 6.62 m wide, skid trails totalled 8523 m and 3.53 m wide) • Felling gaps ranged from 100 to 1000 m^2 (average 380 m^2), resulting in 2.81 ha of gaps or 0.47% of area • Road secondary damage was 17.29 ha or 2.87% of area • Total area directly under roads,			Gullison, R. & Hardner, J. 1993

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					secondary damage and gaps was 26.41 ha or 4.39% of area • Road damage could have been reduced by 25% through better planning (straight main road with skid trails running off of it) • On the other hand more disturbance is required to get sufficient regeneration of mahogany			
Bolivia	• Significant quantities of mahogany (total volume 159-180 m^3/ha and 100 m^3/ha respectively) were found in the study area.		• Minimum cutting diameter of 80cm dbh	• 10% of commercial sized trees should be left as seed trees • Processing efficiency at the mill is estimated as 60% • Quantities of residual branch wood are substantial, ranging from 0.85 m^3 to more than 16.3 m^3 per tree • Utilisation of mahogany ranged from 49.2 to 90.5%, and decreased significantly with increasing diameter • Stem cut-offs, buttresses and the stump usually account for 20.2% of the total tree volume				Gullison, R. & Hardner, J.J. 1997
Bolivia			• Harvest intensity ranged from 1-6 trees /ha	• Damage level for the residual basal area was very low (mortality mainly in smaller size classes)	• Both harvest mortality and total mortality were quadratic increasing functions of harvest intensity when expressed in terms of basal area.			Panfil, S.N. & Gullison, R.E. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Bolivia	• The impact of skidder disturbance on recruitment of commercial tree regeneration within logging gaps was studied using paired scarified and unscarified plots as well as whole-gap surveys of scarified and unscarified areas in a Bolivian tropical humid forest.			• More than a year following gap creation, variability in the density of regeneration among logging gaps was high, but commercial tree regeneration density tended to be greater in scarified areas than in unscarified areas within gaps for most species. • Although initially devoid of vegetation and litter cover, scarified areas had vegetation and litter cover levels similar to unscarified areas after 7 months. • Vegetation cover on scarified areas tended to be dominated by early successional tree species while unscarified areas were dominated by forbs and grasses.				Fredericksen, T.S. & Pariona, W. 2002
Bolivia	• Nearly 1 million hectares of Bolivian forest are now certified by the Forest Stewardship Council. • To ensure sustainable forest management, however, Bolivian foresters need to go beyond the basics of planned logging and apply silvicultural treatments to secure regeneration, improve tree growth and maintain stand quality. • This change is a tall order in a developing country battered by a deep economic recession, where timber-mining interests are still powerful and silviculturists are in short supply.							Fredericksen, T.S., Putz, F., Pattie, P., Pariona, W. & Pena-Claros, M. 2003
Bolivia	• The area disturbed and damage to the residual stand caused by planned diameter-limit logging was assessed in a tropical humid forest of Bolivia and compared with disturbance and damage reported in other studies in the neotropics	• The harvest incorporated many reduced impact logging practices including pre-harvest tree	• A total density of 4.35 trees/ha and 12.1 m^3/ha of wood were harvested.		• It was estimated that logging disturbed 45.8% of the stand including 25% ground area disturbance in the			Jackson, S.M., Frederickson, T.S. & Malcolm, J.R. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	with similar harvesting intensities.	inventories, planned placement of roads and skid trails, vine cutting, and directional felling.			form of skid trails, logging roads, and log landings and an additional 25% in canopy openings due to tree felling. • On average, 44 trees were damaged for every tree extracted including 22 trees killed or severely damaged, 6 of them commercial species. • The most common types of damage included uprooted stems, stem wounds to the cambial layer, and bark scrapes. • Damage to trees sustained along skid trails was found to be significantly less than the damage incurred along logging roads. • Residual damage in felling gaps was positively related to the diameter-at-breast height of the harvested trees. • Comparisons with other planned operations revealed a higher percent ground area disturbed and a greater felling gap area per tree extracted. • Higher ground area disturbance was mostly due to the greater area in skid trails, many			

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					of which appeared to be unnecessary. • Larger felling gap sizes appeared to be at least partially attributed to the larger size of trees harvested relative to those in other forests.			
Bolivia	• One-year-old logging gaps were sampled in dry and humid selectively-logged Bolivian tropical forests to determine the density of commercial tree regeneration. • Liberation treatments designed to enhance the growth and survival of sapling regeneration was evaluated over a period of 2 years.			• Of the nine species harvested in each forest type, only two species in each type had relatively abundant regeneration in logging gaps. • Only two species in each type had relatively abundant regeneration in logging gaps			• Treatment costs were relatively low US$1-2.3 per gap), but time until return on investment is long (20-30 year cutting cycles).	Pariona, W., Fredericksen, T.S., Licona, J.C. (in press)
Brazil	• Article summarises key findings of the IMAZON low impact logging study		• Brazilian producers can yield an additional 7.3 m^3/ha by introducing RIL • Harvesting cycle of 70 years with CL may be reduced to 25-30 years through RIL	• CL: 7 m^3/ha of wood lost during skidding operations by not finding all felled trees • 0.3m^3/ha were lost due to poor felling and bucking practices	• RIL: 5% of the block area disturbed by skid trails, roads and log decks • RIL: 30% fewer trees damaged and 25% less of the canopy disturbed when compared to CL		• RIL machine time reduced by 20%	Blate, G. 1997
Brazil	• Based on the IMAZON reduced impact logging study				• RIL: damage to residual stand reduced by 30% compared with CL • RIL: soil disturbance is significantly reduced	• Up to 19% of the harvest volume (7m^3/ha) were left behind because skidder operators could not locate the logs		Bowyer, J.L. 1997
Brazil	• Average growing stock (dbh >10 cm) was 247.9 m^3/ha or 133.9 m^3/ha for trees with dbh >50 cm • When the subject of sustaining wood production over a number of cutting cycles is considered, it becomes obvious that planned exploitation is the key to ensuring		• Logging intensity 20 m^3/ha		• With RIL maximum canopy opening was 15% • 22.5 m/ha of road built (5 m wide), 60 m/ha of skid trails • With RIL the			d'Oliveira, M. & Braz, E. 1995

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	that the growing stock is maintained at a desirable level				number of damaged trees (dbh >10 cm) per tree logged was 5.3 (or 0.27 m^3 damaged per m^3 extracted)			
Brazil	• This study was carried out in the Amazon region of Brazil, testing the applicability of the *FAO Model Code of Forest Harvesting Practice.*		• Harvesting cycle of 25 years · The average harvesting intensity is 35m^3/ha with a maximum of 40m^3/ha (about half of the average harvestable volume per hectare found for the project area) • RIL: the timber removal amounted to 33% of the volume found by the commercial inventory prior to harvesting (equals 26% of the trees of commercial interest) • CL: timber removal amounted to 73% of the volume and 69% of the trees of commercial interest.	• The total timber losses amounted to 8.5% in the CL area and 3.9% in the RIL area. • In both units losses due to skidding or caused by forgotten, unextracted logs did not occur since all trees had been numbered.	• Severe harvesting damage to potential crop trees was found to be more than twice as high with the traditional logging system (51.5%) as compared to the environmentally sound forest harvesting system (22.2%) • RIL: skid trials occupied 4.2% of he total area, whereas in the CL system the affected area amounts to 18.7% • RIL caused canopy gaps totalling 10.8% of the area while CL resulted in canopy gaps on 24.7% of the area		• Referring to the costs of CL per cubic metre of saw log at landing site as 100%, the costs of RIL come to 109% and would amount to 101.5% if RIL had been carried out according to the planned changes	FAO 1997c
Brazil	• Currently the study site is managed for the production of commercial timber, palm hearts and honey.		• Harvesting reduced the stand density from 851 to 645 trees/ha (basal area reduced from 48.5 to 29.2 m^2/ha), • A cutting cycle of 12 years at 25% harvesting • The annual harvesting rate would equal 2.56 m^3/ha intensity appears to be sustainable	• Harvesting intensities of up to 25% of the basal area ensure sufficient regeneration of primary forest tree species.			• A comparison of management scenarios for a forest area of 2208 ha indicated that sustainable management practices result in a present value of US$ 2.2 million compared to US$ 5.6 million with timber exploitation.	Hering, K.G. 1993
Brazil	• Study of RIL with vine cutting 18 months prior to logging • Directional felling made 85% of the			• Improved skidding operations resulted in less forest damage,	• RIL looked much better, skid trails had good			ISTF 1995

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	felled trees easier to skid · vine cutting, directional felling and removal of buttresses clearly helped reduce damage and increased skidding efficiency • The potential impact of an industry conversion to RIL is enormous • Adoption of RIL throughout the tropics would result in more efficient use of production forests which in turn would reduce pressure on primary forests • IMAZON results suggest costs may be reduced by one-third with RIL			less timber extraction time and lower extraction cost, than in the conventionally logger area	regeneration and canopy cover, the canopy openings looked very similar to natural tree fall gaps			
Brazil							• RIL: the main costs arise in the planning stage • RIL could result in a net financial benefit of US$ 3.70 per m^3 (Barreto *et al.*1998)	Sist, P. 2000
Brazil	• The study was carried out in floodplain forest • RIL: logs are floated out of the forest (few environmental impacts)		• RIL: highly selective harvest, with only 1-2 trees/ha removed • CL: harvesting intensity >10 trees/ha (50 species harvested) • With RIL sustainable cutting cycles might be reduced from 70-100 years to 30-40 years • Cutting cycles of 50 years and harvesting intensities of 5 trees/ha were proposed	• CL: approximately 30% of each harvested log is converted into sawn wood. • Processing efficiency could be increased to nearly 50% through simple improvements in machinery maintenance and by training the workers	• Logging often changes to high impact practices as frontiers age and infrastructure and access to markets improve • RIL: 25% reduction in the ground area affected by machine movements • Vine cutting two years before logging, resulted in a 30% reduction in damages to trees >10cm dbh	• CL: 7 m^3/ha are felled but never found by the skidder operator • CL: Waste associated with felling and bucking could be reduced to 30% by training loggers	• RIL has an added cost of US$ 50 /ha for forest inventory, vine cutting and careful planning • The monetary losses from CL through unnecessary wood waste may be greater than the additional costs of implementing RIL • Machine operation time could be reduced by 20% through implementing RIL	Uhl, C., Barreto, P., Verissimo, A., Vidal, E., Amaral, P., Barros, A.C., Souza, C. Johns, J. & Gerwing, J. 1997
Brazil	• Objectives were to determine vine species composition, stem densities, and the abilities of different vine species to resprout following cutting				• Vine cutting prior to logging can reduce logging damage		• Vine cutting costs approximately US$ 16 per hectare. • This is equivalent to 8% of the profits of a typical logging-only operation • These costs could be reduced by	Vidal, E., Johns, J. Gerwing, J.J., Barreto, P. & Uhl, C. 1997

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							focusing efforts on aggressive species likely to cause problems	
Brazil (Amazon)	• The results of the CELOS Silvicultural System Study were applied to 80,000 ha • The basal are of the initial stand was 30 m^2/ha.		• Felling cycle of 20-30 years · The maximum harvesting intensity was 30m^3/ha • The target diameter is 60cm dbh • Where forest management proceeds towards classical selection felling in succeeding cycles, the frequency of harvesting may be increased to 5-10 years, with a low volume taken per ha.	• Applying RIL for production of marketable timber without any further steering of forest development will probably result in a steady decrease in standing volumes of timber of marketable species.	• It is estimated that about 5% of the area is influenced, mainly by compaction , by machines, mostly due to permanent infrastructure (skidding trails, log landings, truck roads)		• The cost per m^3 of standing round wood produced is in the order of half a man-day.	de Graaf, N.R. 2000
Brazil (Amazon)	• This study was designed to evaluate long-term impacts on soil properties in areas harvested with a selection system.		• An average of 16 trees/ha was harvested (equal to a volume extraction of 75 m^3/ha) • Cutting limits of 55cm and 45cm dbh respectively were applied		• 16 years after harvesting, 99% of the area were classified as minimally disturbed, 1% as skid trails • Bulk density data indicated that soils remained compacted in all disturbance classes after 16 years			McNabb, K.L., Miller, M.S., Lockaby, B.G., Stokes, B.J., Clawson, R.G., Stanturf, J.A. & Silva, J.N.M. 1997
Brazil (Eastern Amazon)	• Study compared the net present value for 20and 30 year cutting cycles with and without forest management		• The logging intensity ranged from 35 to 40 m^3/ha • With RIL, 68% more timber volume could be extracted over a 30-year period		• RIL techniques reduce damage to the forest, leaving a well-stocked stand.	• CL: 26% of the volume of felled timber was wasted • RIL: 1% of felled timber was wasted	• The cost to plan logging operations was estimated as US$ 72/ha or US$ 1.80 - 2.50/ m^3 • RIL operation resulted in financial benefits of US$ 3.7/m^3, (2x cost of planning) • Using discount rates from 6 to 20%, the net present value of timber extraction were 38 to 45% with RIL	Barreto, P., Amaral, P., Vidal, E. & Uhl, C. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Brazil (Eastern Amazon)			• 20, 40 and 60% of all trees over 40cm dbh were harvested		• Restricting vehicles to designated trails significantly reduces the total area affected • Signs of soil compaction were found 12 years after skidding		• The position of the log after felling is directly correlated with the operational productivity	FAO. 1997b
Brazil (Eastern Amazon)	• By reducing the size of logging gaps RIL techniques can reduce the risk of fire		• Cutting cycle of 30-50 years were applied • Extraction intensity 30-40m^3/ha		• RIL reduced the mean size of canopy gaps by 53% relative to CL.		• RIL: US$ 50/ha are required to carefully plan and execute logging operations	Holdsworth, A.R. & Uhl, C. 1997
Brazil, Amazon	• Várzea • Terra firme		• Logging intensity averages 4-5 trees/ha • Logging intensity of 4-5 trees/ha	• Loss of only about 5% of standing trees • Total loss of 60% of standing trees due to heavy equipment, landings & roads				Ayres, J. & Johns, A. 1987
Brazil, Amazon	• Para State • Small sawmill LRF 35.1% • Medium sawmill LRF 34.3% • Veneer and plywood mill recovery • 37.2% with logs floated from as far as 2500 km		• In the Varzea forest the average logging intensity is 56 m^3/ha (N. Maciel, pers.comm. 1994) • In terra firme forest the average logging intensity is 38 m^3/ha (Verissimo *et al*. 1992)					Barros, A. & Uhl, C. 1995
Brazil, Amazon	• Para State • Wood waste and increased canopy openings increase fire risk • Wood processing industry is old and inefficient • Conventional logging gives 30 m^3/ha @ 35% lumber recovery or 10.5 m^3/ha of lumber, while planned logging and more efficient processing gives 38.3 m^3/ha @ 50% lumber recovery or 19.2 m^3/ha of lumber (increase in product yield of 83% per ha)		• Felling intensity typically 30 m^3/ha (volume extracted)	• Majority of trees found were buried under the crowns of other trees or isolated from other timber trees (i.e., lack of map for skidder showing locations of felled trees)	• In conventional logging 28.7 trees (dbh >10 cm) were damaged per tree felled, compared to 20.5 trees with planned operation • In conventional skidding 11.5 trees were damaged for each log skidded, compared to 4.4 trees damaged per log skidded in planned operations	• In three previously logged sites 6.6 m^3/ha of usable timber was felled but never skidded (represents 1 tree/ha) • Other waste was high stumps, improper felling so log splits, bucking too far from top (these losses totalled 0.41 m^3/tree or 2.3 m^3/ha or 7% of the harvestable volume • With a trained		Gerwing *et al*. 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
						feller and directional felling similar losses were 0.11 m^3/tree or 1.7 m^3/ha less wastage		
Brazil, Amazon	• Terra firme forest		• Logging intensity 35 m^3/ha					Ivo *et al*. 1996
Brazil, Amazon	• Terra firme rain forest • Amazonas State • Initial stand basal area 35 m^2/ha		• Logging during 1975-1985 with a logging intensity of 3-5 trees/ha	• Forest had regrown over 11 years to a basal area of 15 m^2/ha	• Considerable damage at the time due to careless placement of skid roads			Johns, A. 1991
Brazil, Amazon	• Amazon floodplain • Selective logging in high density *Virola* stands • Logging of *Virola* destined to be a short-lived activity in the Rio Preto basin		• Estimated that 145 m^3/ha of *Virola* are removed with current logging operations	• First logging started with removal of larger trees (dbh >45 cm) for plywood production, followed successive logging by saw millers removing material <30 cm dbh • Minimum felling limit for *Virola* supposed to be 45 cm dbh • After 5 years of logging the understorey consisted of a dense secondary community dominated by vines and herbs • *Virola* basal area plummeted from 24.6 m^2/ha to 2.3 m^2/ha after the first year of logging, and over a 5-year period seedling density per m^2 declined from 2.3 (year 0) to 0 (year 5)				Macedo, D. & Anderson, A. 1993
Brazil, Amazon	• Amazon forest, clay soils and slopes 0-25%		• A 100% inventory of trees >50 cm dbh yielded 18.7 m^3/ha of commercial volume (12.5 m^3/ha plywood logs, 1.0 m^3/ha veneer logs, 5.2 m^3/ha saw logs, and 4.1 m^3/ha of non- commercial species)					Malinovski, J. 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Brazil, Amazon	• Silvicultural treatments (e.g., climber cutting, crown liberation thinning) at 10-year intervals are prescribed in new regulations		• Average logging intensity of 40 m^3/ha recommended • Minimum cutting cycle of 20 years was initially accepted, although 30-40 years may be more realistic in practice					Silva, J. 1992
Brazil, Amazon	• Tapaajos Region, Central Amazon · volume increment was 1.6 m^3/ha/a in unlogged and 4.8 m^3/ha/a in logged forest							Silva *et al*. 1996
Brazil, Amazon	• Várzea forests (wet, flood areas) • Average tree diameter at stump height was 1.1 m, average height was 44.4 m and average log volume was 11.1 m^3 • Sustainable tropical forest management requires economically and environmentally acceptable harvesting practices		• 140 m^3/ha of all trees with dbh >20cm, but only 43 m^3/ha of potentially commercial species	• Estimated diameter of selected trees at least 50 cm • Stump height always above 1.5 m, but could be higher depending on the buttress	• Gap size after felling averaged 845 m^2, or twice that in the terra-firme forest			Stokes *et al*. 1997
Brazil, Amazon	• Paragominas region • Of all the options for economic development in the Amazon region, the selective harvest of valuable timber species on a rotational basis is one of the most ecologically sound • Fires set to control weeds in adjacent degraded pastures spread readily into and through poorly logged forests causing extensive damage, but fires reaching the edge of unexploited forests quickly die out (penetrate only a few metres) • Careless logging of a fire-resistant ecosystem changes it to a fire-prone ecosystem			• Although regeneration occurs rapidly without further disturbance, poorly done selective harvesting leaves the forest in an open, fuel-rich, fire-prone state				Uhl, C. & Buschbacher, R. 1985
Brazil, Amazon	• State of Para • Entering an era in which fire will be a dominant disturbance in rain forest regions		• Logging intensity in study area 50 m^3/ha	• Woody debris input exceeded 150 m^3/ha due to careless logging • The opening up of the canopy (>50% gap area) allows the fuel to dry during the dry season to a point that it will burn (e.g., 5-6 rainless days)				Uhl, C. & Kauffman, J. 1990

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Brazil, Amazon	• Paragominas region of the State of Para • Terra firme forest with about 100 trees species/ha (>10 cm dbh), 25-35 m tall, basal area 20-30 m^2/ha and above ground biomass of 250-300 t/ha • Brazilian forests normally only have 5-20% of their area in a gapped condition at any one time • Severe damage to mid-size trees (20-50 cm dbh) caused by careless logging, and elevated probability of windfall and ground fires in these logged stands, suggests relatively long rotation times of 75 to 100 years before the next crop can be harvested • In reality once loggers provide access to the Para forest, ranchers and land-hungry settlers follow close behind foreclosing the possibility of future timber harvests • Structural reforms in regulation, enforcement and forest tenure are required to halt the reckless use of the forest timber resources in the Amazon		• Logging intensity typically 30-50 m^3/ha (4-8 trees/ha or 1-2% of all tree stems >10 cm dbh) of 30-60 species • First study area 52 m^3/ha extracted (1.7% of all trees >10 cm dbh) • Second study area (52 ha) • Logging intensity 31 m^3/ha (4.3 trees/ha)		• 700 m of tractor trail in the 6.8 ha area or 13 m/ha • 178 m/ha of tractor trail and 8% of total area was scarred (some places >20%) • Primary trail were 12 m wide and 1670 m were built (32 m/ha); secondary trails 3 m wide and 5380 m built (103 m/ha); tertiary trails 2.2 m wide and 2180 m built (42 m/ha) • 26% of all trees existing prior to harvest are killed or severely damaged (12% lost their crowns, 11% were uprooted by bulldozing, 3% had severe bark damage which may eventually lead to mortality) • 16% of the stand basal area was extracted, while an additional 28% was destroyed or severely damaged • Forest canopy cover was reduced from 80% to 43% • Removal of only 3-5 m^2/ha resulted in 34% reduction in basal area (usually 20-30 m^2/ha in pre-harvested stands)			Uhl, C. & Viera, I. 1989
Brazil, Amazon	• Tailandia • 2-3 m^3 of logs required to produce		• Average 2 trees/ha (16 m^3/ha) were extracted in three	• 0.37 trees/ha were not extracted due to defect (usually rot)	• On average 56 m of logging road were constructed			Uhl *et al.* 1991

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	1 m^3 of sawn wood • 15 months after logging had ceased, logging openings contained an average 63 seedlings of timber species • An average 127 m^3/ha of harvestable wood was present in the logged stands, which were then often burnt by colonists to create farms		study area (each about 16 ha) • 16 m^3/ha extracted + 3 m^3/ha felled but left + 18.6 m^3/ha destroyed = 37.6 m^3/ha bole volume loss		for each tree harvested · on average 5.8% of the area was cleared to establish logging roads and landings • On average 126 m^2 of forest were cleared next to each cut tree to allow room for the equipment to manoeuvre • 52 trees/ha (dbh >10 cm) were damaged or 26 trees/tree extracted • Half the trees damaged were in gaps, while the other half were on roads and landings .loss of canopy cover averaged 8.1% • 1.2 m^3 of wood was destroyed for each m^3 harvested			
Brazil, Amazon	• In the Amazon, as elsewhere in humid tropics, timber extraction is done carelessly and has significant impacts on forests, leading to severe canopy loss, increased likelihood of fire, and vine and grass invasion • Timber is undervalued and thus used carelessly • Sawmill yield is only 33% of each harvested log, but could easily be increased to 50% through simple improvements to equipment maintenance and worker training • By increasing logging efficiency, forest management and processing efficiency, companies would only need a third of the forest land they require now for the same sawn wood output		• Logging intensity of traditional small-scale logging in Várzea and terra firme forests is 1-3 trees/ha · logging intensity of larger high impact logging is 5-10 trees/ha • Logging in Para State covers about 4000 km^2 annually to produce about 8 million m^3 = 20 m^3/ha logging intensity • With RIL the cutting cycle can be 30-40 years, otherwise it will need to be 70-100 years			• One or more trees per hectare (amounting to almost 7 m^3/ha) are felled but never recovered by the skidder operation • Trained loggers were able to achieve a 3 times reduction in waste associated with felling and bucking (cuts closer to ground and reduced butt splitting)	• Machine operating time reduced by 20% • Cost associated with extra inventories, mapping and vine cutting is about US$50/ha • Cost savings from more efficient use of equipment and better wood utilization could be greater than the planning cost	Uhl *et al*. 1997

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Brazil, Amazon	• Paragominas • 238 sawmills studied with a lumber yield of 47% (2.13 m^3 round wood per 1 m^3 of sawn wood) • Natural tree falls in region open gaps 150-300 m • Early 1970s only a few high-value species harvested and forest impacts were small • 20 years later more than 100 tree species harvested • Annual dbh growth of 0.8 cm/a in managed stands (vine cutting and thinning), and 0.3 cm/a in unmanaged stands • Just considering commercial species the increased yield in managed stands after 35 years is 22 m^3/ha • Management cost would be about US$5/$m^3$ extracted, but loggers only pay stumpage of US$1-3/$m^3$ extracted		• On 3 sites average logging intensity was 6 trees/ha or 38 m^3/ha (range from 2.9-9.3 trees/ha and 18-62 m^3/ha) • Typical logging intensities range from 20-50 m/ha		• Opening about 40 m (218 m^2 of scraped ground surface per tree harvested) of logging road and 663 m^2 of canopy opening per tree harvested. • 27 trees (dbh >10 cm) were severely damaged for each tree harvested (150 trees/ha damaged), 48% uprooted, 41% broken stem, 11% severe bark damage • Tree damage did not increase in direct proportion with logging intensity (e.g., 18 m^3 extracted in area 1 damaged 5 m^2 of basal area, while in area 3, 3 times more wood extracted but basal area damage increased only 50% (7.5 m^2)			Verissimo *et al*. 1992
Brazil, Amazon	• Mahogany extraction • One band sawmill will on average produce 4500 m^3/a of mahogany sawn wood from 9900 m^3 of round wood (45.5% yield) • After logging there is a growing trend to convert forests to cattle pastures		• On average 5 m^3/ha of mahogany extracted (1 tree/ha) • The logging cycle for mahogany may be as long as 80-100 years when relying on natural regeneration	• Future mahogany cuts are in doubt; only 0.25 mahogany tree/ha of at least 30 cm dbh found on recently logged sites and no trees between 10-30 cm dbh (mahogany seedlings were also rare) • After mahogany logging volume still remaining was 31.3 m^3/ha of sawable wood, 13.1 m^3/ha in the potential use category, and 51.3 m^3/ha without wood-related uses	• About 1100 m^2 of forest ground was scraped clean or trampled for each mahogany tree extracted • 31 trees (dbh>10 cm) were severely damaged for each mahogany tree extracted			Verissimo *et al*. 1995

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Brazil (Amazon)	• This study is a follow-up to a previous study in this series (Winkler 1997). • Both studies were undertaken in a managed natural forest near Itacoatiara, in the Amazon region of Brazil. The two studies were conducted in collaboration with precious Woods Amazon (PWA). • The purpose of this re-examination was to assess the condition of the forest four years after logging had been completed. • Assessments were undertaken of regeneration within felling gaps and on skid trails, water infiltration rates on skid trails, the current status of potential crop trees and the condition of residual trees of commercial species. • Two plots, one treated with "conventional" logging techniques and the other with "environmentally sound" harvesting system were examined.							Wellhofer, S. 2002
Brazil, Amazon	• Test of environmentally sound forest harvesting. Detailed inventory, mapping and climber cutting 2 years in advance of cutting work studies showed that felling productivity did not decrease with the planned changes from traditional logging • In traditional logging a crawler tractor or skidder have no plan and drive throughout the stand searching for logs		• Logging intensity 35-40 m^3/ha (about half of the average harvestable volume of commercial species per hectare) • Logging cycle of 25 years	• 71.7% of potential crop trees undamaged	• 100 m spacing between skid trails planned • In RIL areas the skid trails were 3.5 m wide, 1200 m in length and covered 4200 m^2 • Traditional skid trails 4.98 m wide, 2646 m in length and covered 13177 m^2 • In RIL area roads, skid trails and landings covered 4.5% of area • In traditional logging area roads, skid trails and landings covered 14.4% of area • Average gap opening 124.7 m^2 • In RIL, felling and bucking losses			Winkler, N. 1997

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					were 3.9% of utilizable stem volume, while in traditional logging it was 8.5%			
Brazil, Eastern Amazon	• Paper outlines RIL in detail and improvements possible • With the implementation of RIL authors feel overall profits will be increased based solely on the short-term costs		• With planned harvesting subsequent logging intensities will be the same as the first (38 m^3/ha) on a 30-year cycle, while in unplanned harvesting it is estimated to be 17 m^3/ha on a 30-year cycle		• For each commercial tree felled, unplanned logging damaged 16 more trees with dbh >10 cm and affected a ground area that was 100 m^2 greater than in planned logging operations Unplanned vs. planned • = severe crown damage 7.4 vs. 4.5 trees/tree felled; • = trees smashed to the ground 7.2 vs. 4.9 trees/tree felled			Johns *et al.* 1996
Brazil	• Research on RIL in select tropical forest regions has demonstrated clear ecological benefits relative to conventional logging (CL) practices while the financial competitive-ness of RIL is less conclusive. • We conduct a comparative analysis of financial returns to one and two cutting-cycle logging entries for representative RIL and CL operations of the eastern Amazon.						• Despite the perceived investment risks, RIL harvesting operations generate competitive or superior returns relative to CL for a wide range of discount rates due to gains in harvest efficiency and forest conservation.	Boltz, F., Carter, D., Holmes, T. & Pereira Jr., R. 2001
Brazil			• Two scenarios are studied, one with reduced impact logging (RIL) and sparing of reserves without silvicultural follow-up in a 100-year cycle option needing four times as much land as the 25-year cycle option.				• A cash flow analysis over the 100-year period for both options with an 8% discount rate shows that the total costs on the land-intensive option (25 years) with silviculture are considerably less than in the land-	De Graaf, N., Filius, A., Huesa Santos, A. 2003

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							extensive option; the lower cost of infrastructure, log transportation and land acquisition offset the cost of silviculture. • Because the annual revenues from timber sale are the same in both options, the NPV of the intensive option is also much higher. • A sensitivity analysis shows that the land-intensive option is expected to give still a positive NPV in less favourable situations.	
Brazil	• In eastern Amazonia permanent plot studies, forest fuel moisture measurements, and hemispheric canopy photographs were used to study the impacts of fire on a selectively logged forest, the microclimatic conditions that foster forest fires, and the measures that loggers might take to reduce fire incidence. • In a recently logged forest, large logging gaps (>700 m^2) reached fire susceptibility after 6 days and medium sized logging gaps (≈200 – 700 m^2) reached fires susceptibility after 15 days. • Special low-impact logging techniques remove the same amount of timber as do the more typical high impact logging techniques, but fire is significantly less likely because the more careful operation avoids the creation of large logging gaps, the most fire susceptible areas.			• In large logging gaps the density of regenerating pioneer species increased by >60% in burned plots 15 months after the fire, while it decreased by >40% in unburned plots.	• Significant tree mortality followed a typical ground fire in a selectively logged forest. • Forty-four percent of all trees ≥ 10 cm in diameter at breast height died in a burned plot while only 3% died in an unburned plot.			Holdsworth, A. & Uhl, C. 1996
Brazil	• Indicators of financial performance for three case studies in the Brazilian Amazon are compared. • Case study results were disaggregated into common	• RIL investments in inventory, planning, vine cutting and				• At Fazenda Cauaxi, CL operations wasted 4.08m^3/ha and	• CL sawyers were 10 to 22 percent more productive in volume produced per hour (m^3/hr)	Holmes, T.P., Boltz, F. & Carter, D. 2002

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	measures of productivity, cost and profitability. • The Case Studies used were 1. Agrosete: The RIL-CL comparison was conducted on private forestland of Fazenda Agrosete, approximately 20 km southeast of Paragominas, Pará, Brazil. RIL was conducted on a 105-ha plot and CL on an adjacent 75-ha plot. 2. Cauaxi: Research was conducted on private forestland of the CIKEL timber company of Fazenda Cauaxi, some 120 km southwest of Paragominas, Brazil. RIL was conducted by trained operators of Fundação Floresta Tropical (FFT) on 100 ha of undisturbed forest, while CL was implemented by local contractors hired by CIKEL on an adjacent 100-ha plot. 3. Itacoatiara: The study examined private forestland of Mil Madeireira Itacoatiara S.A., a Brazilian subsidiary of Precious Woods, Ltd., which is located 227 km east of Manaus. Efficiency and environmental impact studies were conducted in two adjacent 10-ha cutting blocks.	infrastructure development up to a year before logging increases the proportional cost of pre-harvest operations				RIL operations wasted 1.32 m^3/ha. • At Fazenda Agrosete, CL (RIL) operations wasted 8.83 m^3/ha (0.40 m^3/ha) in the forest. • At Mil Madeireira Itacoatiara, CL (RIL) operations wasted 2.99 m^3/ha (1.31 m^3/ha)	than comparable RIL-felling teams. • Skidding operations are more productive under RIL. • RIL utilizing rubber-tyre skidders increased productivity by 41 to 49 percent over CL bulldozer operations. • RIL operations incur costs associated with pre-harvest activities (block layout and line cutting, inventory, vine cutting, data processing and mapmaking) and harvest planning activities (tree marking, road planning, log deck planning and skid trail layout) that are not incurred by CL operations. • In addition, RIL requires special training of personnel that incurs costs beyond the on-the-job training received by CL operators. • RIL training costs comprise 1 to 18 percent of total harvest cost for CL and RIL operations. • RIL direct costs [16] (in US$/ m^3) ranged from 3 percent lower to 34 percent higher than CL direct costs. • When direct and indirect waste costs	

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							are accounted for, RIL net revenues are 18 percent to 35 percent greater than CL net revenues	
Brazil	• A comparison of costs and revenues was made for typical RIL and CL operations in the eastern Amazon. • An economic engineering approach was used to estimate standardised productivity and cost parameters. • Detailed data on productivity, harvest volume, wasted wood and damage to the residual stand were collected from operational scale harvest blocks. • Productivity and cost data were also collected using surveys of forest products firms.						• RIL was less costly, and more profitable, than CL under the conditions observed at the eastern Amazon study site. • Full cost accounting methods were introduced to capture the direct and indirect costs associated with wasted wood. • The impact of wasted wood on effective stumpage price provided the largest gain to RIL. • Large gains attributable to RIL technology were also observed in skidding and log deck productivity. • In addition, investment in RIL yielded an “environmental dividend” in terms of reduced damage to trees in the residual stand and reduction of the amount of ground area disturbed by heavy machinery.	Holmes, T., Blate, G., Zweede, J. Pereira Jr., R., Barreto, P., Boltz, F. & Bauch, R. 2002
Brazil	• This article examines the planning undertaken within the context of the ITTO funded project 'Integrated sustainable development of the Western Amazon based on resources'. • Three levels of harvesting are proposed and local people will be							Munoz-Braz, E. & d'Oliveira, M.V.N. 1996

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	trained to carry out the harvests. • The first two levels will prepare them to consider the logistical, technical, social and economic implications of the third level.							
Brazil	• Ground and canopy damage and recovery following conventional logging (CL) and reduced impact logging (RIL) of moist tropical forest in the eastern Amazon of Brazil. • Paired conventional and RIL blocks were selectively logged in 1996 and 1998.		• Harvest intensity was approximately 23 m^3/ha.		• Ground damage in the CL treatments occupied 8.9-11.2% of the total operational area as compared with 4.6-4.8% for RIL. • Blocks logged in 1998 had integrated canopy gap fractions of 21.6 and 10.9% of total area for CL and RIL blocks respectively. • Blocks logged in 1996 had 16.5 and 4.9% gap fraction for CL and RIL blocks respectively.			Pereira Jr., R., Zweede, J. Asner, G. & Keller, M. 2002
Brazil and Bolivia	• Many companies in Bolivia and Brazil have made substantial progress toward the adoption of RIL practices between 1995 and 2000. • In general, these companies have adopted the RIL elements that increase efficiency, reduce costs, improve marketing and enable companies to comply with the law. • Still lacking is implementation of the RIL elements that particularly benefit the forest, including directional felling and skid trail layout to protect future crop trees, minimal impact skidding and watercourse protection. • Many factors influence the degree to which companies are adopting specific RIL elements and these differ somewhat between Brazil and Bolivia. • In Bolivia, improving market access by becoming certified is probably the most important							Blate, G.M., Putz, F. & Zweede, J. 2002

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	reason why companies have adopted many RIL practices. • In Brazil, the most important factor driving RIL adoption has been the increased efficiency and cost savings derived from the adoption of the planning elements of RIL.							
Cameroon	• Littoral zone		• 1.05 trees/ha (dbh > 80 cm) extracted over a region of 474 km^2 (range 0.1-4.0 trees/ha)	• Mean gap size 400 m^2 (n=100) with damage or death to 5.2 adjacent trees >25 m tall, and 6.2 trees between 15-25 m tall • Less than 5% of trees had lianas	• Logging disturbance affects 8.4% of the area · 45.3 +/- 14.7 m of tractor trail per tree extracted • In 47 407 ha area 0.8% was compacted roadbed, 1.8% was road shoulder, 1.5% was trails and 4.2% was tree fall gaps (total 8.3%)			Bullock, S. 1980
Cameroon (Dimako)			• Harvesting intensities of >1 tree/ha on a 30 year cutting cycle recommended					Durrieu de Madron, L. & Forni, E. 1997
Cameroon (Dimako)	• Harvesting intensities of 0.5-1 tree/ha (5-15 m^3/ha) • A sufficient number of seed trees must be retained to provide for regeneration and biodiversity.		• Maximal harvesting intensity (A.P.I. de Dimako) was increased from 0.8 trees/ha (10m^3/ha) to 3 trees/ha (40 m^3/ha)		• Approximately 3% of the site is damaged during skidding operations • Main and secondary roads affect 1-2% of the area.	• Approximately 25% of the felled volume is left behind as waste or due to oversight.	• Governments should provide economic incentives for the implementation of RIL techniques	Durrieu de Madron, L., Forni, E. & Mekok, M. 1998
Cameroon (south)	• The study area is located on poor soils on the Central African Shield • The basal area is 34 m^2/ha		• The felling intensity ranges from 0.3 to 1.8 trees/ha	• The volume delivered to the sawmill was 70% of the amount felled	• 5.1% of the harvested area was disturbed (felling 1.4%, skidding 1.1%, road and landing construction 2.7%) • 30% of the damage due to roads and landings and 20% of the skidding damage could have been avoided	• Losses occurred during felling (21%), topping (7-10%), logs not found (4%) and cutting off both ends of the log to give the timber a better appearance (4%)	• Skidding restrictions following rain also reduced damage, but leads to losses of output in all production phases which may outweigh the benefits	Jonkers, W.B.J. & van Leersum, G.J.R. 2000

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					• Liana cutting did not have a noticeable effect on logging damage • Using the full range of RIL, damage to the residual stand could be reduced from 5 to 4%			
Cameroon	• The Tropenbos Cameroon Program (TCP) together with ITTO commenced a program in 1994: 'Development of methods and strategies for sustainable management of moist tropical forest in Cameroon'. • The study was conducted about 80 km east of Kribi in South Cameroon.	• Results indicated that improved planning, training and control could substantially reduce the area disturbed by skid trails and landings.		• Approximately 15% of harvestable timber was not harvested in the Wijma concession and only 70% of timber felled was actually delivered to the sawmill.	• Construction of roads and tracks should be avoided or minimized on slopes steeper than 10o to prevent excessive erosion. • Liana cutting before logging did not reduce the size of canopy gaps.	• Income could be increased by reducing waste.		Foahom, B., Jonkers, W.B.J. & Schmidt, P. 2001
Cameroon	• In the lowland rain forest in southern Cameroon, an experiment was set-up to test whether pre-felling climber cutting could reduce logging damage. • The abundance of lianas in the forest and their resprouting capacity after cutting was assessed. • Logging damage was considered as tree mortality and tree damage in the felling gaps and the sizes of the creates gaps after felling.		• The average harvest level in the study area was one tree or about 13 m^3 ha -1.	• Lianas were very abundant: on average nearly 5000 individuals (at breast height) of which over 100 large ones (≥5 cm DBH) per ha. • Some 70% of monitored lianas had died 22 months after cutting. • Resprouting capacity was high but variable among species.	• Felling gap sizes (average 550 m^2 per felled tree), tree mortality (12 trees per felled tree) and damage (20 trees per felled tree) were not significantly affected by pre-felling climber cutting. • A minority of the damage was severe. ▪ Smaller trees were most prone to destruction and severe damage. • The results show that pre-felling climber cutting has no significant effect on resulting gap-sizes, tree mortality and damage levels.			Parren, Marc & Bongers, F. 2001

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Canada	• A 7-year monitoring study was established to evaluate the effects of careful logging on vegetation development in the southern boreal forest of Quebec. • A total of 255 sample plots (2 m^2) were located in seven cutovers in predominantly black spruce (*Picea mariana*) forests that were whole-tree "careful logged": 120 on fresh to moist silty clays or silty clay loams and 135 on dry to fresh loamy sands. • Three microsites were sampled: skid trails and the edge and the centre of protection strips.			• Softwood stocking 7 years after harvest after harvest (based on 2- m^2 plots), ranged from 69 to 74% on sites.	• A gradient of disturbance from the skid trail to centre of the protection strip was evident for finer textured sites. • Higher disturbance levels in skid trails favoured establishment of larch, raspberry and graminoids.			Harvey, Brian & Brais, S. 2002
Central Africa	• Field report of visit to two timber concessions in central Africa: CIB (Société Congolaise Industielle des Bois) and SBL (Société des Bois de Lastoursville). • Both CIB and SBL are at an early stage in the process of developing comprehensive forest management plans for their timber concessions.	• Inventories will be carried out on a 1% sampling basis by both companies. • Regeneration surveys will be done at a lower sampling rate.				• Conversion ratios for both companies' sawmills average around 30%.		Dykstra, D., Toupin, R. & Othman, M. 2001
Central Africa	• A comparison between unlogged, 6-month and 18-year post-harvests forest stands indicates lasting effects of highly selective, high grade logging. • A better approach to manage timber zones for timber production and conservation would be an adaptive management approach based on increased species selection and canopy disturbance. • Zones targeting the conservation of closed forest obligate species should not be logged.			• Stem densities of both saplings and trees in unlogged forest were significantly higher than those in forest sampled 18 years after logging. • Evidence suggests inadequate recruitment of *Entandrophragma cylindricum* and *E. utile*, the principal timber species. • There will also be an abundance of other top quality timber species remaining after selective removal of African mahogany.				Hall, J.S., Harris, D.J., Medjibe, V. & Ashton, P.M.S. (in press)
Central America	• Generally 400 trees/ha with dbh >10 cm, and 40 trees/ha with dbh >50 cm • Can be 100-150 species/ha and with increasing wood scarcities			• Loggers paid based on the volume removed, therefore they only take out the best and largest logs			• Cost of detailed inventory for CATIE (RIL) is US$27/ha	Quirós *et al.* 1997

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	previously unutilized species are being increasingly logged • Lack of planning and control in logging operations and government paperwork and policies lead to illegal logging • Lack of integration between logging and the timber using industry, thus the industry has little incentive to control how logging is done			• This results in 20-25% of the cut volume not being extracted due to felling damage or poor quality • This type of material is suitable for supplying local markets through small-scale sawmilling				
Congo	• The study was carried out in a closed-canopy, broad-leaved forest located in southern Congo at the border to Gabon • An Inventory revealed an average density of 455 trees/ha of which 3.3% is Okoume (*Aucoumea klaineana*) • The average density of harvestable trees in the study area is less than one tree per hectare • The harvestable volume (80cm dbh) of Okoume is 11.8 m^3/ha (total volume of Okoume 37.5 m^3/ha)		• Harvesting intensity 5.8 m^3 (1 tree per hectare, target diameter 80cm dbh)	• The total recovery, expressed as net log volume compared to the standing stem volume (including stump, up to the first branch of the crown) is 70% • The average wood recovery rate is 86% after felling and 70% after crosscutting.	• Soil disturbance was recorded on 8.4% of the total area. Felling sites accounted for 3.8%, skid trails for 2.7%, secondary roads for 1.0%, primary roads for 0.7% and landings for an estimated 0.2% • The damage frequency for all species and size classes is 6.3% (17.7 damaged trees per felled tree) • The overall damage frequency for Okoume in all diameter classes is 7.2% and of those trees 40-80 cm dbh (immature future crop trees) it is 9%	• The loss of 14% of the volume during felling is in stump wood and in stem wood that does not meet quality requirements (stump wood is not considered usable).		FAO 1997a
Congo, Republic of	• Three 50 ha harvesting compartments studied • Under the prevailing conditions the observed forest operation could be called "low impact" since only 1 tree/ha was removed		• Average logging intensity 1 tree/ha or 5-6 m^3/ha • Average 455 trees/ha with dbh >10 cm • All Okoumé trees >80 cm dbh extracted	• Extracted log recovery was 70% of stem volume (includes stump and stem volume up to the first branch of the crown)	• Average skidding distance 403 m (crawler tractors used for short hauls and concentrating logs, while wheeled skidders used for the long haul to the landing) • A total of 8.4% of			Scharpenberg, R. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					the area had soil disturbance (felling sites 3.8%, skid trails 2.7%, secondary roads 1.0% and primary roads 0.7%) • Of the 8.4%, 0.8% was seriously disturbed skid trails and landings and 5.8% was slightly disturbed. on average 17.7 trees per tree felled (3 trees per m^3 extracted) were damaged during felling • The average number of skidding damaged trees was 11.8 per tree felled (11.5/ha or 212 trees/km of skid trail) • In total 29 trees/ha were damaged during logging (30 damaged trees/tree felled or 5 damaged trees/m^3)			
Costa Rica	• This study was carried out in the natural forests of Costa Rica • A polycyclic system was established in order to maintain irregular structure and species diversity		• The harvesting intensity for the first harvest in natural forests ranges from 40 to 60 m^3/ha • Secondary forests are managed on a 15 year cutting cycle with a harvesting intensity of 20 to 30 m^3/ha	• Up to 60% of the commercial volume may be extracted with a minimum harvesting diameter of 60cm dbh			• Additional costs are associated with the implementation of RIL ("buen manejo forestal") techniques	BOLFOR, IURFO & CIFOR 1997
Costa Rica			• Logging intensity was 6 trees/ha in oxen logged area and 7.33 trees/ha in tractor logged area	• In oxen logged area 1.3% of original stems extracted, 11.8% very severe injury or killed, 3.2% severe injury, 12.4% minor injury, 68.5% had no injury, and non-logging				Cordero, W. & Howard, A. 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
				damage was 2.8% • In tractor logged area 4.8% of original stems extracted, 19.2% very severe injury or killed, 0.9% severe injury, 14.1% minor injury, 60.7% had no injury, and non-logging damage was 5.3%				
Costa Rica	• Montane forest • Mean annual rate of mortality in unlogged forest was 2.2% (2.1% for 10-30 cm dbh trees, 2.8% for >30 cm dbh trees) • In lowland tropical forests the annual mortality rate ranges from 1-3%							Matelson *et al*. 1995
Costa Rica	• The commercial volume ranges from 90 to 1712 m^3/ha						• With a total sales price of US$ 80.39, the planning process accounts for costs of US$ 2.99/m^3 • The total management costs are US$ 129.58/m^3 • Average labour costs are US$ 2.39/m^3	Muñoz, R.R. 1997
Costa Rica	• This study was conducted in the Atlantic lowlands of northeast Costa Rica (poorly drained swamp forest) to evaluate a selective logging system		• Harvesting was limited to trees of at least 70cm dbh, 10cm above the legal limit in Costa Rica • Extraction intensity averaged 6.3 trees/ha for 28ha and 45.8 m^3/ha for a 7 ha sub-sample	• Felling, immediate residual mortality and skid trail construction reduced the basal area by 18.3% • Canopy cover averaged 91.4% in undisturbed plots and 73.4% in logged forest. • The relationship between extraction intensity and post-logging canopy cover was linear	• Skid trails covered 4% of the area · 17.6% of the residual stand was killed or damaged during logging (12.4% damaged, 5.2% killed) • Severe damage (trunk snapped or uprooting) usually did not occur to trees >50cm dbh • Moderate damage types (canopy damage, bark removal) were relatively more frequent in size classes of >40cm dbh		• Logging gaps with a low commercial value can comprise a substantial proportion of improperly managed forests	Webb, E.L. 1997

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					• The relative level of damage during controlled logging did not appear to deviate substantially from uncontrolled logging operations			
Côte d'Ivoire	• Productivity restored 9 years after logging and with the protection from brush fires the number of new stems increase 2.3-2.5 fold • Increase in productivity from 1-1.5 m^3/ha/a to 2-3 m^3/ha/a (regions 700 mm rain per year) and 3-3.5 m^3/ha/a (regions up to 1500 mm rainfall per year)							Catinot, R. 1994
Costa Rica	• Compatibility of different commercial uses of a montane tropical oak-bamboo forest in Costa Rica was assessed for selective logging and harvesting of non-vascular pendant epiphytes. • Nine years after selective logging no negative impacts were detected on the biomass of these epiphytes at 1-3m range (the heights at which they are harvested).							Romero, C. 1999.
Costa Rica	• The study was conducted in the Cordillera de Talamanca, Costa Rica, at the Villa Mills experimental site administered by CATIE. • Jan 1991 – July 1992, controlled logging applied to 21 ha. • Area divided into nine 1 ha plots, separated by 20-25 m wide buffer strips. • Two logging treatments were randomly assigned to 4 replicate plots per treatment (total of 8 plots), plus a single control plot. • Height and diameter growth were assessed 5 years after logging along with individual survivorship of juveniles. • Target species – *Quercus costaricensis, Q. copeyensis, Drymis granadensis, Ocotea austinii, Weinmania pinnata*.		• The treatments consisted of extracting 20 (light) and 30% (moderate) of the stand basal area (stems ≥ 10 cm DBH).		• For seedlings, the overall 5-year mortality rate (exponential model) was significantly higher under the lightest harvest intensity while for saplings, no significant differences in mortality were detected among harvesting intensities.			Saenz, G. & Guariguata, M. 2001

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Democratic Republic of Congo			• Yield of exportable species is limited for marketing and ecological reasons to 6-10 m^3/ha on a 25-year cycle, where the forests have already been selectively cut • On newer concessions logging intensity can be expected to be 20-22 m^3/ha • If all species currently used by foreign and home markets are taken into consideration the yield could be 50 m^3/ha					Kelvin, A. 1993
Ecuador	• Tropical forests • Most common skidding equipment is large rubber-tired skidders • Safety is more or less disregarded • No communication between sawyers and skidder operators	• Through better planning and control of logging operations, increased productivity and reduced maintenance and repair cost would cover the planning and control costs, as well as inventory holding costs for the approx. five months of shutdown time required • Preplanned skid trails and directional felling can reduce the area covered by skid trails to 15% • If only advanced planning of skid trails and			• With haphazard operations 40% of ground surface area disturbed · in wet soil conditions bulldozers dig out trails to mineral soil to a depth of 0.25-0.5 m • On slopes over 10% trails are dug out even deeper in hope of getting better traction · in wet conditions damage is amplified and up to 75% of area can be covered by skid trails (trails used until troughs of mud 1 m or more in depth) • By confining skidders to skid trails and using the winch more, skid trails could be reduced to 4% of area		• When operating in wet conditions one company experienced a 100% increase in machine maintenance and repair cost, and productivity was only 15% of that in dry conditions· loggers receive no formal training in felling or bucking • With the use of proper felling and bucking techniques a 15-30% increase in wood volume at the mill could be realized	DeBonis, J. 1986

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
		wet-weather shutdown were implemented, most of the current skidding damage could be eliminated						
Fiji	• The local forest owners were capable of applying the prescribed activities. Tree selection was mainly based on silvicultural and ecological criteria.		• The harvesting intensity for RIL was 38.7% of the initial volume. With CL 81.6% of the volume were harvested					De Vletter, J. & Mussong, M. 1995
Fiji			• Logging intensity 40-50 m^3/ha (>35 cm dbh), from a total wood biomass estimated to be 250 m^3/ha		• 62% of area disturbed (45% light disturbance; heavy disturbance, skid tracks and skid roads 12%; landings and roads 5%)			Margules *et al.* 1987
Fiji	• The most favourable management concepts are *High Impact* and *Medium Impact Logging*. These options also ensure that non-timber forest products can be produced on a sustainable basis • For minimum risk, the ML option seems to be most favourable.		• CL: harvesting intensity <80% of volume of trees >35cm dbh (cutting cycle 45 years) • RIL: harvesting intensity 15 [LL], 35[ML] and 55% [HL] of volume of trees >35cm dbh (cutting cycle 10, 15 and 30 years respectively)				• CL: overall harvesting costs US$ 39.08/m^3 • RIL: overall harvesting costs US$ 37.52 to 41.24 /m^3 • Revenue: CL -2.52 US$/$m^3$, HL -0.10 US$/m^3, ML +0.74 US$/$m^3$, LL-1.16 US$/m^3	Mussong, M., Singh, K., Laqeretabua, J. & de Vletter, J. 1996
Fiji	• Study of two logging concessions with mixed tropical hardwoods • Payment rate based on production results in excessive logging damage, improper log bucking and other poor practices • 40 species utilized		• Stocking about 200 m^3/ha of which 50 m^3/ha is merchantable wood above the minimum felling limit of 35 cm dbh		• Surveys of the logging areas indicated that soil disturbance was moderate, but acceptable			Sundberg, U. 1987
French Guiana	• Average volume in area (>10 cm dbh) 350 m^3/ha and basal area 31 m^2/ha		• Base treatment removes 33 m^3/ha (2.6 m^2/ha of BA)					Bariteau, M. & Geoffroy, J. 1989
Gabon	• Lowland tropical forest in the Lopé Reserve • In 1988 estimated that 46% of Gabon's forest had been selectively logged at least once, and each year about 2500 km^2 is		• Logging intensity 1-2 trees/ha using conventional logging with chain saw felling and crawler tractor extraction	• 26 trees >70 cm dbh felled, 23 extracted (2 missed and 1 was hollow), plus 5 killed during operations • Of the 175 stems dbh	• 2 trees >70 cm dbh killed during road construction • 1.4% of surface area covered by a major road, 5.0%			White, L. 1994

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	logged; 60% of which has not been previously logged • Extraction rates and damage levels in other parts of central Africa are similar due to the low logging intensity		• 70 cm minimum legal felling diameter for commercial exploitation • In 11.25 ha study area logging intensity 2 trees/ha	>70 cm 17.7% of stems and 20.6% of basal area removed (26 felled and 5 killed trees) · three trees >70 cm dbh killed during falling • For stems >10 cm dbh sample area 1.25 ha had 505 trees and 6 lianas • Basal area before logging 39.1 m^2/ha (408.8 stems/ha) and after logging 34.3 m^2/ha (364.8 stems/ha) • = 10.8% of stems lost, mostly due to incidental damage	covered by secondary extraction roads (6.4% of area bare and compacted) • 5.0% of surface area had skidder trails and 16.9% was covered by crowns of fallen trees • 71.7% of area was not physically altered by logging • On newer concessions logging intensity can be expected to be 20-22 m^3/ha • In adjacent area logged in 1986 roads covered 1.6% of site, skidder trails and secondary extraction roads made up 7.5% of site, and 51.2% of canopy suffered some disturbance • In adjacent area logged 10-15 years prior, roads accounted for 1.8% of area and skidder and secondary extraction trails 7.2% of area			
General					• On skid trails >15% side slope, blading causes excessive damage			Andrewartha, R. 1998
General	• Lesser known/utilized species • Danger in placing too much emphasis upon the development of new products and technology for lesser known species because it provides an excuse for not doing things properly today		• Logging intensity levels in southeast Asia and Latin America varies from 4 to 48 m^3/ha	• Final yield of product from a tree can be as lows as 10-20% and typically averages no more than 30%				Bethel, J. 1984

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
General	• Tropical moist forest		• A felling intensity of 5-8 trees/ha is considered to be sustainable for most types of tropical forests					Boerboom, J. & Wiersum, K. 1983
General	• Tropical secondary forests		• Wood production based on short-term measurements (1-2 years) are variable and range from 2-11 t/ha/a, which are greater than for mature tropical forests of 1-8 t/ha/a (all trees to 10 cm dbh)	• Factors to convert volume to wood biomass are 1.1 for dry and moist forests and 0.9 for wet forests (or biomass to volume 0.909 and 1.111, respectively)				Brown S. & Lugo, A. 1990
General	• Tropical rain forests • Conservation and management • Outlines advantages of RIL • Well-established knowledge from experience in temperate and tropical forestry that well-planned and executed timber harvesting costs less than haphazard and unskilled logging • Forest misuse and abuse remain rampant, over logging and underutilization persist in tropical forests and elsewhere		• With conventional logging (at least in Malaysia) future yields will be reduced to half or a third of the sustainable potential under proper selection felling systems • Harvest rates of 40-60 m^3/ha on a 25-year cycle as envisaged in Malaysia will certainly exceed the rates of replenishment of any of the nutrients • Lowering of felling limits to increase logging intensity must be avoided, should not be lower than 60 cm in dipterocarp forests • 30-60 m^3/ha removals on a >40 year cycle with RIL can be held as sustainable	• Over logging removes more than 50% and up to 80-90% of the canopy • Conventional selective logging as currently practised causes 70-80% damage to residuals, with only 10-20% of the basal area removed	• Conventional logging with crawler tractors 20-60% of the soil surface is loosened, moved or compacted • With excessive roading and skidding, and thus excessive compaction and erosion, felling cycles of 25-50 years are not sustainable, and 60-100 years is more realistic (even longer on poor soils)			Bruenig, E. 1996
General					• 15-35% of all residual trees damaged in polycyclic systems • 40-60% of all residual trees damaged in monocyclic systems			Bruijnzeel, L. 1992

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
General	• Fibre for virtually all pulp and paper and reconstituted panels can be derived from plantations and/or from heavily modified temperate forests • Tropical timber will increasingly change from a bulk commodity to an exclusive, high-value product for niche markets • Any interventions that reduce the commercial value of TMF will undermine the economic basis for their retention, thereby accelerating conversion to agriculture							Byron, N. & Perez, M. 1996
General	• Tropical moist forests • Smaller the volume logged the more elaborate and complete must the pre-harvest survey be				• Successful logging operations and a good network of trails depend essentially on a good pre-harvest survey		• Skidding operations represent 20-40% of the cost of wood delivered to roadside	Chauvin, H. 1976
General	• Implementing RIL can lead to a gain of as much as 50% in the "carbon storehouse" benefits from the remaining vegetation				• RIL: impacts to the soil from heavy logging machinery can be reduced by 25% • RIL: damage to advanced regeneration was reduced by 50% relative to CL			CIFOR 1998
General	• Amount of logging and mill residues generated in the tropics estimated to be 208 million m^3 or 89% of the total annual production of industrial round wood			• Estimated felling recovery rates • Africa 54% • Asia/Pacific 46% • Latin America and Caribbean 56% • total tropics 50% • Of all the industrial wood felled annually in the tropics 50% remains in the forest as unused residues			· Harvesting operations in natural tropical forests can reduce logging residues by 10-30% without a significant increase in harvesting cost	Dykstra, D. 1992
General	• Sufficient information exists to permit sustainable harvesting operations in virtually any area of tropical forest worldwide							Dykstra, D. & Heinrich, R. 1992
General				• Experience in training programmes to improve cross-cutting				Dykstra, D. & Heinrich, R. 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
				skills suggests that improved utilization of 20% or more and increased log values of 10-50% can be attained				
General	• It may be preferable to reduce the rate at which new areas are logged by practising more intensive logging in areas currently being harvested.		• In selection systems, individual trees are selected for harvesting in order to sustain yield. In contrast, selective harvesting involves cutting selected trees based on economic considerations without respect to sustained yield		• Van Gardingen (1998) observed an absence of regeneration of dipterocarp seedlings on sites with disturbed soils and in large logging gaps • Tropical forests are resilient to disturbances on a much larger scale than those created by single treefalls. (Lugo 1995)			Fredericksen, T.S. 2000
General	• Low forest revenues can result either from low forest fees, set at levels well below the value of the timber, or from low collection rates, the result of inefficient collection systems.			• Low forest fees, which mean that timber is under priced • Encourage poor utilisation of timber in the forest and inefficiency in utilisation in processing industries.			• Economic incentives and better designed forest revenue systems can contribute to and support RIL. Higher prices and values of tropical timber would make improved forest management economically attractive.	Gray, J.A., 1997
General	• If the costs of implementing RIL are at a level acceptable to the industry, then RIL will be widely adopted.		• Harvesting intensities are highly sensitive to the spatial distribution of commercial stems	• Stable supplies of currently marketed timber species will only be enhanced in stands where RIL techniques are employed if the resulting level of disturbance is consistent with the regeneration requirements of the target timber species.	• The interaction between slope, soil and stem size will constrain the achievable environmental benefits without further technological and financial inputs.		• RIL will ultimately fail to produce the expected benefits when harvesting levels overshadow the gains made through careful planning • Differences in topographical, soil and hydrological conditions will alter the savings made by RIL when costs of environmental impacts are	Hammond, D.S., van der Hout, P., Roderick, J.Z., Marshall, G., Evans, J. & Cassells, D.S. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							counted • RIL: The capital costs of equipment must be incorporated into the calculation of costs and benefits associated with better planning. • The spatial distribution of commercial trees has important effects on the expenses of foregone timber.	
General			• Possible action 13: the annual allowable cut (AAC) should be set conservatively in the case of absence of reliable data on regeneration and growth dynamics of tree species, especially in regard to diameter increment and response to the effect of logging on trees and soils					ITTO 1992a
General	• A certain level of RIL can be achieved simply through careful planning, scheduling and control of logging operations						• RIL cost US$2.05/$m^3$ and logging cost saving of US$2.47/$m^3$, resulting in an overall saving of US$0.42/$m^3$ • Also would be a substantial long term increase in timber yield	ITTO 1996
General	• A logging operator with only a short-term lease will be concerned only with a single cut and will not be motivated to minimize environmental damage • Lack of financial interest in the future crop is probably the main reason for the excessive damage levels typical of short-term extraction operations • In most tropical forests, the most		• Harvesting intensity in tropical forests varies considerably from 1 to 72 trees/ha depending on the forest type and country • Malaysian dipterocarp forest average 14 trees/ha, but up to 72 trees/ha extracted • Most Amazonian terra					Johns, A. 1992

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	effective form of forest management is undoubtedly protection and encouragement of advanced growth in optimally sized gaps created during logging, with planting of gaps where no advanced growth exists		firme forests yield 3-5 trees/ha (10-15 m^3/ha) • Some African forests as lows as 1.1 trees/ha · in the 1980s 8.4-13.5 m^3/ha in neotropical and African forests • In Asian dipterocarp forests generally 50 m^3/ha and in Sabah up to 110 m^3/ha					
General	• Report on state of logging in the tropical moist forests (TMF) based on a literature review and site visits • TMF can be sustainably managed for timber and non-timber products, however, systems for sustained management of TMF are rarely implemented in practice • RIL methods are well known but not implemented • If a bulldozer is oversized there is a temptation for the operator to use power instead of skill, while if it is undersized too much winching and equipment manoeuvring, and thus increased cost and impact can result		• A compartment within a concession should be logged at one occasion and then closed off to allow the forest to recover: i.e., 30-40 years • Re-entry prior to the full logging cycle to harvest another species should be prohibited				• Theoretical simulations of cost and yield showed a 20% reduction in cost through improved logging practices, with 5 m^3/ha (7%) more volume (logging intensity 60 m^3/ha) could be extracted through improved felling and bucking techniques	Jonsson, T. & Lindgren, P. 1990
General	• Directional felling is done to minimize damage to the log and residual stand, and to facilitate log extraction • Direction felling is more time consuming than haphazard felling, but gains in these three areas will almost certainly outweigh the costs							Klassen, A. & Cedergren, J. 1996
General	• Sustainable management of tropical forests • Loggers are often ignorant and not aware of how the economy of their operations benefits from using more efficient and better adapted machines and work methods							Lindgren, P. 1992
General	• Tropical mixed forests • Growth of volume actually commercialized for mixed forests is between 0.1 and 0.5 m^3/ha/a		• Logging intensities in Latin America 8 m^3/ha/entry, Africa 13 m^3/ha/entry and Asia dipterocarp 40-100 m^3/ha/entry, and	• Common to find 40-70% of the advance growth destroyed in the harvesting process, leaving only 12-33 stems/ha for the				Masson, J. 1983

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			overall average 37 m^3/ha/entry	next cut • Very heavy damage (70-100%) can be expected when basal area extracted rises about 12 m^2/ha				
General	• Tropical high forests · harvesting operations utilizing detailed planning cost 20-45% less than comparable operations with minimal planning • Found that better planning had better organization and supervision, fewer accidents, fewer merchantable trees left unfelled and few logs lost after felling							Mattsson-Marn, H. & Jonkers, W. 1982
General	• Tropical moist forests • The impact of tropical downpours causes substantially more soil erosion than anywhere else in the world, thus need to maintain cover • Need to have a cautious approach in the use of TMF							Myers, N. 1983
General	• Product yields that can be generally expected are: • sawn wood 56-68% • plywood 50% • wafer board 75-80% • strand board 85-90% • particleboard 90-95% • thin particleboard 100% • high density fibreboard 95% • medium density fibreboard 85-90% • plywood substitutes will result in better forest utilization							Niedermaier, P. 1984
General	• One of the many paradoxes of tropical forestry over the past 30 years is that the rise in public interest has been paralleled by a decline in the application of systematic management • Another paradox is that the same period has seen a great increase in research on tropical biology but little corresponding incorporation of research results into management practice • The absence of security and tenure discourage forest managers from investing time and		• Control of harvesting operations is the most important condition for sustainable management after the long-term security of the forest itself	• Re-entry - the return of loggers to take previously non commercial species or sizes, which was demonstrated to be highly damaging to regeneration more than 35 years ago • Is still a problem in many countries	• While the merits of various forest management systems are being debated, tropical silviculturalists are of one voice in advocating the use of RIL techniques			Palmer, J. & Synnott, T. 1992

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	money in management for future production and often led to such investments being lost							
General	• Ecological guidelines for the management of tropical moist forests • Management of natural forests is preferred over plantations · where options still exist, countries should attempt to derive the maximum of their timber needs from a managed "natural forest estate"				• Tropical soils are highly susceptible to degradation, particularly if they are physically disturbed or exposed to sun or the direct impact of heavy tropical rainfall			Poore, D. & Sayer, J. 1987
General	• It can not be assumed that timber production in tropical forests is feasible in a sustainable manner considering the ecological and socio-economic components of sustainable resource management						• RIL will increase the initial costs of harvesting operations and therefore reduce the land value and revenue at least on the short run	Pretzsch, J. 1997
General	• Commercially exploited forests are important components of local, regional and global conservation and development strategies							Putz, F. & Viana, V. 1996
General	• The success of selective silvicultural systems depends very much on the quantity and quality of the future crop trees left after logging • The logger makes or unmakes the next harvest in the same area • The growth rate of residual trees has been reported to be about 3.2 m^3/ha/a • Various research results listed range from 1.6 to 8.6 m^3/ha/a				• Width of logging roads varies from 5 to 10 m, with the right of way extending from the road centre-line up to 15 m on both sides of main roads, and 10 m for spur roads • In high lead settings damage to residuals due to felling was 23-28% and yarding damage was 4-6% • In tractor skidding felling damage to residuals was 9% and skidding damage 2% • The higher felling damage in the high lead setting is probably due to working on steep			Rapera, R. 1978

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					terrain (>40%), where felled trees tend to roll more and thus cause more damage to residuals			
General	• "Natural forest management" [NFM] can be categorised as a polycyclic felling system		• Cutting cycle of 25-40 years was applied · In the conversion phase of primary forests, a large volume of mature timber is harvested. In the subsequent phase a constant, smaller amount of wood is cut at regular intervals.	• CL: little attention is paid to the condition of the residual stand • CL is unsustainable, because the forest will not yield another harvest of the target species for a long time, if ever.	• Where the topography is flat and commercial trees occur at very low densities (<1 tree/ha harvested), CL is unlikely to cause excessive damages.		• Investments in [NFM] are financially unattractive and governments are generally unwilling or unable to force loggers to make such investments.	Reid, J.W. & Rice, R.E. 1997
General	• In management systems based on selective felling there are limits to harvesting intensity above which felling and skidding damage will be so high as to jeopardize the forest's regenerative capacity, no matter how well the operation is planned and executed • In many forests in South America many commercial species require small canopy openings, while in Asia and Africa heavier canopy opening is almost always desired • Increased harvesting of lesser used species can have both positive and negative impacts, depending on whether logging intensity is increased (thus jeopardizing the forest) or whether it offsets logging pressure on the more desired species		• 10 trees/ha has been quoted as the order of magnitude for the upper limit of logging intensity • However, it is impossible to set universal threshold values for logging intensity since logging intensity depends on damage to the remaining stand and acceptable damage limits vary according to the physical and biological characteristics of each forest					Reitbergen, S. & Poore, D. 1995
General	• Increasing the use of lesser used species is seen by many as the way of making natural forest management more viable • Harvesting more m^3/ha means that less area needs to be harvested and the forest generates more revenue							Sarre, A. 1995
General	• The single most important thing that foresters can change is the way that forests are logged • There is no doubt that most current logging techniques cause unnecessary damage to the forest							Sarre, A. 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• Better logging techniques will have an immediate positive effect on post-harvest value of the forest and will increase the long-term chance of sustainability							
General	• New technologies for transporting and converting heavy hardwoods have radically changed the situation • Plywood mills in the Amazon have already captured a major share of an international market where south-east Asia had previously expected to retain a long-term competitive advantage • Also new developments in composite wood products and pulping technologies							Sayer, J. & Byron, R. 1996
General	• Humid tropical forests • Low-impact logging techniques are not difficult to implement and may be cheaper than conventional logging practices		• Recommends logging cycles 20-40 years long with fewer trees extracted, rather than a very intensive cut every 70-80 years					Sayer *et al.* 1995
General	• Technologically there is no reason why plantations cannot supply most of the world's wood requirements by early next century • Demand for a few speciality products that can be obtained only from natural forests may not increase greatly, and can probably be satisfied from ecologically sensitive logging operations in areas where forests are retained primarily for their environmental and amenity functions • Expect the natural forests to become less able to compete with outputs of the rapidly expanding plantation sector in the tropics and subtropics • Increased use of RIL should lead to a reduction in environmental impacts and greater productivity in future cycles							Sayer *et al.* 1997
General	• Tropical rain forest management · plantations yield great benefits but cannot replace the functions of current natural forest areas, they are complementary with each one supplying different products and		• If residual crop trees are 10 cm dbh on average a minimum logging cycle of 40 years is required to get average 50 cm					Schmidt, R. 1987

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	most applicable to different types of terrain • Average dbh growth in natural tropical forests varies with many factors but is seldom greater than 1 cm/a and is often less		dbh • If larger trees can be released a shorter 25-30 year logging cycle could be possible • Brazil: inventory found 54 m^3/ha of stems >45 cm dbh, of which 36 m^3/ha were of 28 commercial species (study extraction produced 72 m^3/ha of which 64 m^3/ha were commercial) • Peru: the VAC started at 15 m^3/ha (15 commercial species), but has increased to 30 m^3/ha as 20 more species became commercially viable • Colombia: 114 m^3/ha of total stem volume and 33 m^3/ha of commercial volume • Suriname: CELOS system should get 40 m^3/ha on a 20 year logging cycle with 13.5 trees/ha being commercial • Africa: the net volume of logs extracted varies from 5 to 35 m^3/ha					
General	• Based on general considerations in different forests the annual growth potential can be estimated to be 1-2 m^3/ha/a for Africa, 1-3 m^3/ha/a for Latin America and 2-4 m^3/ha/a for Asia							Sommer, A. 1976
General	• Need to determine acceptable levels of increased logging intensity with harvesting of lesser used species before environmental damage is unacceptable • Where logging intensities are low the lesser used species are a good potential source of wood		Logging intensity • in many tropical American countries 8.4 m^3/ha • in many African countries 13.5 m^3/ha • Peninsular Malaysia 45 m^3/ha • Sarawak 75 m^3/ha • Sabah 90 m^3/ha • Philippines 90 m^3/ha	• Studies in Sabah have shown only 34% of residual stand undamaged				Yeom, F. 1984

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
General	• Effective RIL programs include elements of monitoring, auditing, and enforcement of rules, laws, regulations and guidelines. • There are a number of linkages between RIL and other necessary conditions for sustainable forest management. • The links only become apparent when examining the impediments to the adoption of RIL and in particular the effects that illegal logging has on profitability and decision making by forest concessionaires.							Durst, P. & Enters, T. 2001
General	• RIL has become associated with logging technologies that have been introduced into tropical forests explicitly for the purpose of reducing the environmental and social impacts associated with industrial timber harvesting. • This paper discusses the requirements for RIL and some of the impediments to its implementation in the tropics.							Dykstra, D. 2001
General	• RIL involves the application of technologies that have been known for many years and are utilized as a matter of common practice in many industrialized countries. • RIL requires both a new mindset and also a new approach to tropical forest management.							Dykstra, D. 2002
General	• RILSIM is a computer software package designed to permit users to rapidly estimate the cost and net revenue associated with logging operations so that they can compare short-term financial costs and returns expected from reduced impact logging with those expected from conventional logging under identical local site conditions. • The purpose of the software is to help users learn about reduced-impact logging and its potential financial advantages as compared to conventional logging. • The focus of efforts to introduce							Dykstra, D. 2003

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	RILSIM is on users in tropical countries where logging impacts are widely considered to be incompatible with sustainable forest management.							
General	• Minimizing the negative environmental impacts of logging and other silvicultural treatments is the primary conservation goal in tropical forests managed for timber production. • While it is always environmentally beneficial to minimize unnecessary damage, more intensive silviculture should not be discouraged in tropical forests in which regeneration and growth of commercially valuable timber species requires such treatments. • Failing to regenerate commercial species may render forests more susceptible to conversion to other, more lucrative land uses.							Fredericksen, T.S. & Putz, F.E. 2003
General	• Two hundred and sixty-six studies and articles on RIL and/or CL, conducted in closed broad-leaved tropical forests, were reviewed and classified. • These publications dated back to 1950. Following compilation and analysis, the data extracted were summarized in order to give an indication of some general trends. • It should be noted, however, that the data found in the various reports are not adjusted to account for inflation.		• From a summary 130 observations (n=37 for RIL and n=93 for CL). • The median[2] volume harvested was 8 m^3/ha lower, with RIL at 37 m^3/ha and CL at 45 m^3/ha. • In the majority of the RIL studies the logging intensity was <60 m^3/ha, while for CL there was a significant portion >60 m^3/ha. • 101 observations (45 RIL and 56 CL) showed no significant difference in the number of trees harvested per hectare between the two forms of logging. • The median number of trees harvested was 8 trees/ha for each cutting cycle.	• 21 observations indicated that utilization rates are better with RIL; however, many more studies are needed.	• From 75 observations RIL had 41 percent less residual stand damage, when compared to 49 percent for CL systems. • Other studies which measured stand damage in a different manner, found that median rates of damage for RIL and CL were 124 and 131 trees per hectare, respectively. • In 15 observations the damage to trees per trees felled was 56 percent less in RIL operations when compared to CL operations. • The area covered by skid trails in	• In 33 observations the adoption of RIL resulted in the volume of lost timber being 60 percent lower than in CL operations.	• In 10 observations the median cost of RIL was US$ 0.28/m^3 higher than that of CL. In another two observations the planning costs were reported as costs per hectare. • The range of US$ 5.06 to US$ 50.00/m^3 indicates serious shortcomings in the statistics on planning at this time. • In a total of 10 observations, the median felling cost of RIL was US$ 0.56/ m^3 higher than that of CL. • This represents a cost that is 48 percent higher. In a review of 11 articles no	Killman, W., Bull, G. Q., Schwab, O. & Pulkki, R.E. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					RIL operations is almost 50 percent less than in CL. • From eight observations of road damage, the trend was as expected with a much lower level of damage (41 percent) when using RIL techniques. • In 25 observations with RIL the canopy opening was 36 percent smaller.		appreciable difference in skidding costs between the two forms of logging was found.	
General	• Harvesting trees is a tool for accomplishing many management objectives, and operations can be conducted to protect environmental quality and reduce visual impacts. • Key requirements for environmentally sound harvesting will include good planning, reputable contractors, skilled workers, and professional foresters who understand the concepts and application of sound forest practices.							Long, A.J. 2001
General	• This paper reviews the evidence regarding the viability and desirability of sustainable forest management in the tropics. • Empirical studies suggest that although sustainable timber management sometimes provides reasonable rates of return, conventional timber harvesting is generally more profitable. • This implies that without additional incentives, one cannot expect companies to adopt sustainable management. • In many cases, sustainable timber management performs better in terms of carbon storage and biodiversity conservation than conventional logging approaches, as well as producing more timber.							Pearce, D., Putz; F.E. & Vanclay, J.K. 2003

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• If new carbon markets emerge, it may also provide a sufficient incentive for sustainable forest management in certain circumstances.							
General	• Despite abundant evidence that both the environmental damage and the financial costs of logging can be reduced substantially by training workers, pre-planning skid trails, practicing directional felling, and carrying out a variety of other well-known forestry practices, destructive logging is still common in the tropics. • The main reasons for this are: 1. RIL is too expensive. 2. There's nothing wrong with current logging practices. 3. Lack of governmental incentives to change logging practices. 4. The forest will be converted anyway. 5. Available equipment is unsuitable for RIL. 6. Lack of training and guidance by RIL experts. 7. Lack of focused pressure for better logging from environmental groups. ▪ Well-managed forests can provide income as well as many of the forest resources and ecosystem services that society increasingly demands, but what is required is nothing less than a cultural change from timber mining to forest management.							Putz, F., Dykstra D.P. & Heinrich, R. 2000
General	• This paper focuses on the potential for using carbon trading to stimulate adoption of reduced impact logging (RIL)-based sustainable forest management. • While the incremental carbon benefits of improving harvesting alone may be rather limited, significant carbon benefits could result if carbon payments could support sustainable forest management in a favourable policy and institutional environment.							Smith, J. & Applegate, G.B. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
General	• The planning and construction of forest harvesting roads is a major and expensive operation that is critical to the orderly flow of logs. • Codes of practice have aimed at setting basic standards to reduce the adverse effects of forest road alignment whilst still meeting operational and other needs. • Such new standards are often opposed by the timber industry as being impractical and uneconomic. • Experience in code development in the Asia-Pacific region indicates that proper road construction, sound environmental management, beneficial social outcomes and operational economics need not necessarily conflict. • It may be necessary to collate, publish and disseminate road construction and management information. • Training for roading supervisors, forest supervisors, forest officers and operators.							Wells, C.H. 2002
General: - Ghana - Cameroon - Indonesia, East Kalimantan - Malaysia, Sarawak	• Greater efficiency in forest and processing operations could greatly enhance the sustainability of the tropical timber industry • Sawn timber yields varied from 36 to 57% depending on country and lumber market • Need to modernize equipment • Need to raise the skill of the workers by practical training and education • Need to establish quality control in mills • Need for better utilization of the mill residues			• Of the total tree on average 4.6% in stump, 5.2% in buttress, 53.5% extracted log, 10.4% stem off cuts, 26.3% in crown with diameter >20 cm • Of stem between crown and stump 77.4% extracted as log				Noack, D. 1995
General: Ghana, Brazil, Venezuela, Indonesia, Malaysia	• Report on sawmill recoveries • Low yields generally the result of lack of skilled labour and management, poor maintenance and saw sharpening, obsolete equipment							Loehnertz *et al.* 1996
Ghana				• Harvesting >3.5 m^2/ha of basal area will exceed the forest's ability to regenerate				Agyeman *et al.* 1995a

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Ghana	• Bura Forest Reserve		• Logging intensity 2.3 trees/ha	• Gap opening per felled tree ranged from 350 to 1800 m^2	• Telling 2.6 trees/ha resulted in 13% logging disturbance • Canopy openings accounted for 50% of the disturbance, skid trails 38% and haul roads 12%			Ayeman *et al.* 1995b
Ghana	• This study evaluated options to make RIL profitable (based on an average concession of 10,000 ha		• Cutting cycle of 40 years • 1/3 of the trees >50cm dbh are allocated for harvest		• RIL: 20% of residual stand damaged • CL: 40% of residual stand damaged • RIL: stocking levels of most valuable timber species improved by 30-50%		• There is a lack of economic incentives for the concessionaire to introduce RIL • An area dependant subsidy of US$ 92.5/ha or a price increase by 147% would be necessary to make RIL financially viable. • Target subsidies fit well into the current institutional setup.	Bach, C. F. 1999
Ghana	• Selection system (dates from 1956) • Detailed location mapping of all commercial trees >68 cm dbh, improvement thinning of immature trees, vine cutting		• Cutting cycle 25 years • 2.5-5.0 trees/ha removed • 26 out of 190 trees that grow to timber size are economically valuable					Baidoe, J. 1970
Ghana	• There is no good evidence that plant biodiversity would suffer as a consequence of logging, providing that careful logging measures are adopted		• Ground-based logging systems for selective logging on a 40 year cycle are used					Hawthorne, W. 1997
Ghana	• The study focussed on the harvesting efficiency and the environmental and social impact of timber harvesting in the area. • For the harvesting efficiency time and production studies were undertaken along with an appraisal of the equipment and personnel. • For the environmental impacts an assessment was made of skid trails and the damage to the residual stand as well as the extent of the canopy openings		• Mean volume extracted per cycle: felling = 13.04; skidding = 10.02.		• 86 trees < 50 dbh were totally destroyed whilst 48 were partially damaged. • n the > 50 cm dbh size class 5 trees were partially damaged.			Odoom, F. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	resulting. • Forest-fringe communities were assessed to determine the sociological impacts of the forest operations.							
Ghana	• The majority of existing market and fiscal incentives (demand side incentives) encourage and promote extraction of high-value species • Control (supply) measures, including management plans, yield allocation, etc., attempt to conserve high-value species and promote extraction of a wider range of lesser used species • Demand side incentives are ineffective, and even deleterious, without attention to supply side issues • Industry will need to accept a far greater responsibility for the resource if current predictions of the extinction rate of key economic species are to be avoided							Sargent *et al*. 1994
Ghana	• Nearly 93% of all forest land in West Africa (Benin, Ghana, Guinea, Guinea Bissau, Côte d'Ivoire, Liberia, Sierra Leone and Togo) has sustained some timber harvesting • As long as harvesting mimics the natural disturbance regimes, the tropical forests of Ghana can be sustained while being harvested • Growth 3-6 m^3/ha/a • Logging methods should be revised to reduce the amount of understorey disturbance • Harvesting secondary species is often encouraged, however, this could lead to great disturbance at each entry		• Minimum felling limit is 70 cm dbh • Cutting cycle has just recently been increased from 25 to 40 years					Wagner, M. & Cobbinah, J. 1993
Guyana	• Comparison of RIL and CL		• 8.2 m^3/ha (2.4 trees per hectare)	• RIL: no merchantable trees were missed	• RIL: 30% reduction of skid trail length possible • Felling trees with vines attached caused significant damage	• CL: 3% waste wood	• RIL: production increased by 7% • RIL: production costs per m^3 reduced significantly	Armstrong, S. & Inglis, C.J. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Guyana	• Ekuk Compartment, Mabura Hill		• Logging intensity 57 m^3/ha (ecological reserve plot 1988) • Ekuk compartment logging intensity 37 m^3/ha (1990) • Low intensity logging of 20-25 m^3/ha on sandy soils appears to have fairly little impact on the hydrological and nutrient cycle at the catchment level		• Uncontrolled skidding is a major cause of damage to the ecosystem • 12.6% of area with gap openings in logged area vs. 3% in natural area • Average logging gap size three times the size of a natural opening			ter Steege *et al.* 1996
Guyana	• This study was carried out in the Upper Demerara district of Guyana		• RIL was studied with harvesting intensities of 4, 8 and 16 trees/ha respectively • With CL an average of 8.7 trees/ha was harvested (basal area 2.2 m^2; volume 27.8m^3/ha). The variability was high (0 to 25 trees/ha harvested) • With a cutting cycle of 25 years and neglecting mortality a next harvest at 8 trees/ha intensity may be possible. But for the following cutting cycle all trees will have to be recruited from the 20 to 40cm dbh size class, which will take much longer than 25 years. With the same assumptions, stand table projection with a harvesting intensity of 8 trees/ha will result in 27 trees/ha in the 40cm and above size class after 25 years, which suggests that this exploitation level may be sustainable.	• 85% of the residual stand will probably survive at a harvesting intensity of 8 trees/ha with CL, this rate will be reduced to 77% at a harvesting intensity of 16 trees/ha. • With RIL, 89% of the residuals will probably survive at 8 trees/ha and 78% at 16 trees/ha • In the CL operation the average recovered volume per tree amounted to 2.9 m^3 whereas a volume of 3.1 m^3 was recovered on average in the RIL operation	• Ground disturbance in felling gaps occurred significantly more often in CL (6.7% of total area) than in RIL (1.1% of total area). • CL severely damaged a basal area of 1.5 m^2/ha (an estimated 5.1% of the original stand) with no significant relation to logging intensity. RIL seriously damaged a basal area of 0.5 m^2/ha (2.1% of the initial stand) after a light harvest, and a basal area of 1.8 m^2/ha (7.6% of the initial stand) was damaged with a logging intensity of 16 trees/ha • In this study RIL resulted in a reduction in damage to the residual stand by 6% at an extraction level of 8 trees/ha and by 3% at an		• In CL, felling reached a productivity of 10 m^3/h per crew while in RIL productivity only reached a level of 5.8 m^3/h (reduction in felling performance 37% while the operative machine time was increased by 66%) • For skidding the volume delivered at the landing per operative machine hour increased from 11.8 m^3/h to 14.4 m^3/h due to implementation of RIL • CL: costs for pre-harvest planning: US$ 5.06/ m^3 • RIL: costs for pre-harvest planning: US$ 15.52/ m^3 • CL: Costs of harvest preparation US$ 14.87/ha • RIL: Costs of harvest preparation US$ 17.24/ha • RIL increases the up-front costs by US$ 12.83/ha (NPV = $14.69/ha) • CL: Cost of felling, skidding and	van der Hout, P. 1999

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					extraction level of 16 trees/ha • RIL resulted in a reduction of the skid trail coverage from 13% to 8% of the total area at a logging intensity of 8 trees/ha and from 21% to 8.5% at an intensity of 16 trees/ha • Felling and skidding damage taken together, this meant a reduction of irreversible residual damage from 15% to 11% (at 8 trees/ha) and from 22% to 21% (at 16 trees/ha) respectively		landing operations US$ 5.24$/$m^3$ • RIL: Costs of felling, skidding and landing operations US$ 5.58 $/$m^3$ • CL: overhead costs US$ 10.17/m^3 • RIL: overhead costs US$ 9.40/m^3 • RIL: the change in the aggregate logging costs (per m^3) is small (increase of 5%) when the logging intensity is reduced from 16 to 8 trees/ha (from 50 to 25 m^3/ha). The costs rise more strongly, when the intensity is further reduced to 4 trees/ha and even more when subsequently being reduced to 2 trees/ha • RIL is cost competitive with CL. The direct cost per cubic metre may have been higher at the moment but will likely decrease in the future • In the long term several benefits are associated with RIL. Attempts to place a financial value on this are neither realistic nor even desirable for that very reason	
Guyana	• In this case CL featured felling in groups while trees selected for harvesting were scattered in the RIL operation • RIL resulted in a very modest		• CL: harvesting intensity 8 and 16 trees/ha (0-78 m^3/ha) • RIL: harvesting intensity 4, 8 and 16	• Gross volume recovery increased from 2.9 to 3.1m^3 over bark by implementing RIL	• RIL: felling damage was reduced by 16% at a logging intensity of 8		• CL: logging costs US$ 28.29/m^3 • RIL: logging costs US$ 28.23/m^3	van der Hout, P. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	reduction in residual stand damage and canopy loss. Only the reduction of the skidding trail coverage is in agreement with the results of other studies.		trees/ha; 8 trees/ha corresponds to 25 m^3/ha		trees/ha, whereas it was augmented by 9% at a logging intensity of 16 trees/ha • CL: the average canopy opening per felled tree decreased by 23% when the harvesting intensity was increased from 8 to 16 trees/ha • Liana cutting and directional felling as carried out in this study did not reduce the amount of canopy lost. • RIL reduced the area traversed by the skidder by about 2/3, while skidder movements in felling gaps were reduced by about ¾, both depending on the logging intensity.			
Guyana, Northwest	• Original 227 trees/ha (dbh >20 cm) • CELOS system has partly guided the logging operations at BCL		• Minimum felling dbh is 50-60 cm for the plywood mills • Logging intensity 5 trees/ha or 15 m^3/ha	• Of original stand 183 trees/ha were not felled or damaged	• For every 6 trees logged a further 21 were either pushed or pulled over, or were snapped (1 bent, 17 pushed over, 4 crown snapped, 4 severe crown damage)			Inglis *et al*. 1997
Guyana	• The work on which this paper is based was carried out within the BCL concession and developed from studies of merchantable wood left in the forest and the resulting impact on operational and financial efficiency. • BCL operates a 1.67 million ha concession in Northwest Guyana. • Some very important changes that are required relate to behavioural		• Stocking of commercial species is poor, with harvesting volumes averaging 8.2 m^3/ha. • At an average volume of 3.4 m^3 per tree, this equates to a harvesting intensity of 2.4 trees/ha.					Armstrong, S. & Inglis, C. 2001

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	rather than technical issues. • Involving people in planning change increases the likelihood of success as fears are overcome. • Impractical recommendations and poor communication threaten the change process. • Effective management is the key to improving harvesting operations. • Retaining people with the range of skills needed to implement, manage and supervise improved harvesting practices requires incentives. • New concepts should be suited to local conditions, developed and tested in collaboration with operators and management. • Changes that have been tested and which build on current resources, and skills are more likely to be adopted than new systems.							
Guyana and Cameroon	• Two projects concerning the impact of reduced impact logging on the vegetation in Guyana and Cameroon are compared.		• Exploitation level was the most important damage factor as compared with logging method in both studies.		• In Guyana if felling intensity exceeds 8 trees/ha, the accumulated gap area is less in a conventional operation than in the experimental RIL operation. RIL however produces smaller mean gap sizes. • With an intensity of 8 trees/ha, canopy loss is the same with either method, but, an intensity of 16 trees/ha, canopy loss was higher with RIL. • Skidding damage in canopy gaps is negligible with RIL and extensive with conventional logging.			van der Hout, P. & van Leersum, G.J.R. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					• In Cameroon large scale climber cutting did not decrease gap size or the level of damage to individual trees. • In Guyana liana cutting did not have any effect on canopy opening. • In Guyana skidding damage was reduced by applying RIL, regardless of logging intensity. • While directional felling and winching are important tool in RIL in Guyana, their application in Cameroon is constrained by the size of the trees.			
Indonesia	• Indonesian Selective Cutting System and Planting System		• Minimum felling limit is 50 cm on a 35-year cutting cycle (specified by law) • Concession rights are 20 years			• Inefficient logging practices have resulted in relative high logging waste of 35-40% partly due to low skill of workers		Brotoisworo, E. 1991
Indonesia	• Tropical lowland forest in Sumatra • Tropical high forest in steep terrain in South Kalimantan		• Average 5 trees/ha (15.8 m^3[sob]/ha) extracted in block studied • Other blocks averaged 18 and 21 m^3(sob)/ha • 155 m^3/ha of total 198 m^3/ha extracted (78% of total volume)		• Average road density was 15-20 m/ha with average skid trail density of 33 m/ha			Buenaflor, V. & Heinrich, R. 1990
Indonesia	• Evaluating the Indonesian Selective Cutting and Planting System				• This system is often considered to cause forest degradation.			Elias 1999
Indonesia	• Project developers believe this project will generate savings of 56,400 tons of carbon over its projected 40-year term				• RIL is expected to reduce the damage to the residual stand by 50%		• A carbon investment would provide training and pay for various RIL activities.	FAO 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Indonesia	• Rainfall 250-350 cm/a and periods of rain for 30-60 days can stop operations completely • Good utilization of all species and log grades (quality) is the cornerstone of intelligent forest resource development and long-term management		• In traditional operations forest stands with gross volumes up to 150 m^3/ha had logging intensities of 20 m^3/ha • Increased to 60-75 m^3/ha through better utilization of felled trees and increased use of lesser used species • A typical stand would consist of 77 m^3/ha of all species with dbh >50 cm • a seasonal logger would extract 36 m^3/ha • a contractor operating on a license would extract 45 m^3/ha • an all-weather logging operation would extract 65 m^3/ha (good infrastructure gives the ability to improve utilization and also a need for better utilization to cover fixed costs)					Schoening, J. 1978
Indonesia	• Both large and small sawmill yield is 45% and waste is 55% (sawdust 10%, slabs 25%, log trim 17%, other 3%) • In 1981 plywood mill yield was 40% and waste 60% • A more recent study showed plywood mill yield at 45% due to technological improvements				• Average road density of 15-20 m/ha is acceptable	• Study 1 wood waste was 12% and 22% stem wood in cut-over, 11% and 17% left at collection sites • Study 2 12% and 18% was in felling and bucking areas, 2.9% and 2.5% in log yard • Broken and defective log volume was 15.5% when calculated on a clear bole basis, and 17.5% when based on		Silitonga, T. 1987

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
						minimum 30 cm diameter • Study 3 found waste wood based on a clear bole basis to be 25.1% in Kalimantan and 21.9% in Sumatra • Study 4 average waste wood was 19 m^3/ha (minimum 1.0 m length and 10 cm diameter inside bark) • Waste wood in tropical rain forest is 24-26% of the extracted volume • If going down to a 30 cm diameter waste wood is 32-35% of the extracted volume • For mangrove forests waste wood is 9% and for teak forests 11%		
Indonesia (Central Kalimantan)	• The average stocking density is 583 stems/ha with a basal area of 34.4 m^2/ha		• 4 scenarios were evaluated: Primary forest, manual extraction, CL (10 trees/ha removed) and RIL (following the FAO model code for forest harvesting practice) • The optimum disturbance regime for seedlings establishment and regeneration will be associated with small gaps (<650 m^2) created by logging and extraction of < 2 trees /gap	• 6 months after logging dipterocarp seedlings were already growing rapidly in disturbed areas	• With CL, 38% of the canopy were completely removed, and 52% of the ground was covered by logging debris or skid trails • Poor growth and survival of naturally regenerating dipterocarps in logged forest could be the result of the removal of host- or site-specific mycorrhizal fungi • The lowest			Van Gardingen, P-R., Clearwater, M.J., Nifinluri, T., Effendi, R. Rusmantoro, W. Noor, M., Mason, A., Ingleby, K. & Munro, R.C. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					intensity of damage was observed when timber was manually removed • The highest intensity of damage was observed in plots logged by CL (soil disturbed on 30% of the area)			
Indonesia (East Kalimantan)	• The study area was covered by primary and secondary lowland mixed dipterocarp forests		• RIL techniques were applied with two diameter limits (50 and 60cm dbh respectively) • The net annual increment increased from 0.7 m^3/(ha*a) [CL] to 1.3 m^3/(ha*a) [RIL]		Logging damage to the residual stand can be reduced significantly from 40-50% to 20-30% if several recommended improvements to CL methods are implemented.		• The comparison of production costs shows no significant difference in cost between CL and RIL methods	FAO 1997b
Indonesia (East Kalimantan)	• The study was designed to compare CL and RIL under the Indonesian Selective Cutting and Planting system. • The objective of the study is to test the applicability of the *FAO model code of forest harvesting practice (1996)*		• The cutting cycle is 35 years • The harvesting intensity is 3-4 trees/ha		• Opened area caused by felling in CL units is 11.1% and in RIL units it is 7.65%. • Opened area caused by skidding in CL units is 8.73% and in RIL units it is 5.21%. • RIL can reduce the opened-up area by up to 35% when compared to CL • As compared to CL, RIL can lessen damage up to 50% without a significant decrease in productivity		• CL: total cost of harvesting is US$ 2.94/m^3 • RIL: total costs of harvesting is US$ 2.97/m^3 (excluding topographic maps and planning costs) • Assuming a profit ratio of 30% the value of timber damages caused by CL is twice as high as the value of timber damages caused by RIL (US$ 2.94/ha : US$ 1.29 /ha)	FAO 1998
Indonesia (East Kalimantan)	• Data were collected from the STREK project in East Kalimantan		• Three options were analysed (CL, RIL with felling limit 50cm and 60cm respectively)				• · CL: total costs US$ 4.03/m^3 (productivity 35.65 m^3/h) • RIL >60cm dbh: total costs 3.14 US$/$m^3$	Karsenty, A. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							(productivity 46.53 m^3/h) • RIL >50cm dbh: total costs 2.95 US$/$m^3$ (productivity 48.42 m^3/h) • The additional costs for RIL should not exceed US$ 20 to 25 per hectare • The cost-benefit analysis shows that $50 to $74 can be saved per hectare with RIL	
Indonesia (East Kalimantan)			• Stand inventories indicated that 15-20 trees of commercial species could be harvested per hectare (estimated volume of 70-90 m^3/ha). • Harvesting was limited to 12 trees/ha with a volume of 75 m^3/ha. • It is expected that the second harvest in the RIL plots could be undertaken within shorter time frame compared to CL operations	• RIL: canopy opened on 18.7% (winching <30m) or 20.4% (winching <15m) • CL: canopy opened on 26% of the total area • The percentage of healthy trees in the residual stand could be increased from 35 to 47% by RIL • The exploitation factor in the RIL plots was greater (85%) than in the CL plots (81%) • The utilisation of timber above the first branch could be increased (often about 4-6m of utilisable timber were left) • At the given harvesting intensity the timber production could be increased by 2 m^3/ha through higher utilisation standards	• CL: undamaged residual stand 22 m^3/ha (dbh 20-40cm); 76 m^3/ha (dbh > 40cm) • RIL: undamaged residual stand 25 m^3/ha (dbh 20-40cm); 100 m^3/ha (dbh >40 cm)		• CL: total production costs 2.74 Us$/$m^3$ • RIL: total production costs 3.51 Us$/$m^3$ • RIL: costs increased by US$ 1/m^3 compared to CL • RIL: under the conditions of this case study a direct financial benefit of US$ 50 per hectare could have been generated, if the company had been allowed to harvest the "additional timber" gained by improved utilisation under its given AAC • There are also long term benefits of higher quality of the residual stand, reduced need for rehabilitation and the possibility of shortening the cutting cycle.	Ruslim, Y., Hinrichs, A. Sulistioadi, B. & Limbang Ganacea, PT. 2000
Indonesia (East Kalimantan)			• Three options were analysed (CL, RIL with felling limit 50cm and	• Only 53.7% of the volume felled were extracted from the	• On average logging affected 34.4% of the area			Sist, P. & Bertault, J.G. 1998

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			60cm respectively • Timber volume extraction must be limited to 80m^3/ha to achieve the positive effects of RIL	forest	(felling 16.4%, skidding 23.6%) • The main cause of mortality was uprooting during skidding and felling (76.5% and 10.1% respectively) • In this study logging damage was reduced from 48.8% in CL to 30.5% in RIL (felling limit 60cm dbh) • The different logging intensities with RIL did not have a significant impact on the level of logging damage			
Indonesia (East Kalimantan)	• Impacts of CL and RIL on forest ecosystems were compared		• Logging intensity ranged from 1 to 17 trees/ha (9-247 m^3/ha) and averaged 9 trees/ha (86.9 m^3/ha). • With high harvest intensities, a sufficient harvesting volume will not be reached within the cutting cycle of 35 years.	• Leaving only few potential crop trees will result in a seriously depleted residual stand	• With RIL logging damage to the residual stand could be reduced by 50% compared to CL • Above a felling intensity of 8 trees/ha the effectiveness of RIL in limiting damages to the residual stand was significantly reduced, mainly due to the increasing felling damage			Sist, P., Nolan, T., Bertault, J.-G. & Dykstra, D. 1998
Indonesia (East Kalimantan)	• This study was carried out in Indonesia (east Kalimantan) as part of the STREK project • Silvicultural treatments and RIL techniques are evaluated • MAI 0.75 to 4.9 m^3/(ha*year)		• CL: minimum harvesting diameter 60cm dbh • RIL: minimum harvesting diameters of 50cm and 60cm dbh respectively		• 26% of residual stand were damaged during harvesting, resulting in 51% of the total mortality two years after harvesting.			STREK, CIRAD-Forêt & FORDA. 1999
Indonesia (Eastern Kalimantan)	• The average commercial volume found in primary forests in this		• 10 harvestable trees were found per	• On the study site, the volume extracted was	• In the study area, 5.4% of the area		• The average skidding costs were	Ahrenholz, T. 1991

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	region is 101.90 m^3/ha for trees >20cm dbh. • Two harvesting systems were evaluated: the TPI system (Indonesian Selection System) and the HTI system (clear felling and artificial regeneration)		hectare (79.40 m^3/ha) • In plantation forests, 200m^3/ha of commercial timber could be produced on a 12 year rotation. • The following cutting cycles were proposed: saw logs 20-30 years, pulpwood 8-20 years, fuel wood 5 years	equal to the volume damaged or left behind (76.3 m^3/ha)	was affected by roads (primary roads 1.6%, secondary roads with water bound surface 0.5%, temporary secondary roads 3.2%) • 20.7% of the area were affected by skidding • Between 25 and 48% of the skid trails were traversed 4 to 8 times		US$ 2.2 to 2.5 per cubic metre	
Indonesia (Eastern Kalimantan)	• In primary forest, the overall annual mortality rate was 1.5% in number of stems (9 stems /ha*year; 0.57 m^2/ha* year)		• RIL: _80% of the basal area remaining · Intermediate: between 70 and 80% of basal area remaining • CL: _70% of basal area remaining	• The mortality after logging over a period of 2 years was 2.5%/year	• 26% of the remaining stand was damaged after logging (representing 51% of the trees that died during the next 2 years.)	• The drastic reduction of damages obtained with RIL did not result in a significant reduction of the subsequent mortality.		Nguyen-The, N., Favrichon, V., Sist, P., Houde, L., Bertault, J.G. & Fauvet, N. 1998
Indonesia (Eastern Kalimantan)	• Site A: The initial basal area was 33.19 m^2/ha • Site B: the initial basal area was determined as 103.63 m^2/ha		• Cutting cycle 35 years • Site B: harvesting intensity 39.1 m^2/ha	• Minimum residual density of potential crop trees of 25 trees/ha • Site A: The residual basal area was 23.1 m^2/ha • Site B: 44% of the initial basal area remained undamaged	• The area affected by skidding ranged from 11.1% to 13.4% • Site A: a residual basal area of 8.58 m^2/ha was damaged • Site B: 19% of the residual stand were damaged during harvesting			Ruslim, Y. 1992
Indonesia (Eastern Kalimantan)	• This study refers to the Indonesian Selection and Planting System (TPTI) • Winching of logs to the skid trail was not possible due to the large volumes harvested per stem.		• Cutting cycle 35 years	• 20 trees of merchantable size (dbh 50cm) per hectare must be retained	• On average 13.5% of the area were affected by skidding (on 8.7% of the area the topsoil was exposed) • Felling and skidding damage amounted to 30% of the initial basal area • Between 20 and 40% of the			Ruslim, Y. 1994

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					potential crop trees were damaged during harvesting operations			
Indonesia (Eastern Kalimantan)	• Silvicultural treatment can result in growth rates of 10 to 15 m^3/ha		• A 35 year cutting cycle and a harvesting intensity of 35 to 105 m^3/ha appear to be sustainable					Weidelt, H.J. 1989
Indonesia (South Kalimantan)			• The average volume of marketable tree species with a diameter >50cm is 120 m^3/ha • A harvesting intensity of 40m^3/ha is possible with a 35 year cutting cycle					Kuusipalo, J., Kangas, J. & Vesa, L. 1997
Indonesia (Southern Kalimantan)					• CL: 10.6% of the study area were affected by skid trails and log landings			Supriyatno, N. 1993
Indonesia, East Kalimantan	• Lowland dipterocarp • (Lempake)		• 11 trees/ha • (stumps 80-150 cm diameter)		• 41% residual stand damage			Abdulhadi *et al.* 1981
Indonesia, East Kalimantan	• Study comparing conventional logging to RIL • Original stand density 530 +/-63.3 stems/ha; BA 31.4 +/- 3.2 m^2/ha		• Logging intensity ranged from 5-15 stems/ha or 43-174 m^3/ha or 9.8-30 m^2/ha	• Felling mainly injured trees, especially crown damage to trees 30-50 cm dbh • Skidding mainly cause mortality, especially uprooting trees 10-20 cm dbh • RIL reduced damage or death to trees from 48.4% to 30.5% (extra 95 trees/ha >10 cm dbh remained undamaged) • In Borneo damage often exceeds 50%, which is more than in Africa or South America				Berthault, J. & Sist, P. 1997
Indonesia, East Kalimantan	• Dipterocarp forests • Indonesian Selection Cutting and Planting System (TPTI) • Mortality of trees in natural stands varies between 0.9- 2.4%/year, average 1.1%/year		• Cutting cycle is 35 years and the minimum felling dbh is 50 cm • Logging intensities at Narkata Rimba were	• Residual stand damage increases as slope increases (at Narkata Rimba 9.4, 21.1 and 35.4% residual tree damage	• 75% of injuries caused by skidding and 25% by felling • Higher residual stand damage			Elias 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• At Kiani Lestari the average dbh growth on trees with dbh >10 cm was 0.8-0.95 cm/a one and two years after logging, and 0.47-0.69 cm/a 4, 9, 13 and 17 years after harvesting • dbh growth in virgin forest is 0.51-0.74 cm/a • In plots at Narkata Rimba dbh growth of trees >10 cm dbh was 0.55-1.25 cm/a after logging, but reduced to 0.41-1.04 cm/a after a few years • At both areas average growth rate of commercial trees ranged from 0.90-2.97 m^3/ha/a		2, 6 and 17 trees/ha on slope classes 0-15, 16-25 and >25% • Logging intensities at Kiani Lestari were 8, 9 and 8 trees/ha on slope classes 0-15, 16-25 and >25%	on 0-15, 16-25 and >25% slope, while at Kiani Lestari 38.6, 46.2 and 46.8% residual stand damage on 0-15, 16-25 and >25% slope)	results in higher mortality			
Indonesia, East Kalimantan	• Average standing volume (dbh >50 cm) was 115 m^3/ha (68 m^3/ha dipterocarps; 24 m^3/ha non-dipterocarps; 23 m^3/ha non-commercial)		• Estimated exportable volume 48.5 m^3/ha • Forestry Service in Indonesia accepts 30% waste, thus net extractable volume is 34 m^3/ha • Too optimistic to assume that trees of saw log size will mature in 35 years after logging and that they will constitute the second crop in the following cutting cycle		• 42 m/ha of road to log an area and day-lighting (road right of way clearing) can extend to 50 m from the centre-line of the road on both sides			Hamzah, Z. 1978
Indonesia, East Kalimantan			• Logging intensity 25 trees/ha		• 30% of ground surface covered with tractor paths			Kartawinata, K. 1978
Indonesia, East Kalimantan	• Tropical forest		• Model showed an optimum felling intensity of 71.9 m^3/ha on a 35-year cutting cycle					Mendoza, G. & Setyarso, A. 1986
Indonesia, East Kalimantan	• Sawmill recovery rate was 50% and residue 35% by volume for logs received at the mills • Plywood conversion efficiency was 42-65%, with the average being 55%		• Logging intensity was 5.2-6.9 trees/ha or 42-67 m^3/ha at four logging sites totalling 130 ha	• Logs produced accounted for 63.2% of the felled trees, with residues being 36.8% (stump 5.3%, buttress 3.8%, defective logs 6.0%, branches 21.7%)				Muladi, S. 1996
Indonesia, East Kalimantan	• Mechanized equipment is used in logging and results in considerable damage to the remaining stand		• Logging intensity 25 trees/ha in 4 ha study area • (14 in 14-29.9 cm dbh class; 6 in 30-49.9 cm	• 41 (commercial species) trees/ha left after logging of which 13 trees/ha were dipterocarps	• 50.1% of residual trees had no damage (958 residual trees or 240 trees/ha left			Tinal, U. & Palenewen, J. 1978

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			dbh class; 19 in 50-69.9 cm dbh class; 60 in >70 cm dbh class)		with dbh >14 cm) • 13.7% were overgrown with climbers • 1.7% had bark damage • 5.2% had crown damage • 0.7 had bark and crown damage • 28.6% of the trees were fallen or broken off			
Indonesia, South Kalimantan	• Study of regeneration capacity of logged over rainforest • In practice currently applied management and harvesting systems do not fulfil the criteria of sustainable forest management • Increasing gap size had a negative effect on height growth of dipterocarps • Larger gap sizes favoured pioneer species		• Recommended maximum gap size is 500 m^2 • In the Indonesian Selective Logging System 10-15 trees/ha can normally be harvested from natural forests					Tuomela *et al*. 1996
Indonesia, West Kalimantan	• Lowland rainforest		• Harvest removed 43% of pre-cut basal area or 62% of pre-cut dipterocarp basal area (average 5.1 m^2/ha)	• Residual dipterocarp (<50 cm dbh) suffered high mortality after logging, possibly limiting future wood supply • 76% of crown cover had moderate to heavy disturbance (45% heavy) • 8 years after logging total basal area was still only half of that in adjacent unlogged areas	• 18.4% of forest floor was disrupted by roads, tractor tracks and skid trails			Cannon *et al*. 1994
Indonesia	• Four case studies were conducted in similar dipterocarp-dominated lowland and hilly forests in East Kalimantan, Indonesia. • The studies were undertaken in Berau; Kutai Induk (near Kutai National Park); PT Sumalindo Lestari Jaya IV concession and the Centre for International Forest Research (CIFOR) Bulungan Research Forest, Malinau District. • The analysis compared the costs of the components measured in	• The selected RIL studies had the felling compartments outlined in the harvesting plans, which were based on accurate topographic maps of between 1:2 000-5 000			• RIL produced a reduction (almost 50 percent) in the damage caused to the residual stand.		• The results from the cost analyses are inconsistent. • The observed inconsistencies and differences do not allow for comprehensive and meaningful comparisons.	Applegate, G.B. 2002

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	the four studies.	scale, with contour intervals of between 5 and 10 m. • The harvesting plans identified planned skid trails and landings and individual tree locations. • Most CL activities on the sites used for the case studies did not have adequate maps for implementing harvesting activities. • There was no planning of skid trails, and directional felling techniques were not employed.						
Indonesia	• Widespread adoption of reduced impact logging (RIL), particularly in tropical forests, will probably remain an elusive goal wherever the forestry policy environment is overly prescriptive, dictating how to achieve sustainable forest management (SFM). • Instead, the focus should be on forest management outcomes that allow site-specific adaptations as well as sufficient regulatory oversight. • Forestry policy development in Indonesia from 1967 to 1999 illustrates the policy problem as well as opportunities to advance RIL. • This paper argues that the basic problem has not been lack of							Bennet, C. P.A. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	enforcement and implementation but the nature of the policy framework itself. • Prevalent and often counter-productive, prescriptive regulations should be reoriented towards outcome-based policies to promote RIL as well as other aspects of SFM.							
Indonesia	• Most forest concessionaires follow the Indonesian Selective Cutting and Planting System (TPTI) and carry out 100% inventories and most of the regulatory requirements. However, combined with an almost total absence of effective field monitoring and enforcement of existing regulations, TPTI is ineffective. • RIL research results in Southeast Asia indicate clear benefits from a productivity point of view and well as environmental benefits. However the financial benefits are not clear and in light if the uncertainties facing the industry in Indonesia, financial benefits must be clearly articulated. • The focus should now be on the implementation of RIL in Indonesia. • Forest companies and forest managers must educate themselves on RIL. Forest operations must be examined and adjustments made where necessary. Gaps in the knowledge and skill levels need to be identified and filled by thorough training. • Governments and funding agencies need to place greater emphasis on the development and delivery of training and extension programs for the forest industry.							Klassen, A.W. 2002
Indonesia	• Sustainable management of logged over forests requires an understanding of the potential yield from the forest and likely financial performance of the management system. • The growth and yield model		• The systems evaluated included one defined by a maximum of 8 harvested stems per ha and others based on maximum volume extracted of either 50	• Average yields from the TPTI system decreased from over 80 m^3/ha for the first simulated cycle to between 35-40 m^3/ha for the third and fourth harvests.			• The TPTI system is not economically viable after the second harvest leaving the only financially viable alternative of land conservation after	Van Gardingen, P.R., McLeish, M.J., Phillips, P.D., Fadilah, D., Tyrie, G. & Yasman, I. (in press)

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	SYMFOR was linked to a financial model derived for a forest concession managed under the Indonesian selective logging and replanting system (TPTI). • This combined approach was used to predict the likely timber yield for contrasting management regimes and then to calculate estimates of the financial performance described as the internal rate of return (IRR) and net present value (NPV) of the forest estate using both the TPTI system and reduced impact logging (RIL).		or 60 m^3/ha. Cutting cycle lengths evaluated ranged from 25 to 45 years.	• Systems based on RIL with a cutting cycle of 35 years with yield regulated to 50 m^3/ha or 45 years with a regulated yield of 60 m^3/ha were the best alternatives to the TPTI system.			clear felling of the remaining forest. • RIL systems were unable to consistently achieve an IRR of 16% unless there were also decreases in waste.	
Indonesia	• PT Inhutani II, a state owned logging company, collaborated with CIFOR in an ITTO funded project to test the RIL approach in its operations. • The main components of the include the development of appropriate logging guidelines and staff training.				• The area of skid trail per volume of timber extracted was twice as high in the conventionally logged blocks as in the RIL blocks (18.6 m^2/ m^3 vs. 8.6 m^2. m^3). • Damage to the stand and canopy increased with felling in the RIL blocks but not in the conventionally logged blocks. • Under high felling intensity (> 9 trees/ha), the proportions of damaged and dead trees in RIL were similar to those recorded in conventionally logged sites.			Machfudh, Sist, P., Kartawinata K. & Efransjah 2001
Indonesia (East Kalimantan)	• PT. Sumalindo Lestari Jaya is an integrated wood-based industry company headquartered in Jakarta, Indonesia. It is operating in the natural forests in East Kalimantan. • This project addressed road construction activities in the swamps of East Kalimantan, and conducted analysis of the logistics of all harvesting options and							Aulerich, D.E. & Sirait, J. R. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	activities. • The objective was to conduct cost-effective harvesting operations while reducing impacts on the environment. • After the initial evaluation of the ongoing operations, cable logging (primarily skylines) seemed to provide the most promising alternative for improving production, decreasing costs and reducing environmental impacts. The primary reasons for this conclusion were the steepness of the terrain, the high rate of soil erosion and the heavy rainfall, which could shut down tractor operations. • Workshops were organized to introduce top management and middle management to the alternatives to the basic ground-based systems being applied. • Meetings were also held with the regulatory agencies and operations people were then identified for training programs.							
Indonesia (East Kalimantan)	• Detailed damage assessments were carried out in five 1-ha plots within two 100-ha compartments, one of which was harvested using RIL and the other by conventional logging.		• Volume felled in all plots was 65 m^3/ha (11-12 trees /ha)		• Opening up caused by skidding decreased by 66% with RIL, while overall opening up decreased by 29%. • Stand damage caused by skidding decreased by 56% with RIL, while overall stand damage decreased by 28%.	• Logging waste was reduced by 20% under RIL		Hinrichs, A. & Ruslim, Y. 2001
Indonesia (East Kalimantan)	• In 1998, the management of P.T. Limbang Ganeca/East Kalimantan and the Sustainable Forest Management Project (SFMP-gtz) launched a RIL pilot project. • The private company was testing and implementing RIL under the			• The net exploitation factor in the RIL plots was higher (85 percent) than that in the CL plots (81 percent). • Efforts have been	• Stand openings following RIL were 29 percent lower than after CL. • In particular, opening up by tractors was	• Logging waste was reduced by 20 percent, although the CL operators were also instructed to reduce waste.	• RIL reduces skidding productivity by 15 percent, volume skidded is therefore reduced to 25.5 ha/mth.	Hinrichs, A., Ulbricht, R., Sulistioadi, B., Ruslim, Y., Muchlis, I. & Hui Lang, D. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	several conditions: RIL should not lead to major additional investments (re-engineering of harvesting machinery and change in methods are not required); RIL should neither reduce productivity nor increase operational costs; RIL should reduce logging waste and RIL should be in line with government regulations and certification requirements. • In 1999, a comparative study was conducted in five 1-hectare plots of two compartments. • The effects of conventional logging (CL) vs. RIL were evaluated, with regard to damage, efficiency, productivity and costs. • Implementation started in 2000 on a 2 350 ha annual cutting block with ongoing monitoring/evaluation by the company, SFMP-gtz and a joint implementation team from the Ministry of Forestry the company and SFMP-gtz.			made to increase timber usage efficiently by cutting the buttresses and placing the undercut properly	reduced drastically (by 65 percent). • The damage caused by tractors usually delays natural regeneration. • The large reduction indicates considerable environmental benefits and demonstrates that forest concessions adopting RIL can pass forest certification more easily. • The residual stand damage due to felling was not particularly different between the two treatments (dbh of trees measured was 20 cm up). • However, damage to the residual stand caused by skidding in CL was far greater. RIL caused 26 percent less overall damage to the residual stand. • In particular, RIL reduced residual stand damage from skidding by 55 percent as compared to CL		• Operational variable machinery costs are estimated to be reduced by between 5 to 15 percent. • The variable tractor costs (especially maintenance and fuel costs) could be reduced by 5 to 15 percent, although additional tractor costs accrue due to the use of higher quality cables in RIL. • Harvesting costs (including planning and operational cost up to roadside/log landings) were approximately US$1.00/ m^3 higher (at an exchange rate of US$1.00 = Rp 6 000). • Additional overheads for human resource development block inspection, team coordination and planning technologies still need to be considered. • Increased operational costs were covered directly by the financial gains due to higher timber utilization (increased net exploitation factor of about 4 percent).	
Indonesia (East Kalimantan)	• P.T. Inhutani I is an Indonesian state forest enterprise managing forest concessions located in several regencies in East Kalimantan and covering a total	• Successful implement-tation of RIL is based on improved			• The results indicate that environmental damage is much lower under RIL		• The results indicate that log production costs are much lower under RIL than CL.	Natadiwirya, M. & Martikainen, M. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	forest area of 1.1 million ha. • Three logging methods were studied at an operational scale, covering 237 trips extracting 1 500 m^3 of timber from three compartments. • Compartment A was logged using a bulldozer and RIL techniques. • Compartment B used RIL techniques and a combination of a bulldozer and a wheeled skidder. • Compartment C was logged using conventional bulldozer techniques.	planning of harvest operations. • Reliable tree and topographic data for the compartments to be harvested are required.			than CL. • The skid trail area opened in CL areas was 1.7 times that of skid trails in the RIL compartment. • Cross-slope trails and cutting depths were also greater in the conventional plots, increasing soil disturbance and machine time.		• The total cost of bulldozer skidding in a well-planned compartment applying RIL was only 67 percent of the cost of CL, mainly because of lower skid trail construction costs and avoidance of delays, both resulting from better planning. • For a standardised compartment (100 ha with 3000 m^3 timber extracted) under CL, the total costs were Rp154 million, and an estimated 48 days were required to log the compartment. • A bulldozer using RIL techniques completed the same work in 32 days at a total cost of Rp 103 million. • The combination of wheeled skidder and bulldozer completed the work in 30 days at a total of Rp 94 million. • The additional cost of improved planning required to execute RIL is estimated at Rp 4 million per 100 ha compartment.	
Indonesia (East Kalimantan)	• The effects of logging damage on forest dynamics processes were assessed in a lowland dipterocarp forest of East Kalimantan, Indonesia. • From 1990 to 1991, twelve 4 ha plots (200 m x 200 m) each divided into four 1 ha subplots were set up and all trees with dbh		• Felling intensity varied from 1 to 17 stems ha-1 (50-250 m^3 ha-1).	• Recruitment remained constant at 8 trees ha-1 per year in primary forest and varied from 14 – 32 trees ha-1 per year in logged-over stand in proportion with the amount of damage. In stands	• In primary forest, mean annual mortality remained constant to 1.5% per year throughout the study period while mean annual			Sist, P. & Nguyen-The, N. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	≥ 10 cm measured and identified at least at the generic level. • Logging was carried out from November 1991 to March 1992 in nine plots while three plots served as control. • Remeasurements were carried out just after logging in 1992and then every two years until 1996.			with the lowest remaining basal area, the establishment and growth of dipterocarps was strongly limited by the strong regeneration of pioneer species.	mortality rate was significantly higher in logged-over forest (2.6% per year). • This higher rate resulted from a higher mortality of injured trees (4.9% per year). • Four years after logging, mortality rates in logged-over and primary forest were similar.			
Indonesia (East Kalimantan)	• Reduced-impact logging (RIL) and conventional techniques (CNV) were compared in a mixed dipterocarp hill forest in East Kalimantan in three blocks of about 100 ha each.				• RIL techniques nearly halved the number of trees destroyed (36 vs. 60 trees/ha). • RIL's main benefit was in the reduction of skidding damage (9.5% of the original tree population in RIL vs. 25% in CNV). • Before logging, mean canopy openness in CNV (three plots only) and RIL (9 plots) was similar (3.6 and 3.1%) and not significantly different. • After logging, the mean canopy openness was 19.2% in CNV and 13.3% in RIL. At a larger scale, the area of skid trail per unit timber volume extracted was halved in the RIL compartment (15 m^2 vs. 27 m^2 m-3 for CNV). • However, under			Sist, P., Sheil, D., Kartawinata, K. & Priyardi, H. 2003

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					high felling intensity (>8 trees/ha), both stand damage and canopy disturbance in RIL approached those recorded in CNV under low or moderate felling regime.			
Indonesia (East Kalimantan)	• Because mixed dipterocarp forests exhibit high densities of timber trees, selective logging based on the minimum diameter cutting rule leads to high felling intensities from 10-20 trees/ha and high extracted volumes of 100-150 m^3/ha. • Under such high logging intensities, RIL objectives cannot be achieved, in terms of damage reduction, yield sustainability and biodiversity.		• Using the model STREK six felling cycles were simulated under constant time and constant extracted number of trees and applied several rotation lengths varying from 20 to 100 years with the several intermediary values: • The extracted number of trees was the mean number of felled trees in the three damage groups: G_1 -6 trees/ha, G_2-8 trees/ha and G_3-14 trees/ha. • The extracted volumes were calculated based on the average volume of dipterocarps in each dbh class tabulated in Favrichon and Cheol (1998). • In G_1, G_2 and G_3, the shortest sustainable rotations were respectively 23, 41 and 92 years, and significantly different. • These rotation cycles give mean harvesting volumes of 2.4 m^3/ha/yr, 2.0 m^3/ha/yr and 1.4 m^3/ha/yr respectively in G_1, G_2 and G_3.	• There is a strong impact of logging damage intensity on forest dynamics: the higher the damage the longer the time of forest recovery. • After logging, density of pioneers increases proportionally with the amount of damage; the most damaged stands show the highest density of pioneers. Results suggest that 30 years after logging, pioneers enter a phase of senescence to reach their original density recorded before logging at about 80 to 100 years after logging. • Commercial species face drastic shifts in their density and structure. • Their capability to adapt to altered environmental conditions created by logging and to maintain populations in the ecosystem after logging will depend mainly the original population density, population structure, regeneration dynamics and breeding systems.	• RIL clearly failed to reduce felling damage on the forest stand significantly. • Skidding damage on residual trees decreased from 25 percent of the original stand in CL to 9.5 percent in RIL. • The proportion of trees destroyed during logging is reduced significantly in RIL by 40 to 50 percent in comparison with CL techniques. • In two experiments in Indonesia (Berau and Bulungan), the proportion of trees destroyed and damaged in RIL plots under the high felling intensity (n >8 trees/ha in Berau, n >9 trees/ha in Bulungan) was similar to that recorded in CL; in both techniques, this affected about 50 percent of the original stand.			Sist, P., Bertault J.G. & Picard, N. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Indonesia (Kalimantan)	• In 1995, the Alas Kusuma concession of PT Sari Bumi Kusuma (SBK), collaborated with the USAID- funded Natural Resource Management Project (NRMP) in conducting an operational trial in which some RIL components were implemented. • One of the main objectives of this study was to evaluate differences in productivity and environmental impact by pre-planning harvesting activities and exerting a tighter control over felling and skidding. • The potential for improved harvesting economics, combined with obvious beneficial environmental results, as indicated by the initial SBK trial, prompted Alas Kusuma to attempt to duplicate this operational experiment on a slightly larger scale on its PT Suka Jaya Makmur (SJM) concession in West Kalimantan. • Results indicated that if large-scale adoption of RIL was to succeed, a number of significant improvements and changes still had to be made in the way the company organized its activities and in the technical competence of its staff. • The company carried out informal 'in-house' workshops where results were presented and discussed. • The staff was also able to discuss the problems and challenges which still need to be overcome before full adoption of RIL is achieved.	• The company's existing contour maps were used as a basis for planning a systematic harvest on a 25 ha area. • Skid trails were planned, located and opened prior to the start of felling activities. • Results suggested that there was the potential of increasing productivity and reducing environmental impact through the adoption of improved operational planning and control.						Suparma, N., Harimawan & Hardiansyah, G. 2002
Japan			• Shown that if the natural forest is managed at a stock level of 70-80% of the climax and a low percentage cutting (13-17%) is carried out on a short cycle (8-10 years) the total harvest volume can be increased without	• Found that it is difficult to keep the stand composition intact with selection cutting of more than 30% of the stand (basal area assumed) • When the cutting percentage reaches 65% the stand composition is				Watanabe, S. 1992

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			losing the productivity and health of the forest	destroyed				
Madagascar			• Logging intensity 10 m^3/ha					Ganzhorn *et al*. 1990
Malaysia			• Increased from 24 m^3/ha(1971-78) to 45 m^3/ha (1979-90)					Abhluwalia & Karnasudirdja 1995
Malaysia	• Virgin dipterocarp			• Climber cutting prior to logging reduced number of trees pulled down by 50% • Climber cutting and poisoning productivity 1 ha/5 hours				Appanah, S. & Putz, F. 1984
Malaysia	• Dipterocarp		• Simulations show that a 35-year cutting cycle may be too low in the selective management system • (dipterocarps >60 cm and non-dipterocarps >45 cm removed)	• Critical in all simulations is the need to maintain pole size material in the residual stand · if not, no residual stand will develop for the third cut				Appanah *et al*. 1990
Malaysia	• Tropical forest. • Rainfall 3084 and 2308 mm/a for the two-year study period				• Surface runoff generated 454, 10070 and 13341 kg/ha of soil loss in the first year after logging from undisturbed soil, skid trail and logging road, respectively. • In the second year soil losses decreased by 80% for skid trails and 77% for logging road • Recommends skid trails and logging roads not be build on slopes >20%			Baharuddin, K. 1995
Malaysia	• Hill dipterocarp forests		• Average 15 trees/ha felled	• 40.5 ha logging area 35% of basal area (BA) undisturbed, 55% of BA destroyed during extraction and 10% of BA actually extracted	• Road making the greatest damaging factor in hill forest exploitation			Burgess, P. 1971

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Malaysia	• Dipterocarp forests			• Average residual damage in contractor operated areas was 27.8% of dipterocarps and 38.5% of non-dipterocarps • Average residual damage in company operated areas was 32.8% of dipterocarps and 34.5% for non-dipterocarps				Canonizdo, J. 1978
Malaysia				• Greatest menace to advance growth is careless extraction rather than felling				Chai, D. & Udarbe, M. 1977
Malaysia	• After a pilot stage of 3 years (1,400 ha) the calculated greenhouse-gas-benefits were sufficiently positive to warrant the concession for implementing RIL on up to 9,000 ha over the coming 3 years.						• RIL: The approximate cost, based on greenhouse gas savings, is around US$ 1.40 per ton of CO_2	FAO 1998
Malaysia			• Average logging intensities • Sabah 120 m^3/ha • Sarawak 90 m^3/ha • Peninsula 52 m^3/ha	• In coupes logged during the late 1980s, tree losses during felling reached 62% under conventional tractor logging techniques, and 80% under overhead cable techniques	• Levels of damage of the forest are correspondingly high			Grieser-Johns, A. 1996
Malaysia	• Humid tropical forests. • Incidence of injury can be reduced by regular inspections and direction of operations by trained and experienced staff, and by post-logging inspection and enumeration. • A minimum felling limit is needed to limit the intensity of the logging operations; this, however, needs to be complemented by improvement thinning			• Loggers disregard the protection of standing stems of desirable species. • Only 15 desirables/ha were recorded as being both of potential commercial log grade and free from injury • Selective logging eliminated 20% of the total number of stems that existed in the virgin forest	• Selective logging snapped the trunks of 5% and injured more than 66% of all stems >10 cm dbh • 40% of medium-sized trees were damaged, thus jeopardizing the yield in the second cut			Hutchison, I. 1987b
Malaysia	• While the need for plantations cannot be denied, particularly in meeting long-term wood supply objectives, sustained yield management of the natural forest is imperative in most tropical							Jabil, M. 1993

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	countries. • The successful practice of tropical rainforest management for sustained yield requires not only technical expertise and appropriate technologies, but also careful planning and implementation							
Malaysia	• Contract fellers have scant regard to felling sequence considerations or to damages to forest growth					• For every 100 m^3 extracted, 80-105 m^3 of logging wastes are left behind considering materials with minimum dimensions of 0.91 m long and 30 cm diameter (9.3% stumps, 31.4% tops and branches, 2.3% end trims, 50% damaged residual trees and abandoned logs)		Malvas, J. 1987a
Malaysia	• RIL must ensure that an adequate number of 20-60 cm dbh trees/ha are retained in a healthy state after logging		• In ground skidding 89 m^3/ha available for harvest	• 23.1 trees/ha marked for retention • With RIL 19.0 trees/ha remaining (4.2 trees/ha >50 cm dbh) • With unsupervised felling 12.2 trees/ha remaining (1.1 trees/ha >50 cm dbh) • Direction felling saves more crop trees than uncontrolled felling (19 vs. 12 trees/ha) • Bucking length instructions imposed in the woods definitely increases log utilization efficiency of wood processing mills	• Optimum feeder road density 12.5 m/ha (800 m spacing). • 70.4 m/ha of skid trails laid out (average width 4.67 m) and covered 3.3% of area. • Minimum area covered by roads, landings and skid trails slightly over 5%			Malvas, J. 1987b
Malaysia	• Three land use options (catchment protection [CP], conventional logging [CL] and reduced impact logging [RIL]) were evaluated for forested catchments in Malaysia . These findings cannot be		• Harvesting intervals were 30-35 years, (cutting limits >50cm dbh for dipterocarp and 45cm dbh for non-dipterocarp species	• Residual stocking minimum is 32 trees/ha of commercial species of good quality from diameter class 30-45			• Net Present Value of CP option: US$ 5,772,685 • Net Present Value of RIL option: US$ 6,240,075	Mohd Shahwahid, H.O., Awang Noor, A.G., Abdul Rahim, N., Zulkifly, Y. &

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	extended to other forest catchments without making adjustments to the numerical results, such as incorporating different rates of sedimentation, rainfall and sediment concentration.		• For both the RIL and the CL option the net timber yield is 49.3 m^3/ha for the first cutting cycle and 31.6 m^3/ha for the second cutting cycle	cm or its equivalent			• Net Present Value of CL option: US$ 5,396,344 • The efficient choice among the two logging methods is the RIL option owing to the higher returns and the lower externality imposed upon the status quo water users • Complementing water uses with logging in forested catchments is efficient where hydro-electric power is produced.	Tazuni, U. 1999
Malaysia	• Prior to logging, forest structure and composition were similar in CL and the RIL areas, with mean basal area ranging from 25-33 m^2/ha		• CL: minimum cutting limit 60 cm dbh • RIL: Harvesting intensity 87-175 m^3/ha • CL: Harvesting intensity 90-173 m^3/ha	• Four years after logging, woody plant regeneration was better (more stems, greater species richness) in RIL than in conventionally logged areas. Churned skid trails in general showed a greater regeneration potential than bladed trails	• CL: 59% of the residual trees <60cm dbh were damaged • RIL: 29% of the residual trees <60cm dbh were damaged • CL: 140 m^2 of soil were disturbed per harvested tree (6.8% of total area) • RIL: 94 m^2 of soil were disturbed per harvested tree (16.6% of total area) • Skid trails with intact topsoil and litter layer were uncommon with CL, but covered about 12% of the skid trails in RIL units • Soil disturbance was positively associated with harvested volumes in CL areas, but not in		• Tay (1999) observed a greater efficiency of skidding in RIL units compared to CL areas. The skidding costs were US$ 1.98/m^3 for RIL techniques and US$ 4.51/m^3 for CL.	Pinard, M.A., Barker, M.G. & Tay, J. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					RIL areas • The proportion of skid trails with subsoil disturbance was less than half in RIL areas compared CL areas			
Malaysia	• Diverse in tree species and heavily stocked with commercial trees; average basal area 25 to 33 m^2/ha (dbh> 10cm), about 68% commercial species		• CL: modified uniform system with 60 year cutting cycles, target diameter 60cm dbh • RIL: 70 % of the basal area extracted with CL was harvested • The difference in stocking levels and the higher volume increment could reduce the cutting cycle by 50%. (Kleine 1997)		• RIL reduced the soil disturbance substantially compared to CL, both in terms of area damaged (from 13% to 9%) and degree of disturbance • The damage to the residual stand could be reduced from 50% to 28% of the original stems by implementing RIL		• RIL caused additional direct operating costs of US$ 135/ha or US$ 1.27 /m^3 (Tay, 1999) • RIL: US$ 45 /ha was spent on monitoring (less intensive monitoring may be sufficient on operational scale)	Pinard, M.A., Putz, F.E. & Tay, J. 2000
Malaysia	• Lowland dipterocarp forest · wood vines increase damage associated with felling and slow rates of regeneration after selective logging. • Vine cutting should occur sufficiently before felling to allow the vines to die and decay							Putz 1985
Malaysia			• RIL: felling cycle may be reduced		• Forests harvested with RIL may recover faster (canopy openings create favourable conditions for re-generation) • The only method for reducing felling damage that is currently available is to limit the level of cut.		• The long term benefit of RIL will most likely arise in the reduction of the felling cycle	Sist, P. 2000
Malaysia	• Comments based on 1987 visits to several SMS sites • As practised then did not hold much hope of success in respect of sustained commercial volume production, except where		• The SMS by design may yield a second cut of comparable volume to the first; however, it will contain a proportion of less-		• Logging damage and undue selection of logs extracted (in 1987) still appeared			Wyatt-Smith, J. 1988

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	Dryobalanops aromatica (kapur) predominates • Economic cut of the best commercial species equitable to the logger appeared to carry the greatest weight in practice rather than ensuring sustained yield management of the valuable species		desirable commercial species (current standards) • The major problem will be in the volume available in the third and subsequent cuts		excessive • Quite clear that the operations in the concessions visited were not sustainable • In reference to Thang (1987) states that a 30% damage factor (built into growth model) to intermediate-size trees at each cutting is unacceptably high, although unfortunately probably realistic			
Malaysia	• Logged in 1959				• Area damaged by logging roads and compartment boundary 9%, covered by crowns 28%, covered by boles 2% (total 39%)			Wyatt-Smith, J. & Foenander, E. 1962
Malaysia (peninsular)	• The system incorporates directional felling and improved road construction		• Cutting limit 45-50cm dbh · Cutting cycle of 30 years		• RIL: 30% of the total volume were damaged during harvesting · CL: 40% of residual stand assumed to be damaged		• Higher skidding efficiency in RIL operations • RIL: logging costs reduced by 4% (RIL 13.39 US$/$m^3$; CL 13.93 US$/ m^3) • RIL: damage equals 61.92 US$/$m^3$ (discount rate 4%) • CL: damage equals 85.88 US$/ m^3 (discount rate 4%)	Ahmad, S., Brodie, J.D., & Sessions, J. 1999
Malaysia (Sabah region)	• Dipterocarp forest with a high density of commercial logs • The mean carbon storage over a 60-year cycle is -38.39 tonnes per logged hectare with RIL and -94.31 per logged hectare with CL. • Particularly because of the potential opportunity costs associated with RIL, this outcome should not be relied upon for other regions		• At the second cut (60 year cutting cycle) greater yields are expected from RIL areas than from CL areas • With RIL, 59.4 m^3/ha were harvested • With CL, 135.2 m^3/ha were harvested	• Following logging, 50% of the logged material is assumed to be converted to timber products			• Organisational and operational expenditures increase when implementing RIL • Revenue will be foregone through the lower timber volume logged by RIL operations • Comparison with	Tay, J., Healey, J.R. & Price, C. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							carbon prices derived in other ways shows that, using the same discounting assumptions, the costs of retaining carbon by RIL is expensive compared with most other carbon prices.	
Malaysia, Peninsula	• Hill dipterocarp forest				• Disturbance to 17.8% of soil area with tractor logging and minimum felling diameter of 60 cm· damage to seedlings in high-lead areas (50-57%) was higher than in tractor-logged (38-48%) areas • Damage to trees >10 cm in high-lead area were 24%, 26% and 38% with 45 cm, 60 cm and 52 cm minimum felling limits • Tractor damage (trees >10 cm dbh) ranged from 8% (45 cm min. dbh) to 21% (60 cm min. dbh)			Borhan *et al.* 1987
Malaysia, Peninsula	• Mean basal area 26.9 m^2/ha • Conventional logging had a minimum felling limit for dipterocarps of 65 cm dbh and 45 cm for non-dipterocarps • Planned logging (RIL) had a minimum felling limit of 90 cm dbh for dipterocarps and 60 cm for non-dipterocarps			• Stocking removed in conventional logging was 40% while in the planned and supervised logging it was 33%	• Conventional logging had 60 m/ha of logging road and 80 m/ha of skid trail and no buffer strips were specified • Planned logging had 70 m/ha of logging road and 30 m/ha of skid trail, and 20 m buffer strips on each side of the			Nik, A. & Harding, D. 1993

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					stream • Conventional logging area had 55% higher water yield than the planned logging area, although the percent of forest removed was only 21% higher • Ground disturbance area (skid trails, logging roads, landings) was limited to 5.1% in the planned area, while in the conventional logging area it was 7.1%			
Malaysia, Peninsula	• In hill and dipterocarp forests a shift to more selective management • Need appropriate felling limits and leaving an adequate number of medium sized trees of marketable species for natural ingrowth into commercial sizes		• Under the Malaysian Selective Management System a logging intensity of 30-40 m^3/ha on a 25-30 year logging cycle is expected					Thang, H. 1986
Malaysia, Peninsula	• Data based on a series of 100 continuous inventory plots (0.4 ha each) and another 100 experimental cutting or silvicultural treatment plots		• With average annual growth rates of trees >30 cm dbh of 0.8-1.0 cm and 2.0-2.5 m^3/ha/a in commercial gross volume, about 75% of the hill forests are capable of producing 40-45 m^3/ha on a 30-year logging cycle • This is about the current average outturn level of virgin hill forest	• To account for harvesting losses such as felling breakage, defects, high stumps and short logs left in the forest, potential net volume extracted is 60% of the gross volume for trees with dbh <60 cm and 70% for trees with dbh >60 cm	• Damage levels by dbh class in SMS were >60 cm=20%, 45-60 cm=30%, 30-45 cm dbh=40%, 15-30 cm=50% • Important to curtail logging damage to the residual stand to not more than 30% of the intermediate-sized trees (30-45 cm dbh)			Thang, H. 1987 (same data presented in FAO 1989b)
Malaysia, Peninsular	• With average growth rates of 2-2.5 m^3/ha/a in commercial volume for trees .30 cm dbh and 0.8-1.0 cm/a of dbh, about three quarters of the hill forest is capable of producing at least 40-45 m^3/ha on a 30-year logging cycle		• Current average logging intensity in hill forests is 40-45 m^3/ha					Mok, S. 1992

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• Growth and yield studies in Sabah and Sarawak have shown similar results							
Malaysia, Sabah	• Logging residues were all pieces >2 m in length and >45 cm diameter			• On average 9.4% of the actual log production was left as residues in the landings and almost 54% of the residue logs were free of any • By moving from a 60 cm dbh felling limit to 40 cm the allowable harvest volume would increase from 114.5 million m^3 to 169 million m^3 • 1984 sawmill recovery 50% • 1984 plywood mill recovery 44%		• On average logging waste amounted to 18.3% of the actual log production defects • Total utilizable waste based on removed log volume was 27.7%		Bhargava, S. & Kugan, F. 1988
Malaysia, Sabah	• Mixed dipterocarp forests · 20 plots, each 5.76 ha • 310-440 trees/ha (dbh >10 cm), of which 10-20 stems/ha with dbh >60 cm • Basal area 28.3 m^2/ha of which 57% were dipterocarps		• Felling intensities >100 m^3/ha are common · minimum felling limit is 60 cm	• Climber cutting had no impact on felling accuracy	• Skid trail placement at 60 m and planned			Cedergren *et al.* 1996.
Malaysia, Sabah					• Total damage from logging amounts to as high as 30-50% of the total land surface			Chai, D. 1975
Malaysia, Sabah	• Dipterocarp · preferable to manage the regenerating forest than plant dipterocarps in open areas • Undue destruction of regenerating forests should not be allowed, and the Forestry Department should endeavour, as far as possible, to impose rules and regulations in respect to logging damage			• In one study 13.7% of original number of seedlings present before logging were still alive 3 years after logging (19350 seedlings/ac reduced to 2450 seedlings/ac) • Major mortality occurred during logging				Chim, L. & On, W. 1973
Malaysia, Sabah	• 80% or more of the stand >60 cm dbh is generally dipterocarps		• Logging intensity generally 89 m^3/ha, although stands may reach 267 m^3/ha	• Top diameter is 48 cm, but sometimes smaller material is removed • Also found that the higher the felling cut on the tree, the higher	• 33.6% of residuals had little or no damage, 53.5% were fallen or broken off and 12.9% had major crown and/or bark			Fox, J. 1968

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
				the losses to log shattering, splitting and torn bases	damage • Of 42.5 potential dipterocarp residual crop trees/ha in the study area, only 14.3 trees/ha had little or no damage			
Malaysia, Sabah			• Based on silvicultural experience in Sabah, a dipterocarp stand can produce 15-30 trees/ha or 45-90 m^3/ha (>60 cm dbh) of marketable timber species each cutting cycle • Article does not give length of cutting cycle (assuming 30-40 years)					Kleine, M. & Heuveldop, J. 1993
Malaysia, Sabah					• New tractor tracks (D4 and D6 class crawler tractors) cover 25% of areas with mechanical extraction • For manual extraction (kuda-kuda) skid trails cover 4% of area • During rain the extraction stopped, and for heavy storms normally stopped for one or two days due to the tracks being too slippery • Along the most heavily used parts of the tracks, up to 1 m of the upper soil layers were pushed aside			Malmer, A. & Grip, H. 1990
Malaysia, Sabah	• Dipterocarp forest · RIL and proper selection harvesting are essential elements of sustained		• In eastern Sabah the average log weighs 7-9 tons and 80-100	• RIL not only minimized all external environmental costs	• Research plots demonstrated a 50% reduction in			Marsh *et al.* 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	management of tropical forests • After logging the area must be closed from further operations and skid trails rehabilitated		m^3/ha are extracted • RIL logging intensity 103 m^3ha (8.8 trees/ha) • Conventional logging intensity 139 m^3/ha (13.6 trees/ha)	but also assures greatly improved future harvests with little or no need for further silvicultural treatments	all measures of damage with RIL when compared to conventional logging, for an increase of about 10-15% in direct logging costs • Restrictions in wet weather skidding slowed operations considerably in RIL areas and added to cost • In RIL logged areas skid trail area average 3.8% of the area, compared to 12% in adjacent conventionally logged areas			
Malaysia, Sabah	• Average dipterocarp forests in Sabah can produce between 1.25-2.075 m^3/ha/a of millable timber over a 40-year period (50-83 m^3/ha)		• Average logging intensity 69 m^3/ha • 50-83 m^3/ha possible on a 40-year logging cycle	• 40 years after logging (high lead logging) the average dipterocarp volume per hectare is half of that of adjacent unlogged forest	• Between 20-40% soil disturbance with heavy equipment			Meijer, W. 1970
Malaysia, Sabah	• Analysis suggests that 2-3 m^3/ha/a net growth rate after logging is achievable, compared to plantation growth rates of 12-20 m^3/ha/a			• With logging severity 20% and 23% net growth was 0.8 and -1.7 m^3/ha/a 7 years after logging • With logging severity of 36 and 76 % net growth was -2.4 and -16.3 m^3/ha/a 2 years after logging • Mean dbh growth for trees in 35-44.9 dbh class were 0.7, 0.4. 1.0 and 1.6 cm/a for virgin forest, and 4%, 15% and 20% logging severity, respectively	• With logging severity (% of original stems cut, damaged and destroyed per plot) less than 15% net growth rates of 3.4-5.9 m^3/ha/a were found 7 years after logging			Miller, T. 1981
Malaysia, Sabah	• Hilly area • Training required for all levels of the hierarchy, from tree fellers to senior management • In the initial analysis of RIL it was more expensive due to the extra activities required (detailed		• 8-15 trees/ha (80 m^3/ha) normally extracted • 800 ha area studied with logging intensity of 120 m^3/ha with RIL and conventional		• In RIL area 20 m/ha of roads (1.6% of area), 71 m/ha of skid trails (4% of area) and 57 m^2/ha of log landings (0.6% of			Moura- Costa, P. 1997

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	inventories, training, climber cutting, intensive supervision) • After the initial period of training and learning it is expected that RIL operations will run more smoothly and efficiently than conventional operations, and thus savings will accrue through lower bulldozer use, fuel and maintenance costs		logging		area), for a total coverage of 6.2% • In conventional logging area 24 m/ha of road (3.3% of area), 205 m/ha of skid trails (13% of area) and 103 m^2/ha of landings (1.0%), for a total coverage of 17.3 • In RIL area 29% of residual trees damaged • In conventional logging area 56% of residuals damaged			
Malaysia, Sabah					• Soil disturbance by tractor trails bare of regeneration averages 14% of the logging area			Nicholson, D. 1958a
Malaysia, Sabah	• Study showed that even with 45% severe to moderate damage to residuals, there were still 20 trees/ha between 10-60 cm dbh which had received no damage and which could yield a stand as good or better than the one just logged		• Logging intensity 11.6 trees/ha or 116.5 m^3/ha	• 35% of the undamaged trees had good form and 12% had poor form	• 53% of residual trees were damaged (fallen or broken off trees 30%, bark damage 11%. crown damage 4%, minor damage 8%) • Amount of damage to residuals increases with logging intensity			Nicholson, D. 1958b
Malaysia, Sabah	• Dipterocarp forests • A well-regenerated forest depends on a careful logging operation • Only extraction has the potential to reduce the regenerating forest to a mass of useless weeds, by destroying existing seedlings and poles				• General tendency for the intensity of logging to increase with the passage of time and for tractor damage to increase • In 1958 14% of the area was impacted, while in 1965 bared area had increased			Nicholson, D. 1965

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					and figures as high as 40% were estimated • Though some rise is probably inevitable, it is not conceded that tractor damage must rise in proportion to the intensity of logging • The most destructive damage appears to stem from inefficient use of tractor tracks and landings • Should also avoid excessive use of the dozer blade and increase the use of the winch and cable			
Malaysia, Sabah	• Dipterocarp forests • Cost of rehabilitating 7 ha of log landings with mixed indigenous species with a 2x1 m spacing was US$1100/ha		• Logging intensity varies but rarely exceeds 10-12 trees/ha					Nussbaum, R. & Hoe, A. 1996
Malaysia, Sabah	• Refers to same study as Pinard *et al*. 1995		• First cuts in Amazon usually <50 m^3/ha • First cuts in Africa usually <30 m^3/ha	• More and larger trees remained undamaged in RIL, hence future biomass increment and yields of marketable timber are expected to be greater in RIL areas than in the conventional logging areas	• No correlation found in study between volume removed and damage to residuals			Pinard, M. & Putz, F. 1996
Malaysia, Sabah	• RIL results in reduced bulldozer maintenance cost, lower bulldozer skidding time, no need for enrichment planting and logging cycle time can be reduced due to less damage to residuals • Need for good training of all people involved from fellers to technicians and foresters		• Minimum felling limit 60 cm dbh • Logging intensity typically 8-10 trees/ha or 80-100 m^3/ha, although it ranges from 50 to 120 m^3/ha • In the study area the logging intensity was 154 m^3/ha in conventional logging area and 104 m^3/ha in		• In RIL areas skid trail coverage was 3.4%, while in adjacent conventional logging areas it was 12% on average • 38% of trails in RIL areas had soil exposed, while in conventional			Pinard *et al*. 1995

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			RIL area		logged areas 87% were exposed · RIL resulted in 50% less damage to soil and residual trees • An associated 40-70% of the residual stand is damaged • Vine cutting reduces damage, reduces post felling vine infestations, and increases light to the forest floor before felling and thus smaller trees can adjust • 37% of trees uprooted in conventional logging, while it was 13% in RIL			
Malaysia, Sabah			• Trees >60 cm dbh logged and average logging intensity 94 m^3/ha		• Even in 15-year old logged-over forests of Ulu Segama, the traces of log landings and skid trails are visible as treeless patches and corridors			Pinard *et al.* 1996
Malaysia, Sabah	• Clear felling operations		• Volume extracted at site W4 146 m^3/ha (145 trees/ha) and site W5 129.7 m^3/ha (146 trees/ha) (based on volumes transported to landings)		• Tractor tracks covered 24% of the clear felled area			Sim, B. & Nykvist, N.1991
Malaysia, Sabah	• Increase in fires due to forests becoming more prone to fire after disturbance by logging (debris and opening up of canopy) • Of the 1 million ha burnt in Sabah in 1983, 85% has been logged over • Of the estimated 3.5 million ha of tropical forest burnt in Kalimantan, 77% had been logged-over forest							Woods, P. 1989

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	• In addition to more fires, tree mortality in burned logged-over forest is higher than in unlogged forest (38 to 94% vs. 19-71%)							
Malaysia, Sarawak	• Moist dipterocarp forest • Mean annual dbh increment of all trees >10 cm dbh in control areas was 0.22-0.34 cm/a, in overstorey removed areas 0.37-0.44 cm/a, and liberation thinning areas 0.45-0.56 cm/a (if only reserved trees measured in this case 0.77-0.99 cm/a)		• 1974-1980 selective logging extracted an average 5-15 trees/ha (10-50 m^3/ha) • With improvement thinning could have a polycyclic system with 60-year rotation and 30-year cutting cycle					Hutchinson, I. 1987a
Malaysia, Sarawak	• Predicted timber yields in cut-over hill mixed forest assuming RIL • Quality group 1 contains 179 timber tree species (5% of tree flora) and group 1-3 contains 785 tree species (23% of tree flora) • The practices of the labour force in the forest directly cause much of the damage; practically no formal training for fellers or tractor and skidder operators (experience is passed from one to the other) • Tractor and skidder operators are paid piece rates by most companies, and fellers by all companies; the emphasis is on output and not on the minimization of damage • Safety standards are usually low • These weaknesses are exacerbated by inadequate staffing of the Forest Dept. and the consequent inability to exercise the degree of supervision required of		• Present logging intensity 38 m^3/ha • 40-year cycle untreated with 60 cm minimum dbh felling limit 25.7 m^3/ha (quality group 1) and 32.6 m^3/ha (quality group 1-3) • 40-year cycle untreated with 45 cm minimum dbh felling limit 37.7 m^3/ha (quality group 1) and 47.6 m^3/ha (quality group 1-3) • 40-year cycle treated with 60 cm minimum dbh felling limit 33.2 m^3/ha (quality group 1) and 42.4 m^3/ha (quality group 1-3) • 40-year cycle treated with 45 cm minimum dbh felling limit 63.8 m^3/ha (quality group 1) and 82.4 m^3/ha (quality group 1-3) • if the harvest were limited to trees 60 cm dbh or more and quality group 1, cutting cycles of 45-50 years would be necessary to attain the present harvest level of 38 m^3/ha		• The yields indicated can never be achieved by continuing present practice, which is damaging to the environment and the residual stand			ITTC 1990

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Malaysia, Sarawak	• Hill forests	• Lack of planned skid ways in the forest leads to the creation of numerous tractor paths for seeking logs	• Logging intensity varies from 4-20 trees/ha • Average logging intensity (1974-1978) was 25 m^3/ha, with the standing volume being 94-145 m^3/ha • Planned logging cycle is 25 years, but it is doubted this short of a cycle is appropriate, especially due to the high damage factor					Lee, H. 1982
Malaysia, Sarawak	• Recommends RIL • In mixed dipterocarp hill forests the average tree size is 5-6 m^3/stem and 60-80 cm dbh		• Minimum felling limit is 45 cm dbh • Volume greater than 46 cm dbh (all species) 131.4 m^3/ha • Logging intensity 28.7 m^3/ha					Mattsson-Marn, H. 1982
Malaysia, Sarawak	• Mixed dipterocarp hill forest • Study comparing 122 ha area logged with RIL and 122 ha area logged conventionally • Total skidding cost (including RIL associated planning, layout and supervision costs) was M$4.56/$m^3$ compared to M$5.94 for the current system		• RIL logging intensity 55 m^3/ha · Conventional logging intensity 53 m^3/ha	• Found that 11 m^3/ha (20% of total volume of sound timber felled) of logs had been felled and bucked, could not be found by the skidder in current operations versus 5.5 m^3/ha in the planned block	• With RIL overall damage to residuals reduced by 50%, skidding efficiency increased 36% and there was no cost increase with directional felling			Mattsson-Marn, H. & Jonkers, W. 1981
Malaysia, Sarawak	• Total cost of wood delivered to mill (including all planning, layout, logging, roads, road transport, overhead costs) was M$31.71 in unplanned area and M$29.88/$m^3$ in planned area				• More defects, splitting and other felling damage in the unplanned area • 174 m/ha of skid trail in unplanned area vs. 136 m/ha in planned area (22% less) • 7% of area covered by trails in unplanned area vs. 5% in planned area (4 m wide trails)			Mattsson-Marn *et al.* 1981
Malaysia, West	• RIL may add M$51-70/ha, whereas post logging silviculture treatments (including planting of roads and landings) may cost M$200/ha							Andel, S. 1978

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Malaysia, West	• Dipterocarp forest		• Logging intensity 18 trees/ha (24 m^2 basal area/ha), with minimum felling diameters of 45 and 60 cm depending on species		• The mechanized extraction of 3.3% of trees >30 cm dbh destroyed 50.9% of the trees (3.3% extracted, 4.8% destroyed during road building, 3.6 % destroyed when building landings, 39.2% destroyed during felling operation and log dragging • Of the 49.1% remaining standing trees 6.0% were damaged			Johns, A. 1988
Malaysia	• Rimbaka Forestry Operations has recently started introducing RIL to its operations. • The Rimbaka Timber Harvester is an innovative machine developed by the company to reduce the density of skid trails during log extraction.				• Average length of skid trails in forest logged with the Rimaka Timber Harvester was less than 40 m/ha and the total area damaged was approximately 15%; well below the threshold set within the Malaysian Criteria and Indicators.			Sarre, A. (2001)
Malaysia (Sabah)	• Reduced-impact logging (RIL) is one means of reducing the carbon emissions held responsible for global warming. • Comparable effects of RIL and conventional logging were studied in Sabah, Malaysia.			• RIL reduced the area logged within a tract by 44% and resulted in a 22% reduction in timber yield per logged hectare when compared to conventional logging.	• RIL resulted in less damage than conventional logging.		• RIL resulted in an 18% increase in costs per m^3 logged as compared to conventional logging. • Per m^3 of timber logged RIL was beneficial without discounting, but had a net cost at a 2% discount rate and higher. • The overall cost of RIL's carbon retention varied in both discount rate and level of	Healey, J.R., Price, C.& Tay, J. 2000

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							analysis, from negative price to more than US$ 50 per mega gram at a 10% discount rate. • RIL appears most cost-effective on a per m^3 logged basis at low discount rates. • However, at commonly applied discount rates (4% and above) RIL's carbon price exceeds most published estimates for carbon prices.	
Malaysia (Sabah)	• In a recently logged forest, the seed sources and seedling establishment between conventional logging (CL) and reduced impact logging (RIL) and between two soil disturbance classes.			• More pioneer seedlings established on RIL than on CL plots, but survival of planted seedlings was lower under RIL, due to denser canopy cover.				Howlett, B.E. & Davidson, D.W. (in press)
Malaysia (Sabah)	• From 1992 through 1998, PG&E National Energy Group (NEG) conducted a series of projects to test and demonstrate the application of reduced impact logging as a method for producing verifiable and quantifiable carbon sequestration. • NEG verified that RIL had been successfully implemented by the inspection reports of an Environmental Audit Committee. • It is estimated that over the 40 years following harvest, the first RIL project will sequester 485,000 tons of carbon.							PG&E National Energy Group 2002
Malaysia (Sabah)	• The study was conducted as part of a project located in the Sabah Foundation forest concession area in Sabah, Malaysia. • The pilot phase of the project comprised 1 400 ha and lasted three years from 1992 to 1995. • In 1996, the project area was expanded by another 1 000 ha.	• Prior to harvest, total stem densities for trees greater than 1 cm DBH in the CL and RIL units were 4 382 and 3 798	• The mean volume of timber extracted in the RIL and CL units of 106 and 136 m^3/ha, respectively, was within the extraction intensity of 40-160 m^3/ha reported in other parts of the	• Of the 176 ha allocated to the CL units for logging, almost all of the area was logged. • In RIL units, only 129 ha (56 percent) of the 230 ha was logged. • The net timber volume	• In extracting 9 to 13 trees of above 40 cm DBH, the overall damage inflicted on the residual forests averaged 60 percent and 30 percent in the CL		• The net contribution of RIL from the first harvest (t_0) was less than half of CL. • The lower NPV_{RIL} was due to high extraction costs,	Tay, J., Healey, J. & Price, C. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• The objective of the financial assessment was to compare RIL with CL in terms of costs and benefits. • The assumption is that observed post-logging differences between RIL and CL can be attributed to the different logging methods rather than to variations between the sites. • The data were generated directly in the study area through the establishment of a network of growth and yield plots. Eight forest management units totalling 406 ha were divided into four pairs. In each pair, one unit was subjected to RIL and the other to CL during 1993 and 1994. • The analysis covered two cutting cycles at year 0 (t0) when the first harvest was undertaken in the primary forest, and at year 60 (t60) when the second harvest will be made.	trees/ha. • The original stand structure did not differ significantly for the six DBH classes (1-5, 5-10, 10-20, 20-40, 40-60, >60 cm DBH) except for trees with 1-5 cm DBH.	study area.	foregone in RIL amounted to approximately 35 m^3/ha. • The benefit of directional felling was most evident for trees in the 5-40 cm DBH range where the remaining stem density was higher in the RIL units compared with the CL units.	and RIL units, respectively. • The total area of skid trails, log landings and roads in the RIL units was only 40 percent of that in the CL units. • They represented approximately 7 and 17 percent of the total area logged in the RIL (129 ha) and CL units (175 ha), respectively. • All three categories of openings (skid trails, log landings and roads) in the RIL units were smaller than in the CL units, but only skid trails showed a significant difference in area between the treatments. • RIL units had a smaller area of skid trails occupying 4 percent of the total area logged compared with 12 percent in the CL units.		and a lower yield. • RIL costs 18 percent more than CL. • The bulk of the additional cost comprised extraction costs at RM18/m^3 or 12 percent of CL. • Harvest yield at t0... RIL=106 m^3/ha CL=136 m^3/ha. • Harvest yield at t60... RIL=111 m^3/ha CL=85 m^3/ha • For the second harvest (t60), RIL and CL yielded RM223/ m^3 and RM289/ m^3 resp., without discounting. The reduction in profit due to the adoption of RIL was 23 percent of CL. • For the first harvest, the profits generated from using RIL and CL were RM2 912/ha and RM7 715/ha, respectively. • The 62 percent lower profits for RIL were due to lower harvested volumes. However, if only extraction activities were considered, RIL costs RM344 more than CL (RIL = RM9 573 and CL = RM9 917). • For the second harvest, the NPVRIL and NPVCL without discounting were RM24 701/ha and RM24 554/ha, respectively.	

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Malaysia (Sarawak)	• The WTK Organization was the first company to implement helicopter logging in Sarawak in 1993. • Helicopter logging in usually applied to areas inaccessible to more conventional extraction methods.		• Average volume per turn 5 - 7.5 m^3; average turn time 3-4 minutes; average volume per effective working day 600-700 m^3.		• Helicopter logging caused considerably less damage to soil and residual forest than tractor logging. • Number of trees damaged or removed per tree extracted was 1.4-3.1 for helicopter logging compared to 5.5 for tractor logging. • Open space created by canopy openings and skid trails as a percentage of logging area was between 4-11 for helicopter logging vs. 15.9 for tractor logging.		• Helicopter logging is more expensive per unit volume than conventional logging.	Chua Kee Hui, D. 1996
Malaysia (Sarawak)	• Helicopter harvesting was introduced to Sarawak in April 1993 by WTK Organisation (a local timber company). • This system of extraction is now used by many timber operators in Sarawak because of its high production performance and its ability to extract logs from otherwise inaccessible areas with minimal damage to the surrounding forest.			• No. trees felled and extracted = 1.4 - 3.5 per ha compared with 8.7 per ha for tractor logging.	• No of trees damaged or removed per tree extracted = 1.45 - 3.13 compared with 5.49 for tractor logging. • Area covered in canopy gaps = 4% - 11% compared with 15.91% for tractor logging.	• The volume of remnant and rejected logs left in the field is quite high (as compared to tractor logging) due to the selection of only good merchantable logs for lifting. • Based on a per tree extracted basis, about 1.8 to 2.3 m^3 of utilized timber are left behind in an area harvested by helicopters compared to 0.08 m^3 for tractor based harvesting.	• High capital and operating costs of the helicopter. • Higher contract rates for felling crews. • Helicopter harvesting cots twice as much as conventional tractor harvesting.	Chua Kee Hui, D. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Malaysia (Sarawak)	• The FOMISS - Sampling Pilot Area (FSPA) a is located in the Upper Baram of northeast Sarawak, covering 169 000 ha. • Comparative financial and economic analyses of CL and RIL with tractors for the FSPA were carried out. • The financial costs and benefits of CL were analysed over two different time frames: (a) after one-year of harvesting and (b) after a 40-year rotation period in a logged-over forest. • The project established 13 RIL trial blocks in the FSPA. • Additional data were obtained from RIL trials in the Model Forest Management Area (MFMA) in Sibu.	• Fifty percent of the FSPA comprises primary forests with an average commercial volume of 303 m^3/ha. • The average stocking of logged-over forests averages 170 m^3/ha.					• The costs of harvesting and royalties per m^3 are approximately 23% higher under RIL relative to CL for the 1-year period. • If the introductory costs for training and damage assessment are excluded, the difference is reduced to 14%. • The profit was estimated at RM29/ m^3 and RM45/ m^3 under CL and RIL, respectively. • If the introductory costs are excluded the profit increases to RM52/ m^3. • The profit is reduced to RM20/ m^3 if the concessionaire does not obtain a certification premium. • The profit per ha of the net production area totals RM1176 for CL and RM883 for RIL. • CL was slightly more profitable and exceeds the NPV of RIL by a factor of 1.3 after 40 years. • The BCR for RIL exceeds that of CL by a factor of 1.1. • This means that RIL is more robust with regard to cost increases. • In terms of the financial cash flow, the first harvest was more profitable under CL than	Dagang, A.A., Richter, F., Hahn-Schilling, B. & Manggil, P. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							under RIL, whereas the financial benefits of the second harvest were higher under RIL. • The economic analysis showed that the RIL system provided a higher level of overall benefits as opposed to CL after the 40 year period.	
Malaysia (Sarawak)	• In June 1996, the Sarawak Timber Association (STA) collaborated with the SFD, to start a tree-felling training program to supplement existing training programs provided by the SFD and other government agencies. • STA has been involved in the training of tree fellers for about 36 months and has so far trained 508 persons. • The training concentrated mainly on occupational health and safety and directional felling. • STA faced the following problems: (a) lack of availability of qualified trainers and an appropriate curriculum (b) difficulties in access to the training sites (c) cultural (esp. language) barriers and (d) the high cost of training.							Kho, P.C.S. & Chan, B.S.T. 2002
Malaysia (Sarawak)	• Data on cost, productivity, and damage to the residual stand as well as data on soil compaction were obtained from RIL and CL trial blocks in the FOMISS-Sampling Pilot Area (FSPA). • In addition, timber wastes due to poor utilisation and lost logs are estimated based on data collected in the FSPA. • Figures on forest growth are predicted with the Dipterocarp Forest Growth Simulation Model (DIPSIM).		• Overall harvesting volume of the first harvest under CL averaged 44.5 m^3/ha and in the RIL blocks the harvesting volume averaged 27.8 m^3/ha. • The potential harvesting volume in the second harvesting operation 40 years after the initial harvest would be 23 m^3/ha in CL and 83 m^3/ha in RIL. • However, the		• The percentage of severely damaged trees was reduced from 54% under CL to 28% under RIL.	• Timber wasted: RIL a UF of 80% was calculated and for the CL a UF of 75% was estimated. • Under CL the volume of timber wasted due to logs left on the log landing or due to second trimmings amounts to 20% of the total extracted volume, whereas	• The economic value of timber revenues averaged RM 351/m^3 for CL and RM 387/m^3 for RIL (including a 10% certification premium). A total NTFP value of RM 6,798 per block (100 ha) and year was calculated for CL and a value of RM 9,764 for RIL. • The annuity per block with regard to soil erosion	Richter, F. 2001

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			maximum harvesting intensity under RIL was set at 40 m³/ha/y.			in a planned harvesting operation the log wastage approaches 0%.	benefits was estimated to be RM 1,442 (year 1-10) and RM 9,034 (> year 10) under CL and RM 4,526 (year 1-5) and RM 10,126 (> year 5) under RIL. • In addition the following annual recreational benefits per block were obtained: RM 189.5 for CL and RM 1,895 for RIL. • The annual economic value of biodiversity per block amounts to RM 625 for CL and to RM 898 for RIL. • The profit was estimated at RM 29 and RM 45 per m³ under the CL system and the RIL system respectively. • However, considering the extracted volume, 4,005 m³/100 ha NPA under CL vs. 1,942 m³/100 ha NPA under RIL, the CL system is more profitable. The total profit per 100 ha NPA amounts to RM 117,566 under CL and to RM 88,318 under the RIL system.	

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Malaysia (Sarawak); Guyana; Indonesia	• In this paper, four cases are discussed in which the author was involved directly: the RIL methods developed in Sarawak in the 1970s, in Suriname in the 1980s and in Guyana and Cameroon in the 1990s. • The Sarawak method was tested in a dipterocarp forest on undulating terrain, in a logging concession approximately halfway between the towns of Miri and Bintulu. • About 14 trees/ha were harvested, yielding about 54 m^3/ha. • The Celos Harvesting System developed by Hendrison (1990) was meant for the "Forestry Belt", a 40 to 120 km wide and 400 km long zone in the northern part of the country. • The terrain is flat to undulating. • Some 5-8 trees/ha are harvested, seldom yielding more than 20 m^3/ha. • The spatial distribution of commercial timber trees is usually random. • Several RIL studies have been conducted in Guyana, but only the activity at the Tropenbos site near Mabura Hill is discussed here. • Two RIL studies have been conducted in Cameroon, but only the Tropenbos study is discussed here. • The Tropenbos site is located in the southwest of the country. • In conventional logging, the area under skid trails was only 4.3 percent. • With RIL just a modest reduction to 3.9 percent could be realized. • More important is that after RIL skidding, part of the vegetation had survived on 47 percent of the trail length, compared to 29 percent after conventional logging. • A difference in costs between RIL and conventional logging could not be demonstrated, although the RIL method is probably somewhat less				• In the case of the Sarawak Study: although the method had not been designed to reduce logging damage, the number of trees destroyed by logging had almost been halved. • The Celos method (Suriname) significantly reduced logging damage. • The area under skid trails was reduced by about 50 percent to a mere 5 percent of the total area. • For Guyana, again, RIL reduced the area under skid trails by about 50 percent. • The number of trees damaged by skidding was reduced by the same percentage. • Felling damage was not reduced, however, and may even be more severe than in conventional operations if felling intensity is high. • This is because in conventional logging, trees are more likely to be felled into existing felling gaps, thus creating less damage but larger canopy openings.		• In the case of the Sarawak Study: the planned way of working, logging costs per cubic meter extracted were reduced by 23 percent, which is due partially to lower skidding costs and partially because less timber had been wasted. • For the Suriname study, the results were comparable to those obtained in Sarawak: additional expenditures for surveys, planning and pre-harvesting operations added about 5 percent to the logging costs. • This increase was more than compensated for by reduced skidding costs and improved efficiency. • For Guyana, the costs per cubic meter extracted under RIL were slightly less than under conventional logging. • The difference would have been more substantial if the same felling limits had been applied in both methods.	Jonkers, W.B.J. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	expensive.							
Mexico	• Cable yarding operation in selective cutting. • Initial stand volume 163.1 m^3/ha (113 adult trees/ha) • marked volume 65.3 m^3/ha (45.3 adult trees/ha) • Average piece size 0.78 m^3		• Extracted volume 41.4 m^3/ha (45.3 trees/ha felled)	• 63% of marked and felled trees utilized	• Of residual component 4.6 m^3/ha or 4.7% of the residual component had severe or medium damage			Hernandez-Diaz, J. & Delgado-Pacheco, M. 1996
Mexico			• With a cutting cycle of 15-20 years, 0.5 to 1 tree can be harvested per hectare		• Felling and skidding cause canopy gaps of 200 to 350 m^2 per tree felled		• For 1986 the following production costs were recorded: furniture wood 2,532.41 US\$/m^3, secondary wood 1,823.34 US\$/m^3 • The costs for pre-harvest inventory were estimated at 253.24 US\$/m^3 (1-1.5% of the revenue)	Steger, N.E.1988
Mozambique	• Five companies were studied in detail In order to establish information on the efficiency of commercial forest harvesting in Mozambique.		• Mean volume produced per cycle (Vm) varied between 0.26 m^3 and 1.34 m^3. • Mean distance from one felled tree to the next ranged from 22 to 79 m.			• Recovery rate (RR) ranged between 35% and 63%	• Mean annual investments in machinery with annual production volume indicated capital intensities (IC) between 20.45 and 63.03 US\$/m^3 • Operational costs accounted for most of the unit costs (between 52% and 78%), whereas labour costs did not exceed 16%. • Ownership costs ranged between 9% and 40%, depending on how heavily the companies invested in	Fath, H. 2002

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
							extraction machinery and transport vehicles. • Total effective unit costs ranged between 80.40 and 364.14 US$/$m^3$.	
Nigeria				• Average log conversion rate at the stump was 36.2% with a maximum of 54% recorded		• A large amount of useful wood is left in the forest because of the adherence of the dealers and buyers to specific flitch dimensions		Agom, D. 1994
Nigeria					• Extraction in the concession was heavily mechanized and productive, but caused considerable disturbance to the surrounding areas	• 12.2% waste		Agom, D. & Ongar, D. 1994
Nigeria	• Moist tropical forest • Study of 5 high forest reserves show mean annual increments of about 5.0 m^3/ha/a +/- 1.0 m^3 (of which 2.5 m^3 was exploitable species and 1.2 m^3 was veneer quality species)		• Results suggest the forest can withstand a logging intensity of 35 m^3/ha of log removals on a 25-year felling cycle (50 m^3/ha of bole volume) • Need to set minimum felling limits					Lowe, R. 1992
Nigeria	• Nigerian tropical shelter wood system • Increment in natural forests about 2 m^3/ha/a • On average <20 stems/ha with dbh >50 cm • Total volume in stems >40 cm dbh was 100 m^3/ha and for dbh >60 cm 75 m^3/ha • Growth rate for plantations 15 m^3/ha/a with a total exploitable volume of 300 m^3/ha		• Logging intensity in the 1940-1950s was 20 m^3/ha compared to a total stem volume >200 m^3/ha • With current methods, the total exploitable volume averages 100 m^3/ha of which 30 m^3/ha is actually extracted on a cutting cycle of 50 years					Lowe, R. 1978
Nigeria	• Omo Forest Reserve • Lowland rainforest • Basal area in undisturbed forest 29 m^2/ha; disturbed forest 14.3 m^2/ha; and secondary regrowth 11.7 m^2/ha		• Logging intensity 9 m^3/ha • Manual logging with logs lifted directly onto lorries		• 8% of area bared for manual and lorry method compared to 30% for mechanized operations			Ola-Adams, B. 1987

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					• 17.7% of residual trees damaged • 51 trees were knocked over (mostly in the >30 cm girth classes)			
Papua New Guinea	• Wawoi-Guavi case study showed logging planning and engineering costs were more than offset by skidder productivity increase of 44% • (planning cost 1.08 K/m^3, while skidding costs saving was 1.43 K/m^3)		• Logging intensity about 30 m^3/ha, but can be as low as 15-25 m^3/ha • Estimated that with RIL harvest intensity could be 60 m^3/ha on a 30-year cycle	• Over 40% of residual trees 20-50 cm dbh are damaged by uncontrolled skidding • Wawoi-Guavi case study showed 67% of residuals damage in uncontrolled logging area with 23 m^3/ha removed, while in controlled logging area 22% of residuals damaged with 32 m^3/ha removed	• Over 30% of most logged areas are destroyed by uncontrolled skidding • Skid roads about 100-120 m/ha or 4.0-4.8% of area • Vanimo case study with non-compliance of logging plan had road right-of-way widths of 25 and 18 m, when 14 m was planned; skid roads 5 m wide when planned to be 4 m; 20-30% of area damaged • Wawoi-Guavi case study area had 13.7% of area damaged in uncontrolled logging and 11.0% of area damaged in controlled logging			Buenaflor, V. 1989
Papua New Guinea	• Manus Province • AAC calculations assume 30 year cutting cycle and average 0.75 cm dbh growth per year, along with 10% reduction for breakage and defects • Proper selection logging is not seriously practised by many logging operators			• RIL needs to be implemented to maintain environmental stability in the area and there is a need to retain some of the trees in the 50-60 cm dbh class				Buenaflor, V. 1990
Papua New Guinea	• *Araucaria cunninghamii* dominated tropical rainforest • Initial basal area 42.1 m^2/ha of which 29.4 m^2/ha was *A. cunninghamii* • Dbh increment in the logged area was 0.71 cm/a and 0.36 cm/a, one and two years after logging		• 64 of 67 commercial sized (dbh >40cm) *A. cunninghamii* extracted	• Selective logging was very destructive to all size classes of *A. cunninghamii* • Of the 101 remaining *A. cunninghamii* 60 were destroyed during logging and 4 more	• Destruction of advance growth will increase the logging cycle of *A. cunninghamii* by 100 years due to the slow initial growth			Enright, N. 1978

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• Corresponding dbh increment in undisturbed site was 0.39 and 0.42 cm/a			died within 14 months after logging (56 *A. cunninghamii* >10 cm dbh remained of initial 168 • The number of sapling was reduced from 66 to 7, and a further 4 died within 18 months • Of the 143 trees of non-commercial species only 9 survived				
Papua New Guinea	• In planned operations skidder production is increased from 8.4 m^3/machine hour to 12.1 m^3/machine hour (+43.7%) • Planning is essential if logging operations are to be applied in an orderly manner and damage to the forest and the environment reduced to a minimum		• Logging is very selective with a minimum felling limit of 50 cm dbh (59 m^3/ha +/- 13.3 m^3/ha), although companies dealing with export markets have a 60 cm dbh minimum felling limit with an average logging intensity of 30 m^3/ha • Companies rarely log areas with less than 20 m^3/ha • Potential yield increase is 50% if all commercial species down to 50 cm dbh harvested (45 m^3/ha) • The MAI at its worst will be 0.6 m^3/ha/a and best 2.5 m^3/ha/a and the logging cycle will be from 30 to 40 years • A felling cycle of 30 years should be adopted for tactical planning and 40 years for strategic planning • Also justified to use a volume increment between 0.8 and 1.7 m^3/ha/a for predicting future volume availability	• Poor logging adds another 10-20 years to the logging cycle due to the loss of advanced growth	• The greater than 30% of area covered by landings, roads and skid trails could be reduced to 15%	• High stumps and bucking to a 40 cm top results in considerable waste, with further losses due to excessive trimming, lost logs and unfelled trees of commercial quality		FAO 1991

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Papua New Guinea	• Tropical high forest • Average portable sawmill recovery 55% (44-56% range)		• Logging intensity 5-8 stems/ha or 30 m^3/ha on average	• 10-35% of the export volume was left at the harbour as not fulfilling export grade rules	• Volume of trees damaged during traditional logging operations and left in the forest was found to be about 15 m^3/ha in size classes from 20-50 cm dbh (17% of total volume) • Number of stems damaged (dbh >20 cm) was 229 of 673 residual trees or 34%	• Studies by FAO have shown that nearly half of the timber volume felled during commercial harvesting operations in tropical forests remains as unutilized residues • After logging 60 m^3/ha of merchantable size standing timber left, plus 30 m^3/ha of uncommercial mature trees		Kilkki, R. 1992
Papua New Guinea	• Clear felling was not as disastrous as many people predicted				• Within a few months of clear felling, bare ground was covered with natural regeneration, but new growth was less diverse • In the clear felled area soil phosphorous was 50% of that in closed forest • Compacted tractor trails and landings, and denuded slopes and hilltops developed in many cases into grassland			Saulei, S. 1984
Papua New Guinea	• The study was carried out in the concessions of Vanimo Forest Products Pty Ltd. (VFP), holder of Timber Permit TP10-8, and Stettin Bay Lumber Company Ltd. (SBLC), holder of Timber Permit TP14-52. • The study documents each phase of the forest harvesting system currently applied by the above-mentioned companies, and		• The time required to fell a single tree was greater on Set-up M38/SBLC (21.48 min) than on Set-up BL14/VFP (17.37 min) although the average stem volume was almost the same, 5.9 m^3 and 5.8 m^3 respectively.		• The forest area occupied by skidtrails amounted to only about 5% due to the hilly to mountainous terrain conditions in Set-up BL14/VFP.	• 90% of the total timber loss at study site BL14/VFP was due to undiscovered decay prior to felling and stems split during felling. • Total timber		Winkler, N. 2001

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	compares planning and implementation of harvesting operations in the field against relevant regulations as published in the *Papua New Guinea Logging Code of Practice*.					losses amounted to about 8.2% at the study site, or 1.57 m^3/ha.		
Paraguay	• This study evaluates the potential for investments in degraded subtropical forests			• When forests are clear-felled, only 10% of the timber volume is used as commercial timber or fuel wood (Bozzano and Weik, 1992)			• Even without consideration of interest rates, depreciation and overhead administrative costs the initial treatment of degraded forests produces a deficit of US$ 137.77/ha	Wippel. B., Grulke, M., Becker, M. & Huss, J. 1997
Philippines					• Increased horsepower utilization is directly related to degree of forest devastation • Regeneration of dipterocarps in a mixed dipterocarp forest (Quezon) is enhanced by the conditions present in a properly logged forest			Blanche, C. 1978
Philippines	• Virgin dipterocarp forest		• Volume removed in two logging settings 205 m^3/ha and 120 m^3/ha		• Supervised logging settings had significantly more uninjured trees in 20-60 cm and +70 cm dbh classes than unsupervised settings • (i.e., 65-72% vs. 26-48% in 20-60 cm class, and 40-47% vs. 23-36% in +70 cm class)		• Sensitivity analysis showed that production costs could increase 30%, yield per hectare decrease by 30% and product price decrease by 20% and a profit could still be made	Bote, P. 1983
Philippines	• Tropical rainforest, Eastern Mindanao • General poor logging performance has resulted in secondary growth that is below the optimum potential		• Growth plots in residual stands show a total volume of 90 m^3/ha just after logging, whose					Reyes, M. 1978

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	of the forest • To have more young trees left uninjured after logging requires the training of fellers in felling techniques and yarding crews in yarding and skidding techniques, all with the objective of minimizing destruction and injury to young trees		predicted volume 30 years after logging is about 260 m^3/ha of which the harvesting volume of trees >60 cm dbh is 160 m^3/ha (growth 2.33 m^3/ha/a) • Growth models show that on a 40-year cycle a silviculturally treated stand could yield 375 m^3/ha compared to 182 m^3/ha in an untreated stand					
Philippines	• Stem distribution charts showing stocking levels by diameter class to ensure successful regeneration of dipterocarp forests using selective logging • There has been a noticeable shift in attitude from predominantly exploitive-oriented to conservation-oriented logging		• Assumes MAI of 3 m^3/ha/a on a 35-year cutting cycle (105 m^3/ha) • Empirical data shows that old growth saw timber cuts vary from 60 to 180 m^3/ha • Based on prescriptions for the new selective logging system the yields may only be 30-90 m^3/ha • When selective logging is done properly it has been shown in three study areas that permissible cuts at the end of the cutting cycle were almost equal if not greater than the average from the old growth	• Field studies done in the 1950s found that 58% or more of the young trees could be saved by the loggers using their ingenuity to avoid hitting marked young trees				Reyes, M. 1983
Philippines	• Shows a commercial forest industry can make a profit and at the same time protect the integrity of the environment and practice sustainable operations • With adequate protection the second forest can return to almost its original form • Control is required of illegal logging, shifting cultivation and the urge to re-log areas close to the mill before the full cutting cycle time is up		• Cutting cycle of 35 years • Field study 33 years after logging shows 123.5 m^3/ha available of all species in the >60 cm dbh class • Growth modelling has projected the third growth volume to be 322 m^3/ha (>20 cm dbh), vs. 200 m^3/ha in second growth and					Tabudar, E. 1984

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			261 m^3/ha in original stand • However, they have a problem of meeting the Government requirement that the second growth forest should yield a minimum 67 m^3/ha					
Philippines	• Average volume in dipterocarp forest ranges from 100-200 m^3/ha					• For every 100 m^3 removed from the forest, 50 m^3 of logging waste and residues are left		Virtucio, F. & Torres, M. 1978
Philippines					• Studies indicate that a harvest of 50% of the basal area results in damages to 25% of the residual stand			Weidelt, H.J. 1989
Philippines, Eastern Mindanao	• Dipterocarp forest in rough terrain				• Uncontrolled removal of utilizable timber at 10-15 years after initial logging caused excessive destruction to the residual stands • Only 49.9% of the original stand was undamaged			Mauricio, F.P. 1984
Republic of Congo	• Rain forest • Any form of utilization which relies on natural regeneration must be based on a wider range of species		• Logging intensity 1-2 trees/ha (10-15 m^3/ha dbh >= 80 cm) on a 30-35 year cycle • Expected rotation of individual trees is 100 years (dbh 70-80 cm)					Fickinger, H. 1992
Solomon Islands	• As the intensity of logging increases, the decrease in shading allows climber species to become the dominant vegetation • One example required nine maintenance operations annually to control the climbers, at considerable cost				• In the 1960s and early 1970s logging was more selective and soil damage by extraction affected 10-15% of the area and the canopy was broken in places but by no means removed			Neil, P. 1984

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					• In the late 1970s, with the increase in the number of species utilized and acceptance of small logs, logging because increasingly intensive became essentially a clear felling with 70% of the area disturbed or compacted • The result of the very intensive logging was a massive invasion of climbers which choke out the natural regeneration and planted trees			
South America	• Timber species are not uniformly distributed throughout the forest; logging intensity can therefore vary significantly within the same locality		• Logging intensities of 5-6 trees/ha or 30-50 m^3/ha were found in the study area		• 25-40 % of the original tree population were damaged during logging			Sist, P. 2000
South America	• Indicators of environmental impact and financial performance were compared for case studies of tropical forest logging from the Brazilian Amazon, Guyana and Ecuador. • Each case study presents parameters obtained from monitoring initial harvest entries into primary forests for planned, reduced impact logging (RIL) and unplanned, conventional logging (CL). • Differences in cost definitions and data collection protocols complicate the comparative analysis, and suggest that caution is necessary in interpreting results. • Uncertainties concerning the marginal benefits of RIL relative to familiar, profitable conventional practices pose an obstacle to broader adoption. • Moreover, CL firms face few incentives to alter their operation						• RIL can generate competitive or superior profits relative to CL if the financial costs of wood wasted in the harvesting operation are fully accounted for. • Increased operational efficiency is an important benefit of RIL, one that largely determines its cost-effectives relative to conventional practices.	Boltz, F., Holmes, T.P. & Carter, D.R. 2003

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	unless they face dramatic changes in market signals. • Adoption of RIL techniques as part of a long-term forest management regime faces additional challenges related to the opportunity cost of silvicultural prescriptions and timber set-asides to maintain productivity and ecosystem integrity.							
Southeast Asia Southeast Asia	• In Malaysia data 100-0.4 ha continuous inventory sample plots and 100-4 ha experimental and/or silvicultural treatment plots gave average growth rates of trees >30 cm dbh as follows • all species 0.8 cm/a • meranti 1.05 cm/a • medium-heavy marketable species 0.75 cm/a • light non-meranti marketable species 0.8 cm/a • non-marketable species 0.75 cm/a • 2.2 m^3/ha/a gross volume growth for all marketable species • 2.75 m^3/ha/a gross volume growth for all species • Some sceptical of increasing increment of dipterocarp forests above 2-3 m^3/ha/a, and in India the average growth rate is only 0.5 m^3/ha/a after a century or more of management • Mixed dipterocarp forest • Increasing impact of logging probably due to a reduction in quality of supervision and training, increased use of mechanized equipment, careless handling of equipment by unskilled operators, and increasing reliance on horsepower rather than on technical competence • Dipterocarps need a heavy logging and then a long period of closure as can be provided by a bicyclical system. However, it may be necessary to impose limits on the first cut in the interest of those that follow • It is reasonable to use a minimum dbh growth of 1 cm/a for all sizes		• Minimum felling diameter 50 cm for dipterocarps and 45 cm in non-dipterocarps in Malaysia SMS • In Malaysia minimum cutting intensity to be economic estimated to be 35-40 m^3/ha, with a cutting cycle of 35-40 years • Logging intensity in Malaysian Peninsular hill forest could 40-45 m^3/ha on a 30-year cycle (assuming 0.8-1.0 cm dbh growth per year), however, need to limit logging damage to not more than 30% of intermediate-sized trees • Shortening felling cycle and increasing logging intensity in natural tropical forests will lead to a vicious cycle of liquidation • Wide range of logging intensities in the region • In a Philippine case study longer logging cycles had higher MAI (30-year cycle had 1.6-2.8 m^3/ha/a MAI, while 40-year cycle had 2.0-3.5 m^3/ha/a) • even the 40-year cycle suggested may be too short if significant	• Felling damage to intermediated sized trees (dbh >30 cm) assessed to be 30%	• For 1974-1983 forest destruction occurred over an average 21% of the area logged per year • in the 1950s 14% of the area was bared by tractors, while in the 1970s >40% was being bared • Area destroyed by tractors needs to be limited to a maximum of 20-25%	• Wastage due to breakage and poor bucking 6.5-8% of the gross timber volume		FAO 1989b (also in Thang 1987)

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	and the error if any, would be on the safe side; for silviculturally treated stands a minimum value of 1.25 cm/a could be used • Very short pulpwood rotations in conjunction with enrichment with fast-growing species cannot be considered in dipterocarp management since no seeding will occur		seeding does not occur by this time • In the Philippines a 40-year logging cycle is recommended • In Sabah, due to excessive logging and stand damage in the past, a 60-year cycle will be needed to get the stands back into better shape, after which a 40-year cycle could be used • In Sarawak a 40-year cycle is recommended, but believes the 45 cm diameter cutting limit is too low • In West Malaysia, due to problems in inventory and logging, a 60-year cycle is recommended, but it should be possible to go to a 40-year cycle once the forest becomes stable • In Indonesia a 40-year cycle with a minimum yield of 2 m^3/ha/a is possible when silviculturally treated					
Southeast Asia	• Examples of sustainability criteria for dipterocarp forest management		• Minimum felling limit 60 cm		• <15% of harvested area with bare soil exposure • <20% felling damage to residual stem number • <15% extraction damage to residual stem number			Nicholson, D. 1979
Southeast Asia	• Dipterocarp forests • Avoidance of damage should be the primary objective of management • Although MAI of 1.0 cm/a dbh growth and 1.0 m^3/ha/a or higher			• A less severely damaged forest recovers more quickly after logging				Ong *et al.* 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	are achievable with good management, it is wrong to use these numbers when conventional logging is practised							
Southeast Asia	• An additional source of damage which is increasing alarmingly is illegal cutting • In the Philippines strict guidelines are prescribed for selective logging and the use of devices to minimize damage in felling and yarding is required; however, proper supervision is lacking in most cases		• Projected harvest levels in the second cycle cut projected to be from 63.6 m^3/ha (36% less with 40-year cycle) to 83.2 m^3/ha (44.5% less on a 35-year cycle)					Putz, F. 1994
Southeast Asia	• Dipterocarp forests • Volume increment without deducting mortality on an area of primary forest may range from 1-5 m^3/ha/a • Imperative that damage is minimized to both the soil and the residuals		• The absolute minimum logging cycle in dipterocarps is 35-40 years • The minimum felling diameter should be 50 cm, since dipterocarps generally reach fruiting age at dbh 35-40 cm	• If 15 trees/ha are felled 30% of the area would sustain felling damage	• 30% of the area sustains skidder damage • With directional felling techniques about 200 m^2 of area is damaged per tree felled			Serna, C. 1986
Southeast Asia - Peninsular Malaysia - Philippines - East Kalimantan	• Hill dipterocarp • In Malaysia average dbh growth from plots ranges 0.3-0.9 cm/a		• SMS with cutting cycle of 25-30 years and min • Economic cut of 30-40 m^3/ha with initial removals at about 100 m^3/ha • RIL not done so current selective systems are not sustainable on a 35-40 year cycle • PSLS cutting cycle 30-40 years and logging intensity of 70-90 m^3/ha but must be drastically reduced • Richer forests in Mindanao 100-120 m^3/ha but such high yield forests have dwindled quickly	• For success need an effective monitoring system and logging damage must be drastically reduced • Need to leave sufficient numbers of trees 30-45 cm dbh to form trees of next cut, plus sufficient seed trees to obtain new regeneration • In SMS logging damage to residual (dbh >30 cm) estimated to be 30%, not including mortality several years after logging • Need to implement RIL				Weidelt, H. 1996
Southeast Asia, mainly Malaysia, Sarawak	• Mixed dipterocarp forest of southeast Asia • Sustained level of production estimated at 2-3 m^3/ha/a of net industrial volume of desired species >30 cm dbh		• On a cutting cycle of 40 years the logging intensity should be 80 m^3/ha of which 50% can be used • The average net		• In many cases half or more of the trees remaining after logging are damaged, some of them so badly			Appanah, S. & Weinland, G. 1990

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	• Careful harvesting extracts more of the felled trees and leaves a less disturbed forest with greater potential to rehabilitate itself • There is no reason to tolerate harvesting operations that are wasteful and damaging		industrial volume possible to take out after 40 years will be about 40 m^3/ha, which is equivalent to that of the initial harvest • The above assume RIL		that they will die • Entry into the stand to remove additional trees before the full logging cycle is up causes heavy damage to saplings and seedlings • If continued, the re-logged forest often deteriorates into a state of unproductive weeds			
Southeast Asia: Indonesia Malaysia Philippines	• Broadleaved tropical forests		• When extracting lower value smaller and lesser used species a minimum logging intensity of 20-30 m^3/ha is required for the operation to remain economical		• Road densities in moderate and hilly terrain logged by tractors and managed on a sustained yield basis are often from 10-20 m/ha, with 15 m/ha being a good average • 20 % main roads, 20-30% area roads and 50-60% feeder roads			Korsgaard, S. 1985
Sri Lanka	• Wet zone natural forest • These forests have been logged a number of times and the growing stock has reached a very low level in many areas					• Up to 70% of wood being logged from natural forests is wasted owing to both the methods of harvesting and utilization, and the non-availability of markets for all wood		Sundberg, U. 1978
Surinam	• These silvicultural experiments were carried out in Surinam over a period of 30 years • Harvesting might have a similar effect of release as removing competitors around potential crop trees		• With an initial thinning of non-commercial species from 20 to 6-10 m^2 of basal area, enough volume for a harvest of 20-30 m^3/ha had grown after 20 years		• Intensive harvesting is usually more destructive for the residual stand per unit basal area removed than a silvicultural treatment in which			Buenaflor, V. & Karunatilleke, T. 1992

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					trees area killed standing by means of girdling			
Suriname	• Controlled logging found to be more efficient than conventional logging • Controlled logging reduces the impact of logging intensity • Controlled logging is less costly than conventional logging • The extra costs of planning are returned by improved operational efficiency and logging intensity on the next cycle can more or less be maintained at the same level		• Polycyclic silvicultural system on a 20-30 year cycle is most appropriate for rainforests in Suriname • Felling intensity is restricted in Suriname to not exceed 30 m^3/ha, in order to maintain the ecological, conservational and protective functions of the forest • A felling intensity of 5-8 trees/ha is considered to be sustainable for most types of tropical forests (Boerboom and Wiersum 1983) · period 1957-1970 logging intensity was 8-10 m^3/ha • CELOS silvicultural systems aim for a logging cycle of 25 years and a logging intensity of 30 m^3/ha		• 40% more felling gaps in uncontrolled logging • Skid trail area was 50% less in controlled logging areas (5.4-7.3% vs. 14.5-16%) • On average an efficient trail system should be limited to 5-8% of the area • Wood damage, involving serious loss of quality, can occur during positioning and collecting (bunching) logs with the blade of a skidder • In selection felling every effort is made to keep the remaining stand in a healthy state, by carrying out each periodic harvest with the greatest care • Wood damage was substantially higher in the uncontrolled conventional logging area (24.3-28.3% vs. 6.1-8.5%)	• Poor work methods and techniques during felling and terrain transport lead to splitting and breaking of felled trees		De Graaf, N.R., Poels, R.L.H. & van Rompaey, R.S.A.R. 1999
Suriname	• Growth rates of plantations in Suriname have not met expectations • Plantation forests should only be established where the forest has already been destroyed • If tropical rainforest are used economically, other management systems more adapted to the		• Logging intensity seldom exceeds 20 m^3/ha		• After logging the most likely impression of a visitor, walking on a skid trail shortly after conventional unplanned logging, is one of almost complete destruction			Hendrison, J. 1989

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	ecological conditions have to be developed and used (e.g., CELOS) • Commercial species account for 117.1 stems/ha (BA=10.11 m^2/ha) (dbh >10 cm) • All species account for 476.9 stems/ha (BA=25.2 m^2/ha) (dbh>10 cm)				• Damage is considerable, but the forest is not destroyed			
Suriname	• The study documents each phase of the conventional logging system, which is used almost exclusively in Suriname's small timber concessions and was applied on one sample plot at the study site. • The productivity and environmental impacts associated with this system are compared with those of planned harvesting as applied on the other sample plot in Concession 387.	• The average time required to fell a single tree was greater in the conventional logging system (8.67 min) than in planned harvesting (7.92 min) due to the time spent by the chainsaw operator (almost 10% of total time) searching for harvestable trees under the conventional system. • Skidding under planned harvesting, productivity averaged 8.15 m^3/h of workplace time, whereas skidding productivity under conventional logging averaged only 5.91 m^3/h of workplace time.			• The percentages of residual trees found damaged was 5.5% for conventional logging and 2.5% for planned harvesting. • No damage was registered during skidding operations during planned logging, whereas skidding damage was observed on the conventional logging operation. • For the planned harvesting system an average of about 5.4% of the area harvested was affected by primary skidtrails, whereas in conventional logging the corresponding value more than twice as high-12.4%. • In addition, conventional logging utilized secondary skidtrails, thus disturbing an additional area of soil which is not included in this figure. • Canopy opening by tree felling	• Timber wastage ranged between 11.7% and 15.7% on the sample plots.	• If the labour cost per cubic metre of logs delivered to the landing under conventional logging is assigned an index value of 100%, then the comparable cost under planned harvesting would amount to only 77.5%, despite the additional labour cost required for pre-harvest inventory under planned harvesting. • The substantially higher felling and skidding productivity under planned harvesting not only offsets the additional cost of the pre-harvest inventory but reduces the overall labour cost by more than 20%.	Jonkers, W. & Schmidt, P. 1984

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
					ranged from 6.5% to 7.7% of the area for the two sample plots			
Sweden	• This study presents a new approach for clustering harvest activities in time and space in long term forest planning. • The planning problem essentially consists of maximising the weighted sum of the net present value of future forest management and the clustered volume of timber to be harvested. • This objective is subject to the restriction that a certain volume should be harvested each period. • Since the spatial dimension leads to a problem that is difficult to solve with ordinary optimization techniques; the ensuing problem is solved with a heuristic technique called simulated annealing. • In a case study the suggested approach is applied to a landscape consisting of 2600 stands in southern Sweden. • The results indicate that the model is effective for clustering the harvest and that it is possible to aggregate the harvest with only a small sacrifice of the net present value.							Winkler, N. & Nobauer, M. 2001
Thailand	• A study of a teak forest 25 years after logging shows good regeneration of teak but a lack of large trees, especially in the 40-45 cm dbh class (harvest was too intense) • Average teak dbh growth in study area was 1.61 cm/a		• Selective logging of teak reduces the volume of trees (dbh >60 cm) from 100.7 m^3/ha to 9.5 m^3/ha (logging intensity = 91.2 m^3/ha) • Minimum 40 years logging cycle needed in the study area (however lower volume than initial harvest)	• Logging intensity too high • In the study area 49 of the 89 stumps were less than 60 cm dbh • Only 5 residual trees left with dbh >60 cm				Ohman, K. & Lamas, T. 2003
Uganda	• Tropical high forest • Recommends a uniform silviculture system rather than polycyclic due to excessive damage to residuals during		• Presents data for MAI of 2.1 m^3/ha/a and a logging cycle of 40 years		• Area of damage with the removal of one tree of 70 cm dbh is not likely to be less			Gajaseni, J. & Jordan, C. 1990

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
	logging				than 200 m^2 • In one study mean felling damage per tree was 405 m^2 and could have been reduced to one-half through directional felling			
Uganda	• Medium altitude tropical moist forest • Kibale Forest		• Light cut 14 m^3/ha • Heavily cut 21 m^3/ha • Annual rates of live tree falls were 1.3 trees/ha in light cut, 3.3 trees/ha in heavily cut, and 1.7 in uncut mature forest					Dawkins, H. 1958
Uganda	• Budongo Forest Reserve • Those areas logged and treated with arboricide showed a greater tree species richness per unit area than the unlogged and untreated areas (may be due to the succession towards mono-dominance that occurs in Budongo)		• Logging intensities • 1930-1939, 32.3 m^3/ha • 1940-1949, 42.9 m^3/ha • 1950-1959, 42.1 m^3/ha • 1960-1969, 25.1 m^3/ha • 1970-1979, 38.0 m^3/ha • 1980-1989, 24.9 m^3/ha	• Measures of forest structure show that more than 50 years is required for the forest to recover to pre-logging levels				Kasenene, J. & Murphy, P. 1991
Uganda	• Kibale Forest • Results indicate that levels of destruction typical of mechanized timber harvesting seriously disrupt the dynamic balance of the forest		• Maximum allowable basal area reduction in selective logging was projected to be 35% to maintain natural tree falls at an acceptable level • In unlogged area natural tree falls were 1.4 trees/year (256 stems/ha, BA 35.5 m^2/ha, canopy cover @15 m 72%) • In area with logging intensity of 14 m^3/ha tree fall rate was 1.3 trees/year 12 years after logging (267 stems/ha, BA 26.7 m^2/ha, canopy cover @ 15 m 50%) • In area with logging intensity of 21 m^3/ha tree fall rate was 6.2 trees/year 12 years after logging (125		• Conventional mechanized logging operations can destroy up to 50% of the original stand and are not a sustainable method for exploiting the Kibale Forest • Highest tree fall rate was in the heavily logged site			Plumptre, A. 1996

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
			stems/ha, BA 19.0 m^2/ha, canopy cover @ 15 m 32%)					
USA	• To examine the value of state-wide regulatory data for Massachusetts as a unique source of this critical information, 17 years of timber harvest data gathered for regulatory purposes for a 168,000 ha forested landscape in Massachusetts was analyzed. • The predominant form of harvesting was selective removal of commercially valuable tree sizes, grades and species. • The spatial pattern of logging was random with regards to major physical, biological, or cultural factors. • However, logging was strongly related to landowner class. • NIPF owners control 60% of the forest area and were responsible for 64.1% of harvest area, but the highest logging intensity (volume per area harvested; 69.3 m^3 ha-1) among major landowners was conducted by the state agency responsible for managing southern New England's largest conservation property, the watershed of Boston's drinking reservoir.		• Annual disturbance rate of 1.5% and a mean intensity of 44.7 m^3 ha-1 (approximately one-fourth of average stand volume).					Skorupa, J. & Kasenene, J. 1984
USA	• Environmentally sensitive harvesting is used to define and promote improvements in common harvesting systems. The forest industry needs to look towards new technologies and systems to provide the required environmentally sensitive harvesting techniques. • Regardless of the machinery involved, it is the people that must make the decision about what harvesting strategy to use and what equipment to employ to protect water, soil, and overall forest quality.							Kittredge Jr., D.B., Finley, A.O. & Foster, D.R. 2003

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Venezuela	• Humid evergreen tropical forest • Felling with chain saws and extraction with skidders • Tree basal area in unlogged area 32 m^2/ha, logged 23 m^2/ha, and logged with linear strip planting 20 m^2/ha		• Minimum felling dbh 40 cm • In 1988 2.9-7.3 trees/ha (5.8-14.2 m^3/ha) were authorized for extraction, but the actual rate was lower at 2.3 trees/ha (7.1 m^3/ha)					Visser, R. 2002
Venezuela	• Western llanos		• Logging intensity 14-24 trees/ha >40 cm dbh (average 18.3 trees/ha with 15.2 m^2/ha of basal area removed) • Estimated rotation age of individual trees is 80-100 years • 20 year logging cycle is proposed, with a maximum logging intensity of 7.5 m^2/ha (36 m^3/ha)					Mason, J. 1996
Venezuela	• The study was carried out in the Caparo Forest reserve which lies on the western plains of Venezuela. • Three stands logged 5, 8 and 19 years prior to sampling were selected and compared with a mature forest stand. • In each stand the area affected by logging was delimited. • The impact of logging on the stand structure and spatial pattern of commercial species was studied along a chronosequence of 5-19 year old logged stands in the Forest Reserve of Caparo, Venezuela. • For comparison, a mature forest stand was surveyed. • A systematic sampling design was applied. • Up to the mid-1980s, covered by this study, only *Bombacopsis quinata*, *Swietenia macrophylla*, *Cedrela odorata* and *Cordia apurensis* were logged.		• A polycyclic management system with a 30 year cutting cycle is prescribed in the study area. • On average 10.2 trees/ha with a bole volume of 66.5 m^3/ha were removed.	• The 5, 8 and 19 year old logged stands showed a mean basal area of 17.8, 21.3, and 22.2 m^2/ha, respectively, whereas 33.2 m^2/ha were measured in the mature forest. • The share of undamaged trees in the basal area increased from 30.8% in the 5 year old logged stand to 43.9% in the oldest logged stand. • The number of emergent trees (>30 m height) was considerably reduced by logging; even 19 years after logging only 8 stems/ha were found in this height class comparing to 51 stems/ha in the mature forest.				Plonczak, M. 1989

Location	Descriptive Information	Planning and inventory	Logging Intensity and Cycle	Residual Density and Utilization	Stand and site damage	Waste	Economic Aspects	Source
Vietnam	• Tropical low elevation and flat dipterocarp forest • Stand volume in trees >50 cm dbh was 54 m^3/ha (19 trees/ha) • Chain saw felling and tree-length skidding to landings							Kammesheidt, L. 1998
West Africa	• Limited forest land base in West Africa • Enormous pressure for its conversion to other uses • Failure of natural regeneration and increasing demand for wood make the plantation system the most logical choice for the region							Seppanen, H. & Malvas, J. 1986